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Estimation Of Soil-To-Plant Transfer Factors For ^{238}U, ^{232}Th, ^{40}K And ^{137}Cs Radionuclides For Some Selected Medicinal Plants In Some Part Of Minna And Kaduna, Nigeria

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Abstract: This study was carried out in some part of Minna (River basin (9.66667ºN, 6.55000ºE) and Mekunkele (9.5836ºN, 6.5463ºE)) and Kaduna (Mando (10.590030ºN, 7.430019ºE) and Kachia (9.8734ºN, 7.9552ºE)) were Moringa leave, Goat weed, Ginger, and Turmeric are mostly grown in Northern Nigeria. Eleven samples of the medicinal plants comprising of three samples each of Moringa leave, Goat weed, Ginger and two sample of Turmeric, and eleven soil samples of corresponding area where the medicinal plant are grown, were analysed for activity concentrations of natural and artificial radionuclides using HPGe gamma spectrometry. The average annual committed effective dose (AACED) due to the ingestion of radionuclides from medicinal plants were also estimated. The Annual effective dose equivalent (AEDE) for soil sample radiological assessment was estimated. The activity concentrations ^{238}U, ^{232}Th, and ^{40}K were found to vary in the range of 9.512 to 58.984 Bqkg^{-1}, 17.852 to 71.972 Bq kg^{-1}, and 309.836 to 729.451 Bqkg^{-1}, respectively, in the soil samples and 1.343 to 10.367 Bqkg^{-1}, 5.215 to 13.752 Bq Kg^{-1}, and 11.700 to 239.765 Bq kg^{-1}, respectively, in the medicinal plants corresponding to the soil samples. The activity concentration of artificially produced radionuclide ^{137}Cs was BDL to 0.062 Bqkg^{-1} in the soil and it was below detectable level (BDL) in all the plant samples. The soil to plant transfer factors (TF) varied from 0.330 to 1.089 Bq Kg^{-1}, 0.067 to 0.762 Bq Kg^{-1} and 0.0740 to 0.318 Bq kg^{-1}, respectively, for ^{238}U, ^{232}Th, and 40K. The AACED due to the ingestion of radionuclides from the medicinal plants varied from 0.0107 to 0.0542 mSvy-1. The AEDE estimated for soil samples vary between 0.0358 to 0.1279 mSv y^{-1}. The reported AACED and AEDE values in this study are much below the world average value of 0.30 mSv y^{-1} and ICRP recommended safe limit of 1mSv y^{-1} for an individual respectively. This indicates that it is safe to use these plants for medicinal purposes as there is no radiological health risk attached to the plant and members of the public. This study may also contribute data on local medicinal plants to formulate regulations related to radiological healthcare.

Keywords: Medicinal Plants, Soil to Plant Transfer Factors (TF), and Average Annual Committed Effective Dose (AACED) .

1 Introduction

Every environment of human habitation contains traces of natural radionuclide though in varying degrees of concentration from one location to another. Naturally occurring radioactive materials (NORM) may be found in the human body, air, water, plants, soil, rocks and other geological formations depending on the geology of the area. All radioactive materials emit ionizing radiation of different kinds and energy. Man is exposed to ionizing radiation mainly from natural and man-made sources [1, 2]. Knowledge of various radionuclides in the soil is essential in health physics. Radionuclides (such as Radium, Thorium, and potassium) are located in the earth crust with varying concentration from place to place along with other non-radioactive trace elements (such as Ca, Na, Co) [3,4].

It is well-known that there are many contaminants and residues that may harm the consumers of herbal medicines, and naturally occurring radionuclides are one type of contaminants amongst them [2,5]. In most places on earth, natural radioactivity varies only within relatively narrow limits, whereas in some other localities significant deviations have been observed. All these radionuclides present in the environment are taken up by the plants through the metabolic process and are present in varied concentrations in different parts of the plants [2, 3].

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Moreover, the plants absorb many elements present in the soil of their root area with or without the necessity of these elements. Sometimes, the uptake of some non-essential radioactive elements to the plants may occur along with chemically similar essential elements required for the plant metabolism [4]. The transport of these radionuclides also depends on the chemical form of the nuclide, its distribution coefficient, the metabolic requirements of the plant, and physicochemical parameters of the soil such as pH, organic matter, moisture content, etc. [2, 6, 7].

Radionuclides release accidentally together with their decay products culminate naturally in water, soil and air ecosystems. A couple of these radionuclides can be anthropogenic produced and by accident released in the surroundings resulting in associated health risks [1].

