Journal of Chemical Research Advances
ISSN: 2582-7995

Research Article
Open access

Carcinogenic effects of accumulation of trace elements in water and edible plants of Jos East and Jos South, Plateau State, Nigeria

Waida J[1], Umaru I[2], Goki NG[3], Yusuf SD[2] and Rilwan U[4]
[1]Department of Physics, Borno State University, Maiduguri, Borno State, Nigeria
[2]Department of Physics, Nasarawa State University, Keffi, Nasarawa State, Nigeria
[3]Department of Geology and Mining, Nasarawa State University, Keffi, Nasarawa State, Nigeria
[4]Department of Physics, Nigerian Army University, Biu, Borno State, Nigeria

Corresponding author: rilwan.usman@naub.edu.ng

Received on: 09/11/2022 Accepted on: 15/01/2023 Published on: 23/01/2023

ABSTRACT

Aim: This study was aimed to unveil the activity concentration of radioactive trace elements (^{40}K, ^{226}Ra and ^{232}Th) in soil, water and edible plants and assess their carcinogenic role to biological tissue.

Method and Materials: The samples were 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.

Results: The Geo-Accumulated Index (I_{geo}) for various trace elements showed slight variations between the locations. The geo-accumulation index of soil in Jos East decreased in the order of ^{232}Th (7.632) >^{226}Ra (3.812) >^{40}K (4.727). Soil in Jos South decreased in the order of ^{232}Th (7.708) >^{226}Ra (4.202) >^{40}K (4.348). Water in Jos East decreased in the order of ^{232}Th (7.581) >^{226}Ra (3.738) >^{40}K (4.689). Water in Jos South decreased in the order of ^{232}Th (7.656) >^{226}Ra (4.148) >^{40}K (4.309). Edible plants in Jos East decreased in the order of ^{232}Th (7.523) >^{226}Ra (3.658) >^{40}K (4.650). Edible plants in Jos South decreased in the order of ^{232}Th (7.603) >^{226}Ra (4.091) >^{40}K (4.250).

Conclusion: It was concluded that water and such edible plants are to be prohibited for public consumption. Hence, strict radiological laws and orders in the study areas are recommended.

Keywords: Carcinogenicity, Trace elements Epidemiology, ROS Exposure.

How to cite this article: Waida J, Umaru I, Goki NG, Yusuf SD and Rilwan U (2023). Carcinogenic effects of accumulation of trace elements in water and edible plants of Jos East and Jos South, Plateau State, Nigeria. J. Chem. Res. Adv., 04(01): 01-09.

Introduction

Carcinogenic substances are those that induce tumors (benign or malignant), increase their incidence or malignancy or shorten the time of tumor occurrence when they get into the body through inhalation, injection, dermal application or ingestion (Allen et al., 1988). Carcinogens are classified as either genotoxic or nongenotoxic depending on their modes of action (Ames and Shigenaga, 1992). Genotoxic carcinogens are those which initiate carcinogenesis by direct interaction with DNA, resulting in DNA damage or chromosomal aberrations that can be detected by genotoxicity tests (Anil et al., 2011).

On the other hand, nongenotoxic carcinogens are agents that indirectly interact with the DNA, causing indirect modification to DNA structure, amount, or function that may result in altered gene expression or signal transduction (Rilwan et al., 2019). Substances that induce tumors in animals are also considered human carcinogens until proven otherwise (Rilwan et al., 2020).

All known human carcinogens that have been evaluated adequately in animal bioassays have been found to be also carcinogenic in animal bioassay studies. In fact, it has been reported that of the nearly 100 known genotoxic and non-genotoxic human carcinogens, one-third were shown first to be carcinogenic in animals. Other studies have demonstrated a strong correlation between carcinogenic potencies estimated from epidemiological data and those from animal carcinogenesis bioassays (Augusto and Rhian, 2011 and Auld, 2001). These observations have been used as guidelines to avoid human exposure to such chemicals found to be carcinogenic in laboratory animals (Huff, 1999). According to evaluations done by the International Agency for Research on Cancer (IARC), carcinogenicity data reviewed of various trace elements are classified as reported by IARC (1989) as: (i) sufficient, when a casual association is established between exposure to an agent and human cancer; (ii) limited, when an association has been observed but chance, bias, and confounding cannot be ruled out and (iii) inadequate, when the data are of insufficient quality, consistency or statistical power to allow a conclusion.

