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Transfer of ^{40}K, ^{226}Ra and ^{232}Th from Soil to Water and Edible Plants and Associated Radiological Effects in Jos East and Jos South, Plateau State, Nigeria.

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Abstract: Abundance of resinized biotite results in the activities of mining and exploration in the Jos since 1904. The mining has been operating for the past 50 years, and radioactive nature of the minerals was realized not before 1974. This work intends to unveil the extent to which K^{40}, Ra^{226}, and Th^{232} transfers from soil to water and various species of food crops in Jos East and Jos South. The results of the study revealed that, the TF for different trace elements in soil-edible plants for Jos East decreased in the order of ^{232}Th (0.928) > ^{226}Ra (0.900) > ^{40}K (0.948). On the other side, Jos South has soil-edible plants based on sample points decreased in the order of ^{232}Th (0.930) > ^{226}Ra (0.926) > ^{40}K (0.935). The total TF for different trace elements in soil-water for Jos South decreased in the order of ^{232}Th (0.965) > ^{40}K (0.950) > ^{226}Ra (0.974). On the other side, Jos South has soil-edible plants based on sample points decreased in the order of ^{232}Th (0.965) > ^{40}K (0.963) > ^{226}Ra (0.973). It can be concluded that the water and edible plants in the study area are good for public consumption, though, regular checking of radioactive traces in the study areas are recommended.

Keywords: Radioactive; Trace Elements; Soil-Plants; Soil-Water; Transfer Factor.

1 Introduction

Since there is need to explore natural resources for social and economic purpose using industrialized mining and milling activities, natural radioactivity levels might surely increase in the environment [1,2,3,4]. This results from the waste coming out of these activities which alter the level of radioactivity in the agricultural soil. Therefore, the level of radioactivity in crops also rises through various uptake process from soil [5,6,7,8]. This may result in economic pressure in using farmlands with such high levels of radioactivity because of the rapid growth in population and movement which might also affect food security, as is evident in the geologically identical areas in India, Brazil, and Iran, which often has exposures of tens of mSv/yr [9,10,11,12]. Consumption of such radionuclides by the intake of food might results in high fraction of average dose of radiation to various body organs, and this might also result in long-term health implications [13,14,15,16]. For instance, it was reported that at least one out of eighth of the average annual effective dose resulting from natural sources are attributed to food intake [17,18]. Particularly, the radionuclides like U^{238} and Th^{232} series results in about 30–60% dose of radiation [19,20]. The stream and well water we mostly consume also get these radionuclides through erosion [20].

The United Nations for Sustainable Food Security has three major goals which are: (1) to ensure all people have access to sufficient, nutritionally adequate and safe food; (2) to continue and sustain contribution of agriculture to economic and social progress, and (3) to conserve and sustain utilization of natural resources, like water, land genetic resource base for food and agriculture [21,22]. One of the hot areas realized for priority action and relevant consideration to the mandate of both the International Atomic Energy Agency (IAEA) and the Food and Agriculture Organization is consumer protection, plant and animal. Although, similar research was conducted in the same study area by the same sole author, but the research focused on the transfer factor (TF) of heavy metals like Cd, As, Cr, Pb and Ni, while the present study focused on

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transfer factor (TF) of radioactive traces like K^{40}, Ra^{226} and Th^{232}. This work intends to unveil the extent to which K^{40}, Ra^{226}, and Th^{232} transfers from soil to water and various species of food crops in Jos East and Jos South in order to ensure the safety of food and also to maintain the specific safety limits of the effective doses. This work will also provide basic data for the radiometric judgment of potential radioactive release to the environment, and for setting up of a radiometric control of foodstuffs to support the Nigerian Nuclear Regulatory Authority (NNRA) in their food policy, administration and regulatory functions.