Developing countries such as Nigeria, Ghana, Cameroon, Brazil, Mexico etc employ the use of medicinal plants and traditional medicine as a normative basis for sustenance of good health. In addition, increasing reliance on the use of medicinal plants in developed countries (Japan, China and USA, say) have been traced to the extraction and improvement of numerous drugs and chemotherapeutics from these shrubs along with customary used rural herbal antidote [8]. For instance, in Australia 48% of its population has used such medicines at least once, 42% in the United States of America, 49% in France, in Belgium 31%, and in Canada 70% [9].

Medicinal plants of different species are consumed in different forms all over the world to remedy clinical symptoms, treat ailments and to promote good and healthy living. The forms in which these herbs are taking most times depend on culture, ailment and local prescriptions. It varies from plant extract, leaves, roots, and to the entire plant. They may also be mixed with food in the form of ingredients, cuisines and drinks. As herb, plants absorb nutrients from soil to grow. The chemical composition in plants relates linearly solely to its average concentration in the rooting zone of the soil. While different plants have different affinity for different soil nutrients, the nutritional demand of plants may thus influence their absorption rate. This suggests that different plants even when grown on the same soil may possess different absorb nutrients. The soil is a product of rock weathering, thus possessing primordial radionuclides in varying quantities depending on parent rock type and other factors. Primordial radionuclides can thus find their way into human diet and internal biological structure through the food-chain. In view of the radiological risk involved in the internal exposure of man to ionizing radiation, the risk of developing radiation induced sickness can be inferred from the radioactive content of ingested (food) items. The degree of internal radiation contamination thus depends on the level of radionuclide in food which can be inferred from their soil-to-plant radionuclide transfer-factor. Consequently, to ensure the safety of consuming medicinal herbs, radionuclide levels of different plants consumed for their medicinal value need to be investigated [10, 11, 12].

This study aimed to investigate the soil-to-plant transfer factors of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs, and the uptake in some farms in Minna and Kaduna since there are limited TF data for some of these medicinal plant species.

Materials and Methods

2.1 Sampling Area

The area of study is composed of farms located in Kachia on coordinates 9.8734ºN and 7.9552ºE in Kaduna state, Nigeria and home to ginger. Turmeric also grows well in this region. Ankwa on coordinates 9.9236ºN, 7.7634ºE is a town located in Kachia where samples of ginger, turmeric, and goat weed may be found. Also, Samples of Moringa oleifera will be found at Maikunkele on coordinates 9.5836ºN and 6.5463ºE Minna, Niger state. Moringa farm located at Upper Niger River Basin premises on coordinates 9.66667ºN and 6.55000ºE will provide some samples, goat weed will be obtained likewise. In addition, at a farm in Mando Kaduna state on coordinates 10.590030ºN and 7.430019ºE, moringa and goat weed was acquired.

2.2 Sampling Technique

Plant samples to be used for the study were collected from the study areas, and with the use of some farm tools, leaves and roots parts of the plant would be gotten:, seeds and. From each sampling spot, plant samples will be collected by putting-together a material equivalent to about 1 kg dry weight. Every plant sample will be thoroughly washed, free of adhering soil particles, peeled when necessary. The samples will further be open-air-dried for 10 days, followed by oven drying at a temperature of 85-1000C for about 2-3 hours. Samples' roots will be gently washed with water to let-go of fine soil particles that may still adhere. . In order to obtain homogeneous samples, dried plants and soil samples will be pulverized by a grinder into fine powder and passed through 10-mesh and 50-mesh screens.

2.3 Sample Preparation

The samples were milled in a Laboratory Mortar Grinder serial number 0101 manufactured by Fritsch GmbH Germany. Analysis was performed on each sample. For activity concentration measurement, the samples were transported to the laboratory and prepared into 1 litre Marinelli beakers, the beakers were thick enough to prevent the permeation of radon. The beakers were closed by screw caps and plastic tape was wrapped over the caps and then stored for measurement. This step was necessary to ensure that radon gas is confined within the volume and that the daughters will also remain in the sample.

2.4 Sample Measurement and Analysis

By means of a non-destructive analysis using a computerized gamma ray spectrometry system with high purity germanium (HPGe), the activity concentrations of the samples were determined. The relative efficiency of the detector system was 40 %, and resolution of 1.8 keV at 1.33MeV of 60Co. The gamma spectrometer is joined to conventional electronics connected to a multichannel analyzer card (MCA) installed in a desktop computer. A software program called MAESTRO- 32 was used to accumulate and analyze the data manually using spreadsheet (Microsoft Excel) to calculate the natural radioactivity concentrations in the samples. A cylindrical lead shield of 5 cm thickness houses the detector with internal diameter of 24cm and height of 60cm. The lead shield is lined with various layers of copper, cadmium and Plexiglas, each 3mm thick. A counting time of 36,000 seconds (10hrs) was used to acquire spectral data for each sample. The activity concentrations of the uranium-series were determined using γ-ray emissions of ^{214}Pb at 351.9 keV (35.8%) and ^{214}Bi at 609.3 keV (44.8%) for ^{226}Ra, and for the ^{232}Th-series, the emissions of ^{228}Ac at 911 keV (26.6%), ^{212}Pb at 238.6 keV (43.3%) and ^{208}Tl at 583 keV (30.1%) were used. The ^{40}K activity concentration was determined directly from its emission line at 1460.8 keV (10.7%). The γ-ray emission of ^{137}Cs was determined at 661.66 keV.

