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Assessment of Radioactivity Contents of Food in the Oil and Gas Producing Areas in Delta State, Nigeria

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ABSTRACT

The radioactivity concentrations of ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs in eighteen species of foodstuffs in the oil and gas producing areas in Delta State, Nigeria have been measured using a high purity germanium, (HPGe) detector system. The mean specific activities of ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs vary between 36.48 – 68.02; 2.33 – 5.18; 1.26 – 2.98 and 0.27 – 2.47 Bq kg^{-1} respectively in vegetables while in fruits the mean specific radioactivities of these radio-nuclides vary between 31.22 – 61.91; 1.17 – 2.67; 0.10 – 1.60 and 0.70 – 3.26 Bq kg^{-1}. In tubers the mean specific radioactivities vary between 49.10 – 202.75; 9.58 – 17.78; 6.92 – 16.60 Bq kg^{-1} in ^{40}K, ^{238}U, ^{232}Th and below detection limit for ^{137}Cs. Similarly the specific radioactivities of the three nuclide vary between 14.41 – 18.17; 4.34 – 6.79; 3.23 – 5.66 Bq kg^{-1} respectively in maize and in meat its mean vary between 329.33 – 392.40; 2.85 – 6.99; 0.67 – 2.84 Bq kg^{-1} respectively while ^{137}Cs is below detection limit in the maize and meat samples. The transfer factor soil-to-food vary between 0.10 – 0.94; 0.03 – 0.57; 0.01 – 0.80 and 0.21 – 0.31 for ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs respectively. Generally the results are low and within the range of internationally recommended limits and no significant radiological hazard was found. The results of this study may be considered as the baseline levels of radioactivities in the foodstuffs in these areas of Nigeria to check future activities in the area. Meanwhile regular monitoring is necessary due the presence of man-made radionuclides ^{137}Cs, to avoid health hazard which may arise as a result of the cumulative effects from the radionuclides.

Keywords: *Radioactivity, Transfer factor, Food, Oil and Gas producing area, Nigeria.*

1. INTRODUCTION

Radionuclides enter the human body through complex mechanism including foodstuffs via the food chain from natural sources. The season of the year determines to a great extent the magnitude of contamination of different foods (IAEA, 1989; Strand et al., 2002). Green leafy vegetables are very prone to external contamination during the raining season, while roots and tubers may also become contaminated (Badran et al., 2003). Grain are subjected to contamination mostly during storage and if fallout occurs during the growing season. Radionuclides may be transported into grains through the plant growth process (Albrecht et al, 2002). Contamination of meat is mainly the result of animal grazing and consumption of contaminated drinking water. Grass is a direct pathway of radionuclides to animals and then to man through meat and milk. The radionuclides contents of grass may provide a basis for deciding whether cattle can be permitted to graze in a given area (Thiry et al., 2002). The most predominant naturally occurring radionuclides in foodstuffs is ^{40}K, Other contributions to the radio-nuclides in foods include deposited fallouts from fission and activation products released during nuclear accidents and constituents of weapons tests released after detonation.

Industrialization has increased several hundred folds in Nigeria from the 1960s, when petroleum was discovered and this encompasses primary, secondary and tertiary industries. The oil industry is the crown jewel of the industrial sector in Nigeria, being responsible for over 80% of the external revenue of the country. It is also the largest user of ionizing radiation. The Niger Delta, with the fragile ecosystem is the oil producing area of the country. It is also a region of intensive shipping. Incidentally, it is a food basket and the sanctuary for one of the world's greatest biodiversity. Yet, wastes from several oil-related activities such as exploration, drilling, production, processing and crude transportation are continuously released into the intricate creeks and creek lets systems of the Niger Delta. In an attempt to protect the environment and ensure sound and good industrial practice, the Department of Petroleum Resources (DPR) and the Federal Ministry of Environment through the Federal Environmental Protection Agency (FEPA) placed a number of regulations to control limits of effluents dischargeable to the environment. It is in order to investigate compliance or otherwise with the Guidelines and Standards of DPR that this research work was instituted amongst others with the directive to carry out radioactivity measurement in some foods samples around the oil and gas production areas of the Delta state. This work is aimed at providing accurate knowledge of the radiation levels and radioactivity concentrations in some foodstuffs from the oil and gas production areas in Delta State, Nigeria. The data collected will be of immense benefits to:

i. assess the significance of these levels in the food chain to man;

