ACCUMULATION OF RADIOACTIVE TRACE ELEMENTS (^{40}K, ^{226}Ra and ^{232}Th) IN BASSA, PLATEAU STATE, NIGERIA.

[1]Waida, J., [2]Rilwan, U., [3]Mundi, A. A., [2]Ikpughul, S. I., [4]Aisha, B. A. and [2]Ugwu, E. I.
[1]Department of Physics, Borno State University, Maiduguri, Borno State, Nigeria
[2*]Department of Physics, Nigerian Army University, Biu, Borno State, Nigeria
[3]Department of Physics, Nasarawa State University, Keffi, Nasarawa State, Nigeria
[4]Department of Physics, Federal University, Lafia, Nasarawa State, Nigeria
Correspondence: rilwan.usman@naub.edu.ng; waidajasini@gmail.com +2348037772627.

ABSTRACT

This work intends to unveil the extent of trace elements (^{40}K, ^{226}Ra and ^{232}Th) accumulation in soil, water and edible plants using Sodium Iodide Thallium Gamma Spectrometry (NaI (Tl)) from 12 sample point each of soil, water and edible plants and assess their carcinogenic role to biological tissue that might result in cancer. The results of this study showed that the Accumulation (I_{geo}) of soil decreased in the order of ^{40}K (0.334) > ^{226}Ra (0.302) > ^{232}Th (0.259), that of water decreased in the order of ^{40}K (0.252) > ^{232}Th (0.226) > ^{226}Ra (0.197) and that of edible plants decreased in the order of ^{232}Th (-0.940) > > ^{40}K (-1.028) > ^{226}Ra (-1.116). Soil and water in all the study areas are moderately contaminated while edible plants are uncontaminated compared with the World Health Organization limit. It can be concluded that the soil, water and plants in the area required serious concern and regulatory control. Hence this study can be used as a reference data for regulatory bodies like NNRA and the rest.

Keywords: Radioactive Trace Element; Soil; Plant; Water; Geo-Accumulation Index.

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 (MacLeod *et al.* 2015). 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 (WHO 2017). 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 (Ibrahim *et al.*, 2014). Substances that induce tumors in animals are also considered human carcinogens until proven otherwise (Waida *et al.*, 2022). 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 (Usman *et al.*, 2020). 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). No formal evaluation of anti-carcinogenic effects of these trace elements has been made by IARC. 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 (Naser *et al.*, 2011). 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 (Rilwan *et al.*, 2020). 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 (Naser *et al.*, 2011). 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 according to Waida *et al.* (2022) and WHO (2017) 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.

World Average Values and Ranges of Geo-Accumulation Index according to World Health Organization are $I_{geo} \leq 0$ as uncontaminated, $0 < I_{geo} \leq 1$ as uncontaminated to moderately contaminated, $1 < I_{geo} \leq 2$ as moderately contaminated, $2 < I_{geo} \leq 3$ as moderately to strongly contaminated, $3 < I_{geo} \leq 4$ as strongly contaminated, $4 < I_{geo} \leq 5$ as strongly to extremely contaminated and $I_{geo} > 5$ as extremely contaminated.

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.

STUDY AREA

The geology of the Jos Plateau is made-up of the Precambrian Basement migmatite-gneiss-quartzite complex which underlies about half of the entire State and in some places has been intruded by Precambrian to the late Paleozoic Pan-African granite (Older Granite), diorite, charnockite etc. Intrusive into these Basement Complex rocks are the Jurassic anorogenic alkali Younger Granites. In association with the Younger Granites are volcanic rocks such as basalts and rhyolites that overly or cross-cut this formation as well as the Basement rocks. These volcanic rocks are believed to have been formed during the early Cenozoic (Tertiary) "Older Basalts" and Quaternary "Newer Basalts" (Macleod *et al*., 2015). The description of Macleod confirm the presence of minerals of economic importance such as tin and columbite which where extensively mined between 1902 and 1978. The present geological map and Satellite imagery suggests and indicates that the mining activity has devastated the arable land. The study area is therefore littered with several mine spoils and ponds in addition to severe erosion of the landmass which potent serious limitation to urban expansion and agricultural development amongst others.