Prior to the measurements, the measuring assembly and detector were calibrated for energy and efficiency to facilitate both quantitative and qualitative analysis of the samples to be performed. The energy and efficiency calibrations were performed using mixed radionuclide calibration standard evenly distributed in the form of solid water, serial number NW 146 with approximate volume 1000 mL and density 1.0 g cm^{-3} in a 1.0 L Marinelli beaker. The standard was supplied by Deutscher Kalibrierdienst (DKD-3), QSA Global GmBH, Germany and contains radionuclides with known energies (241Am (59.54 keV), ^{109}Cd (88.03 keV), 57Co (122.06 keV), ^{139}Ce (165.86 keV), ^{203}Hg (279.20 keV), ^{113}Sn (391.69 keV), ^{85}Sr (514.01 keV), ^{137}Cs (661.66 keV), ^{60}Co (1173.2 keV and 1332.5 keV) and ^{88}Y (898.04 keV and 1836.1 keV) and activities in a 1000 ml Marinelli beaker was used.

2.4.1 Soil-to-Plant Transfer Factor (TF)

The uptake of radionuclide by plants from radioactive contaminated soil represents a key step of radionuclide input into the human food chain; this phenomenon is described by soil-plant transfer factor that is defined as the ratio between plant specific activity and soil specific activity. Plants are the primary recipients of radioactive contamination to the food chain following atmospheric releases of radionuclides. The transfer factor (TF) is a value used in evaluation studies on impact of routine or accidental releases of radionuclide into the environment for most important agricultural products is known. For other areas and especially the developing countries TFs are less known. The soil –to- plant transfer factor is regarded as one of the most important parameters in environmental safety assessment needed for nuclear facilities. This parameter is necessary for environmental transfer models which are useful in prediction of the radionuclide concentrations in agriculture crops for estimating dose intake by man.

The soil-to-plant transfer factor (TF) is defined as the ratio of the concentrations of radionuclides in plant (Bq kg^{-1}, dry mass) to that in soil (Bq kg^{-1}, dry mass) and was calculated using the following formula [11, 12].

$$TF = \frac{Activity\ of\ radionuclides\ in\ plant\ (Bq\ kg^{-1}, dry\ mass)}{Activity\ of\ radionuclides\ in\ soil\ (Bq\ kg^{-1}, dry\ mass)} \quad (1)$$

2.4.2 Average Annual Committed Effective Dose (AACED)

The Average annual committed effective dose (AACED) due to ingestion of naturally occurring radioactive materials (NORMs) in medicinal plants was estimated using the equation [6,13]:

$$\text{AACED} = C_r x DCF_i x A_i \quad (2)$$

where Cr is the consumption rate of radionuclides, and DCF_i is the dose conversion factor for each radionuclide (2.8 x 10^{-7}, 6.9x10^{-7}, 2.3x10^{-7}, 6.2 x10^{-9}, and 1.3 x10^{-8} SvBq^{-1} for ^{226}Ra, ^{210}Pb, ^{232}Th, ^{40}K, and ^{137}Cs respectively), and A_i is the activity concentration of each radionuclide. According to equation (1), the committed effective dose to an individual is directly proportional to the consumption rate of the ingredients of medicinal plants as a medicine. Using the same equation, the threshold consumption rate for a medicinal plant can also be obtained from the following relation:

$$C_r = \frac{5E_{av}}{\sum_{i=1}^{5}(DCF_i x A_i)} \quad (3)$$

where, E_{av} 0.3 mSv y^{-1} is the threshold average annual committed effective dose due to ingestion of NORMs in the medicinal plants, A_i is the activity concentration of radionuclide i, and DCF_i is the dose conversion factor for radionuclide I [14].

2.4.3 Dose Assessment Soil Sample

Dose rate

Gamma dose rates was calculated by using the formula given below:

$$D\ (nGy\ h^{-1}) = 0.427C_U + 0.662C_{Th} + 0.043C_K \quad (4)$$

where C_U, C_{Th} and C_K are the specific activity concentrations of potassium, uranium and thorium, respectively.