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ii. provide technical data for the design of environmental protection practices and Safety Standard;
iii. investigate the transfer ratio of radionuclides from soil to some foods; and
iv. advice the federal, state and local governments, as well as the general public on the radiological consequences of uncontrolled radionuclides content in the environmental

2. INSTRUMENTATION AND METHODS

2.1 Study area

The study area covered the entire Delta State with an area of 17,011 km^2 and a population of about 3,062,676 peoples. It supplies about 35% of Nigeria's crude oil and some considerable amount of natural gas. The geology is basically made up of sand, sandstones, gravel, and clay. Delta State is a state in Nigeria with 25 local government areas.

2.2 Sample collection

A total number of 64 samples of various foods items such as vegetables, fruits, tubers, maize and meat were collected from thirty two major supply towns of the state. The sampling was done directly from the agricultural farms owned by some indigenes based on the population density, farms settlements, and most especially the most consumed foods species.
For vegetables many samples of water leaf (Talinum trangulare), bitter leaf (Vernonia amygdalina), ugu (Telfairia occidental), cassava leaf (Manihot esculentum linn), fresh maize leaf (Zea mays) and grass (Penicun maximum, Synedrellanodiflora gaerin, Andropogon tectorum schum & ttonn) were collected from different locations. Similarly fruits such as oranges (Citrus simansis), pine apples (Annanas sativa), bananas (Musa sapientum) and platains (Musa paradisaca) were collected from different locations. The same goes for tubers such as yams (Dioscorea spp.), cassava (Manihot esculentum linn) and coco-yams (Xanthosona esculentum) as well as maize such as fresh maize (Zea mays) and dried maize (Zea mays). The meat samples consist of goats, chicken, sheep and grass cutters reared or found in different areas of the oil and gas producing areas of the Delta State.

All the samples were each oven-dried at a temperature of 87°C until a constant weight is attained. Each sample was then crushed and sieved using a 2 mm sieve mesh. Each sample was placed in a Marinelli beaker, previously washed, rinsed with diluted HCl and dried. Then each sample in a Marinelli baker was sealed for at least four weeks to allow a sufficient time for ^{238}U and ^{232}Th to attain a state of secular equilibrium with their corresponding progenies prior to gamma spectroscopy.

2.3 Instrumentation

The counting equipment used consists of a Canberra vertical cylindrical high-purity coaxial germanium (HPGe) detector with model GC2018-7500 and serial number b 87063, enclosed in a 100 mm thick lead shield to reduce background contributions. The HPGe detector was connected to a Canberra computer-assisted Multichannel analyzer (MCA). Accurate energy and efficiency calibrations of the gamma-spectrometry system were made using standard sources of radionuclides supplied by the International Atomic Energy Agency (IAEA), Vienna, Austria and the Isotope Products Laboratories, Burbank California, USA. The descriptions of the gamma spectrometry system as well as more details on the calibration are well documented (Fasasi et al. 1999). An empty Marinelli beaker with the same geometry as that of the sample was used as background. The counting time for accumulating spectral for both the samples and background was set at 36,000 s. Each container was counted twice in order to check the stability of the counting system. The gamma spectroscopy analysis employed in this work was based on a computer program SAMPO 90,

The resolution of the HPGe detector made it possible to identify a large number of γ–rays in the samples The photopeaks observed with regularity in the samples were identified as belonging to the radioactive decay series of ^{238}U and ^{232}Th and non-series radionuclides ^{40}K and ^{137}Cs. In some samples ^{137}Cs radionuclide appeared at low levels, or occurred at levels below the detectable limit (BDL). All the measurements were each carried out in a time of 36,000 s. The specific radio-activities of ^{40}K and ^{137}Cs were determined directly by their γ –lines of energies 1460.8 and 661.3 keV respectively while that of ^{238}U and ^{232}Th were estimated by taking the mean of specific radio-activities obtained from the γ –ray lines of energies 609.3 and 1120.3 keV of ^{214}Bi; for ^{238}U and 969.0 keV of ^{228}Ac and 583.0 keV of ^{208}Tl for ^{232}Th

3. RESULTS AND DISCUSSION

3.1 Radioactivity Concentration in the Food Samples

The radioactivity concentration in the food samples are listed in Table 1. Stated in the table are range of the mean of the specific activity, the lowest specific activity and the highest specific activity in vegetables, fruits, tubers, maize and meat for the four

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radionuclides ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs. Also stated are the ones whose radio-activities are below detection limits (BDL)..