The degree of solubility of chemical exposure, which influences biological effects as well as the long- or short-term experimental studies must be considered while deciding carcinogenicity classifications (Rilwan et al., 2021). Certain trace elements like zinc and selenium have been found to have anti-carcinogenic effect where as others tend to be carcinogenic in specific organs while showing no such effect in certain organs (Bello et al., 2022). No formal evaluation of anti-carcinogenic effects of these trace elements has been made by IARC. The carcinogenic capability of trace elements depends mainly on factors such as oxidation states and chemical structures. The oxidative concept in element carcinogenesis signifies that complexes formed by these elements, in vivo, in the vicinity of DNA, catalyze redox reactions, which in turn oxidize DNA. The most significant effect of reactive oxygen species (ROS) in the carcinogenesis progression is DNA damage, which results in DNA lesions like strand breaks and the sister-chromatid exchange (IARC, 1993)). It has been estimated that approximately 29104 DNA damaging events occur in every cell per day (Maurici et al., 2005); a major portion of these occur via ROS. Similarly, ROS damage results in lipid peroxidation and depletion of protein sulfhydryls. Even though the increase in oxidative DNA lesions has been frequently attributed to metal exposures, it is important to note that the molecular mechanism leading to tumor formation after such exposures is still not well understood (Mehmet, 2006). The trace elements carcinogenesis is mediated either by the increased generation of ROS on the basis of ESR spin trapping studies or by interference with the repair process of DNA. Some oxygen species are worst carcinogenic molecules. There is a very fine balance between enzymatic [such as superoxide dismutase (SOD), glutathione peroxidase and catalase] and non-enzymatic (such as ascorbic acid, a-tocopherol, b-carotene and isoflavons) antioxidants and free radicals in each cell. When ROS production is higher than the cell reduction capabilities, they can induce lipid peroxidation, depletion of the sulfhydryl groups, change signal transduction pathways, calcium homeostasis and DNA damage. This may result in occurrence of aging effect and cancer infection.

Geo-accumulation Index (I_{geo})

This method assesses the trace elements accumulation in terms of seven (0 to 6) enrichment classes, ranging from background concentration to very heavily polluted as follows:

$$I_{geo} = \log_2\left[\frac{C_m \text{Sample}}{1.5x(C_m \text{ Background})}\right] = \frac{\log_{10}\left(\frac{CF}{1.5}\right)}{\log_{10} 2} = \frac{\log_{10}\left(\frac{CF}{1.5}\right)}{0.3} \quad (1)$$

The factor 1.5 is introduced in the equation to minimize the effects of possible variations in the background values. The recommended World Average Values and Ranges of Geo-Accumulation Index were presented (Table 1).

The purpose of this work is to unveil the extent to which radioactive trace elements (^{40}K, ^{226}Ra and ^{232}Th) accumulates in soil, water and edible plants and assess their carcinogenic role to biological tissue that might result in cancer. This work will compare its results with the world standard limits and unveil whether the inhabitants of the study are liable to be affected by cancer in the long round or not.

Table 1. World Average Values and Ranges of Geo-Accumulation Index

I_{geo} Values	I_{geo} Class	Description of Soil Quality
>5	6	Extremely contaminated
4-5	5	Strongly to extremely contaminated
3-4	4	Strongly contaminated
2-3	3	Moderately to strongly contaminated
1-2	2	Moderately contaminated
0-1	1	Uncont. to moderately contaminated
0	0	Uncontaminated

Materials and Methods

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. Masking tape
vi. Permanent marker and Jotter
vii. Sodium Iodide Thallium (NaI (Tl)) Gamma Spectrometry

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 (Galadima et al., 2022, Ming-Ho, 2005, OECD, 2006 and UNECE, 2004).

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 (Onuk et al., 2022).

The map of Jos South and Jos East showing sample points were presented.

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.

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 300 g 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.

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 WHO (2017):

$$V = \frac{V_w}{TR \times RP} \qquad 2$$

Where Vw is the volume of water evaporated, TR is the total residue obtained, RP is the residue transferred to the planchet (Waida et al., 2022).

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. The results obtained were used to assess the extent of the accumulation of these radioactive traces in water, soil and plants through an index called using equation (1) as reported.

Results and Discussion

It was also observed from Table 2 that the geo-accumulation index of ^{40}K, ^{226}Ra and ^{232}Th in soil has the total of 7.632, 3.812 and 4.727 respectively for Jos East, while in Jos South, the geo-accumulation index of ^{40}K, ^{226}Ra and ^{232}Th in soil has the total values of 7.708, 4.202 and 4.348 respectively.

More so, the geo-accumulation index of Jos East has its trend in descending order based on sample points with P11 (5.905) > P10 (5.675) > P06 (5.620) > P07 (5.441) > P09 (5.429) > P02 (5.393) > P03 (5.358) > P04 (5.342) > P08 (5.214) > P05 (5.198) > P01 (5.157). On the other hand, that of Jos South has its trend in descending order with P11 (5.978) > P10 (5.795) > P07 (5.720) > P01 (5.691) > P12 (5.577) > P05 (5.576) > P03 (5.489) > P08 (5.450) > P06 (5.286) > P02 (5.201) > P04 (5.147) > P09 (5.125).