The Annual Effective Dose Equivalent (AEDE)

The absorbed dose rates were then used to estimate the annual effective dose equivalent (AEDE) in µSv/yr

$$AEDE(mSv\ y^{-1}) = AD(nGy\ h) \times 8760\ h \times 0.7\ Sv\ Gy \times 0.2\ 7$$

Where AD is the absorbed dose rate, 8760h is the total hours per year, 0.7Sv/Gy is the dose conversion factor from absorbed dose in air to the effective dose with an occupancy factor of 0.2 for outdoor exposure as recommended by UNSCEAR [14].

3 Results and Discussion

3.1 Activity Concentration

The activity of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in medicinal plants (Moringa leaves, Goat weed, Ginger and Turmeric) and in the soil samples collected from the corresponding plant sampling locations in Niger and Kaduna state are presented in Table 1. From the result obtained using the gamma-ray spectrometer (HpGe detector), the activity of medicinal plant samples for ^{238}U, ^{232}Th, and ^{40}K ranged from 1.343 to 10.367 $Bqkg^{-1}$, 5.215 to 13.752 $Bqkg^{-1}$, and 11.700 to 239.765 Bq kg^{-1} with average value of 4.725, 8.510 and 88.675 $Bqkg^{-1}$ respectively. ^{137}Cs was not detected in medicinal plant samples.

Soil samples from corresponding sampling location were measured for activity concentration and are found to range from 9.512 to 58.984 $Bqkg^{-1}$ with a mean value of 25.106 Bq Kg^{-1} for ^{238}U, 17.852 to 71.972 $Bqkg^{-1}$ with a mean value of 52.432 Bq Kg^{-1} for ^{232}Th, 309.836 to 729.451 Bq kg^{-1} with a mean value of 507.606 Bq Kg^{-1} for ^{40}K, and <MDA to 0.062 $Bqkg^{-1}$ with a mean value of 0.0218. ^{137}Cs is an artificial radionuclides and may be present in the soil due to fallout as a result of tropical climate in a region with high precipitation and evergreen forest (Chandrashekara & Somashekarappa, 2016).

3.2 Transfer Factor (TF)

The soil-to-plant transfer factor (TF) was calculated from activity of soil and corresponding activity of medicinal plants (Moringa leaf, Goat weed, Ginger and Turmeric) using equation 1 and are presented in Table 1. The mean transfer factors of ^{238}U, ^{232}Th, and ^{40}K are 0.303, 0.226 and 0.227 $Bqkg^{-1}$, and ranged from 0.330 to 1.089 Bq Kg^{-1}, 0.067 to 0.762 $Bqkg^{-1}$ and 0.0740 to 0.318 Bq kg^{-1} respectively. Goat weed has the highest TF value for ^{238}U (1.089 $Bqkg^{-1}$), ^{232}Th (0.762 $Bqkg^{-1}$) and ^{40}K (0.318 $Bqkg^{-1}$), while the lowest TF value are observed for ^{238}U (0.330 $Bqkg^{-1}$) in Moringa leave, ^{232}Th (0.067 $Bqkg^{-1}$) in Ginger and ^{40}K (0.0740 $Bqkg^{-1}$) in Turmeric. Transfer factor depends upon many factors such as: PH, electrical conductivity (EC), and bicarbonate contents of soil, etc. Soil of all samples under study was geologically the same and climatic conditions are also similar. Organic fertilizer affects the ion exchange capacity, stable element content of soil, pH, as well as soil retention properties [15, 16].

Goat weed has the highest TF of ^{238}U and much accumulation was found in the leaves compared to the soil around that point which was identified to be very close to the transfer soil sample. This high value may also be due to other anthropogenic activity.

A study by Vandenhove et al. [12] revealed that ^{238}U has much lower TFs, and they attribute it to its high affinity with soil particles, resulting in minimal uptake of ^{232}U to plants. They added that this small uptake of ^{232}U could be from the fact that ^{238}U is chemically similar to calcium, which is one of the important nutrients for plants; thus, plants may transport ^{238}U along with calcium [2].

Many studies have been carried out to determine TFs for most important agricultural products [17]. Several projects were run by the International Atomic Energy Agency (IAEA) to determine TF mainly for 90Sr and ^{137}Cs [2, 13]. These data have been used extensively in radiological assessment models.

Natural environmental radioactivity arises mainly from primordial radionuclides, such as ^{40}K, and the radionuclides from the ^{232}Th and ^{238}U series, and their decay products are considered to be the main contributor to internal radiation dose. Several studies on transfer of natural radionuclides from soil to plant have been carried out in different regions in the world [18, 19].