2 Materials and Method

2.1 Materials

The materials that were used in carrying out this research are;

i. Hand trowel
ii. Plastic containers
iii. Hand gloves
iv. Polyethylene sampling bottles
v. Geo-positioning System meter (GPS meter)
vi. Masking tape
vii. Permanent marker and Jotter
viii. Sodium Iodide Thallium (NaI(Tl)) Gamma Spectrometry

2.2 Method

2.2.1 Study Area

Plateau is the twelfth-largest state in Nigeria. Approximately in the centre of the country, it is geographically unique in Nigeria due to its boundaries of elevated hills surrounding the Jos Plateau which is its capital, and the entire plateau itself [23,24,25].

Plateau State is known as The Home of Peace and Tourism in Nigeria. Although the tourism sector isn't thriving as much as it should due to meagre allocations to it by the State Government, its natural endowments are still attractions to tourists mostly within Nigeria [26,27].

The maps of the study areas (Jos South and Jos East) showing sample points are presented respectively in Figure 1 and Figure 2.

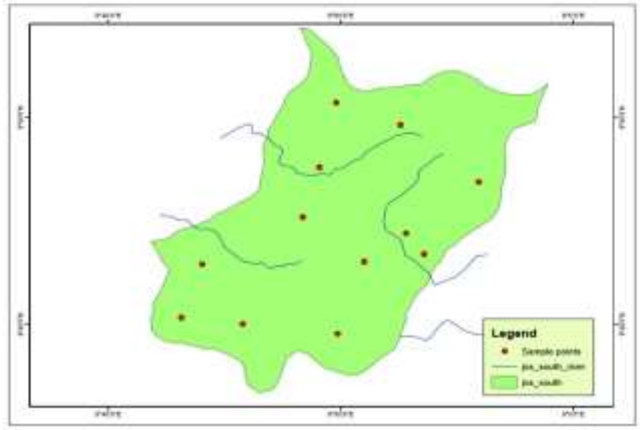

Fig. 1: Maps of the study Jos South showing sample points.

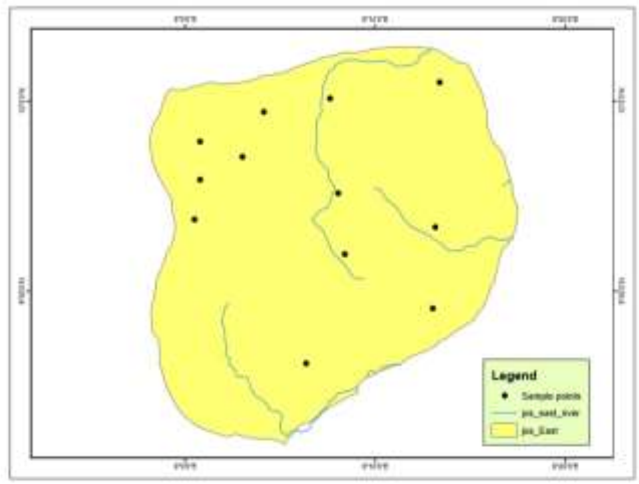

Fig. 2: Maps of the study Jos Eest showing sample points

2.2.2 Method of Sample Collection

Soil, water and vegetable samples were pair collected. A random sampling technique was used to select twelve (12) soil sample, twelve (12) edible plant sample, and twelve (12) water samples each from the Jos East and Jos South local governments of Plateau State. Seventy-two (72) samples in all were analyzed in this study. Vegetables' rooted samples were collected at 0-20 cm depth.

The sample of soil was collected using coring tool to a depth of 5 cm. The collected samples each of approximately 4 kg in wet weight was transferred immediately into a polyethylene bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

The collected edible plant samples were immediately transferred into a high-density polyethylene zip lock-plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

The collected water samples were immediately transferred into plastic containers and was well covered to avoid cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability.