3.1.1 Radioactivity Concentration in Vegetables

The mean specific activity of ^{40}K in vegetables ranged between 36.48 – 68.02 Bq kg^{-1} with the lowest specific activity of 32.56±3.15 Bq kg^{-1} in Fresh Maize leaf (Zea mays) and highest of 69.20±6.28 Bq kg^{-1} in cassava leaf (Manihot esculentun linn). Also, although relatively low, the mean specific activity of ^{238}U ranged between 2.33 – 5.18 Bq kg^{-1} with the lowest specific activity of 1.07±0.39 Bq kg^{-1} in water leaf (Talinum triangulare) and highest of 6.13±1.13 Bq kg^{-1} in grass (Andropogon tectorum schum & thonn) which is much lower than the values obtained for elephant grass (Pennisetum) reported by Jibiri et al. (2005). Similarly, the mean specific activity of ^{232}Th ranged between 1.26 – 2.98 Bq kg^{-1} with the lowest specific activity of 0.42±0.08 Bq kg^{-1} in cassava leaf (Manihot esculentun linn) and highest of 4.30±1.08 Bq kg^{-1} in grass (Andropogon tectorum schum & thonn) is safe compared with the values reported by Jibiri et al. (2005). In addition, ^{137}Cs was detected in some vegetables with the mean specific activity in the range between 0.27 – 2.47 Bq kg^{-1} with the lowest specific activity of 0.27±0.08 Bq kg^{-1} in bitter-leaf (Vernonia amygdalina) and highest of 2.47±0.64 Bq kg^{-1} in water leaf (Talinum triangulare). Most of the radioactivity in the vegetables is from ^{40}K. The specific activity from ^{238}U was higher than that of the ^{232}Th and only three of the vegetable samples have traces of ^{137}Cs. The major bedrocks in the study area are well known to accumulate natural occurring radioactive material (Baeza et al. 2001). The levels detected are within the internationally accepted range and comparable with those reported in different parts of the world (Badran et al., 2003, Baeza et al., 2001, Jibiri et al., 2005). Leafy vegetable seems to absorb more potassium than other crops such as fruits and maize.

3.1.2 Radioactivity Concentration in Fruits

In the Fruit samples the mean specific activity from ^{40}K ranged between 31.22 – 50.87 Bq kg^{-1} with the lowest specific activity of 28.16±4.27 Bq kg^{-1} in oranges (Citrus simansis) and highest of 52.21±5.61 Bq kg^{-1} in plantains (Musa paradisaca). Also, the mean specific activity of ^{238}U ranged between 1.17 – 1.78 Bq kg^{-1} with the lowest specific activity of 0.78±0.09 Bq kg^{-1} in bananas (Musa sapientum) and highest of 2.17±0.37 Bq kg^{-1} this time in oranges (Citrus simansis). Similarly, the mean specific activity of ^{232}Th ranged between 0.10 – 1.02 Bq kg^{-1} with the lowest specific activity of 0.10±0.02 Bq kg^{-1} in bananas (Musa sapientum) and highest of 1.02±0.06 Bq kg^{-1} in plantains (Musa paradisaca). In addition, ^{137}Cs was detected in orange and Platain with the mean specific activity in the range between 0.70 – 3.26 Bq kg^{-1} with the lowest specific activity of 0.70±0.17 Bq kg^{-1} in oranges (Citrus simansis) and highest of 3.26±0.97 Bq kg^{-1} in plantains (Musa paradisaca). Most of the radioactivity in the fruits is from ^{40}K. The specific activity from ^{238}U was higher than that of the ^{232}Th and ^{137}Cs is below the detection limit in pine apples (Annanas sativa) and bananas (Musa sapientum). In fact, the high activity concentration of ^{137}Cs in plantain at location 32 came mainly from the soil at this location which recorded the highest activity concentration of 24.73 ± 2.08 Bq kg^{-1} of ^{137}Cs (Tchokossa et al., 2012). Generally, the radioactivity levels detected are within the internationally accepted range and comparable with those reported by Aborisade et al., 2003).