It was also observed from Table 3 that the geo-accumulation index of ^{40}K, ^{226}Ra and ^{232}Th in soil has the total of 7.581, 3.738 and 4.689 respectively for Jos East, while in Jos South, the geo-accumulation index of ^{40}K, ^{226}Ra and ^{232}Th in soil has the total values of 7.656, 4.148 and 4.309 respectively.

More so, the geo-accumulation index of Jos East has its trend in descending order based on sample points with P11 (5.868) > P10 (5.633) > P06 (5.575) > P07 (5.390) > P09 (5.379) > P02 (5.340) > P03 (5.314) > P04 (5.280) > P08 (5.155) > P05 (5.130) > P09 (5.093). On the other hand, that of Jos South has its trend in descending order with P11 (5.942) > P07 (5.679) > P01 (5.649) > P12 (5.532) > P05 (5.530) > P03 (5.441) > P08 (5.400) > P06 (5.229) > P01 (5.143) > P04 (5.080) > P09 (5.064) > P09 (4.758).

Table 2: Geo-accumulation index of radioactive trace elements in soil samples of 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	7.407	3.371	4.694	**5.157**	8.288	4.141	4.644	**5.691**
P02	7.673	3.861	4.644	**5.393**	7.318	4.242	4.044	**5.201**
P03	7.134	4.308	4.633	**5.358**	7.883	4.312	4.273	**5.489**
P04	8.258	3.159	4.609	**5.342**	7.845	3.676	3.920	**5.147**
P05	7.861	3.046	4.687	**5.198**	7.869	4.717	4.141	**5.576**
P06	8.123	4.168	4.568	**5.620**	7.874	4.135	3.848	**5.286**
P07	7.856	3.841	4.625	**5.441**	8.272	4.206	4.683	**5.720**
P08	7.331	3.807	4.505	**5.214**	7.293	4.283	4.775	**5.450**
P09	7.294	4.421	4.572	**5.429**	7.331	4.002	4.044	**5.125**
P10	7.861	4.426	4.739	**5.675**	6.373	4.184	3.827	**4.795**
P11	8.428	3.720	5.567	**5.905**	8.270	4.206	5.458	**5.978**
P12	6.360	3.621	4.878	**4.953**	7.881	4.327	4.522	**5.577**
Total	**7.632**	**3.812**	**4.727**	5.390	**7.708**	**4.202**	**4.348**	5.420

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

Table 3: Geo-accumulation Index of Radioactive Trace Elements in Water Samples of 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	7.348	3.274	4.656	**5.093**	8.256	4.084	4.605	**5.649**
P02	7.624	3.793	4.605	**5.340**	7.256	4.190	3.983	**5.143**
P03	7.092	4.257	4.593	**5.314**	7.841	4.263	4.221	**5.441**
P04	8.226	3.046	4.568	**5.280**	7.802	3.597	3.854	**5.084**
P05	7.818	2.923	4.648	**5.130**	7.827	4.679	4.084	**5.530**
P06	8.087	4.113	4.526	**5.575**	7.831	4.079	3.778	**5.229**
P07	7.813	3.771	4.585	**5.390**	8.240	4.152	4.644	**5.679**
P08	7.269	3.735	4.462	**5.155**	7.229	4.232	4.739	**5.400**
P09	7.230	4.375	4.531	**5.379**	7.268	3.940	3.983	**5.064**
P10	7.818	4.380	4.702	**5.633**	6.250	4.130	3.894	**4.758**
P11	8.414	3.645	5.547	**5.868**	8.238	4.152	5.436	**5.942**
P12	6.236	3.540	4.844	**4.873**	7.839	4.278	4.479	**5.532**
Total	**7.581**	**3.738**	**4.689**	5.336	**7.656**	**4.148**	**4.309**	5.371

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

Table 4: Geo-accumulation Index of Radioactive Trace Elements in Edible Plant Samples of Jos East and Jos South.

