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Radiation Dose Level of Natural Radionuclide in Plantain Leaves around a Gold Mining Environment in South West Nigeria

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Abstract: With a view to determining the radiological hazard levels in plantain leave in the mining area, samples were analyzed for radionuclide concentration using Gamma ray spectrometry. Leave samples were collected covering both the dry and wet season of 2017 from mining locations of Atakumosa-west Local Government while control samples were taken from Tonkere village in Ife North-Central Local Government, both in Osun State, south western Nigeria. Results of the activity concentrations of ^{40}K, ^{232}Th and ^{238}U in the leave samples showed generally higher values in the wet season than in the dry season in all the mining locations. The evaluated absorbed dose rate (ADR), annual effective dose equivalent (AEDE), annual gonnadial dose equivalent (AGDE) as well as excess lifetime cancer risk (ELCR) for the plantain leaves were all higher than the recommended limits of 30-70 nGy/h, 0.48 mSv/y, 70 uSv/y and 0.29 x 10^{-3} respectively.

Keywords: Radiological, Plantain, Activity, Mining, Hazard.

1 Introduction

Human organs are exposed to radiation largely from the food he eats, water he drinks and the air he breathes. The exposure can be both from cosmic and gamma rays from terrestrial and anthropogenic external sources [1] or from other internal sources. Direct inhalation and ingestion is also another means of human exposure to radionuclides. Plants absorb radionuclides directly from deposition on their foliage as well as their uptake through the roots from the soils [2] Uptake of radionuclides through the root and transfer to other parts of the plant has been recognized and is known to be affected by factors such as soil and plant types, climatic conditions, chemical form of the radionuclide, metabolic requirement of the plant among other factors [3-4]. The radionuclides are absorbed through metabolic processes and are available in different concentrations in different parts of the plants [5-7]

Radionuclides such as ^{40}K, ^{232}Th, and ^{238}U and their progenies which are metabolically absorbed by the plants ends up in man through the plants pathway [8]. Different levels of these harmful elements are transferred into man when consumed, either directly or as supplements [9]. The soil-to-plant transfer factor of radioactive species like ^{210}Pb and ^{210}Po and ^{238}U in some agricultural products such as vegetables and fruit trees has been found to be higher in leaves than in fruits. Plantain is a fruit tree that is largely grown and consumed in Nigeria.

Plantain is an important biennial food crop in Nigeria. It is a popular staple food that is eaten boiled, baked, fried or mashed. Different parts of the plant are used for different purposes. Edible parts of the plants includes the pulp, peel [10] and the stem, while the leafy part fund usage as platters for serving food, for packing and wrapping food materials, especially when dried. It is also a cheap source of food for some domestic animals. The leave and peel has also recently found ready use as adsorbents [11] for heavy metal remediation in the environment which makes the determination of heavy metal content important as it will also serve to indicate the degree of pollution/contamination of the soils on which it is grown[12-13].

Determination of the levels of radionuclide concentrations in leaves of plantain will help in accessing the health risk

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associated with its usage as food for animals and its other food related applications. It can also be sued in evaluating the soil-to-plant transfer factor for the plant.

2 Experimental Sections

2.1 Materials and Methods

Plantain leave samples were collected from three mining villages (Sabo, Itagunmodi and Igun) in Atakumosa west local Government area of Osun state within latitudes 7.51^0 N and 7.65^0 N and longitudes 4.61° E and 4.85° E (Fig 1). The Local Government covers area of 577 km² with a population of 68,643 [14]. The vast majority of the people in the area engage in farming activities second only, to Gold mining. Mining operations in the area involve mainly of several dug pits, both manually and mechanically, in the farming area populated by Cocoa (*theobromine cacao*) and plantain (*musa paradisiaca*) (Table 1). The leafy part of the plant was selected for the study due to the predominance of the plant in all the study area (Fig 1). The leaves were collected and kept in labeled polythene bags; effort was made to avoid soil contamination of the samples. Samples collected were dried at 55^0C for 48hrs. The dried samples were then ground and sieved with a 2 mm mesh. Ground samples from each sampling point were kept for radioactivity study.

Table 1. Description of the Sample locations

Village	Locations	N	E
Itagunmodi	L1	7^0 39' 43.6''	4 39' 10.9''
	L2	7 31' 27.5''	4 39' 10.3''
	L3	7 31' 20.7''	4 39' 13.8''
Igun	L1	7 34' 44''	4 41' 13''
	L2	7 34' 58.7''	4 41' 21.8''
	L3	7 34' 51.9''	4 41' 32.7''
Sabo	L1	7 31' 28.1''	4 39' 55''
	L2	7 31' 29.4''	4 39' 56.3''
	L3	7 31' 46.5''	4 39' 43.3''

Figure 1: Plantain predominantly grown in the mining area.

