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Transfer of Natural Radionuclides from Soil to Plants in Nasarawa, Nasarawa State, Nigeria.

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Abstract: Natural radioactivity and its corresponding gamma radiation exposure demonstrate geological and geographical dependence. Such materials exist at varying levels in different regions worldwide. Primordial isotopes of ^{226} Ra, ^{232}Th and ^{40}k are the main sources of external radiation on earth. The research aimed at assess the Transfer factor of natural radionuclides from soil to plants and grass in the Nasarawa, Nasarawa state, Nigeria. The results revealed that, the plant transfer factor of ^{40}K in Crop has the average of 2.02±0.17 which is higher compared to the IAEA recommended value for soil to plant transfer factor of ^{40}K of 1.4. On ^{226}Ra, IAEA has greater value for soil-to-plant TF for ^{226}Ra compared to the present study which was found to be 0.84±0.8. In general, the values for ^{232}Th TF (1.18±0.72) were lower than those values reported in the default values suggested by IAEA. The mean concentration of all the radioisotopes in the crop may not cause instant health hazard to the public but there may be a long-term accumulative effect following present dose intake from the consumption of the crop (cassava).

Keywords: Transfer Factor, Specific Activity, Cassava, Potassium, Radium and Thorium.

1 Introduction

Natural radioactivity and its corresponding gamma radiation exposure demonstrate geological and geographical dependence. Such materials exist at varying levels in different regions worldwide [1,2]. Primordial isotopes of ^{226} Ra, ^{232}Th and ^{40}k are the main sources of external radiation on earth; [3,4]. These radionuclides, along with essential nutrients, may be absorbed from the soil via plant roots and transported to other parts of the plant [5]. The presence of radioactivity in the edible parts of crops causes human internal exposure to ^{226}Ra and ^{232}Th which are radiotoxic elements, whereas ^{40}K is both radiotoxic and nutritionally important [6]. Natural exposures arise mainly from the primordial radionuclides which are distributed widely and are present in almost all geological materials in the earth's environment. These radionuclides are known as naturally occurring radioactive material 'NORM'. the majority of naturally occurring radionuclide belong to the radionuclides in the ^{238}U and ^{232}Th series, and the single decay radionuclide, ^{40}K, the most common radiation exposure to which all individual are exposed, both in public places and in working environment is the ionizing radiation which arises from the Radionuclides in the earth's environment and the interaction of cosmic rays on the earth's atmosphere (atm) [7]. According to [8] National Council on Radiation Protection and Measurements, the most significant source of radiation exposure to man is from the natural radiation in the environment.

There is always a need to have background level information about natural radionuclides and the radiological impact of radionuclides released in the environment, which is usually predicted by mathematical models in which the transfer of radionuclides from soil to the plant is described with the transfer factor (TF) [9,10]. The most commonly encountered radionuclides are ^{226}Ra, ^{232}Th, their decay products and ^{40}K. It is important to understand the behavior of natural radionuclides in the environment (distribution pathways, mobility, transfers, etc.) because the information can be used as a natural analogue for the long-term behavior of materials, processes in developing and testing models, and in obtaining the associated parameter values appropriate for radiological performance assessments [11,12].

Many studies on food contamination radionuclides in the environment and their transfer or pathway mechanism to

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plant, animals, and human population have been reported. Considerable efforts are being made by many authors in many parts of the world to measure the activity of radionuclides in the food chain and to estimate the soil-plant transfer [13,14].

Interactions between radionuclides and plants are very complicated and depend on many factors such as type and shape of plants, soil characteristics, behavior of radionuclides, climatic conditions, etc [15,16].

In many states across the country, wastes are usually burnt outdoors and ashes are poorly disposed at dump-site, the process destroys the organic components and causes the oxidation of metals. The ashes from the burnt waste is enriched with metal, which results in pollution of the present environment/Soil. [17-20].

Following the fact that food is one of the most important needs of man and the increasing world population has become a threat to global food security. The need to increase food production therefore arises to ensure food security for the growing world population [21].