T/E	^{40}K	^{226}Ra	^{232}Th	Total	^{40}K	^{226}Ra	^{232}Th	Total
Edible Plants		**Jos East**				**Jos South**		
Zogale	7.286	3.170	4.617	**5.024**	8.224	4.026	4.564	**5.605**
Kuka	7.573	3.721	4.564	**5.286**	7.190	4.135	3.920	**5.082**
Rama	7.010	4.206	4.552	**5.256**	7.797	4.211	4.168	**5.392**
Yateya	8.193	2.923	4.526	**5.214**	7.757	3.515	3.786	**5.019**
Alayyahu	7.774	2.789	4.609	**5.057**	7.783	4.640	4.026	**5.483**
Shuwaka	8.050	4.055	4.483	**5.530**	7.787	4.020	3.706	**5.171**
Yakuwa	7.769	3.698	4.543	**5.337**	8.207	4.096	4.605	**5.636**
Karkashi	7.204	3.660	4.417	**5.094**	7.169	4.179	4.702	**5.350**
Ugu	7.163	4.327	4.488	**5.326**	7.203	3.875	3.920	**4.999**
Rogo	7.773	4.332	4.664	**5.590**	6.115	4.073	3.757	**4.648**
Water Leaf	8.385	3.565	5.526	**5.825**	8.205	4.096	5.413	**5.905**
Kabeji	6.100	3.454	4.810	**4.788**	7.795	4.227	4.435	**5.486**
Total	**7.523**	**3.658**	**4.650**	**5.277**	**7.603**	**4.091**	**4.250**	**5.315**

It was also observed from Table 4 that the geo-accumulation index of ^{40}K, ^{226}Ra and ^{232}Th in edible plants has the total of 7.523, 3.658 and 4.650 respectively for Jos East, while in Jos South, the geo-accumulation index of^{40}K, ^{226}Ra and ^{232}Th in soil has the total values of 7.603, 4.091 and 4.250 respectively.

More so, the geo-accumulation index of Jos East has its trend in descending order based on sample points with Water Leaf (5.825) > Rogo (5.590) > Shuwaka (5.530) > Yakuwa (5.337) > Ugu (5.326) > Kuka (5.286) > Rama (5.256) > Yateya (5.214) > Karkashi (5.094) > Alayyahu (5.057) > Zogale (5.024) > Kabeji (4.788). On the other hand, that of Jos South has its trend in descending order with Water Leaf (5.905) > Yakuwa (5.636) > Zogale (5.605) > Kabeji (5.486) > Alayyahu (5.483) > Rama (5.392) > Karkashi (5.350) > Shuwaka (5.171) > Kuka (5.082) > Yateya (5.019) > Ugu (4.999) > Rogo (4.648).

Comparison of Results with World Health Organization (WHO)

The results (Table 2, Table 3 and Table 4) were used to plot charts in order to compare the results of the present study with World Health Organization (WHO) as shown (Fig. 3 to 8).

Based on the charts presented in Figure 3, Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8, the Geo-Accumulation Index for all the trace elements in both Jos East and Jos South seem to be between first class contamination to sixth class contamination which indicate that the soil, water and edible plants falls between moderately contaminated and extremely contaminated as reported by the World Health Organization limit of less than unit (< 1).

Radioactive trace elements concentration in plants and water strictly lies on the relative exposure level of plants and water to the contaminated soil. In this study, the Geo-Accumulated Index (I_{geo}) for various trace elements showed slight variations between the locations. Ames and Shigenaga (1992) also corroborated the findings of present study.

On soil in Jos East, the different trace elements in different sample points decreased in the following order: P11 (5.905) > P10 (5.675) > P06 (5.620) > P07 (5.441) > P09 (5.429) > P02 (5.393) > P03 (5.358) > P04 (5.342) > P08 (5.214) > P05 (5.198) > P01 (5.157) with radioactive trace elements decreasing in the following order: ^{232}Th (7.632) >^{226}Ra (3.812) >^{40}K (4.727). Allen et al., (1988) advocated the similar findings.

Also, on soil in Jos South, the different trace elements in different sample points decreased in the following order: P11 (5.978) > P10 (5.795) > P07 (5.720) > P01 (5.691) > P12 (5.577) > P05 (5.576) > P03 (5.489) > P08 (5.450) > P06 (5.286) > P02 (5.201) > P04 (5.147) > P09 (5.125) with radioactive trace elements decreasing in the following order: ^{232}Th (7.708) >^{226}Ra (4.202) >^{40}K (4.348). Augusto and Rhian (2011) also corroborated the findings of present study.

On water in Jos East, the different trace elements in different sample points decreased in the following order: P11 (5.868) > P10 (5.633) > P06 (5.575) > P07 (5.390) > P09 (5.379) > P02 (5.340) > P03 (5.314) > P04 (5.280) > P08 (5.155) > P05 (5.130) > P09 (5.093) with radioactive trace elements decreasing in the following order: ^{232}Th (7.581) >^{226}Ra (3.738) >^{40}K (4.689). Auld (2001) advocated the similar findings.