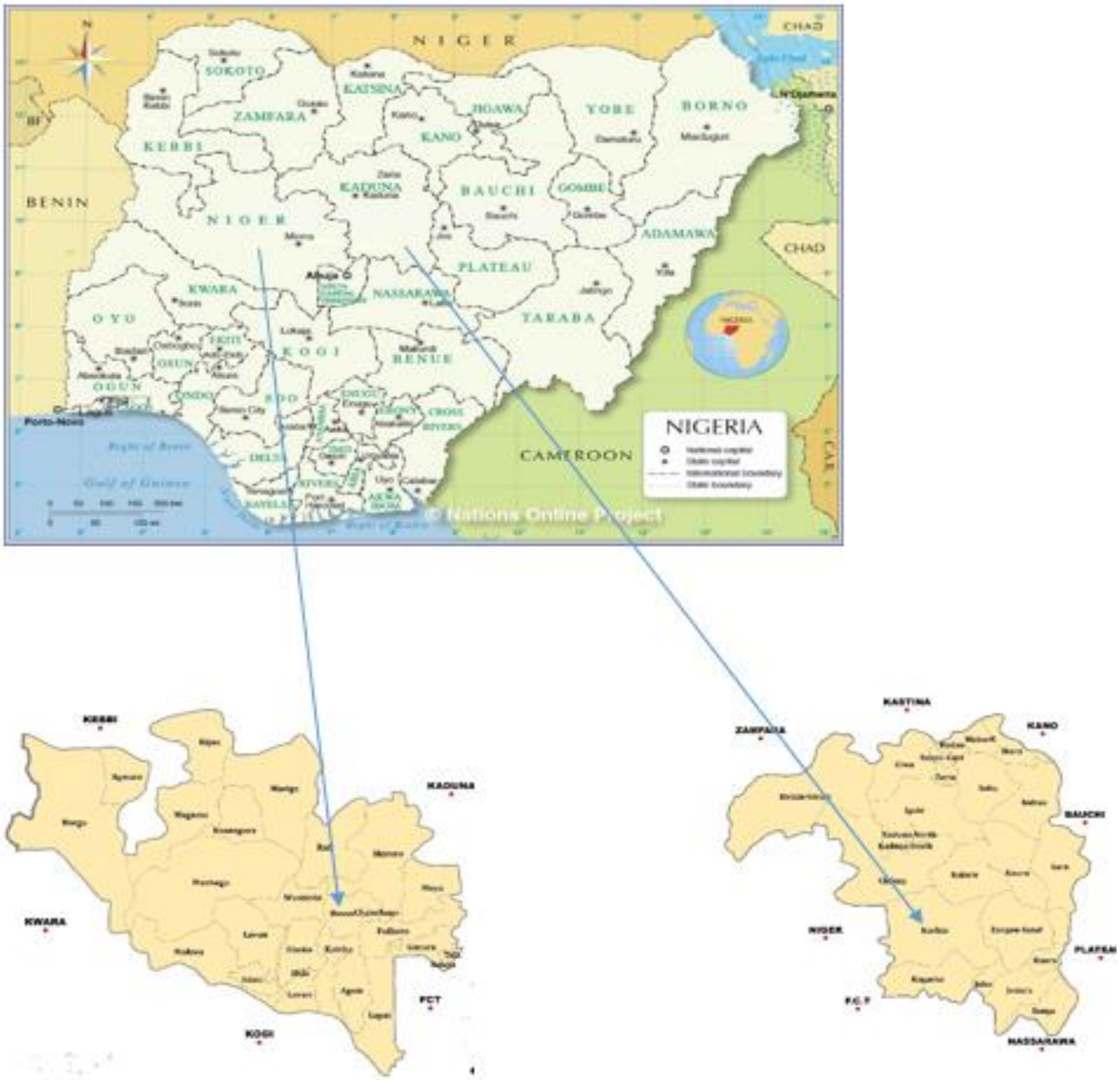

Fig. 1: Map showing the sampling area.

Table 1: Activity concentrations and transfer factors of radionuclides.