2.2.3 Method of Soil and Edible Plants Sample Preparation

The collected samples (soil and edible plants) were taken to the laboratory and left open (since wet) for a minimum of 24 hours in order to dry under ambient temperature. They were grounded using mortar and pestle and allowed to pass through 5mm-mesh sieve to remove larger object in order to obtain a fine powder. The samples were packed to fill a cylindrical plastic container of height 7cm by 6cm diameter. This satisfied the selected optimal sample container height. Each container accommodated approximately 300g of sample. They were carefully sealed (using Vaseline, candle wax and masking tape) to prevent radon escape and then stored for a minimum of 24 days. This is to allow radium attain equilibrium with the daughters.

2.2.4 Method of Water Sample Preparation

The water samples collected was preparation at the instrumentation laboratory, the beakers were washed and rinsed with distil water and Acetone was used to sterilized them. Each of the beaker was rinsed twice with a small quantity of the collected water sample, then 1000 ml of the water sample were poured into the beaker, which were in turn placed on a hot plate in a fume cupboard to allow for evaporation at 50^0C to 60^0C. The beaker was left open without stirring to avoid excessive loss of the residue. As the water in each beaker reduces to about 50 ml, it was then transferred to a pre-weighed ceramic dish where the sample were finally evaporated to dryness using a hot plate. The ceramic dish was weighed again after cooling and the weight of the residue was obtained by subtracting the previous weight of the empty dish. A few drops of Acetone were added to the dry residue so as to sterilize it. It was then stored in a desiccator and allowed to cool, thereby prevented from absorbing moisture.

The volume of water which gave the total residue was obtained from the equation (1) as pointed out by [28]:

$$V = \frac{V_w}{TR \times RP} \qquad 1$$

Where Vw is the volume of water evaporated, TR is the total residue obtained, RP is the residue transferred to the planchet.

2.2.5 Method of Results Analysis

Radioactive trace analysis was done using Sodium Iodide (NaI (Tl)) Gamma Spectrometry available at Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria.

2.2.5.1 Transfers factor

Transfers factor (TF) was calculated to understand the extent of risk and associated hazard due to wastewater irrigation and consequent radioactive trace element accumulation in edible portion of test vegetables according to [29] and the Transfers factor from soil to plant and from soil to water is given by equation (2) according to [29];

$$TF_{soil-plant} = \frac{C_{plant}}{C_{soil}} \text{ and } TF_{soil-water} = \frac{C_{water}}{C_{soil}} \qquad 2$$

The ratio "> 1" means higher accumulation of trace element in plant or water parts than soil [28,29]. If the transfer coefficient of a trace element is greater than 0.50, the plant will have a greater chance of the trace element contamination by anthropogenic activities [29-30].

3 Results and Discussion

3.1 Results

Table 1: Soil-Edible Plants Transfer Factor in Jos East and Jos South.

T/E	^{40}K	^{226}Ra	^{232}Th	Total	^{40}K	^{226}Ra	^{232}Th	Total
S/P	**Jos East**				**Jos South**			
P01	0.92	0.87	0.948	**0.913**	0.957	0.924	0.946	**0.942**
P02	0.93	0.91	0.946	**0.929**	0.915	0.929	0.918	**0.921**
P03	0.92	0.93	0.946	**0.932**	0.942	0.932	0.930	**0.935**
P04	0.96	0.85	0.945	**0.917**	0.941	0.895	0.911	**0.916**
P05	0.94	0.84	0.948	**0.909**	0.942	0.949	0.924	**0.938**
P06	0.95	0.93	0.943	**0.940**	0.942	0.923	0.907	**0.924**
P07	0.94	0.91	0.945	**0.931**	0.956	0.927	0.948	**0.944**
P08	0.92	0.90	0.941	**0.920**	0.918	0.931	0.951	**0.933**
P09	0.91	0.94	0.943	**0.931**	0.916	0.916	0.918	**0.917**
P10	0.94	0.94	0.949	**0.943**	0.837	0.926	0.953	**0.905**
P11	0.97	0.90	0.972	**0.947**	0.956	0.927	0.969	**0.951**
P12	0.84	0.89	0.954	**0.893**	0.942	0.933	0.941	**0.939**
Total	**0.93**	**0.90**	**0.948**	**0.925**	**0.930**	**0.926**	**0.935**	**0.930**

P = Points; K = Potassium; Ra = Radium; Th = Thorium.