3.1.3 Radioactivity Concentration in Tubers

As shown in Table 1 the mean specific activity of ^{40}K in the tubers is relatively high compared with those of vegetables, fruits and maize except those of meat and the values ranged between 49.10 – 202.75 Bq kg^{-1} with the lowest specific activity of 48.42±4.39 Bq kg^{-1} in coco-yams (Xanthosona esculentum) and highest of 207.16±19.68 Bq kg^{-1} in cassava (Manihot esculentun linn). Also, the mean specific activity of ^{238}U was the highest in all the food samples and it ranged between 9.58 – 17.78 Bq kg^{-1} with the lowest specific activity of 9.14±2.70 Bq kg^{-1} in coco-yams (Xanthosona esculentum) and highest of 18.51±3.49 Bq kg^{-1} in yams (Dioscorea spp.). Similarly, the mean specific activity of ^{232}Th was consistently high in tubers compared to other food samples and the values ranged between 6.92 –16.60 Bq kg^{-1} with the lowest specific activity of 6.53±2.08 Bq kg^{-1} in coco-yams (Xanthosona esculentum) and highest of 16.70±5.02 Bq kg^{-1} in yams (Dioscorea spp.). However, ^{137}Cs was not detected in any of the tubers. Most of the radioactivity in the tubers is from ^{40}K. The specific activity from ^{238}U was slightly higher than that of the ^{232}Th. The tubers yams (Dioscorea spp.) and cassava (Manihot esculentum linn) are usually big in size and long penetrating into the soil with increased ability to absorb more natural radionuclides in the soil than the coco-yams (Xanthosona esculentum) which are usually short in length. All the tubers are buried in the soil with poor absorption of man-made ground surface deposited ^{137}Cs. The levels detected, although relatively high, are within the internationally accepted range and comparable with those reported in different parts of the world (Badran et al., 2003, Baeza et al., 2001, Jibiri et al., 2005).

3.1.4 Radioactivity Concentration in Maize

The mean specific activity of ^{40}K in maize is 16.29±3.20 Bq kg^{-1} with the lowest specific activity of 14.41±3.03 Bq kg^{-1} in dried Maize and highest of 18.17±3.38 Bq kg^{-1} in fresh red maize. Also, although relatively low, the mean specific activity of ^{238}U is 5.56±1.15 Bq kg^{-1} with the lowest specific activity of 4.34±1.24 Bq kg^{-1} this time in fresh red maize and highest of 6.79±1.07 Bq kg^{-1} in dried maize. Similarly, the mean specific activity of ^{232}Th is 4.45±1.57 Bq kg^{-1} with the lowest specific activity of 3.23±1.36 Bq kg^{-1} in fresh red maize and highest of 5.66±1.77 Bq kg^{-1} in dried maize However, ^{137}Cs was below

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detected in all the maize samples. Although relatively low, most of the radioactivity in the maize samples is from ^{40}K. The specific activity from ^{238}U was comparable with that of the ^{232}Th. The levels detected are within the internationally accepted range and comparable with those reported by Olomo et. al. (1999).

3.1.5 Radioactivity Concentration in Meat

As shown in Table 1 the mean specific activity of ^{40}K in meat is higher than those of other food samples in this study and the values ranged between 329.37 – 392 Bq kg^{-1} with the lowest specific activity of 274.54±22.05 Bq kg^{-1} in Goat and highest of 428.13±21.75 Bq kg^{-1} in chicken. The reverse is the case with the mean specific activity of ^{238}U ranging between 2.85 – 6.99 Bq kg^{-1} but the lowest specific activity of 2.40±0.97 Bq kg^{-1} in chicken and highest of 7.72±2.15 Bq kg^{-1} in goat. Similarly, the mean specific activity of ^{232}Th ranged between 0.67 –2.84 Bq kg^{-1} with the lowest specific activity of 0.65±0.47 Bq kg^{-1} in sheep and highest of 3.06±0.12 Bq kg^{-1} in goat. However, ^{137}Cs was not detected in any of the meat samples. Most of the radioactivity in the meat is from ^{40}K. The specific activity from ^{238}U was higher than those of ^{232}Th. The radioactivity levels detected, although relatively high compared with that reported by Olomo et al. (1999), are within the internationally accepted range.