Medicinal Plant	Sample ID	Activity concentrations (Bq Kg^{-1})			
		U-238	**Th-232**	**K-40**	**Cs-137**
Moringa leave	MLP1A	5.407±0.811	11.463±1.719	116.579±17.486	BDL
Soil	MLS1A	58.984 ± 8.847	63.735 ± 9.560	729.451 ± 109.417	BDL
Transfer factor	TF1A	0.091668927	0.179854083	0.159817452	
Goat weed	GWP2A	7.947±1.192	8.787±1.318	61.075±9.161	BDL
Soil	GWS2A	23.513± 3.527	33.455 ± 5.018	336.669± 50.500	BDL
Transfer factor	TF2A	0.337983243	0.262651323	0.181409634	

Moringa leave	MLP3B	7.083±1.062	13.752±2.063	122.736±16.014	BDL
Soil	MLS3B	46.736± 7.010	52.425 ± 7.864	385.884± 57.883	0.054±0.023
Transfer factor	TF3B	0.151553406	0.262317597	0.318064496	
Moringa leave	MLP4C	1.343±0.201	5.297±0.795	75.824±11.374	BDL
Soil	MLS4C	40.249 ± 6.037	39.299 ± 5.894	610.308 ± 91.542	BDL
Transfer factor	TF4C	0.033367289	0.134787145	0.124238909	
Goat weed	GWP5C	2.412±0.362	7.684±1.153	45.163±6.774	BDL
Soil	GWS5C	40.249 ± 6.037	39.299 ± 5.894	610.308 ± 91.542	BDL
Transfer factor	TF5C	0.059926955	0.195526604	0.074000341	
Goat weed	GWP6D	10.367±1.555	13.611±2.042	206.343±30.951	BDL
Soil	GWS6D	9.512 ± 0.476	17.852±0.893	309.836±15.492	BDL
Transfer factor	TF6D	1.089886459	0.762435581	0.665974903	
Ginger	GGP7D	4.632±0.323	6.114±0.306	239.765±11.988	BDL
Soil	GGS7D	9.512 ± 0.476	17.852±0.893	309.836±15.492	BDL
Transfer factor	TF7D	0.486963835	0.342482635	0.773844873	
Ginger	GGP8D	3.364±0.505	6.541±0.981	25.932±3.890	BDL
Soil	GGS8D	12.616 ± 1.892	96.923 ± 14.538	810.145 ± 121.521	BDL
Transfer factor	TF8D	0.266645529	0.067486561	0.032009085	
Ginger	GGP9D	5.225±0.784	7.238±1.086	36.78±5.517	BDL
Soil	GGS9D	11.598± 1.740	71.972 ± 10.796	493.742 ± 74.061	0.062±0.095
Transfer factor	TF9D	0.450508708	0.100566887	0.074492346	
Turmeric	TMP10D	2.461±0.369	7.91±1.187	11.7±1.755	BDL
Soil	TMS10D	11.598± 1.740	71.972 ± 10.796	493.742 ± 74.061	0.062±0.024
Transfer factor	TF10D	0.212191757	0.109903851	0.023696586	
Turmeric	TMP11D	1.733±0.260	5.215±0.782	33.532±5.030	BDL
Soil	TMS11D	11.598± 1.740	71.972 ± 10.796	493.742 ± 74.061	0.062±0.024
Transfer factor	TF11D	0.149422314	0.072458734	0.067914012	

Table 2: Absorbed Dose Rate (ADR) and Annual effective dose equivalent (AEDE) (indoor and outdoor).

Soil Sample ID	Geopoint	D (nGy h^{-1})	AEDE (outdoor) ($mSvyr^{-1}$)	AEDE (indoor) ($mSvyr^{-1}$)
MLS1A	9.66667ºN, 6.55000ºE	98.745	0.1211	0.4843
GWS2A	9.66667ºN, 6.55000ºE	46.664	0.0572	0.2289
MLS3B	9.5836ºN, 6.5463ºE	71.255	0.0874	0.3495
MLS4C	10.590030ºN, 7.430019ºE	69.446	0.0851	0.3406
GWS5C	10.590030ºN, 7.430019ºE	69.44	0.0851	0.3406

GWS6D	9.8734ºN, 7.9552ºE	29.202	0.0358	0.1432
GGS7D	9.8734ºN, 7.9552ºE	129.202	0.0358	0.1432
GGS8D	9.8734ºN, 7.9552oE	104.386	0.1279	0.5120
GGS9D	9.8734ºN, 7.9552ºE	73.829	0.0905	0.3621
TMS10D	9.8734ºN, 7.9552ºE	104.386	0.0905	0.3621
TMS11D	9.8734ºN, 7.9552ºE	104.386	0.0905	0.3621
	Mean	**81.904**	**0.0824**	**0.3298**

Table 3: Average annual committed effective dose (AACED) and threshold consumption rates (Cr) of medicinal plants.

