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Full Length Research Paper

Determination of Activity Concentrations and Annual Effective Doses from Cattle parts in Tin Mining areas of Jos South and Barkin Ladi Local Government areas of Plateau State, Nigeria

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Abstract

The activity concentrations of natural radionuclides ^{40}K, ^{226}Ra, and ^{232}Th in blood, liver heart, and kidney of cattle reared, slaughtered and consumed in the tin mining areas of Jos South and Barkin Ladi Local Government Areas of Plateau State- Nigeria, were determined using gamma ray spectroscopy. The activity concentrations of ^{40}K were the highest in all the samples; which may be attributed to the kind of fertilizer use on farmlands where these animals usually grazed on. The liver from sample B3 has the highest value of ^{40}K with activity concentration of 147.589Bq/kg. The heart from sample B2 has the highest value of ^{226}Ra with activity concentration of 39.9768Bq/kg, while the highest value of activity concentration of ^{232}Th is 58.03876Bq/kg in the heart of sample O. The annual effective doses to man through the ingestion of the radionuclides in the organs were also estimated. The mean annual effective doses for blood, liver, heart and kidney are 9.65±3.9354μSv.y^{1}, 92.2±2.8313μSv.y-^{1}, 16.0±5.8214μSv.y^{1} and 11.63±3.3783μSv.y^{1} respectively. From this work there seem to be a very high possibility that consistent intake (ingestion) of these organs of cattle can lead to longtime health risks to those consuming these organs and the blood from these animals.

Key words: *Activity Concentration, Cattle, Effective Dose, Radionuclides and Plateau State.*

Introduction

We live in a world where radiation is everywhere, occurring from natural to artificial sources. The exposure is determined by two principal factors: exposure due to radiation of external sources and internal due to radioactive contamination that enters the body and is deposited in the human organs. The intake of radionuclide can be obtained by four routes: Inhalation, Ingestion, Injection and Absorption.

Internal radiation exposure hazards result from radioactive material that gets inside the body when you breathe it or eat it or when it passes through your skin. It is important to know how radionuclides move through the environment and into the human body. Plants are the primary recipients of radioactive contamination to the food chain from the environment through the uptake of radioactive debris from the atmosphere by above-ground parts of plants and absorption of debris from the soil by the root system of plants (Aarkrog *et al.,* 1994). It is well known that a major source of energy for metabolic activities in living organisms is food. Ingestion of radionuclides through food intake accounts for substantial part of average radiation dose to various organs of the body and also represents one of the important pathways for long term health consideration (Avadhani *et al.,* 2001). Irradiation of humans can occur via external and internal exposure to radionuclides (Voigt *et al.,* 2007). Doses to humans are estimated by considering ingestion of radionuclides in drinking water and food, external irradiation from radionuclides in soil, and inhalation of radionuclides on airborne dust particles, and these accounts for a substantial part of the average radiation doses received by various organs of the human body (Khan *et al.,* 2010 and Voigt *et al.,* 2007).

The natural and artificial radionuclides that are present in the environment are the main sources of radiation exposure for human beings and constitute the background radiation level. The uptake of radionuclides by animals is dependent on the animal species, mass, age, and growth rate of animal and the digestibility of the feed. Ingestion of soil during grazing can be an important contributor to intake of activity, particularly for radionuclides that are not taken up readily by grass. Hence, contamination of meat is mainly the result of animal grazing, but contaminated drinking water might also be an important pathway. People can therefore be exposed internally to radionuclides through eating the products of animals which have eaten contaminated substances. (Ademola, 2014).