The concentrations of radionuclides in the plantain leave samples were determined using Gamma ray spectrometry. The activity concentration in the leave samples collected were determined using a 7.62 cm × 7.62 cm NaI (Tl) detector with adequate lead shielding. The samples were counted for a period of 25,200s with the activities of radionuclide recorded in Bq kg^{-1} and detection limits calculated as 6.77, 11.40, and 12.85 Bq kg−1 for ^{40}K, ^{232}Th, and ^{238}U, respectively, of the NaI (Tl) detector system were. Calibration of the NaI detector was done using the absolute gamma ray energy for easy identification of peaks in the gamma spectrum. This was done using standard sources with specific gamma ray energies (^{241}Am (59.5 keV), ^{137}Cs (662.3 keV), ^{22}Na (511.0 keV) and ^{60}Co (1173.2 and 1332.5 keV) different from energies of radioactive elements expected from the study samples. The standards were obtained from the Isotope Products Laboratories, Burbank California, USA. The standards were counted for a long period to get well defined photo peaks, thereby ensuring the coverage of wide range of radionuclides.

2.2 Determination of Radiological Hazards

Absorbed Gamma Dose Rate (D nGyh-1): This is the amount of radiation energy absorbed or deposited per unit mass of substance. The absorbed gamma dose rates due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) were calculated according to UNSCEAR [15] guidelines:

$$D\ (nGy/h) = 0.462A_u + 0.604A_{Th} + 0.041A_k$$

Where A_k, A_U and A_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th in Bqkg-1 respectively.

Annual Effective Dose Equivalent (mSv y^{-1}): This is the effective dose equivalent received outdoor by a member of the public. The annual effective dose rate equivalent (AEDE) in $mSvy^{-1}$ resulting from the absorbed dose rate values (ADR) was calculated using the following formula [15]:

AEDE (mSvy-1) = ADR (nGy/h) × 8760 h × 0.7 Sv/Gy × 0.2 (1)

AEDE (mSvy-1) = ADR (nGy/h) × 0.00123(2)

Annual Gonnadial Dose Equivalent (AGDE)(uSv y^{-1}): The gonads, the bone marrow and the bone surface cells are considered as organs of interest by UNSCEAR [15] because of their sensitivity to radiation. AGDE is a measure of the genetic significance of the dose received annually by the public reproductive organs [16]. A high AGED (uSv y^{-1}) is known to affect the bone marrow, causing destruction of the red blood cells that are then replaced by white blood cells. This situation results in a blood cancer called leukemia which is fatal.

AGED is determined by the following equation [17]

AGED (μSvy-1) = 3.09(U) + 4.18(Th) + 0.314(K) (3)

Where, (u), (Th) and (K) are the radioactivity concentration of ^{228}U, ^{232Th} and ^{40}K in the sample.

Excess Lifetime Cancer Risk (ELCR): This is the probability of developing cancer over a lifetime at a given exposure level. A higher value of ELCR implies higher probability of the individual exposed can be induced to cancer. This is calculated as:

ELCER = AEDE × DL × RF (4)

Where AEDE, DL and RF are annual effective dose equivalent, duration of life (54.5yrs) and risk factor ($0.05Sv^{-1}$) i.e fatal cancer risk per Sievert.

3 Results and Discussion

The results of Gamma spectroscopic analysis of plantain leave samples collected from the study area are shown in Tables 2, 3 and 4 from March (2015) to February (2016). In all the mining villages, ^{40}K has the highest concentration followed by ^{232}Th and 238U. At Igun, the highest activity concentration of the radionuclide ^{40}K was highest (233.6, 249.6, 297.4) Bq/Kg in all locations in July, during the wet period. For ^{232}Th, highest value was recorded in Jan at L2 (88.2 Bq/Kg) and L3 (89.5 Bq/Kg) and was in May at L1 (96.1 Bq/Kg) while for ^{238}U, it was 44.5 Bq/Kg in April at L1, 77.4 Bq/Kg in July at L2 and 71.2 Bq/Kg in August at L3. The lowest values at Igun mining village were recorded for ^{40}K, ^{232}Th and ^{238}U in the dry month of Feb in all locations; this might not be unconnected with the low mining activity observed in the village during the dry season probably due to heat and the ease of digging. Notably also, the activity concentration recorded in control sample for all the locations were lower than recorded in study samples. In Itagunmodi mining locations, a similar trend was observed as the activity concentration of ^{40}K was highest in all samples and locations with 297.4 Bq/Kg and ^{238}U with 84.3 Bq/Kg in location 3 in the wet month of July. 232Th was highest (77.9 Bq/Kg) in March in location 2. The lowest values recorded, (40K, 123.1 Bq/Kg (L1) Jan; ^{232}Th, 18.6 Bq/Kg (L3) Feb; ^{238}U, 17.2 Bq/Kg (L3) March) were all lower than values recorded in samples collected from the control site.