Medicinal plant	Sample ID	Geopoint	Cr (kgy^{-1})	AACED ($mSvy^{-1}$)
Moringa leave	MLP1A	9.66667ºN, 6.55000ºE	307.803	0.0235
Goat weed	GWP2A	9.66667ºN, 6.55000ºE	324.336	0.0136
Moringa leave	MLP3B	9.5836ºN, 6.5463ºE	253.929	0.0206
Moringa leave	MLP4C	10.590030ºN, 7.430019ºE	726.583	0.0353
Goat weed	GWP5C	10.590030ºN, 7.430019ºE	550.926	0.0167
Goat weed	GWP6D	9.8734ºN, 7.9552ºE	205.125	0.0275
Ginger	GGP7D	9.8734ºN, 7.9552ºE	358.018	0.0542
Ginger	GGP8D	9.8734ºN, 7.9552ºE	575.346	0.0107
Ginger	GGP9D	9.8734ºN, 7.9552ºE	446.990	0.0116
Turmeric	TMP10D	9.8734ºN, 7.9552ºE	581.188	0.0057
Turmeric	TMP11D	9.8734ºN, 7.9552ºE	792.565	0.0178
Mean			**465.710**	**0.0216**

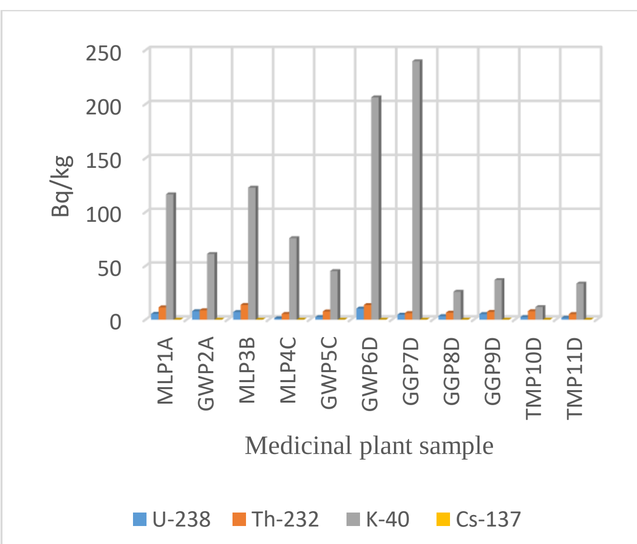

Fig. 2: Activity of radionuclides in medicinal plant samples.

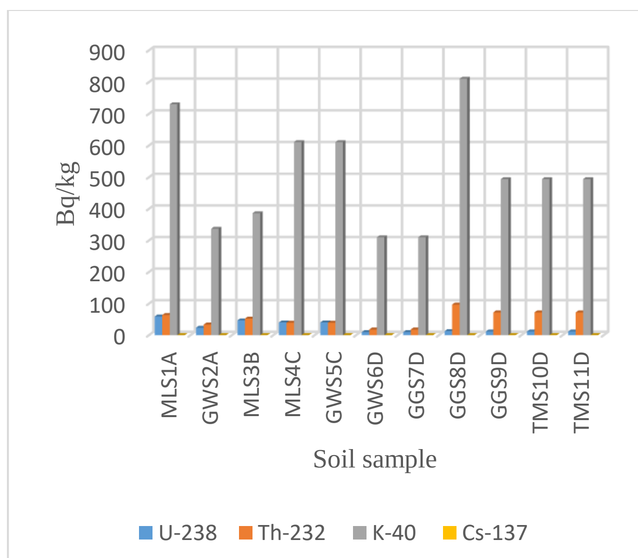

Fig.3: Activity of radionuclides in soil samples.

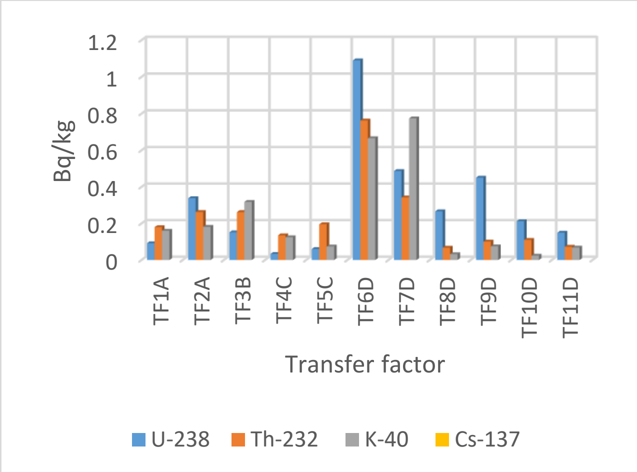

Fig. 4: Soil to plant transfer factors (TF) of radionuclides.

