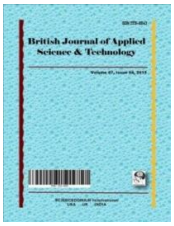

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Gross Alpha and Beta Activity Concentrations in Cassava Tubers (*Manihot esculenta*) from Old Coal Mining Area in Enugu, South Eastern Nigeria

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Authors' contributions

This work was a collaborative effort of three authors. Authors CMA designed the study, collected samples from the field, carried out the laboratory tests and performed the statistical analysis and wrote the first draft of the manuscript. Authors NNJ and CEO managed the literature searches, analyses of the study and literature. All authors read and approved the final copy.

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ABSTRACT

Cassava crops and its food constitute more than 65% of dietary components for the population from the south-eastern Nigeria. Any contamination of this food crop in the environment by radioactive sources through human activities such as mining will affect large portion of the population. Following coal mining activities that took place in Enugu and the likelihood of potential increase in radiation dose burden to the population, the gross alpha and gross beta activity concentration in cassava tuber samples cultivated within the old coal mine area was investigated. The gross alpha activity concentration in the mined area ranged from (BDL) to 670 Bq/kg and for gross beta it was from BDL to 1220 Bq/kg. In the coal processing and distribution area, gross alpha ranged from (BDL) to 590 Bq/kg while for the gross beta it ranged from 70 to 770 Bq/kg. In the control area the gross alpha activity concentration was found to range from 20 to 690 Bq/kg and 370 to1420 Bq/kg for the gross beta. However, as could be seen from the study, the coal mining

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activities in the area has not affected the concentrations of gross alpha and gross beta radiation in the cassava crops within the areas considered.

Keywords: Gross alpha activity; gross beta activity; Natural radionuclide; Cassava; Enugu coal mine.

1. INTRODUCTION

Coal mining has been known to require large areas of land for its operation; this creates disturbances within the areas mined. The disturbance could bring about a change in the biodiversity, physical and chemical structure and the landscape of the entire area where the operation is taking place. These situations have prompted relevant government authorities to put in place steps that should be taken to minimize such environmental degradations. The steps take into consideration the baseline studies of the environmental conditions years before the actual initiation of the mining operations. This enables the relevant government authorities to measure the impact of the coal mining in the environment—and helps the coal industry to put appropriate land reclamation processes in situations where there is mine subsidence [1].

The area under investigation is the Iva-valley coal mine settlement area of Enugu, south-eastern Nigeria, located within the coordinates of $6^0 27' 0'' N$ and $7^0 27' 0'' E$. The area is famous for its coal mining activities. A pilot study carried out by [2] suggests that the Iva-valley coal mine area of Enugu state is one of the areas with high natural background radiation in Nigeria. [3], also carried out some studies in the vicinity of Onyeama coal mines, they recorded a mean activity concentration level of 1,755±52.8 Bq/kg which is higher than the mean activity concentration level of 1026.6±148.6 Bq/kg recorded for other Enugu locations. The area is dominated by subsistence farmers who cultivate varieties of crops including the most widely staple food crop—cassava (*Manihot esculenta*).

The areas of high natural background radiation in different parts of the world present valuable opportunities for investigation of possible long-term consequences of continuous exposure to ionizing radiation upon man. They also offer possibilities for studies of translocation of heavy radionuclides from soil to man, through food chains. The major pathways for radiation exposure may are usually from direct inhalation of contaminated air or ingestion of contaminated water, or from a less direct pathway – the ingestion of contaminated food products; in terms of internal dosimetry, this pathway can be quite significant as a result of biological concentration in the foodstuff [4]. For most, their harmful effects do not come from their chemistry within tissue, but from the radiation associated with radioactive decay and this is well documented to increases the risk of cancer [4]. Among the natural radionuclides, alpha and beta emitters are considered the most important with respect to potential internal radiation exposure. They are responsible for a significant portion of the radiation exposure of humans to background radiation, particularly through ingestion of food [5].