Materials and Method

Different organs of cattle, commonly eaten by the Nigerian populace were collected from two abattoirs. The cattle slaughtered at the abattoirs graze on grasses and eat other feed made from combination of grains grown in the area. The organs include heart, liver, kidney and blood. All the organs were collected from the same cattle at a cost with the exception of the blood and dung. The whole organs from each cattle were collected and labelled to avoid mix up. The samples were frozen before the period of analysis while theblood was sun dried. The other organs were oven dried at a temperature of 100˚C until a constant weight was attained. The dried samples were crushed and grinded. They were weighed and packed in sample containers, sealed and kept for more than four weeks in order to for U, Ra, Th and K short-lived progenies to attain secular radioactive equilibrium.

Each of the soil samples collected were dried and crushed to fine powder with the use of pulverizer. Packaging of the samples into radon-impermeable cylindrical plastic containers which were selected based on the space allocation of the detector vessel which measures 7.6cm by 7.6cm in dimension (geometry) was also carried out. To prevent radon-222 escaping, the packaging in each case was triple sealed.The sealing process included smearing of the inner rim of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight-sealing lid-container with masking adhesive tape. Radon and its short-lived progenies were allowed to reach secular radioactive equilibrium by storing the samples for more than 30 days prior to gamma spectroscopy measurements.

A comparative method between sample and standard was used to calculate the concentration (ppm) of U-238, Th-232 and K-40 in the samples. The Uranium, thorium and potassium standards (RGU-1, RGTh-1 and RGK-1) used in this work were supplied by the International Atomic Energy Agency (IAEA). These are reference materials for gamma-ray spectrometric analysis of organic samples. They are intended for use in calibrating laboratory gamma-ray spectrometers for the determination of U, Th and K in the soil samples.

In RGU-1, the concentration of Uranium on dry weight basis was given as 400ppm and its confidence interval at a significant level of 0.05 was given as ±16ppm. In RG K-1, the concentration of potassium expressed on dry weight basis was given as 44.8%. Its confidence interval was given as ±0.3%. The uranium, thorium and potassium standards supplied by the Centre for Energy Research and Training, A B U, Zaria were counted using the same set up and geometry on the samples and their spectra were acquired. By comparison, between the concentration of radionuclide in samples and standards with their corresponding count rates in count per second per kilogram (c/s.kg), the concentrations of radionuclide were determined for each sample.The activity concentrations of the radionuclides were calculated by first determining the detection efficiencyof the system (Farai, and Ademola,2005 ;Bruzzi *et al*,2000) .

Results and Discussion

The activity concentrations of the three radionuclides in the different organs from cattle in tin mining areas of Jos South and Barkin Ladi Local Government areas of Plateau State followed no particular pattern. There are variations in the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the organs from one sample to the otherand the results are as shown in Tables1-6Radiation doses received due to the intake of food was calculated from the amount of radionuclide deposited on foodstuff, the activity concentration of particular radionuclide in food per unit deposition, the consumption rate of the food products and the dose per unit activity ingested. Annual effective ingestion dose for an adult member of the public due to the intake of radionuclide through ingestion of food can be calculated based on the metabolic models developed by the International Commission of Radiological Protection.

$$H_{T\,r} = \sum(U^i \times C^i_r) \times g_{Tr}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

In the above equation 1 denotes a food group, the coefficients Ui and C^i_r denote the consumption rate (kg·y^{-1}) and activity concentration of the radionuclide r of interest (Bq·kg^{-1}), respectively, and $g_{T,r}$ is the dose conversion coefficient for ingestion of radionuclide r (Sv·Bq^{-1}) in tissue T. For adult members of the public, the recommended dose conversion coefficient $g_{T,r}$ for ^{40}K, ^{226}Ra , and ^{232}Th, are 6.2×10^{-9}, 2.8×10^{-7} and 2.2×10^{-7} Sv·Bq¯1, respectively. Presently, no site specific consumption data exist in the study area and as a result the average per capita of beef consumption between 1961 and 2007 for Nigeria is 0.98 kg·y^{-1} (Ogundari, 2012). This value is used for the other organs of the cattle since there is no such data for them. The above equation was used to calculate the effective dose due to the intake of these organs.