Just like the rest of the world, Nigeria's population is increasing and there is also the need to increase availability of food by increasing the rate of food production that is free from unnecessary exposure to radiation. Cassava as a tuber is one of the staple foods for over one billion (1,000,000,000) people in the developing world, [22,23]. In Nigeria, it appears to be the major staple food that matches population growth [24].

Cassava is a tropical, perennial plant with an dibble root serving as a major source of carbohydrates in human diet as a vegetable and is considered to be toxic in raw form therefore it must be cooked before being consumed [25]. Cassava originated from tropical America and was first introduced in Africa in the Congo basin by the Portuguese around 1558. Cassava has been the major source of the production of dry chips, used as animal feed, ethanol production, with more secondary products like textile, soft drinks adhesives etc [26]. starch making which is used in the production of biscuits, bread custard powder, baby food etc [27]. These products are highly commercialized. Generally, Africans depends much on root and tuber crops more than other Continents in feeding its population, it is processed in several forms in Nigeria such as garri (for making eba popular food in Nigeria), fufu, tapioca, (African salad) served with nuts and coconut [28].
This study tends to unveil the extent to which radionuclides are transferred from soil to crops as well as the hazards of man's continual consumption in Nasarawa.

2 Materials and Methods

2.1 Materials

The materials used for this study are;

- Auger
- Compass
- Global Positioning System (G.P.S)
- Disposable Hand Glove
- Measuring Tape
- Masking Adhesive Tape
- Marker pen
- Jotter and pen
- Polythene Bags
- Sacks
- Mortar and Pestle
- 5mm-Mesh Sieve
- Cylindrical Plastic Container
- Electronic Analytical Balance
- Cutlass
- Sealer
- Sodium Iodide-Thalium Gamma Spectroscopic System

2.2. Method

2.2.1. Sample Size

Total of twenty (20) sample (10 soil and 10 cassava) were collected from selected dump sites in Nasarawa, Nasarawa Local Government Area of Nasarawa State.

2.2.2. Method of Soil Sample Collection and Preparation

Total of ten (10) samples of soil were collected from ten (10) different points using a hand trowel, from the refuse dumpsites dump sites in Nasarawa, Nasarawa Local Government Area of Nasarawa State, at 20cm depth according to [29]. After which, the samples were grinded to powdery form and sieved through a 2 mm mesh and air-dried for 3-5 weeks. The sample were weighed to 200 g of each soil and packed in special air tight polyethlen plastic containers and closed (tightly) sealed using masking –tape for 28 days to give room for secular equilibrium before gamma counting [29].

2.2.3. Method of Cassava (Crop) Sample Collection and Preparation

Total of ten (10) cassava samples were collected from ten (10) different points within Nasarawa dump sites. The samples were peeled and washed with pipe-borne water to remove the dust and mud content from it. The tubers samples were chopped and sun- dried according to its location and sample point for about three (3) weeks, then grinded in a powdered form to achieve homogeneity and then filled in an air-tight polyethylene material for 28 days to achieve secular equilibrium all the samples are in 200 g (0.2kg)

2.2.4. Sample Analysis

The transfer Factor (TF) is defined as the ratio of the activity concentration in a plant part (Bqkg^{-1} dry weight) to the activity concentration in soil (Bqkg^{-1} dry weight). It is calculated following a simple model which is also recommended by International Union of Radioecology (IUR) and it's standardized root location of 10-20 cm in order to deal with the soil depth variability [29].

$$TF = \frac{A_p(Bq/kg)}{A_s(Bq/kg)} \qquad 1$$

Where;

Ap = Activity concentration of radionuclide (isotopes) of plant (Bqkg^{-1}dry weight).

As = Activity Concentration of radionuclides (Isotopes) of soil (Bqkg^{-1}dry weight).

3. Results Presentation and Discussion

3.1. Results Presentation

Table 1: Activity Concentration of Radionuclide in Crops Sample.