It was observed from Table 1 that the soil-edible plant transfer factor for ^{40}K, ^{226}Ra and ^{232}Th has the total of 0.928, 0.900 and 0.948 respectively for Jos East, while in Jos South, the soil-edible plant transfer factors for ^{40}K, ^{226}Ra and ^{232}Th has the total values of 0.930, 0.926 and 0.935 respectively.

More so, on soil-edible plant, the total transfer factor of Jos East has its trend is in descending order based on sample points with P11 (0.947) > P10 (0.943) > P06 (0.940) > P03 (0.932) > P09 and P07 (0.931) > P02 (0.929) > P08 (0.920) > P04 (0.917) > P01 (0.913) > P05 (0.909) > P12 (0.893). On the other hand, that of Jos South has its trend is in descending order based on sample points with P11 (0.951) > P07 (0.944) > P01 (0.942) > P12 (0.939) > P05 (0.938) > P03 (0.935) > P08 (0.933) > P06 (0.924) > P02 (0.921) > P09 (0.917) > P04 (0.916) > P10 (0.905).

Table 2: Soil-Water Transfer Factor in Jos East and Jos South.

T/E	^{40}K	^{226}Ra	^{232}Th	Total	^{40}K	^{226}Ra	^{232}Th	Total
S/P	**Jos East**				**Jos South**			
P01	0.96	0.94	0.97	**0.956**	0.98	0.962	0.973	**0.971**
P02	0.97	0.95	0.97	**0.964**	0.96	0.964	0.959	**0.960**
P03	0.97	0.97	0.97	**0.970**	0.97	0.966	0.965	**0.967**
P04	0.98	0.93	0.97	**0.958**	0.97	0.947	0.956	**0.958**
P05	0.97	0.92	0.97	**0.954**	0.97	0.974	0.962	**0.969**
P06	0.98	0.96	0.97	**0.970**	0.97	0.962	0.953	**0.962**
P07	0.97	0.95	0.97	**0.965**	0.98	0.964	0.974	**0.972**
P08	0.96	0.95	0.97	**0.960**	0.96	0.965	0.975	**0.966**
P09	0.96	0.97	0.97	**0.966**	0.96	0.958	0.959	**0.958**
P10	0.97	0.97	0.98	**0.971**	0.92	0.963	1.047	**0.976**
P11	0.99	0.95	0.99	**0.975**	0.98	0.964	0.985	**0.975**
P12	0.92	0.95	0.98	**0.947**	0.97	0.966	0.971	**0.969**
Total	**0.97**	**0.95**	**0.97**	**0.963**	**0.97**	**0.963**	**0.973**	**0.967**

P = Points; K = Potassium; Ra = Radium; Th = Thorium.

It was also observed from Table 2 that the soil-water transfer factor for ^{40}K, ^{226}Ra and ^{232}Th has the total of 0.965, 0.950 and 0.974 respectively for Jos East, while in Jos South, the soil-water transfer factors for ^{40}K, ^{226}Ra and ^{232}Th has the total values of 0.965, 0.963 and 0.973 respectively.

More so, on soil-water, the total transfer factor of Jos East has its trend is in descending order based on sample points with P11 (0.975) > P10 (0.971) > P06 and P03 (0.970) > P09 (0.966) > P07 (0.965) > P02 (0.964) > P08 (0.960) > P04 (0.958) > P01 (0.956) > P05 (0.954) > P12 (0.947). On the other hand, that of Jos South has its trend is in descending order based on sample points with P10 (0.976) > P11 (0.975) > P07 (0.972) > P01 (0.971) > P12 and P05 (0.969) > P03 (0.967) > P08 (0.966) > P06 (0.962) > P02 (0.960) > P09 and P04 (0.958).