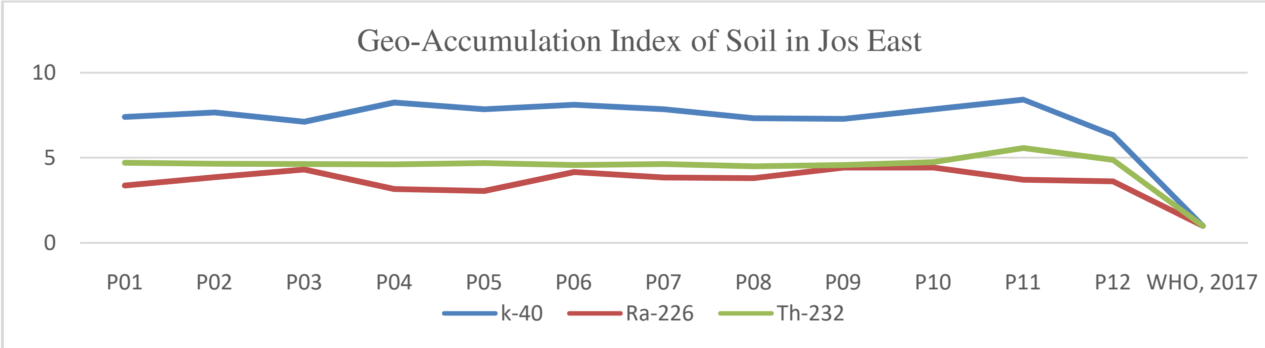

Fig 3: Chart of geo-accumulation index of soil in Jos East with World Health Organization

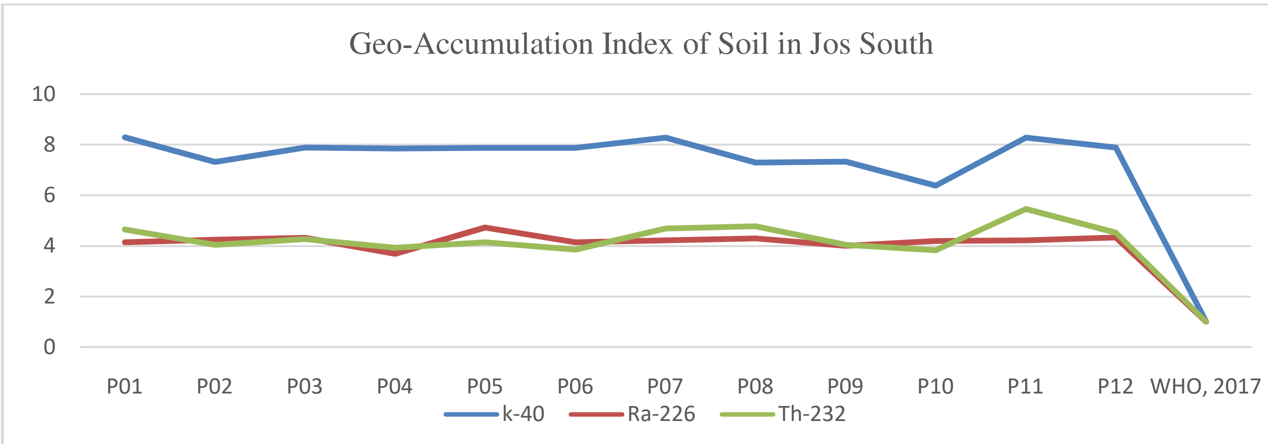

Fig 4: Chart of geo-accumulation index of soil in Jos South with World Health Organization

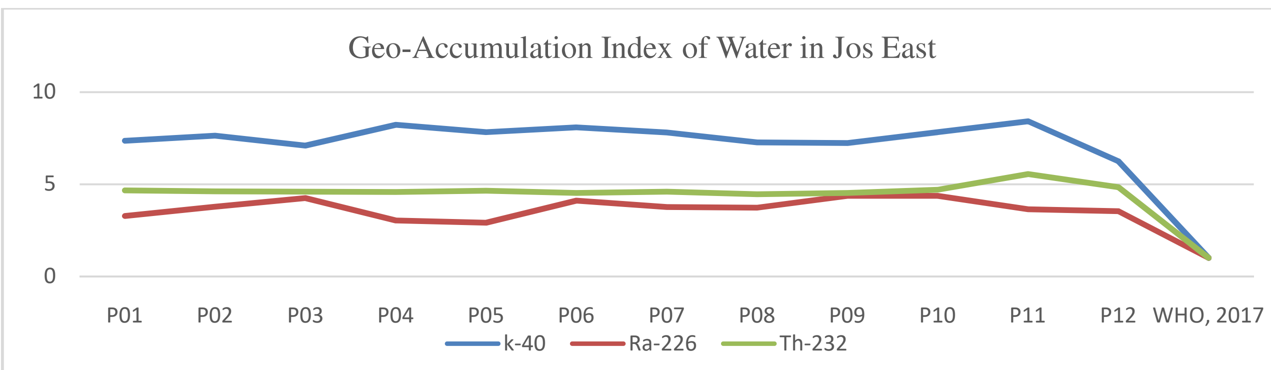

Fig 5: Chart of geo-accumulation index of water in Jos East with World Health Organization