S/N	Sample Code	^{40}K	^{226}Ra	^{232}Th
1	NS CAS 01	264.30±44.75	08.45±2.36	13.20±1.40
2	NS CAS 02	294.33±47.13	20.12±2.34	01.20±0.12
3	NS CAS 03	132.62±34.50	06.16±3.80	29.99±4.92
4	NS CAS 04	223.23±41.80	05.97±1.64	24.32±3.54
5	NS CAS 05	380.22±54.11	01.34±0.25	26.40±3.77
6	NS CAS 06	400.00±66.72	27.29±2.88	03.49±0.36
7	NS CAS 07	126.90±26.40	25.63±8.40	18.32±1.92
8	NS CAS 08	111.02±21.90	07.23±1.23	28.50±2.32
9	NS CAS 09	252.01±21.09	05.33±3.20	23.15±0.34
10	NS CAS 10	053.24±20.12	23.22±2.71	22.51±2.18
11	**Average**	**223.79±33.85**	**13.07±2.88**	**19.11±2.09**
12	**Min**	**053.24±20.12**	**01.34±0.25**	**01.20±0.12**
13	**Max**	**400.00±66.72**	**27.29±2.88**	**29.99±4.92**
14	**ICRP**	**400.00**	**30.00**	**35.00**

The result for the activity concentration of radionuclide of potassium (^{40}K), Uranium (^{226}Ra) and Thorium (^{232}Th) in cassava crop samples are presented in table 1. The activity concentration due potassium (^{40}K) ranged from 053.24±20.12 to 400.00±66.72 with its mean value of 223.79±33.85 Bqkg^{-1}, the concentration of radium (^{226}Ra) varies between 01.34±0.25 to 27.29±2.88 with its mean value of 13.07±2.88 Bqkg^{-1} and the concentration of thorium (^{232}Th) varies between 01.20±0.12 to 29.99±4.92 with its mean value of 19.11±2.09 Bqkg^{-1} respectively.

Table 2: Activity Concentration of Radionuclides in Soil Samples.

S/N	Sample Code	^{40}K	^{226}Ra	^{232}Th
1	NS SOIL 01	019.01±2.13	2.32 ± 0.70	5.32 ± 0.43
2	NS SOIL 02	032.80±2.53	9.42 ± 2.30	3.90 ± 0.30
3	NS SOIL 03	050.32±3.81	9.10 ± 2.10	8.50 ± 0.73
4	NS SOIL 04	291.30±2.04	8.10 ± 1.80	5.32 ± 0.42
5	NS SOIL 05	027.44±3.05	22.11±1.10	22.71±1.55
6	NS SOIL 06	064.50±6.82	19.47±5.51	27.73±8.43
7	NS SOIL 07	127.88±2.81	13.53±3.78	9.00±1.010
8	NS SOIL 08	129.92±3.60	27.15±7.66	22.76±7.08
9	NS SOIL 09	272.86±2.83	22.14±7.66	29.74±3.06
10	NS SOIL 10	089.35±2.66	23.22±3.26	27.22±6.15
11	**Average**	**110.54±3.23**	**15.66±3.59**	**16.22±2.92**
12	**Min**	**019.01±2.13**	**2.32 ± 0.70**	**5.32 ± 0.43**
13	**Max**	**291.30±2.04**	**27.15±7.66**	**29.74±3.06**
14	**ICRP**	**400.00**	**30.00**	**35.00**

The result for the activity concentration of radionuclide of potassium (^{40}K), Radium (^{226}Ra) and Thorium (^{232}Th) in soil samples are presented in Table 2. The activity concentration due potassium (^{40}K), radium (^{226}Ra) and thorium (^{232}Th) ranged from 019.01±2.13 to 291.30±2.04 Bqkg^{-1} with its mean value of 110.54±3.23 Bqkg^{-1}, 2.32 ± 0.70 to 27.15±7.66 with its mean value of 15.66±3.59 and 5.32 ± 0.43 to 29.74±3.06 with its mean value of 16.22±2.92 Bq/kg respectively.

Table 3: Transfer Factor.