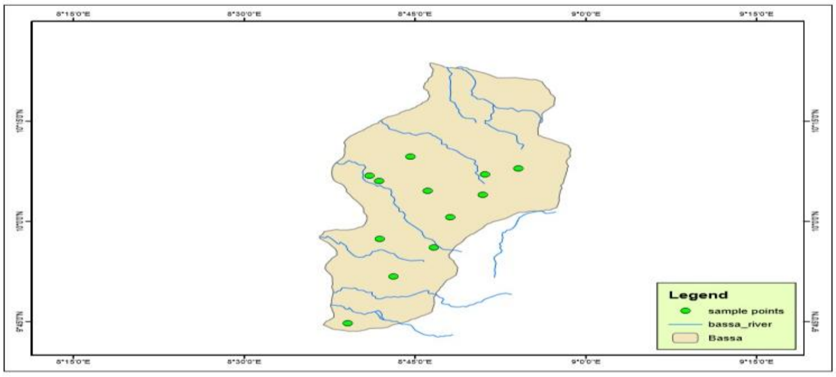

Figure 1: Map of Bassa Local Government Area, Showing Sample Points.

MATERIALS AND METHOD

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 Gamma Spectrometry (NaI (Tl))

Method

Method of Sample Collection

Soil, water and vegetable samples were pair collected. A simple systematic random sampling technique was used to select twelve (12) soil sample, twelve (12) edible plant sample, and twelve (12) water samples from the Bassa local government of Plateau State. Thirty-six (36) samples in all were analyzed in this study. Vegetables' rooted soil samples were taken at 0-20 cm depth.

The soil sample was collected by coring tool to a depth of 5 cm or to the depth of the plough line. The collected samples each of approximately 4 kg in wet weight was 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 and its position coordinates was recorded for reference purposes using GPS meter.

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 brought into the laboratory and left open (since wet) for a minimum of 24 hours to dry under ambient temperature. They were grounded using mortar and pestle and allowed to pass through 5mm-mesh sieve to remove larger object and make it 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.

Method of Water Sample Preparation

The collected water Sample Preparation at the instrumentation laboratory, the beakers were properly washed and rinsed with distil water, after which they were sterilized using Acetone. Each beaker was again rinsed twice with a little quantity of the water sample to be analyzed, then 1000ml of the water sample was poured into the beaker, which was then set on a hot plate in a fume cupboard and allowed to evaporate at a temperature of 50^0C to 60^0C. The beaker was left open without stirring to avoid excessive loss of the residue. When the water in each beaker remained about 50 ml, it was transferred to a pre-weighed ceramic dish where the sample was 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 in order 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 (Waida *et al.*, (2022):

$$V = \frac{V_w}{TR \times RP} \quad (2)$$

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

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 was used to evaluate the extent of the accumulation of these radioactive traces in water, soil and plants through an index called the geo-accumulation index as reported by Waida *et al.* (2022) in equation (1).

RESULTS AND DISCUSSION

Results

Table 1: Mean Geo-Accumulation Index of ^{40}K, ^{226}Ra and ^{232}Th in Soil, Water and Plant

Sample Type	^{40}k	^{226}Ra	^{232}Th	Mean
Soil	0.334	0.302	0.259	0.299
Water	0.252	0.197	0.226	0.225
Edible Plants	-1.028	-1.116	-0.940	-1.028
Mean	-0.147	-0.206	-0.152	-0.168

Based on the Table 1 as could be observed clearly, the soil has the highest mean accumulation of 0.299 (moderate contamination) followed by the water whose accumulation was found to be 0.225 (moderate contamination) and the least in accumulation was found in edible plants with value -1.028 (uncontaminated).

The accumulation found in soil and water, even though they are found within moderate contamination according to WHO (2015), may be attributed to the excavation of these radionuclides from a certain depth to the surface of the soil and that of water may be attributed to the direct flush of these radionuclides from the surface soil to the streams. Unlike soil and water which has direct means of contacting these radionuclides, the edible plants have to tap these radionuclides, which may be the reason why the edible plants are the uncontaminated.

Comparison of Results with World Health Organization (WHO)

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

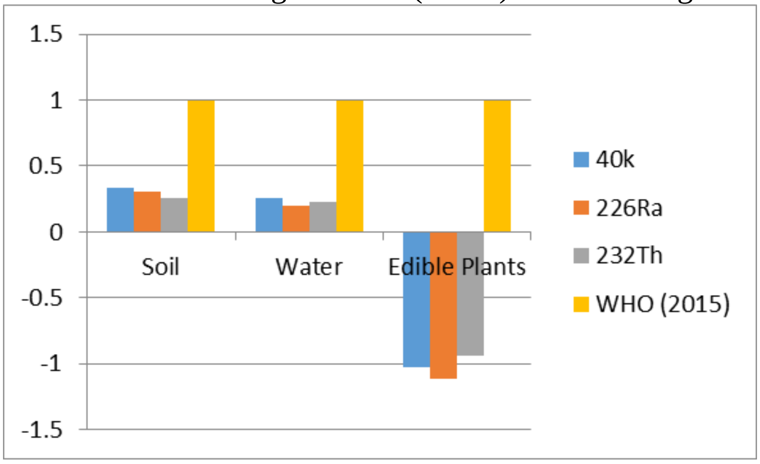

Figure 2: Comparison of Geo-Accumulation Index of Soil, Water and Edible Plants with World Health Organization