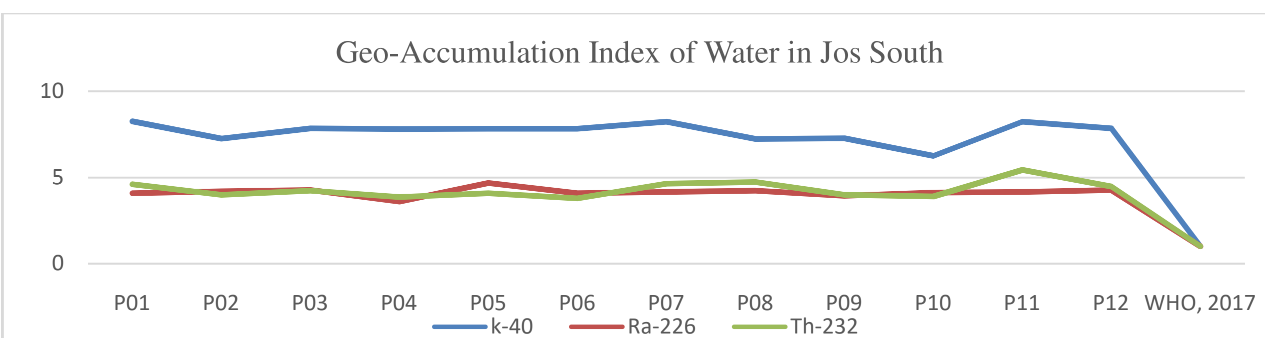

Fig 6: Chart of geo-accumulation index of water in Jos South with World Health Organization

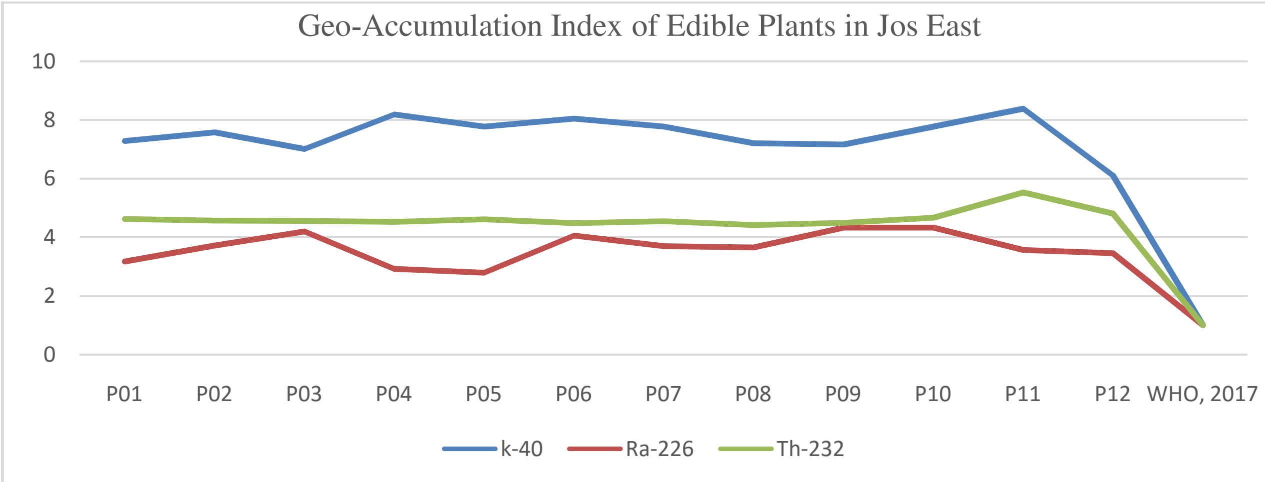

Fig 7: Chart of geo-accumulation index of edible plants in Jos Eastwith World Health Organization