Table 1: Activity concentration of natural radionuclides and effective dose in different organs from sample J1

ORGANS	k-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	EFFECTIVE DOSE(µSv.y^{-1})
BLOOD	137.1695	26.65122	29.07639	14.42
LIVER	71.8507	30.35921	10.83238	11.10
HEART	122.5505	22.36385	36.944	14.85
KIDNEY	106.2208	14.13673	32.7252	11.57

Table 2: Activity concentration of natural radionuclide and effective dose in different organs from sample J2

ORGANS	*k-40 (Bq/Kg)*	*Ra-226 (Bq/Kg)*	*Th-232 (Bq/Kg)*	EFFECTIVE DOSE(µSv.y^{-1})
BLOOD	*104.6656*	*8.922364*	*48.11858*	13.46
LIVER	*72.47278*	*25.95597*	*10.14823*	9.75
HEART	*100.0000*	*20.85747*	*44.12770*	15.85
KIDNEY	*131.5708*	*18.07648*	*17.55986*	9.54

Table 3: Activity concentration of natural radionuclide and effective dose in different organs from sample B1

ORGANS	k-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	EFFECTIVE DOSE($\mu Sv.y^{-1}$)
BLOOD	48.52255	18.8876	19.72634	9.73
LIVER	145.1011	16.5701	22.57696	10.29
HEART	93.15708	24.10197	41.39110	16.10
KIDNEY	90.66874	17.26535	30.55872	11.89

Table 4: Activity concentration of natural radionuclide and effective dose in different organs from sample B2

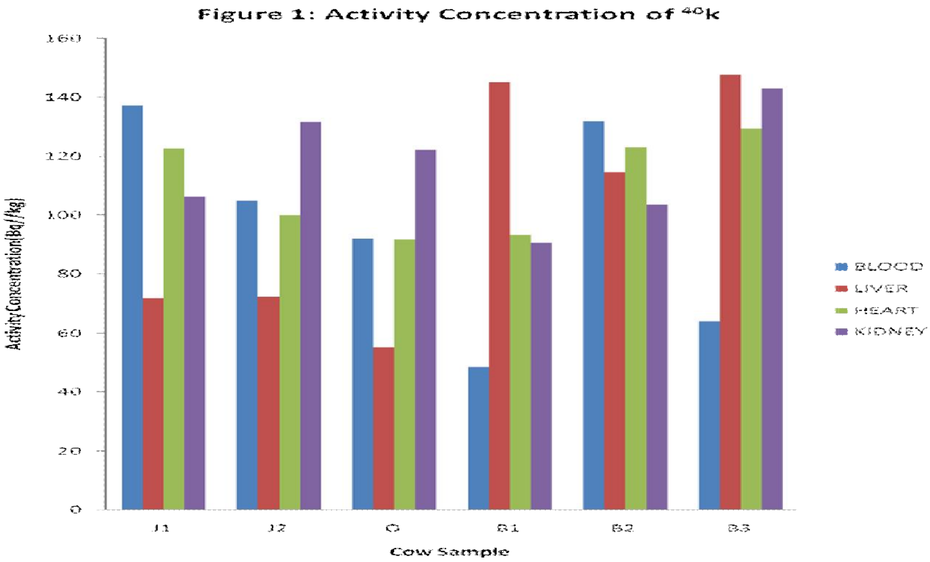
ORGANS	k-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	EFFECTIVE DOSE($\mu Sv.y^{-1}$)
BLOOD	131.8818	19.23523	18.0160	9.96
LIVER	114.7745	24.33372	32.4971	14.38
HEART	123.0171	39.97683	49.03078	22.29
KIDNEY	103.4215	16.5701	21.43671	9.79

Table 5: Activity concentration of natural radionuclide and effective dose in different organs from sample B3