3.3 Radiological Hazard Assessment of Soil Sample

Absorbed Dose Rate (ADR)

The range of calculated absorbed dose rate values is between 46.664 nGy h^{-1} and 129.202 nGy h^{-1} with observed mean value of 81.904 nGy h^{-1}. The mean absorbed dose rate appear to be higher than the recorded world weighted average of 59.00 nGy h^{-1} ([12,20] and lower than recommended safe limit of 84.0 nGy h^{-1} [22, 23] for outdoor exposure. These dose rates result indicates low level contamination of the environment by radiation. Although the health effect to the residents of the locality may not be immediate, there is the potential for long-term health hazards in the future due to the doses accumulated.

Annual effective dose equivalent (AEDE)

The calculated values of AEDE range between 0.0358 and 0.1279 mSv y^{-1} with a mean value of 0.0824 mSv y^{-1} for outdoor exposure, and range between 0.1432 and 0.0.5120 mSv y^{-1} with a mean value of 0.3298 mSv y^{-1} for indoor exposure. This is higher than world average value of 0.07 mSv y^{-1} [20, 22, 24] but within UNSCEAR and ICRP recommended permissible limits of 1.00 mSv y^{-1} for the general public [22, 24]. This indicates that the studied location is radiologically contaminated but still within the ICRP and UNSCEAR permissible limit [14, 22].

3.4 Average Annual Committed Effective Dose (AACED)

The AACED values due to the ingestion of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs for the medicinal plants samples were estimated and are presented in Table 3, and range between 0.0107 to 0.0542 mSv y^{-1} with a mean value of 0.0216 mSv y^{-1}, assuming a consumption rate of 1 kg y^{-1} (26-30).

The maximum value of AACED was obtained for Ginger (GGP7D) and the minimum for the Turmeric plant (TMP10D). Figure 5 presents the variations of AACED values in different medicinal plants. The AACED value is maximum for Ginger because of the higher concentration of ^{238}U and and relatively more concentration of ^{232}Th, while these are minimum in Turmeric, which has the least value of AACED in the plant. The AACED values reported in this study are far below the world average value of 0.3 mSv y^{-1} [22].

The estimated threshold consumption rates of medicinal plants are also computed and presented in Table 3. A plant with higher threshold consumption rate value would have lower AACED and vice versa. The highest threshold consumption rate was obtained for Turmeric with sample code TMP11D (792.565 kgy^{-1}) and the lowest for Goat weed with sample code GWP6D (205.125 kgy^{-1}).

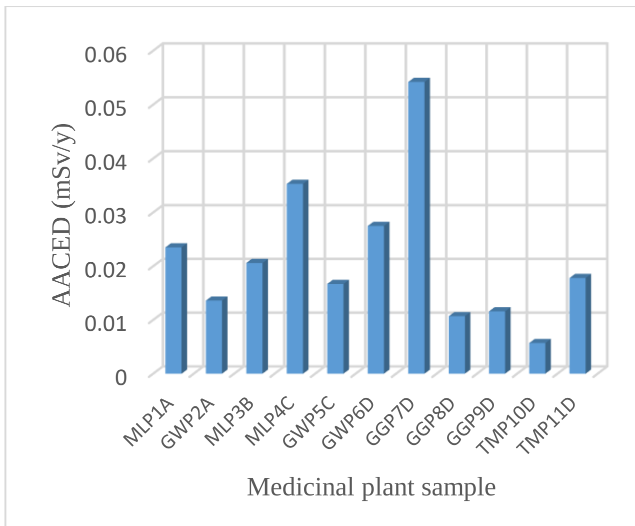

Fig.5: Average annual committed effective dose (AACED).

4 Conclusions

The TF, used as a parameter for the accumulation or the transfer of radionuclides from soil to plants has been evaluated for three medicinal plant species (Moringa leaf, Goat weed, Ginger and Turmeric). The TF of ^{238}U, ^{232}Th, and ^{40}K for four medicinal plant species grown on farm soil in Minna (River basin and Mekunkele) and Kaduna (Mando and Kachia) part of Nigeria indicated that goat weed have higher TF for both ^{238}U and ^{232}Th with lower TF value in

Moringa leave, Ginger, and Turmeric. The study observe that the activity concentration of radionuclides in medicinal plants mainly depends on the type of plants and not on the activity of these radionuclides in soil. The level of activity concentrations of natural radionuclides in the soils under investigation were lower than the ICRP recommended safe limit of 1 $mSvy^{-1}$ for public exposure which indicates that the members of the public are radiologically safe which might not pose any major radiation hazard to the population. The AACED due to the ingestion of radionuclides from the medicinal plants investigated in this study are much below the world average value of 0.30 mSv y^{-1}. This indicates that it is safe to use these plants for medicinal purposes as there is no radiological health risk attached to the plant and members of the public (31-32).

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