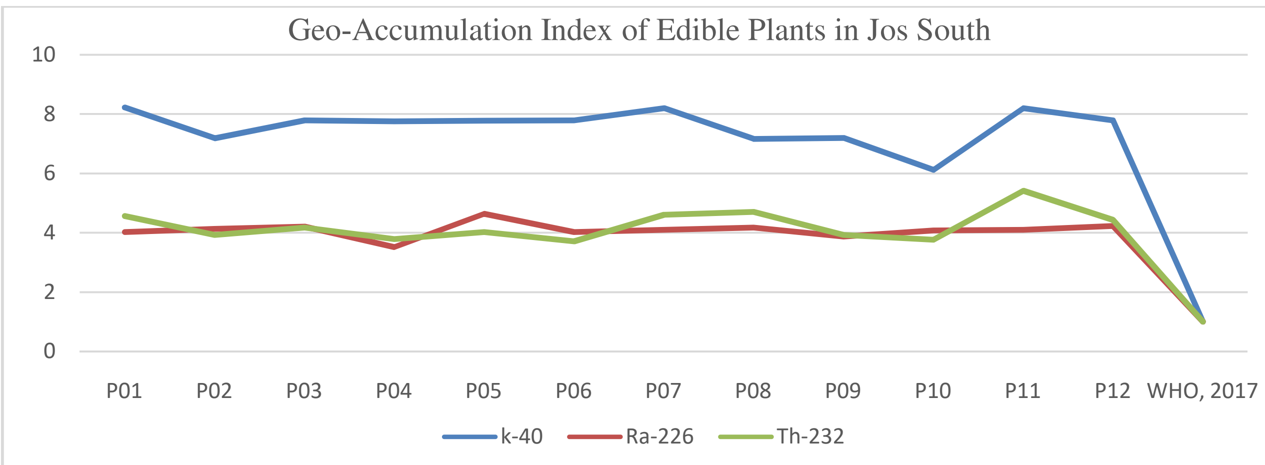

Fig 8: Chart of geo-accumulation index of edible plants in Jos South with World Health Organization

Also, on water in Jos South, the different trace elements in different sample points decreased in the following order: P11 (5.942) > P07 (5.679) > P01 (5.649) > P12 (5.532) > P05 (5.530) > P03 (5.441) > P08 (5.400) > P06 (5.229) > P01 (5.143) > P04 (5.080) > P09 (5.064) > P09 (4.758) with radioactive trace elements decreasing in the following order: ^{232}Th (7.656) >^{226}Ra (4.148) >^{40}K (4.309). Rilwan et al. (2021) also corroborated the findings of present study.

On edible plants in Jos East, the different trace elements in different sample points decreased in the following order: Water Leaf (5.825) > Rogo (5.590) > Shuwaka (5.530) > Yakuwa (5.337) > Ugu (5.326) > Kuka (5.286) > Rama (5.256) > Yateya (5.214) > Karkashi (5.094) > Alayyahu (5.057) > Zogale (5.024) > Kabeji (4.788) with radioactive trace elements decreasing in the following order: ^{232}Th (7.523) >^{226}Ra (3.658) >^{40}K (4.650). Onuk et al. (2022) advocated the similar findings.

Also, on edible plants in Jos South, the different trace elements in different sample points decreased in the following order: Water Leaf (5.905) > Yakuwa (5.636) > Zogale (5.605) > Kabeji (5.486) > Alayyahu (5.483) > Rama (5.392) > Karkashi (5.350) > Shuwaka (5.171) > Kuka (5.082) > Yateya (5.019) > Ugu (4.999) > Rogo (4.648) with radioactive trace elements decreasing in the following order: ^{232}Th (7.603) >^{226}Ra (4.091) >^{40}K (4.250). Waida et al. (2022) also corroborated the findings of present study.

Conclusion

It was concluded that all the point has their accumulation index "> 1" which implies that 100% of the areas under investigation has extremely high accumulation of trace elements in plant, water and soil. On high ingestion of these trace elements through plants or water, cells might get exposed which may later result to cancer to the populace in the study areas. It can therefore be concluded that the water and edible plants of the study areas are not good for public consumption. Hence, strict radiological laws and orders in the study areas are recommended.

Reference

Allen BC, Crump KS and Shipp AM (1988). Correlation between carcinogenic potency of chemicals in animals and humans. Risk Anal., 8(1): 531–544.

Ames B and Shigenaga K (1992). Oxidative stress is a major contribution to aging. *Ann NY Acad Sci*., 663(1), 85–96.

Anil A, Puneet K and Dalim KB (2011). Trace elements in critical illness. J Endocrinol Metab., 1(2): 57–63.

Augusto CM and Rhian MT (2011). Reactive oxygen species and endothelial function—role of nitric oxide synthase uncoupling and NOX family nicotinamide adenine dinucleotide phosphate oxidases. Basic Clin Phamacol Toxicol., 110(1): 87–94.