ORGANS	k-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	EFFECTIVE DOSE($\mu Sv.y^{-1}$)
BLOOD	64.07465	7.300116	12.54275	5.09
LIVER	147.5894	7.068366	15.16533	6.10
HEART	129.549	7.531866	14.02508	5.88
KIDNEY	143.0793	16.68598	16.53363	9.01
DUNG	113.8414	14.13673	40.82098	13.37

Table 6: Activity concentration of natural radionuclide and effective dose in different organs from sample O

ORGANS	K-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	EFFECTIVE DOSE($\mu Sv.y^{-1}$)
BLOOD	92.06843	8.458864	11.06043	5.26
LIVER	55.05443	7.64774	25.42759	7.91
HEART	91.60187	29.31634	58.03876	21.11
KIDNEY	122.084	20.85747	54.04789	18.11



Discussion

It should be noted that J1, J2 represent the cows that are reared in mining areas of Jos South LGA, B1, B2, B3 represent cows that are reared in mining areas of Barkin Ladi LGA and O represent cow that is reared in a non-mining area.

A look at Fig 1, shows clearly that ^{40} K has a high activity concentration in the liver from sample B3 (147.589 Bq/kg)and it lowest value(55.05443Bq/kg) in the liver from sample O. ^{226}Ra has a high activity concentration of (39.97683Bq/kg) in the heart from sample B2 and a low value of (7.068366Bq/kg) in the liver from sample B3 as indicated in Fig 2,while the heart from sample O has the highest value of ^{232}Th(58.03876Bq/kg) and the liver of sample J1 has the lowest value of (10.83238Bq/kg) as shown in Fig 3. Potassium-40 is usually of limited interest because, as an isotope of an essential element, it is homeostatically controlled in the human body (Lalit and Shukka, 1980). As a result, the body content of ^{40}K is determined largely by its physiological characteristics rather than by its intake. Of particular radiological interest are ^{226}Ra and ^{232}Th concentrations in the diets. It has been estimated that a large portion of at least one-eighth of the mean annual effective dose due to natural sources can be attributed to the intake of food (Jibiri and Abiodun, 2012). The radionuclides in the naturally occurring ^{232}Th series contribute about 60% to the internal radiation dose.

Figure 2: Activity concentration of ^{226}Ra

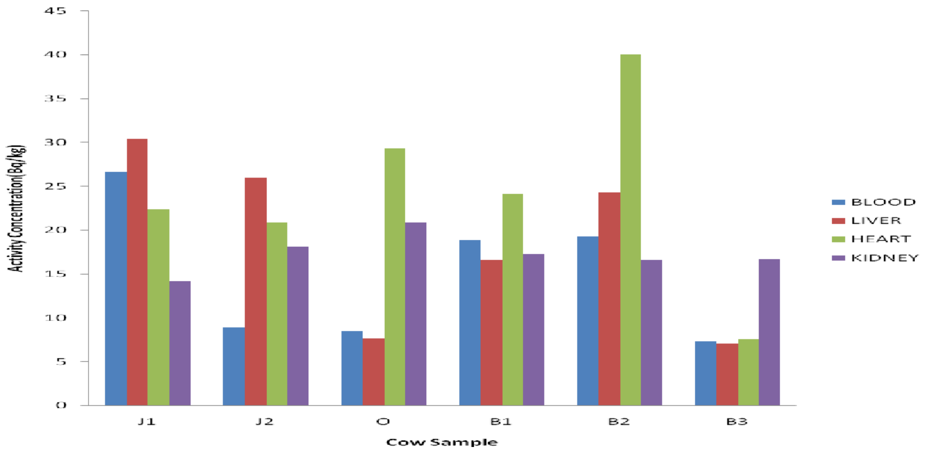
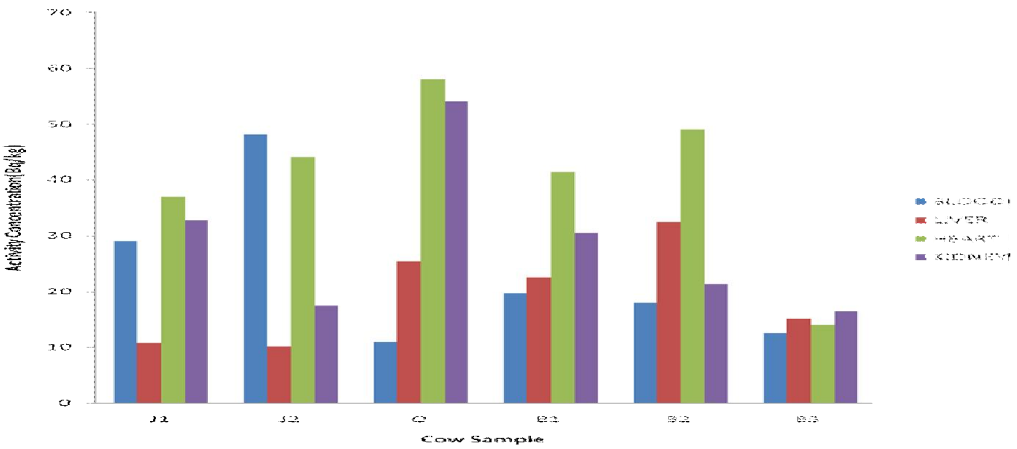


