Journal of Ecology of Health & Environment
An International Journal

http://dx.doi.org/10.18576/jehe/100201

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. Waida[1], *U. Rilwan*[2,*], *O. O. Galadima*[3], *Efe Omita*[4], *J. M. Sawuta*[5], *Peter E. Ojike*[6] and *R. Rebecca*[7]

[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, Federal University, Gashuwa, Yobe State, Nigeria
[4]Nigerian Agip Oil Company, Port Harcourt, Rivers State, Nigeria
[5]Department of Mission and Data Processing, Centre for Satellite Technology and Development (CSTD), National Space Research and Development Agency (NARSDA), Abuja, Nigeria
[6]Federal Medical Center, Owerri, Imo State, Nigeria
[7]Department of Biological Sciences, Federal University, Gashua, Yobe State, Nigeria

Received: 23 Mar. 2022, Revised: 22 Apr. 2022, Accepted: 27 Apr. 2022.
Published online: 1 May 2022.

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 Bassa. The results revealed that, the TF for different trace elements in soil-edible plants for all points decreased in the order P12 (0.716) > P04 (0.660) > P07 (0.581) > P02 (0.579) > P06 (0.574) > P10 (0.568) > P05 (0.542) > P08 (0.540) > P01 (0.534) > P09 (0.532) > P03 (0.520) > P11 (0.517). Considering the individual radioactive traces, the TF decreased in the following order: ^{232}Th (0.666) > ^{226}Ra (0.557) > ^{40}K (0.473). The total TF for different trace elements in soil-water for all points decreased in the order P04 (0.930) > P06 (0.787) > P07 (9.786) > P10 (0.780) > P08 (0.765) > P03 (0.759) > P11 (0.755) > P02 (0.720) > P01 (0.665) > P05 (0.600) > P12 (0.576) > P09 (0.398). Also considering the individual radioactive traces, the TF decreased in the order ^{232}Th (0.828) > ^{40}K (0.715) > ^{226}Ra (0.587). 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

The geological formations of the Jos include biotite, complex basement, new basalts and granite [1,2]. The minerals occurrence in this area is often associated with viscose biotite granite. This abundance of minerals results in the activities of mining and exploration in the area since 1904 [3,4]. The mining has been operating for the past 50 years, and radioactive nature of the minerals was realized not before 1974 [5,6]. The tailings activities were seen as non-radioactive before 1974, therefore, were often used in farming, building construction and industries (furnace blasting). Dust was often produced in the course of milling the Sn-ore in order to obtain tin, columbite, monazite, zircon, and ilemenite, as well as electrostatic and magnetic separations through manual processing methods in the open. These dusts were widely spreads into the surrounding environment. As a result of decades of this mining activities, the water and plants in the area have been of polluted because most of the farmlands and soils are contaminated with naturally radioactive elements above normal levels [7,8]. This drew the attention of the environmental health workers in the country for the last few decades [9,10].

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 [11]. 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

*Corresponding author e-mail: rilwan.usman@naub.edu.ng

process from soil [12]. 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 [13,14]. 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 [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 was focused to transfer factor (TF) of heavy metals like Cd, As, Cr, Pb and Ni, while the present study focused on 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 Bassa 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 releases, 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 will be 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].

Plateau State is celebrated as "The Home of Peace and Tourism". With natural formations of rocks, hills and waterfalls, it derives its name from the Jos Plateau and has a population of around 3.5 million people. Plateau State is located at North Central Zone out of the six geopolitical zones of Nigeria. With an area of 26,899 square kilometers, the State has an estimated population of about three million people. It is located between latitude 08°24'N and longitude 008°32' and 010°38' east. The state is named after the picturesque Jos Plateau, a mountainous area in the north of the state with captivating rock formations. Bare rocks are scattered across the grasslands, which cover the plateau. The altitude ranges from around 1,200 metres (3,900 ft) to a peak of 1,829 metres (6,001 ft) above sea level in the Sheer Hills range near Jos. Years of tin and columbite mining have also left the area strewn with deep gorges and lakes [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].

2.2.2 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 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 was 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]:

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

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 [28,29] and the Transfers factor from soil to plant and from soil to water is given by equation (2) according to [28,29];

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

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 [28,29].

3 Results and Discussion

3.1 Results

Table 1: Concentration of 40K, 226Ra and 232Th for Soil, Water and Edible Plants in Bassa.