As could be observed from Figure 2, all the trace elements in water and soil falls below high accumulation as compared with WHO (2015) with ^{40}K having the highest accumulation water followed by ^{226}Ra and ^{232}Th. high accumulation in ^{40}K might be as a result of the vital role that ^{40}K plays in both human and animal's lives. In edible plants, the ^{226}Ra is the highest followed by ^{40}K and then ^{232}Th, although all falls below high accumulation as compared with WHO (2015)

DISCUSSION

The results of this study showed that the Geo-Accumulation Index (I_{geo}) of soil for different trace elements (^{40}K, ^{226}Ra and ^{232}Th) decreased in the order of ^{40}K (0.334) > ^{226}Ra (0.302) > ^{232}Th (0.259), that of water decreased in the order of ^{40}K (0.252) > ^{232}Th (0.226) > ^{226}Ra (0.197) and that of edible plants decreased in the order of ^{232}Th (-0.940) > > ^{40}K (-1.028) > ^{226}Ra (-1.116). Also considering the values presented in Table 1 and the charts presented in Figure 1 as well, it could be observed that, the geo-accumulation coefficients of the trace elements (^{40}K, ^{226}Ra and ^{232}Th) in soil and water are approaching the moderate accumulation limit of 0.5, which implies that the plant or water might have a greater chance of the trace element contamination by anthropogenic activities. This may be attributed to the illegal mining activities going on in the area where these trace elements (^{40}K, ^{226}Ra and ^{232}Th) are excavated and piled up on the surface of the soil and later flushed to the nearby streams by erosion. It would be an issue of major concern, if these illegal mining activities continue in the area, as the accumulation might be instigated to the moderate contamination level of $0.5 \leq I_{geo} < 1$ which might in turn lead to the soil and water having a greater chance of exceeding the accumulation limit of 1 (unity) in the nearest future. However, the soil, water in all the study areas are moderately contaminated while edible plants are uncontaminated compared with the World Health Organization recommended value of $I_{geo} \leq 0$ as uncontaminated, $0 < I_{geo} \leq 1$ as uncontaminated to moderately contaminated.

CONCLUSION

Based on the findings of this study, it can be concluded that the soil, water and plants in the study area falls within the uncontaminated to moderately contaminated values which calls for serious concern and regulatory control. Hence this study can be used as a reference data for regulatory bodies like NNRA and the rest.

REFERENCES

Ibrahim, A. K., Yakubu, H. and Askira, M. S. (2014). Assessment of heavy metals accumulated in wastewater irrigated soils and lettuce (Lactuca sativa) in Kwadon, Gombe State Nigeria. *American-Eurasian Journal of Agricultural & Environmental Sciences*. 14: 502-508.

J. Waida, U. Ibrahim, N.G. Goki, S.D. Yusuf and U. Rilwan (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.

J. Waida, U. Ibrahim, N.G. Goki, S.D. Yusuf and U. Rilwan (2022). Health Effects of Radiation Exposure to Human Sensitive Organs across Some Selected Mining Sites of Plateau State, Nigeria. *Journal of Oncology Research*, 4(2), 27-37.

J. Waida, U. Rilwan, O. O. Galadima, Efe Omita, J. M. Sawuta, Peter E. Ojike and R. Rebecca (2022). Transfer of K^{40}, Ra^{226} and Th^{232} from Soil to Plants and Water Resulting from Mining Activities in Bassa, Plateau State, Nigeria (Health Implications on the Inhabitants). *J. Eco. Heal. Env.*, 10(2), 5-11.

J. Waida, U. Rilwan, R. Rebecca, Peter E. Ojike, Efe Omita J. M. Sawuta and O. O. Galadima (2022). Contamination Factor of Radioactive Trace Elements (^{40}K, ^{226}Ra and ^{232}Th) due to Mining Activities in Bassa, Plateau State, Nigeria. *J. Eco. Heal. Env.*, 10(3), 13-20.