Figure 3: Activity Concentration of ^{232}Th



A general look at the Tables 1- 6 shows that the cumulative effective dose of cattle reared in Barkin Ladi LGA is higher than those that are reared in Jos South LGA. Cattle B2 have the highest value of the total sum of the effective dose of the individual organs. The mining ponds present in these areas and the fact that these cattle graze freely there, could be responsible for the high value of the radionuclide present in those cattle.The results of the effective dose are also presented in Tables 1 -6 above. The effective dose due to the ingestion of ^{40}K ^{226}Ra and ^{232}Th through the consumption of blood ranged from 5.09 μSv.y^{-1}to 14.42μSv.y^{-1} with a mean value of 9.65±3.9354μSv.y^{-1}, The value for liver samples vary from 6.10 μSv.y^{-1} to 14.38μSv.y^{-1} with a mean value of 9.92±2.8313μSv.y^{-1} and that of the heart samples are from 5.88 μSv.y^{-1} to 22.29μSv.y^{-1}, the mean value is 16.01±5.8214μSv.y^{-1} .The Kidney samples have values ranging from 9.01 μSv.y^{-1} to 18.11 μSv.y^{-1} with a mean value of 11.63±3.3783μSv.y^{-1}. The results obtained in this study are lower than those obtained by Ademola (2013) who worked on the estimation of annual effective dose due to ingestion of natural radionuclide in tin mining area of Jos, Plateau State. The mean effective dose ranges from 28.44 ± 15.70 μSv·y^{-1} to 57.89 ± 38.27.μSv·y^{-1} for lungs and liver respectively. The decline in mining activity in most of these sites may be responsible for the decrease in the mean annual effective dose from this work; nevertheless this can have a longtime health effect on those that regularly use these organs as part of their diet. While the work done by Jibiri in Abeokuta where lower compare to this work, the fact that Jos has been identified as a high background radiation areas may be responsible for it (Oresegun and Babalola, 1993, & Ademola,S 2008).

Conclusion

The activity concentrations of natural radionuclides, ^{40} K, ^{226} Ra and ^{232}Th that are present in different organs of cattle slaughtered and consumed in Jos South LGA and Barkin Ladi LGA had been determined using gamma ray spectroscopy. On the average ^{40} K was found to be the highest in all the organs including the blood. The annual effective dose due to the ingestion of the radionuclides in the organs was estimated. The mean annual effective dose varied from 9.65 $\mu Sv \cdot y^{-1}$in blood samples to 16.01$\mu Sv \cdot y^{-1}$andin the heart samples of the cattle**.** With these values it can be said that consistent intake (ingestion) of these organs of cattle can have a longtime health effect on the populace.

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