3.2 Transfer Factor Evaluation from Soil to Food

The transfer factor (TF) for food according to IAEA (1982) is defined as:

$$TF_{food} = \frac{\text{Activity concentration of Food (Bq kg}^{-1})}{\text{Activity concentration of Soil (Bq kg}^{-1})} \quad \ldots\ldots\ldots\ldots(1)$$

In Table 2 are shown the activity concentration of soil in some locations (Tchokossa et al., 2012), activity concentration in different types of food and the transfer factor for each food type for ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs. The radioactivity of the atmospheric fallouts was very low and below detection limit in some cases. Therefore, the radioactivity from the plants was mostly through the root. The range of the TF of ^{40}K from soil to plant was estimated to be between 0.1- 0.94 for ^{40}K with the highest in dried maize (Zea mays) and the lowest in grass (Panicun maximum). The values of the TF depend on location and the ^{40}K activity concentration. Some areas with low activity concentration recorded high TF. Similarly, the TF ranged between 0.03 - 0.57 for ^{238}U with the highest in fresh red maize (Zeamays) and the lowest in banana (Musa sapientun). Also, the TF ranged between 0.01 – 0.80 for ^{232}Th with the highest in Plantain (Musa paradisaca) and lowest in Pineapple (Annanas sativa). However, it is not the same with ^{137}Cs where activity concentration is below detection limit in most food samples. The TF ranged between 0.06 – 0.31 for ^{137}Cs where detected and measured, with the highest in grass (Panicun maximum) and lowest in Orange (Citrus simansis).

Plantain (Musa paradisaca) is one of the three food samples that the four radionuclides ^{40}K. ^{238}U. ^{232}Th and ^{137}Cs were detected with consistently relatively high TF values. Surprisingly this observation is not the same with similar plants which are planted under similar condition and absorb plenty of water. Banana and pineapple presented the overall lowest TF of 0.10 and 0. 12 respectively for ^{40}K as well as 0.03 and 0.04 for ^{238}U. Potassium-40 seems to concentrate more in dried maize, pineapple and bitter-leafs with a TF of 0.94, 076 and 0.59 respectively. Fresh red maize and bitter-leafs have greater affinity for ^{238}U than others with a TF of 0.57 and 0.56 respectively; while for ^{232}Th, the values of TF in fresh red maize and dried maize are relatively high compared to other food types. Thorium-232 was below detection limit is a few food samples and ^{137}Cs is below detection limit in most of the food samples. Grass seems to absorb ^{137}Cs more than other plants may be because of the soil surface deposition of the radionuclide. Our results are within the ranges investigated by others workers (Chih-Jung et al., 1997; Baeza et al., 2001).

Care must be taken in the use of the transfer factor to assess food type for consumption and the health implications. For example, the TF is 0.46 for ^{40}K with radioactivity concentration of 207.16 Bq kg^{-1} in cassava (Manibot esculentum) while the TF of 0.94 was recorded for ^{40}K in dried maize (Zea mays) with radioactivity concentration of 14.41 Bq kg^{-1}. Radioactivity concentration levels particularly ^{40}K in meat samples are in some cases much higher than that of the grass where they were raised.

4. CONCLUSION

Radioactivity concentration was highest in meat out of all the food types studied and the activity was mainly from ^{40}K. This was closely followed by the activity concentration from tubers which also recorded the highest radioactivity concentration values for ^{238}U and ^{232}Th. Traces of ^{137}Cs, which is associated with fallouts was only found in some vegetables and fruits. The radioactivity of ^{137}Cs was below detection limit in tubers, maize and meat. The transfer factor varies with location and food type. Generally, the level of radioactivity is relatively low in all the food samples and within the limits of internationally acceptable values. Therefore, the food types in this study grown in this area are radio-logically safe for human consumption. Although they are safe, a community based awareness programme on the issue of environmental contamination, its health impacts and possible prevention, is advisable.

REFERENCES

[1]. Aborisade C. A., Olomo J.B. and Tchokossa P. (2003) "Radioactivity in Palm Oil produced at Olabisi

Ogunbanjo University Oil Mill" Nigeria Journal of Physics Vol. 15 (1) 17-19.