S/N	Sample codes	k-40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
Soil	P01	0568.87±07.86	18.25±02.22	78.93±1.03
	P02	0535.29±07.45	23.81±02.02	66.50±0.11
	P03	0531.38±08.39	32.61±06.01	64.06±1.37
	P04	0238.14±04.50	05.39±00.26	51.79±1.77

	P05	0267.17±03.41	21.53±04.32	41.64±4.24
	P06	0645.29±04.81	34.36±20.68	77.35±3.20
	P07	047.42±02.48	43.86±02.61	71.22±0.36
	P08	0560.20±05.43	32.50±05.51	66.24±3.89
	P09	1025.23±06.52	17.21±01.37	63.72±2.51
	P10	0536.38±12.10	36.78±06.77	72.47±1.26
	P11	0283.73±07.30	53.57±07.12	82.13±0.47
	P12	0551.11±05.43	12.45±08.52	62.70±2.14
	Mean	0482.52±06.31	27.69±05.62	66.56±1.86
Water	P01	0457.76±06.75	06.03±00.01	67.82±0.02
	P02	0424.18±06.34	12.70±01.01	55.40±0.01
	P03	0420.27±07.28	21.50±05.00	53.05±0.26
	P04	0238.14±04.50	05.39±00.25	40.88±0.66
	P05	0156.06±02.30	10.42±03.21	30.53±3.13
	P06	0534.18±03.70	23.25±10.57	66.24±2.10
	P07	0036.31±01.37	32.85±01.71	60.11±0.25
	P08	0451.10±04.32	21.40±04.40	55.13±2.78
	P09	0014.12±05.41	06.10±00.26	52.61±1.40
	P10	0425.27±01.00	25.67±05.66	61.56±0.15
	P11	0172.62±06.20	42.46±06.01	71.02±0.36
	P12	0440.00±04.32	01.34±07.41	51.60±1.03
	Mean	0314.17±04.46	17.43±03.79	55.50±1.01
Edible Plant	Zogale	0346.65±05.75	05.02±01.01	56.71±0.01
	Kuka	0313.07±05.34	11.60±02.01	44.31±0.02
	Rama	0310.16±06.28	10.40±04.00	42.04±0.15
	Yateya	0127.03±03.50	04.49±01.25	31.77±0.55
	Alayyahu	0045.05±01.30	20.32±02.21	21.42±2.02
	Shuwaka	0423.07±02.70	12.15±01.57	55.13±1.00
	Yakuwa	0025.20±00.37	21.75±00.71	51.00±0.14
	Karkashi	0340.00±03.32	11.30±03.40	44.02±1.67
	Ugu	0003.01±04.41	16.20±01.26	41.50±0.30
	Rogo	0314.16±01.00	15.57±04.66	50.45±0.04
	Water Leaf	0061.51±05.20	32.36±05.01	60.01±0.25
	Kabeji	0330.00±03.32	11.24±06.41	40.50±1.02
	Mean	0219.90±03.54	14.37±02.79	44.91±0.60

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

3.1.1 Results Analysis

The results for the radioactive trace elements in water, soil and edible plants are presented in Table 2, and are further used to calculate the soil-edible plant and soil-water transfer factors as presented in Table 2.

Table 2: Soil-Edible Plants and Soil-Water Transfer Factor in Bassa.

Soil-Edible Plants					Soil-Water			
S/P	**k-40**	**Ra-226**	**Th-232**	**Total**	**k-40**	**Ra-226**	**Th-232**	**Total**
P01	0.609	0.275	0.718	**0.534**	0.805	0.330	0.859	**0.665**
P02	0.585	0.487	0.666	**0.579**	0.792	0.533	0.833	**0.720**
P03	0.584	0.319	0.656	**0.520**	0.791	0.659	0.828	**0.759**
P04	0.533	0.833	0.613	**0.660**	1.000	1.000	0.789	**0.930**
P05	0.169	0.944	0.514	**0.542**	0.584	0.484	0.733	**0.600**

P06	0.656	0.354	0.713	**0.574**	0.828	0.677	0.856	**0.787**
P07	0.531	0.496	0.716	**0.581**	0.766	0.749	0.844	**0.786**
P08	0.607	0.348	0.665	**0.540**	0.805	0.658	0.832	**0.765**
P09	0.003	0.941	0.651	**0.532**	0.014	0.354	0.826	**0.398**
P10	0.586	0.423	0.696	**0.568**	0.793	0.698	0.849	**0.780**
P11	0.217	0.604	0.731	**0.517**	0.608	0.793	0.865	**0.755**
P12	0.599	0.903	0.646	**0.716**	0.798	0.108	0.823	**0.576**
Total	**0.473**	**0.577**	**0.666**	**0.572**	**0.715**	**0.587**	**0.828**	**0.710**

It was also observed from Table 2 that the soil-edible plant transfer factor for ^{40}K, ^{226}Ra and ^{232}Th has the total of 0.473, 0.577 and 0.666 respectively, while soil-water transfer factors for ^{40}K, ^{226}Ra and ^{232}Th has the total values of 0.715, 0.587 and 0.828 respectively.