S/No	**Sample**	**^{40}K**	**^{226}Ra**	**^{232}Th**
1	NS 01	13.90±21.01	3.64±3.37	2.48±3.26
2	NS 02	08.97±18.63	2.14±1.02	0.31±0.40
3	NS 03	02.64±9.060	0.68±1.81	3.53±6.74
4	NS 04	00.77±20.49	0.74±0.91	4.57±8.43
5	NS 05	13.86±17.74	0.06±0.23	1.16±2.43
6	NS 06	06.20±9.780	1.40±0.52	0.13±0.05
7	NS 07	00.99±9.400	1.90±2.22	2.04±1.90
8	NS 08	00.85±6.080	0.27±0.16	1.25±0.33
9	NS 09	00.92±0.010	0.24±0.42	0.78±0.11
10	NS 10	00.60±7.560	1.00±0.83	0.83±0.35
11	**Min**	**0.60±7.56**	**0.06±0.23**	**0.13±0.40**
12	**Max**	**13.90±21.01**	**3.64±3.37**	**4.57±8.43**
13	**Average**	**02.02±0.170**	**0.84±0.80**	**1.18±0.72**
14	**Sum**	**49.70±119.76**	**12.06±11.50**	**17.07±243.0**

The result for the transfer factor of the activity concentration of radionuclide of potassium (^{40}K), Radium (^{226}Ra) and Thorium (^{232}Th) from soil to water are presented in Table 3. The transfer factor of potassium (^{40}K), radium (^{226}Ra) and thorium (^{232}Th) ranged from 0.60±7.56 to 13.90±21.01 Bqkg^{-1} with its mean value of 02.02±0.170 Bqkg^{-1}, 0.06±0.23 to 3.64±3.37 with its mean value of 0.84±0.80 and 0.13±0.40 to 4.57±8.43 with its mean value of 1.18±0.72 Bq/kg respectively.

3.1.1. Comparison of Results with International Commission on Radiation Protection

In this section, the results presented in Table 1, 2 and 3 were used to plot the charts as presented in Fifure 1, 2 and 3 in order to compare the present study with the International Commission on Radiation Protection.

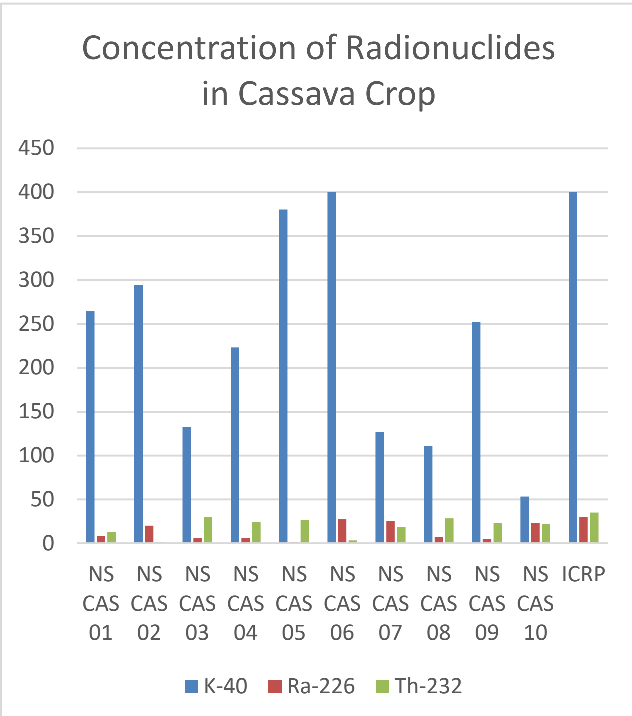

Fig.1: Comparison of the Concentration of Radionuclides in Cassava Crop with ICRP.

Figure 1 showed that, the Concentration of ^{40}K in Cassava Crop for all locations were found to be less than the value recommended by International Commission on Radiation Protection (400 Bq/kg) except that of NAS CAS 06 which was found to be equal to that recommended by International Commission on Radiation Protection.

Figure 1 showed that, the Concentration of ^{226}Ra in Cassava Crop for all locations were found to be less than the value recommended by International Commission on Radiation Protection (30 Bq/kg).

Figure 1 showed that, the Concentration of ^{232}Th in Cassava Crop for all locations were found to be less than the value recommended by International Commission on Radiation Protection (35 Bq/kg).