3.1.1 Comparison of Results with World Health Organization (WHO)

The results presented on Table 1 and Table 2 were used to plot charts in order to compare the results of the present study with World Health Organization (WHO) as seen in Figure 3, Figure 4, Figure 5 and Figure 6.

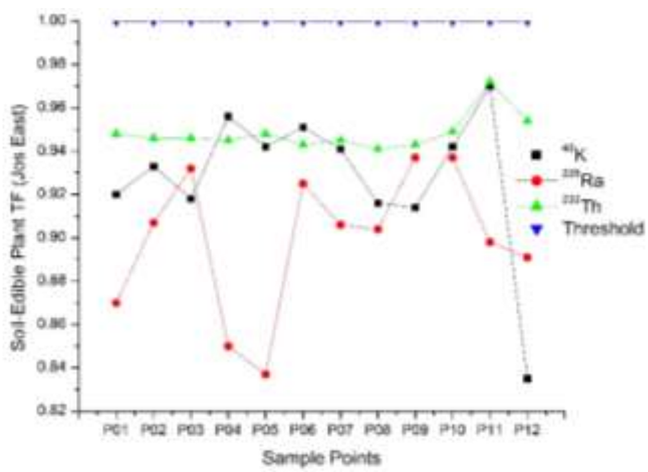

Fig. 3: Chart of Soil-Edible Plants Transfer Factor of Jos East with World Health Organization.

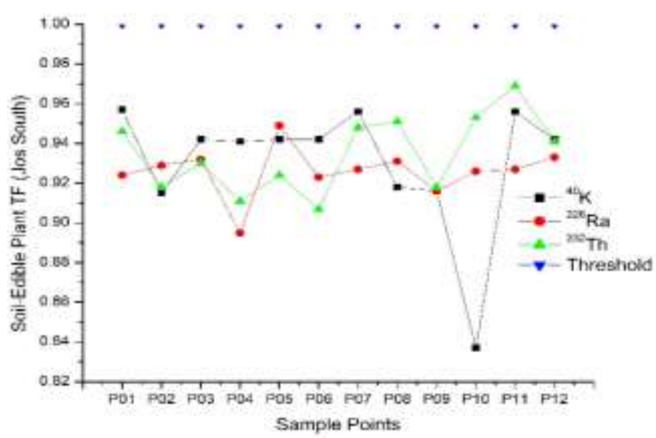

Fig. 4: Chart of Soil-Edible Plants Transfer Factor of Jos South with World Health Organization

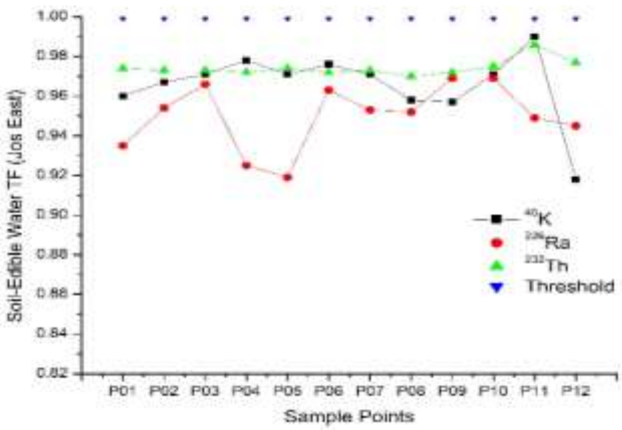

Fig. 5: Chart of Soil-Water Transfer Factor of Jos East with World Health Organization

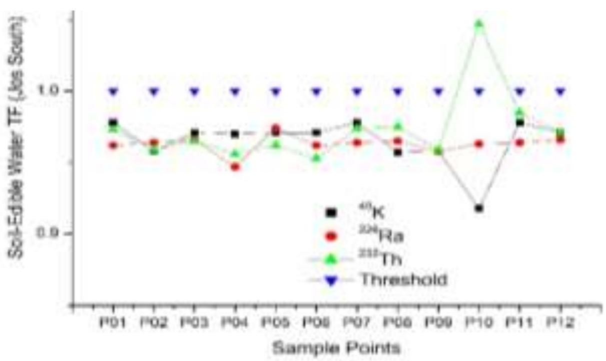

Fig.6: Chart of Soil-Water Transfer Factor of Jos South with World Health Organization