Cassava (*Manihot esculenta*) is a widely grown crop in most countries in the tropical regions of Africa, Latin America and Asia; and ranks as one of the main crops in the tropical countries [6]. Cassava based products are cheap and reliable source of food for many people in the developing world as well as an alternative to maize in livestock feed [7]. In Nigeria, because of its capacity to yield under marginal soil conditions and its tolerant to drought, it plays a vital role in the food security of the rural economy [8]. According to [9], the crop is a major source of calories for 40% of Nigerians. These and other features endowed it with a special capacity to bridge the gap in food security, poverty alleviation and environmental protection [10]. [11] showed that more than 84% of the people in South-eastern Nigeria eat cassava and cassava-based products daily. Household size, household income, and the cost of substitutes are the determining factors on the amount of cassava based products consumed within the area [12]. The importance of cassava in this area cannot be overemphasized, being the major food cultivated and consumed within the area. And since it constitute a major part of the food consumed daily—this made it a potential source of radionuclide pathway to the population within the area. This study is therefore designed to determine the activity concentrations of the gross alpha and gross beta in cassava samples cultivated within and around the Iva-valley coal mine with the objective to establish the radiological health implications of the population due to consumption of cassava tubers from the old coal mine areas.

2. METHODOLOGY

2.1 Sample Collection and Preparation

The area under consideration was divided into three and was labeled area A, B and C respectively. Area A is the coal mine area, B is the coal processing and distribution plant area and C is located before the Iva-valley settlement and as such has no mining activity around it and has therefore been taken as a control site. A total of 32 cassava tuber samples were collected directly from the farms within the Iva-Valley old coal mine area. Twelve samples were collected from area A and C and a total of eight samples from area B. The number of samples collected from each area was influenced by the extent of agricultural cultivation within the area and accessibility.

2.2 Sample Preparation

The cassava samples were individually dried in an electrical oven at 110ºC to obtain a constant dry weight and then pulverized and sieved to grain size of less than 0.63 mm and sealed in a plastic container. The prepared samples were measured out by 2.5 gram portions, each being held by a binder and fused into pellets with the help of a die and hydraulic press and finally dropped into planchet for the alpha-beta spectrometry.

2.3 Gross Alpha and Beta Counting Procedure

AN EURISYS MEASURE IN 20 a low background multiple (eight) channel alpha and beta counter was used for the measurements of the gross alpha and beta in the cassava samples. It is a gas flow proportional counter with 450 $\mu g/cm^3$ thick window of diameter 60 mm. The counting gas is an argon-methane mixture at the ratio of 90% and 10% respectively [13]. The counting system incorporates an anti-coincident guard counters used to reduce the influence of high energy cosmic radiation that would enter the measuring milieu. The background radiation level within the measuring milieu was estimated to be less than 1.0 mSv/hr. The chambers are covered with 10 cm thick lead and the inside dimensions are 480 x 280 x 105 mm^3. The system is connected to a micro-processor IN-SYST, a spreadsheet programmed QUARTTRO-PRO and a graphic programmer [13]. For the alpha activity measurements the standard used are ^{239}Pu α-sources with activity ranging from 133.3 Bq to 185.8 Bq for the eight channels at 2π-stearadians. The radionuclide impurity in each of them varied from 0.74 – 0.82% [14]. For the beta activity measurements the standard used are ^{90}Sr β-sources of diameter 38 mm and an active film of 12 mg. cm^{-3} thick. For the eight channels, eight sources of activities varied from 105.1-Bq to 117.7Bq at 4π-stearadians. The radionuclide impurity in each of them was less than 0.1%. Cerca and LEA Laboratories in France certified all measurements with certificate No. CT001271/00/1778 – 1783 [14]

The beta and alpha specific activities were calculated using the following expression [15].