Figure 2 showed that, the Concentration of ^{40}K in Soil for all locations were found to be less than the value recommended by International Commission on Radiation Protection (400 Bq/kg).

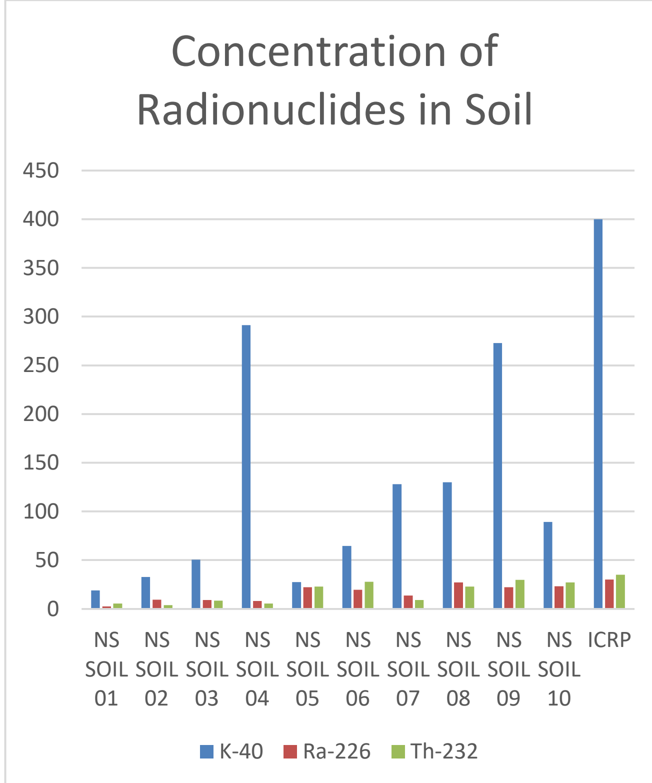

Fig.2: Comparison of the Concentration of Radionuclides in Soil with ICRP.

Figure 2 showed that, the Concentration of ^{226}Ra in Soil for all locations were found to be less than the value recommended by International Commission on Radiation Protection (30 Bq/kg).

Figure 2 showed that, the Concentration of ^{232}Th in Soil for all locations were found to be less than the value recommended by International Commission on Radiation Protection (35 Bq/kg).

Figure 3 showed that, the Concentration of ^{226}Ra in Soil for NS 1, NS 2, NS 6, and NS 7 were found to be higher than the value recommended by International Commission on Radiation Protection (TF > 1), while NS 3, NS 4, NS 5, NS 8 and NS 9 were found to be less than the value recommended by International Commission on Radiation Protection (TF < 1) and NS 10 was found to be less than the value recommended by International Commission on Radiation Protection (TF = 1).

Figure 3 showed that, the Concentration of ^{232}Th in Soil for NS 1, NS 3, NS 4, NS 7 and NS 8 were found to be higher than the value recommended by International Commission on Radiation Protection (TF > 1), while NS 2, NS 6, NS 9, and NS 10 were found to be less than the value recommended by International Commission on Radiation Protection (TF < 1).

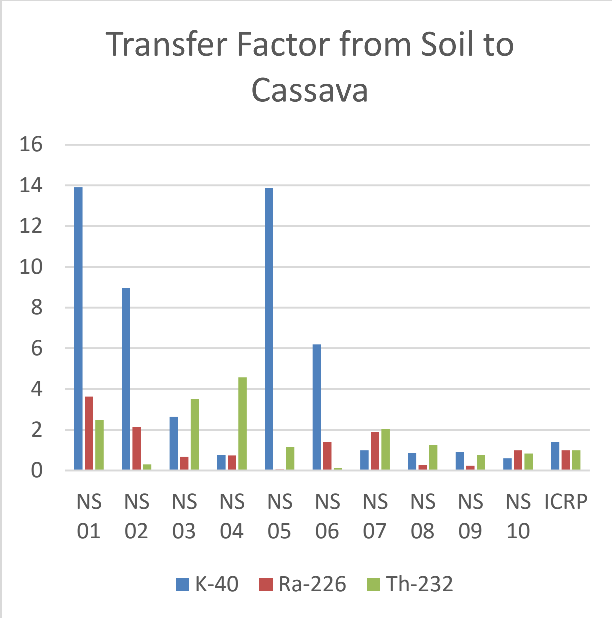

Fig.3: Comparison of the Transfer Factor of Radionuclides in Soil with ICRP.