Auld DS (2001). Zinc coordination sphere in biochemical zinc sites. Biometals. 14(3–4): 271–313.

Bello Aisha Ademoh, Usman Rilwan and Musa Yusuf (2022). "Assessment on Radiation Hazard Indices from Selected Dumpsites in Lafia Metropolis, Nasarawa State, Nigeria". Journal of Oncology Research. 4(1): 20-26.

Galadima OO, Ayagi MD, Rebecca R, Rilwan U and Dauda MA (2022). "Analysis and Assessment of Gross Alpha and Beta in Drinking Water of Some Selected Areas of Gashua, Yobe State, Nigeria". Advances in Theoretical and Computational Physics. 5(3): 485-491.

Galadima OO, Chikwendu Orji, Rilwan U, Peter EO and Efe O (2022)."Assessment of the Effects of Radiation Exposure to Human Sensitive Organs Due to Quarry Mining in Kokona, Nasarawa and Toto of Nasarawa State Nigeria". Journal of Radiation and Nuclear Applications, An International Journal. 7(2): 29-38.

Huff J (1999). *Value, validity, and historical development of carcinogenesis studies for predicting and confirming carcinogenic risks to humans*. In: Kitchin KT (ed) Carcinogenicity. Testing, predicting, and interpreting chemical effects. Marcel Dekker, Inc., New York, pp 21–123

International Agency for Research on Cancer (IARC) (1989). *Antimony trioxide and antimony trisulfide*. IARC, Lyon, pp 291–305 (IARC monographs on the evaluation of carcinogenic risks to humans; vol 47)

International Agency for Research on Cancer (IARC) (1993). *IARC monographs on the evaluation of carcinogenic risks to humans*; vols 1–58. IARC, Lyon, pp 1972–1993.

Maurici D, Aardema M, Corvi R et al (2005). *Genotoxicity and mutagenicity*. Altern Lab Anim 33(Suppl. 1):177–182.

Mehmet Y (2006). Comprehensive comparison of trace metal concentrations in cancerous and non-cancerous human tissues. *Curr Med Chem*., 13(1), 2513–2525

Ming-Ho Y (2005). *Environmental toxicology: biological and health effects of pollutants*, chap 12, 2nd edn. CRC Press LLC, Boca Raton, USA, ISBN 1-56670-670-2

OECD (2006). Detailed review paper on cell transformation assays for detection of chemical carcinogens. DRP No. 31. Fourth draft version

Onuk OG, Chikwendu EO, Rilwan U, Peter EO and Efe O (2022). "Cancer Implication of Background Radiation Exposure to Sensitive Organs in Keffi and Karu Local Government Areas of Nasarawa State, Nigeria". *Acta Scientific Clinical Case Reports*. 3(6), 60-68.

Rilwan U, Galadima OO, Yahaya I and Rufai AM (2022). "Background Radiation Exposure in Keffi General Hospital, Keffi, Nasarawa State, Nigeria". Journal of Radiation and Nuclear Application, an International Journal. 7(1): 79-83.

Rilwan U, Hudu A, Ubaidullah A, Maisalatee AU, Bello AA, Ugwu EI and Okara GO (2021). "Fertility Cancer and Hereditary Risks in Soil Sample of Nasarawa, Nasarawa State, Nigeria". Journal of Oncology Research. 3(2): 22-27.

Rilwan U, Umar I, Abdullahi HA, Ngari AZ and Aboh HO (2019). "Radiometric Evaluation of Naturally Occurring Radionuclides in Mining Sites across Mararraba-Udege of Nasarawa State, Nigeria". Physics Memoir-Journal of Theoretical and Applied Physics. 1(4): 161-170.

Rilwan U, Umar I, Ngari AZ, Abdullahi HA and

Aboh (2020). "Radiometric Evaluation of Naturally Occurring Radionuclides in Some Ongoing Drilled Boreholes across Keffi Town of Nasarawa State, Nigeria". *International Astronomy and Astrophysics Research Journal.* 1(1), 1-9.

United Nations Economic Commission for Europe (UNECE) (2004). Globally harmonized system of classification and labeling of chemicals (GHS). Part 3, Health and environmental hazards, chap 3.6, carcinogenicity

Waida, J., Ibrahim, U., Goki, N.G., Yusuf, S.D. and Rilwan, U. (2022). Transfer Factor of Heavy Metals due to Mining Activities in Some Parts of Plateau State, Nigeria (Health Implications on the Inhabitants). *Journal of Oncology Research*. **4**(2): 13-26.

WHO (2017). *Trace elements in human nutrition: Manganese. Report of a WHO expert committee*. Geneva, World Health Organization, pp. 34–36 (Technical Report Series No. 532).

******