$$Specific\ \ Activity\ (\alpha,\beta)\ Bq/kg = \frac{Counting\ \ Rate\ \ (\alpha,\beta) - Background\ \ \ counting\ \ rate\ \ (\alpha,\beta)}{Sample\ \ \ Efficiency\ \times Channel\ \ \ Efficiency\ \times Weight\ \ of\ \ sample}$$

2.4 Statistical Analysis

Due to the coal mining activities in the areas under study, a statistical analysis was performed on the gross alpha and beta activity concentration values. The essence of the statistical analysis was to establish if the coal mining operations has in any way affected the gross alpha and beta activity concentrations within the area. The statistical tool used to ascertain if there is a significant difference between the activity concentrations obtained in the various areas was a one way Analysis of Variance (ANOVA). In using this statistical tool, two hypotheses were propounded: the null and alternative hypothesis.

i. The null hypothesis (H_0)—implies that there is no significant difference in the mean values of the activity concentrations within the area.
ii. The alternative hypothesis (H_1)—implies that there is a significant difference in the mean values of the activity concentrations within the area.

The statistical analyses were performed at 95% confidence level.

3. RESULTS AND DISCUSSION

The gross alpha and beta activity concentrations of cassava (*Manihot esculenta*) samples in area A is presented in Table 1. As could be seen from the table, the activity concentrations for gross alpha ranged from Below Detection Limit (BDL) to 660 Bq/kg while the gross beta activity concentrations ranged from BDL to 1220 Bq/kg. Table 2 presents the gross alpha and beta activity concentrations of the cassava samples in area B. The gross alpha activity concentrations ranged from 20 to 690 Bq/kg while the gross beta activity concentrations ranged from 370 to 1420 Bq/kg. Table 3 presents the gross alpha and beta activity concentrations in area C. The gross alpha activity concentrations ranged from below detection (BDL) to 590 Bq/kg while the gross beta activity concentrations ranged from 70 to 770 Bq/kg. The ranges of beta activity concentrations was observed to be higher than that of the alpha activity concentrations. The results obtained in this study were slightly low when compared with the mean gross alpha and beta activity concentration reported by [16], which reported a mean value of 497 Bq/kg for gross alpha and 1267 Bq/kg for gross beta. In another study carried out by [17], on medicinal crops in Ghana, the gross alpha and beta activity concentrations found out from our study show a much higher gross alpha and beta activity concentrations than those obtained from their study. Most of the values recorded in our study showed a much higher gross alpha and gross beta activity concentrations when compared with the combined of values of ^{40}K, ^{226}Ra and ^{232}Th gamma activity concentrations in cassava as reported by [18] in cassava samples obtained from Jos—a tin mining area. Our result also showed higher activity concentrations than those of [19] reported for tubers in an oil and gas producing area of the country. From the results, the gross alpha and beta activity concentrations within the areas considered were higher when compared to gamma activities obtained in a tin mining area in the northern part of the country by [20]. This was also in agreement with the earlier observations made by [2] and also by [3] attributing Iva valley coal mine area of Enugu as an area with high natural background radiation compared to other cities from south Eastern Nigeria. The higher values for gross alpha and beta activity concentrations obtained in comparison to gamma activities may be due to the fact that the gamma transitions along the Uranium-238 and Thorium-234 decay series is much less than the beta and alpha emitting radio nuclides in the series.

Table 1. Gross alpha and gross beta activity concentration in cassava samples in mine area (location A)

Samples	Gross alpha (Bq/kg)	Gross beta (Bq/kg)
A1	510.00±0.00	580.00±249.00
A2	460.00±10.00	600.00±170.00
A3	BDL	20.00±260.00
A4	660.00±10.00	10.00±270.00
A5	270.00±10.00	710.00±200.00
A6	680.00±50.00	580.00±10.00
A7	530.00±30.00	1220.00±280.00
A8	520.00±20.00	200.00±50.00
A9	580.00±10.00	220.00±100.00
A10	390.00±20.00	650.00±260.00
A11	400.00±10.00	90.00±280.00
A12	150.00±10.00	BDL
Mean	460.00±10.00	440.00±190.00