3.2 Discussion

The result for the activity concentration of radionuclide of potassium (^{40}K), Uranium (^{226}Ra) and Thorium (^{232}Th) in cassava crop samples are presented in table 1. The activity concentration due potassium (^{40}K) ranged from 053.24±20.12 to 400.00±66.72 with its mean value of 223.79±33.85 Bqkg^{-1}, the concentration of radium (^{226}Ra) varies between 01.34±0.25 to 27.29±2.88 with its mean value of 13.07±2.88 Bqkg^{-1} and the concentration of thorium (^{232}Th) varies between 01.20±0.12 to 29.99±4.92 with its mean value of 19.11±2.09 Bqkg^{-1} respectively. Indicating that there will be no potential radiological risk. The result obtained is less than the one reported by [30].

The result for the activity concentration of radionuclide of potassium (^{40}K), Radium (^{226}Ra) and Thorium (^{232}Th) in soil samples are presented in Table 2. The activity concentration due potassium (^{40}K), radium (^{226}Ra) and thorium (^{232}Th) ranged from 019.01±2.13 to 291.30±2.04 Bqkg^{-1} with its mean value of 110.54±3.23 Bqkg^{-1}, 2.32 ± 0.70 to 27.15±7.66 with its mean value of 15.66±3.59 and 5.32 ± 0.43 to 29.74±3.06 with its mean value of 16.22±2.92 Bq/kg respectively. When compared with the world standard, it is below its permissible limit of 400.00 Bqkg^{-1}, 30.00 Bqkg^{-1} and 35.00 Bqkg^{-1} respectively. Indicating that there will be no potential radiological risk. The results obtained, is above that related by [30,31].

The result for the transfer factor of the activity concentration of radionuclide of potassium (^{40}K), Radium (^{226}Ra) and Thorium (^{232}Th) from soil to water are presented in Table 3. The transfer factor of potassium (^{40}K), radium (^{226}Ra) and thorium (^{232}Th) ranged from 0.60±7.56 to 13.90±21.01 Bqkg^{-1} with its mean value of 02.02±0.170 Bqkg^{-1}, 0.06±0.23 to 3.64±3.37 with its mean value of 0.84±0.80 and 0.13±0.40 to 4.57±8.43 with its mean value of 1.18±0.72 Bq/kg respectively. When compared with the world standard, it is below its permissible limit of 400.00 Bqkg^{-1}, 30.00 Bqkg^{-1} and 35.00 Bqkg^{-1} respectively. Indicating that there will be no potential radiological risk. The results obtained, is above that related by [30,31].

4 Conclusions

The naturally radioactivity levels have been measured in cultivated soil and the most stable crop (cassava) from selected farm lands in Nasarawa, Nasarawa Local Government Area of Nasarawa State in Nigeria.

It is interesting to note that although all the plant species are grown in soils of similar physical -chemical characteristic and similar concentration of these radionuclides, the TF value are different for different species. This indicated that, some plant species concentrate higher 40K radionuclides than others, and plants may uptake potassium from soil as an essential element of metabolism and other radionuclides may be taken as a homologue of an essential element. The data for soil to plant transfer factor of ^{40}K in Crop has the average of 2.02±0.17 which higher compared with IAEA recommended value for soil to plant transfer factor of ^{40}K of 1.4. The higher transfer factor of potassium at that time was not at-risk streak because that value was not at staid position to harm the body. For ^{226}Ra, IAEA has greater value for soil-to-plant TF of ^{226}Ra for compared with the present study which was found to be 0.84±0.8. In general, the values of ^{232}Th TF (1.18±0.72) were lower than those values reported in the default values suggested by IAEA. The mean concentration of all the radioisotopes in the crop may not cause instant health hazard to the public but there may be a long-term accumulative effect following present dose intake from the consumption of the crop (cassava).

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