The trend was not different at Sabo mining village as 40 K has the highest activity concentration in all samples and at all locations. The highest ^{232}Th (100.2 Bq/Kg) and ^{238}U (33.6 Bq/Kg) was recorded in location 2 in the wet months of May and August respectively. Similarly, all control samples have radionuclide concentrations lower than in study samples. The high concentration of ^{40}K recorded in all samples and in all locations is not unconnected with the essential nature of potassium; Also, plants do not have the capacity to differentiate between the isotopes of the metal [18] The mean activity concentration (Fig. 4.8) is however lower than the world range of 240 Bq/Kg reported. The contribution of mining activities to the high value of ^{40}K recorded is evident in much lower concentration recorded in samples from the control site as the soil in the study area is progressively contaminated with the radioelement as the precious metal is mined [19-22] while the mean concentration of ^{232}Th in samples collected from Sabo and Igun are higher than the 40 Bq/Kg limit, ^{238}U was recorded in higher values thanthe 50 Bq/Kg world limit in samples collected from locations 2 and 3. Ease of absorption from the soil as well as atmospheric deposition might have aided in the high values recorded in the wet period. These radionuclides can be transferred into food materials when the leave samples are used as platters or used to serve food such as corn meal. Plantain leaves are also sources of meal for some animals. They have been associated with cell damage and cancer induction [23-24].

3.1 Evaluation of the Radiological Hazards

Parameters of measuring radiological hazards in the plantain leave samples were calculated (Tables 5).

The amount of gamma dose absorbed per unit mass measured in $nGyh^{-1}$ clearly exceeds the 30-70 nGy/h safe limits stipulated by the United Nations Scientific Committee [25] on the Effect of Atomic Radiation in all sampling locations at Igun mining village while in the control samples, lower values were calculated. However, all the mining locations and control site in the studied area recorded a low value for the evaluated annual effective dose equivalent (AEDE). The values recorded were all much lower than the 0.48 mSv/y limit recommended by [19] and UNSCEAR [25]

Table 2: Activity Concentration of ^{40}K, ^{232}Th, and ^{238}U in Plantain Leaf Samples and Control for March to Jun

	March			April			May			June		
	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U
Igun L1	188.1	91.1	35.1	193.1	83.1	44.5	228.1	96.1	40.2	227.1	91.6	38.9
L2	205.1	88.2	31.9	199.8	66.9	51.2	248.2	70.1	63.5	251.8	71.3	65.4
L3	155.8	89.5	38.6	188.6	72.6	38.6	304.2	63.2	51.4	299.3	62.8	53.4
ItagmoL1	151.8	71.8	20.1	168.3	29.3	33.6	188.3	30.1	51.9	191.4	26.6	48.7
L2	163.8	77.9	26.8	188.3	37.5	42.5	231.9	44.5	59.2	227.3	38.7	62.4
L3	159.5	63.1	17.2	197.2	26.9	27.1	279.3	35.8	63.7	270.5	29.4	63.1
Sabo L1	120.2	67.7	10.1	144.9	77.5	17.2	160.2	87.3	16.2	155.4	88.6	15.7
L2	110.3	71.5	12.7	141.8	89.5	26.9	166.8	100.2	30.4	162.6	99.8	31.1
L3	117.3	59.7	13.2	133.7	72.5	29.1	152.3	94.6	25.7	158.7	92.2	24.9
Control	88.2	28.9	15.8	88.9	26.8	14.1	89.5	32.1	14.4	92.9	23.4	13.6

Table 3: Activity Concentration of^{40}K, ^{232}Th, and ^{238}U in Plantain Leaf Samples and Control for July to October