[2]. Albrecht A., Schultze, U., Liedgens, M., Fluhler, H. and Frossard E. (2002) "Incorporating soil structure and root distribution into plant uptake models for radionuclides: toward a more physically based transfer model". Journal of Environmental Radioactivity 59: 329-350.

[3]. Badran, H.M., Sharshar T. and Elnimer T. (2003). "Levels of ^{137}Cs and ^{40}K in edibles parts of some vegetables consumed in Egypt" Journal of Environmental Radioactivity 67, 181-190..

[4]. Baeza, A., Paniagua, J., Rufo, M., Guillen, J. and Sterling, A., (2001) "Seasonal variations inradionuclide transfer in a Mediterranean grazing-land ecosystem". Journal of Environmental Radioactivity 55:283-302.

[5]. Chih-Jung W., Shu-Ying L., Jeng-Jong W. and Yu-Ming L. (1997) "Transfer of radionuclides from soil to grass in Northern Taiwan" Applied Radiation and Isotopes Vol. 48, No. 2, 301 – 303.

[6]. Fasasi, M.K.; Tchokossa, P.; Ojo J.O.; Balogun, F.A. (1999) "Occurrence of natural radionuclides and fallout Cesium – 137 in dry-season agricultural land of South Western Nigeria". Journal of Radioanalytical and Nuclear Chemistry 240, 949.

[7]. IAEA (1982) International Atomic Energy Agency, "Generic models and parameters for assessing the environmental transfer of radionuclides from routine releases", Safety Series 57, 61 – 65.

[8]. IAEA (1989) International Atomic Energy Agency, "Measurements of radionuclides in food and the environment", A guidebook, Technical Report Series No. 295, IAEA, Vienna.

[9]. Jibiri, N. N., Ajao, A. O., (2005) Natural activities of ^{40}K, ^{238}U and ^{232}Th in elephant grass (Pennisetum purpureum) in Ibadan metropolis, Nigeria. J. of Enviro. Radiot. 78, 105-111

[10]. Olomo J.B. (1990) "The natural radioactivity in some Nigerian foodstuffs". Nuclear Instruments and Methods in Physics Research A 299, 666 - 669.

[11]. Strand, P., Howard, B.J., Aarkrog A. et al. (2002) "Radioactive contamination in the Arctic-sources, dose assessment and potential risks". Journal of Environmental Radioactivity 60: 5 – 21.

[12]. Swanson S.M. (1983) "Levels of ^{226}Ra, ^{210}Pb and total U in fish near a Saskatchewan uranium mine and mill". Health Physics 45: (1) 67 – 80.

[13]. Tchokossa P., Olomo, J.B. Balogun F.A. and Adesanmi C.A. (2012) "Radiological Study of Soil in Oil and Gas Producing Areas in Delta State, Nigeria". Radiation Protection Dosimetry 1 – 6. doi: 10.1093/rpd/ncs101

[14]. Thiry, Y., Goor, F., and Riesen T. (2002) "The true distribution and accumulation of radiocaesium in stem of Scots pine (Pinus sylvestris L)". Journal of Environmental Radioactivity 58: 243 – 259.

Table 1: Radioactivity Concentration in Food Samples from the Oil and Gas Producing Areas in Delta State, Nigeria ($Bq\ kg^{-1}$)

Name	Measured Parameters	K-40	U-238	Th-232	Cs-137 *
Vegetables	Range of Mean Specific Activity	36.48±8.31 - 68.02±15.47	2.33±0.93 - 5.18±3.60	1.26±0.66 - 2.98±1.20	0.27±0.08 - 2.47±0.64
	Lowest Specific Activity	32.56±3.15	1.07±0.39	0.42±0.08	0.27±0.08
	Highest Specific Activity	69.70±6.28	6.13±1.13	4.30±1.08	2.47±0.64
Fruits	Range of Mean Specific Activity	31.22±10.91 - 61.91±14.44	1.17±0.18 - 2.67±1.59	0.10±0.02 - 1.60±0.30	0.70±0.17 - 3.26±0.97
	Lowest Specific Activity	28.16±4.27	0.78±0.09	0.10±0.02	0.70±0.17
	Highest Specific Activity	67.34±8.35	3.07±0.86	1.60±0.30	6.30±1.43
Tubers	Range of Mean Specific Activity	49.10±4.70 - 202.75±8.75	9.58±2.32 - 17.78±2.82	6.92±2.01 - 16.60±4.67	BDL
	Lowest Specific Activity	48.42±4.39	9.14±2.70	6.53±2.03	BDL