On soil-edible plant transfer factor, the total transfer factor has its trend is in descending order with P12 (0.716) > P04 (0.660) > P07 (0.581) > P02 (0.579) > P06 (0.574) > P10 (0.568) > P05 (0.542) > P08 (0.540) > P01 (0.534) > P09 (0.532) > P03 (0.520) > P11 (0.517).

On soil-water transfer factor, the total transfer factor has its trend is in descending order with P04 (0.930) > P06 (0.787) > P07 (9.786) > P10 (0.780) > P08 (0.765) > P03 (0.759) > P11 (0.755) > P02 (0.720) > P01 (0.665) > P05 (0.600) > P12 (0.576) > P09 (0.398).

3.1.2 Comparison of Results with World Health Organization (WHO)

The results presented on 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 1 and 2.

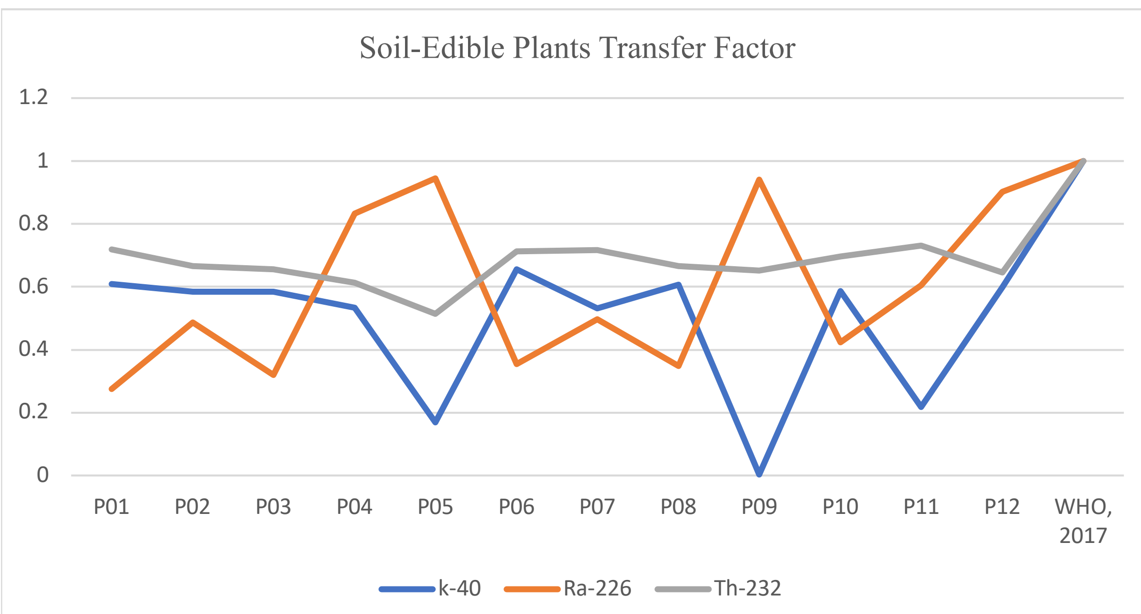

Fig. 1: Chart of Soil-Edible Plants Transfer Factor with World Health Organization.

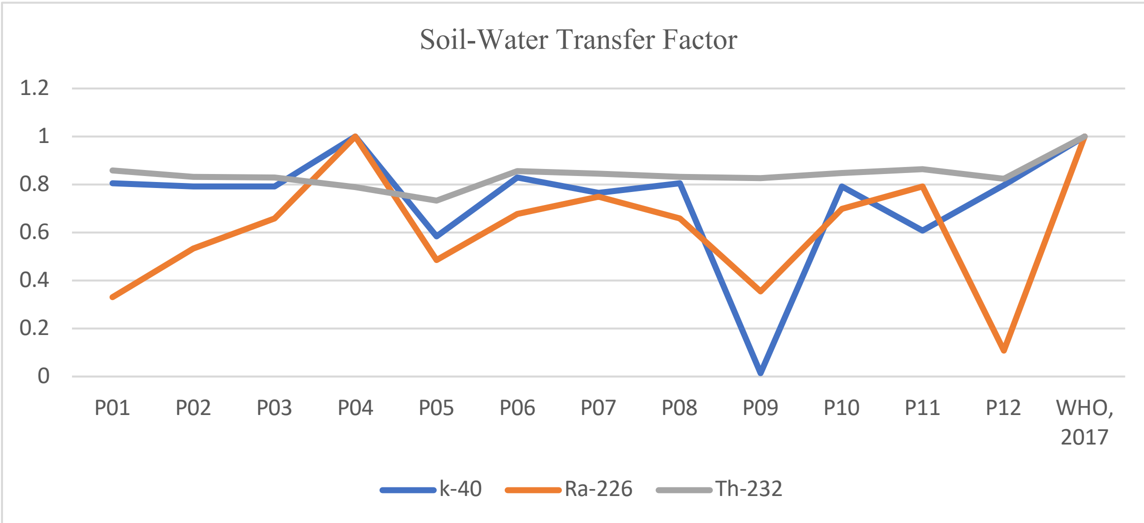

Fig. 2: Chart of Soil-Water Transfer Factor with World Health Organization.