	July			August			September			October		
	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U
Igun L1	233.6	90.5	42.3	240.1	91.4	40.7	221.9	85.9	37.1	228.9	88.7	36.2
L2	249.6	77.5	77.4	178.1	78.2	76.1	237.1	73.6	71.2	244.6	75.9	69.6
L3	297.4	70.6	69.8	170.4	71.3	71.2	282.5	67.1	64.2	291.4	69.1	62.8
ItagmoL1	189.4	31.3	61.3	161.9	31.6	51.9	179.9	29.7	56.3	185.6	30.6	55.1
2	226.9	32.4	78.5	179.2	32.7	69.2	215.5	30.7	72.2	222.3	31.7	70.6
3	275.2	30.6	84.3	185.1	30.9	75.1	261.4	29.1	77.5	269.6	29.9	75.8
Sabo L1	161.9	86.3	22.4	122.6	87.1	21.6	153.8	81.9	20.6	158.6	84.5	20.1
L2	162.8	96.8	30.5	130.8	97.7	33.6	154.6	91.9	28.1	159.5	94.8	27.4
L3	160.4	94.7	33.1	133.4	95.6	31.2	152.3	89.9	30.4	157.1	92.8	29.7
Control	93.2	29.9	21.5	74.4	30.2	20.8	88.5	28.2	20.1	91.3	27.2	19.4

Table 4: Activity Concentration of ^{40}K, ^{232}Th, and ^{238}U in Plantain Leaf Samples and Control for November to February

	November			December			Jan			Feb		
	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U
Igun L1	186.8	67.8	26.19	182.2	65.1	24.9	151.8	56.1	22.1	156.5	55.5	21.7
L2	199.6	58.1	50.3	194.6	55.8	47.9	162.2	48.5	42.5	167.2	47.2	41.7
L3	237.9	52.9	45.3	231.9	50.8	43.2	193.3	43.7	38.3	199.2	43.6	37.6
ItagmoL1	151.5	23.4	39.84	147.7	22.5	38.6	123.1	19.4	33.7	126.8	19.3	33.1
L2	181.5	24.1	51.1	176.9	23.3	48.7	147.4	20.8	43.1	152.3	21.7	42.3
L3	220.1	22.9	54.7	214.6	22.2	52.2	178.8	18.9	46.3	184.3	18.6	45.5
Sabo L1	129.5	64.7	14.5	126.2	62.1	13.8	105.2	53.5	12.3	108.4	52.6	12.6
L2	130.2	72.6	19.8	126.9	69.6	18.9	105.8	60.6	16.7	109.6	59.8	16.4
L3	128.3	71.1	21.5	125.1	68.1	20.5	104.2	58.4	18.2	107.4	57.7	17.8
Control	74.5	21.4	14.4	72.6	21.8	13.4	60.5	16.8	11.9	62.4	20.6	12.1

Table 5: Risk Assessment Indices of Plantain Leave Samples

		ADR (nGy/h)	AEDE (mSv/y)	AGDE (uSv/y)	ELCR 0.24
Igun	L1	71.74	0.09	498.55	
	L2	75.72	0.09	524.02	0.26
	L3	70.75	0.09	491.19	0.24
Itagum	L1	45.35	0.06	313.79	0.15
	L2	54.45	0.07	376.38	0.18
	L3	53.52	0.07	370.77	0.18
Sabo	L1	57.84	0.07	402.45	0.19
	L2	67.02	0.08	465.18	0.23
	L3	64.29	0.08	446.16	0.22
Control		29.9	0.04	207.15	0.1
Limit		(30-70)*	0.48*	70***	0.29E-3

*UNSCEAR (2000) **Caspah et al (2016) *** UNSCEAR (1988).

The story is different for the evaluated annual gonnadial dose equivalent (AGDE). A safe limit of 70 uSv/y has been recommended by the UNSCEAR (1988), this safe limit were clearly exceeded in all samples from the mining villages. High values were estimated for the index at all themining villages as well as the control site. These high values are unpleasant as the bone marrow of people working and living in the area may be affected leading to a destruction of the red blood cells (19). The calculated excess lifetime cancer risk in all plantain leave samples is high. The United Nations scientific committee on the effect of atomic radiation (UNSCEAR, 2000) has recommended a safe limit of 0.29 x 10^{-3} as the excess lifetime cancer risk for people living and working in mining areas. Observably, values calculated for all the studied mining areas have an alarmingly high ELCR values meaning that people in the area are at a high cancer risk.

4 Conclusions

Risk assessment indices have been calculated using approved equation by the UNSCEAR. The absorbed dose rate (ADR), annual effective dose equivalent (AEDE), annual gonnadial dose equivalent (AGDE) as well as excess lifetime cancer risk (ELCR) for the plantain leaves were all higher than the recommended limits.

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