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	Highest Specific Activity	207.16±19.68	18.51±3.49	16.70±5.02	BDL
Maize	Mean Specific Activity	16.29±3.20	5.56±1.15	4.45±1.57	BDL
	Lowest Specific Activity	14.41±3.03	4.34±1.24	3.23±1.36	BDL
	Highest Specific Activity	18.17±3.38	6.79±1.07	5.66±1.77	BDL
Meat	Range of Mean Specific Activity	329.33±33.97-392.40±41.03	2.85±1.76 - 6.99±4.29	0.67±0.08 - 2.84±0.17	BDL
	Lowest Specific Activity	274.54±22.05	2.40±0.97	0.67±0.08	BDL
	Highest Secific Activity	428.13±21.75	7.72±2.15	3.06±0.12	BDL

* BDL means Below Detection Limit.

Table 2: Transfer Factor Soil to Food

Location	Name	Measured * Parameters	K-40	U-238	Th-232	Cs-137
2	Fresh Red Maize (Zeamays)	Soil Spec. Activity	123.59	7.59	7.81	2.07
		Food Specific. Act	18.17	4.34	3.23	BDL
		Transfer Factor	0.15	0.57	0.41	
3	Orange (Citrus simansis)	Soil Spec. Activity	103.92	11.64	18.87	10.70
		Food Specific. Act	28.16	1.24	0.30	0.70
		Transfer Factor	0.27	0.11	0.02	0.06
6	Grass (Panicun maximum)	Soil Spec. Activity	474.11	16.15	14.10	3.49
		Food Specific. Act	47.21	5.62	3.97	1.08
		Transfer Factor	0.10	0.35	0.28	0.31
12	Better Leaf (Vemonia anygdalina)	Soil Spec. Activity	83.99	8.35	7.04	BDL
		Food Specific. Act	49.52	4.65	2.30	BDL
		Transfer Factor	0.12	0.56	0.33	VDC
20	Pineapple (Annanas sativa)	Soil Spec. Activity	388.42	51.55	54.35	BDL
		Food Specific. Act	46.46	1,86	BDL	BDL
		Transfer Factor	0.12	0.04	VNC	VNC
21	Dried Maize (Zea mays)	Soil Spec. Activity	15.30	14.37	14.55	6.28
		Food Specific. Act	14.41	6.79	5.66	BDL
		Transfer Factor	0.94	0.47	0.39	VNC
22	Pineapple 2 (Annanas sativa)	Soil Spec. Activity	55.81	20.17	14.17	1.28
		Food Specific. Act	42.37	0.98	0.11	BDL
		Transfer Factor	0.76	0.05	0.01	VNC
25	Grass (Andropogon tectonum	Soil Spec. Activity	396.55	23.44	45.42	1.09
		Food Specific. Act	56.51	6.11	4.30	BDL
		Transfer Factor	0.14	0.26	0.09	VNC
29	Yam (Dioscorea spp.)	Soil Spec. Activity	696.54	60.12	65.68	BDL
		Food Specific. Act	146.38	18.51	16.49	BDL
		Transfer Factor	0.38	0.31	0.25	VNC
30	Banana (Musa sapientun)	Soil Spec. Activity	104.10	47.70	48.37	BDL
		Food Specific. Act	48.77	1.56	BDL	BDL
		Transfer Factor	0.16	0.03	VNC	VNC
31	Cassava (Manibot esculentun)	Soil Spec. Activity	448.86	43.03	44.22	BDL
		Food Specific. Act	207.16	14.76	11.24	BDL
		Transfer Factor	0.46	0.34	0.25	VNC
32	Plantain (Musa paradisaca)	Soil Spec. Activity	116.93	8.75	12.44	15.57
		Food Specific. Act	52.21	2.17	1.02	3.25
		Transfer Factor	0.45	0.25	0.8	0.21

*Spec. Activity = Specific Act = Specific Activity (**Bq kg^{-1}**); **BDL = Below Detection Limit, VNC=Value Not Computed.**