Table 2. Gross alpha and gross beta activity concentration in cassava samples in coal processing and distribution area (location B)

Sample code	Gross alpha (Bq/kg)	Gross beta (Bq/kg)
B1	280.00±10.00	210.00±20.00
B2	520.00±10.00	640.00±290.00
B3	30.00±20.00	690.00±330.00
B4	20.00±30.00	670.00±40.00
B5	20.00±10.00	120.00±260.00
B6	20.00±20.00	570.00±420.00
B7	590.00±10.00	770.00±270.00
B8	BDL	90.00±290.00
B9	210.00±40.00	560.00±200.00
B10	440.00±30.00	500.00±240.00
B11	BDL	70.00±180.00
B12	60.00±20.00	200.00±310.00
Mean	210.00±20.00	420.00±260.00

Area B, which is where the coal processing plant was situated shows lower gross alpha and beta activity concentration when compared with area A (the coal mine location) and area C (the control area). Generally as could be seen, the highest alpha activity concentrations obtained in the three areas were 680, 590 and 690 Bq/kg, while the minimum alpha activity concentrations were 150, 20 and 20 Bq/kg for areas A, B and C respectively. These show that the least alpha activities in area A where there was coal mining activities were higher than the least alpha activities obtained in areas B—which used to be a coal processing area and also higher than the

alpha activities in area C the control area. For the beta activity concentrations, a maximum of 1220, 770 and 1420 Bq/kg and a minimum of 10, 70 and 370 Bq/kg were recorded for areas A, B and C respectively. This shows high beta activity concentrations within the areas compared to alpha activities. Location as an independent factor reveals not only the nature of transmission of radio nuclides but also their stability and desorption levels are affected by bio-physiological composition of the specific geographic area [21]. Soil features, geological formations and human activities related to radiation and radioactivity are important factors enhancing the background levels of natural radiation [22]. Our result shows that location and human activities has not affected the distribution of gross alpha and gross beta activity concentrations within the areas under consideration. From the test of hypothesis, a one way ANOVA test at 95% statistical confidence level was conducted in order to determine if the coal mining activities over the years has influenced gross alpha and gross beta activity concentrations within the areas. Area C was taken as the control area where mining activities were significantly absent. The one way ANOVA used in testing the mean variations in the gross alpha activity concentrations in the cassava samples for the three areas show an insignificant locational variation for areas A, B and C, at p-value of 0.05. Also, for the gross beta activity concentration, the one way ANOVA test shows no significant locational variation for the gross beta activity concentrations of the three areas A, B and C, at a p-value of 0.05.

Table 3. Gross alpha and gross beta activity concentration in cassava samples in control area (location C)

Sample	Gross alpha (Bq/kg)	Gross beta (Bq/kg)
C1	20.00±10.00	420.00±270.00
C2	200.00±10.00	1050.00±370.00
C3	280.00±10.00	620.00±280.00
C4	500.00±90.00	500.00±240.00
C5	90.00±30.00	370.00±180.00
C6	600.00±10.00	880.00±260.00
C7	690.00±10.00	1420.00±650.00
C8	510.00±20.00	660.00±290.00
Mean	360.00±20.00	740.00±310.00

4. CONCLUSION

Gross alpha and gross beta activity concentrations in cassava samples cultivated around the Iva-valley coal mine of Enugu have been determined. The results showed that the gross alpha and beta activity concentrations within the areas under consideration are relatively evenly distributed. The statistical result shows no significant difference in the mean variations of gross alpha activity concentrations within the three areas considered, while no variation was also observed in the mean gross beta activity concentrations within the area. Results showed that the coal mining activities in the area has not increased the concentrations of gross alpha and gross beta radiation to any significant levels when compared with the control area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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