Based on the results presented in Figure 3, Figure 4, Figure 5 and Figure 6 the soil-edible plants and soil-water transfer factor for P11 in trace elements at both Jos East and Jos South seem to be slightly lower than that recommended by the World Health Organization (unity) while all other points are found to be considerably lower for all the trace elements, on the other hand, the results presented in Figure 4 showed that the soil-water transfer factor of ^{232}Th for P10 was found to be a bit higher than the recommended limit of unity as recommended by World Health Organization, while all other points seem to be slightly lower than that recommended by the World Health Organization (unity) for all the trace elements.

3.2 Discussion

Radioactive trace concentration in plants and water strictly lies on the relative exposure level of plants and water to the contaminated soil. In this study, the soil-edible plant and soil-water Transfer Factor (TF) for various trace elements showed slight variations between the locations.

On soil-edible plant transfer for Jos East, the different trace elements in soil-edible plants based on sample points decreased in the following order: P11 (0.947) > P10 (0.943) > P06 (0.940) > P03 (0.932) > P09 and P07 (0.931) > P02 (0.929) > P08 (0.920) > P04 (0.917) > P01 (0.913) > P05 (0.909) > P12 (0.893). Meanwhile, considering the individual radioactive trace elements, the total TF decreased in the following order: ^{232}Th (0.928) > ^{226}Ra (0.900) > ^{40}K (0.948).

Also, the soil-edible plant transfer for Jos South, the different trace elements in soil-edible plants based on sample points decreased in the following order: P11 (0.951) > P07 (0.944) > P01 (0.942) > P123 (0.939) > P05 (0.938) > P03 (0.935) > P08 (0.933) > P06 (0.924) > P02 (0.921) > P09 (0.917) > P04 (0.916) > P10 (0.905). Meanwhile, considering the individual radioactive trace elements, the total TF decreased in the following order: ^{232}Th (0.930) > ^{226}Ra (0.926) > ^{40}K (0.935).

However, soil-water transfer, the total TF for Jos East, different trace elements in soil-water based on sample points decreased in the following order: P11 (0.975) > P10 (0.971) > P06 and P03 (0.970) > P09 (0.966) > P07 (0.965) > P02 (0.964) > P08 (0.960) > P04 (0.958) > P01 (0.956) > P05 (0.954) > P12 (0.947). Meanwhile, considering the individual radioactive trace elements, the total TF decreased in the following order: ^{232}Th (0.965) > ^{40}K (0.950) > ^{226}Ra (0.974).

Similarly, soil-water transfer, the total TF for Jos South, different trace elements in soil-water based on sample points decreased in the following order: P10 (0.976) > P11 (0.975) > P07 (0.972) > P01 (0.971) > P12 and P05 (0.969) > P03 (0.967) > P08 (0.966) > P06 (0.962) > P02 (0.960) > P09 and P04 (0.958). Meanwhile, considering the individual radioactive trace elements, the total TF decreased in the following order: ^{232}Th (0.965) > ^{40}K (0.963) > ^{226}Ra (0.973).

4 Conclusion

Based on the findings of this study, it is observed that only one point has its transfer factor ratio "> 1" which implies 99% of the areas under investigation has lower accumulation of trace elements in plant or water parts than soil, even though the transfer coefficients of a trace elements in all points for all the trace elements are greater than 0.50, indicating that the plant or water might have a greater chance of the trace element contamination by anthropogenic activities. It can therefore be concluded that the water and edible plants in the study area are good for public consumption, even though, regular checking of radioactive trace elements in the study areas are recommended.

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