J. Waida, U. Rilwan, W. O. Ismail, I. M. Yusuff and B. I. Sunday (2022). Pollution Load Index of Heavy Metals Resulting from Mining Activities in Plateau State, Nigeria. *J. Rad. Nucl. Appl.*, 7(3), 57- 18.

MacLeod, W.N. and Berridge, N.G. (2015). Geology of the Jos Plateau. *Bull. Geol. Surv. Nigeria*, 2(32). 25-34.

Naser, H. M, Sultana, S., Mahmud, N. U., Gomes, R. and Noor, S. (2011). Heavy metal levels in vegetables with growth stage and plant species variations. *Bangladesh Journal of Agricultural Research*. 36 (1): 563-574.

Rilwan Usman, A. M. Kamal, A. Mamman, M.M. Idris, A. Ubaidullah, O.G. Okara and E.I Ugwu (2021). Health Implication of the Accumulation of Heavy Metals Concentration in Ara and Laminga Water Sources of Nasararawa Local Government Area in Nasarawa State, Nigeria. *NAUB Journal of Science and Technology (NAUBJOST)*. 1(1): 101-106.

Rilwan, U., Kamal, A. M., Ubaidullah, A., Ugwu, E. I., Okara, O. G. and Maisalatee, A.U. (2021). Identification of Heavy Metals and their Concentrations in Ushata and Rafin Tsamiya Water Sources of Nasararawa Local Government Area in Nasarawa State, Nigeria. *International Journal of Radiation and Nuclear Applications*. **6**(3): 223-227.

U. Rilwan, A. A. Abbas and S. Muhammad (2020). Heavy Metal Contamination and Its Risk for Swampy Agricultural Soils of Keffi, Nasarawa West, Nigeria. *Asian Journal of Applied Chemistry Research*. 5: 1-11.

Usman Rilwan, Auta Abdullahi Abbas and Hudu Abdulrahman (2020). Heavy Metal Contamination in Swampy Agricultural Soils of Kokona, Nasarawa, Nigeria. *Asian Journal of Applied Chemistry Research*. 5: 28-33.

Usman Rilwan, Auta Abdullahi Abbas and Shu'aib Muhammad (2020). Cancer Implications of Heavy Metals in Swampy Agricultural Soils across Kokona, Nasarawa State, Nigeria. *Asian Oncology Research Journal*. **3**(4): 1-9.

Usman Rilwan, Auta Abdullahi Abbas, Shu'aib Muhammad and Hassan Abdullahi Abdullahi (2020). Heavy Metal Contamination and It's Cancer Risk in Swampy Agricultural Soils across Karu, Nasarawa West, Nigeria. *International Research Journal of Oncology.* **3**(2): 1-12.

Usman Rilwan, Bello Aisha A., Mathew Alpha and Abdullahi Hassan Abdullahi (2020). "Identification of Heavy Metals in Agricultural Soils of Karu, Nasarawa, Nigeria". *Nigerian Journal of Physics*. **29**(2): 96-101.

Usman, R., A.M. Kamal, E.I. Ugwu, I.M. Mustapha, A. Mamman, and A. Hudu. (2020). "Assessment and Analysis of the Presence of Heavy Metals in Water in Ara and Laminga of Nasarawa State, Nigeria: Health Implication on the Populace". *The Pacific Journal of Science and Technology*. 21: 240-246.

Waida, J., Rilwan, Ismail, W. O., Yusuff, I. M. and Sunday, B. I. (2022). Pollution Load Index of Heavy Metals Resulting from Mining Activities in Plateau State, Nigeria. *Journal of Radiation and Nuclear Applications.* **7**(3): 57- 18.

Waida, J., Rilwan, U., Ikpughul, S. I. and Andrew Adamu (2022). Geo-Accumulation Index of Radioactive Trace Elements (^{40}K, ^{226}Ra and ^{232}Th) Across Mining Sites of Barkin Ladi and Mangu, Plateau State, Nigeria. *Water, Energy, Food and Environment Journal.* **3**(1): 13-25.

Waida, J., Rilwan, U., Jafar, M., Alkasim, A. and Yuguda, H. (2022). Contamination Factor of Radioactive Trace Elements (^{40}K, ^{226}Ra and ^{232}Th) due to Mining Activities in Barkin Ladi and Mangu, Plateau State, Nigeria. *Water, Energy, Food and Environment Journal.* **3**(1): 1-12.

WHO (2015). *Trace elements in human nutrition: Manganese. Report of a WHO expert committee*. Geneva, World Health Organization, pp. 34–36 (Technical Report Series No. 532).