Based on the results presented in figure 1, the soil-edible plants transfer factor for P04, P05, P09 and P11 for ^{226}Ra seem to be closely equal to that recommended by the World Health Organization (unity) while all other points are found to be lower for all the trace elements, on the other hand, the results presented in figure 2 showed that the soil-water transfer factor for P04 was found to be equal to the recommended limit of unity as recommended by World Health Organization, P01, P02, P03, P06, P07, P08, P09, P10, P11 and P12 for ^{232}Th seem to be closely equal to that recommended by the World Health Organization (unity) while all other points are found to be lower for all the trace elements.

4 Discussions

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

On soil-edible plant transfer, the total TF for different trace elements in soil-edible plants based on sample points decreased in the following order: P12 (0.716) > P04 (0.660) > P07 (0.581) > P02 (0.579) > P06 (0.574) > P10 (0.568) > P05 (0.542) > P08 (0.540) > P01 (0.534) > P09 (0.532) > P03 (0.520) > P11 (0.517). Meanwhile, considering the individual radioactive trace elements, the total TF decreased in the following order: ^{232}Th (0.666) > ^{226}Ra (0.557) > ^{40}K (0.473).

On soil-water transfer, the total TF for different trace Elements in soil-water based on sample points decreased in the following order: P04 (0.930) > P06 (0.787) > P07 (9.786) > P10 (0.780) > P08 (0.765) > P03 (0.759) > P11 (0.755) > P02 (0.720) > P01 (0.665) > P05 (0.600) > P12 (0.576) > P09 (0.398). Meanwhile, considering the individual radioactive trace elements, the total TF decreased in the following order: ^{232}Th (0.828) > ^{40}K (0.715) > ^{226}Ra (0.587).

5 Conclusions

Based on the findings of this study, it is observed that no transfer factor has its ratio "> 1" which implies no higher accumulation of trace element in plant or water parts than soil, even though the transfer coefficients of a trace elements in most of the points (except ^{40}K in soil-edible plants and P09 in soil-water) are greater than 0.50, which implies 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.

Reference

[1]. U. Rilwan, I. Umar, H. A. Abdullahi, A. Z. Ngari, H. O. Aboh, 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**, 161-170, (2019).

[2]. U. Rilwan, I. Umar, A. Z. Ngari, H. A. Abdullahi, H. O. Aboh, 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**, 1-9, (2020).

[3]. U. Rilwan, I. Umar, A. Z. Ngari, H. A. Abdullahi and H. O. Aboh, Assessment of Gamma Radiation 232Th, 226Ra and 40K in Nassarawa, Nigeria. *Asian Journal of Research and Reviews in Physics*., **2**, 1-10, (2020).

[4]. U. Rilwan, I. Umar, G. C. Onuchukwu, H. A. Abdullahi and M. Umar, Evaluation of Radiation Hazard Indices in Mining Sites of Nasarawa State, Nigeria. *Asian Journal of Research and Reviews in Physics*., **3**, 8-16, (2020).

[5]. U. Rilwan, A. Hudu, A. Ubaidullah, A. U. Maisalatee, A. A. Bello, E. I. Ugwu and G. O. Okara, Fertility Cancer and Hereditary Risks in Soil Sample of Nasarawa, Nasarawa State, Nigeria. *Journal of Oncology Research*. **3**, 22-27, (2021).

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

[7]. U. Rilwan, O. O. Galadima, I. Yahaya and A. M. Rufai, Background Radiation Exposure in Keffi General Hospital, Keffi, Nasarawa State, Nigeria. *Journal of Radiation and Nuclear Application, an International Journal*., **7**, 79-83, (2022).

[8]. Norma E.B., Review of Common Occupational Hazards and Safety Concerns for Nuclear Medicine Technologist, *Journal of nuclear Med. Tech*. 36, 11-17, (2008).

[9]. Sadiq, A. A. Agba, E. H., Indoor and Outdoor Ambient Radiation Levels in Keffi, Nigeria. *S. Work. Liv. Environ. Protec.*, **9**, 19 – 26, (2012).

[10]. Tikyaa, E. V. Atsue, T. Adegboyega, J., Assessment of the Ambient Background Radiation Levels at the Take-Off Campus of Federal University Dutsin-Ma, Katsina State-Nigeria. *FUDMA. J. Sci. (FJS) Maid. Edit*., **1**, 58-68, (2017).

[11]. Ghoshal S. N., Nuclear Physics. S. Chand and Company LTD. India., **51**, 956-1002, (2007).

[12]. U. Rilwan, O. O. Galadima, A. M. Rufai and I. Yahaya, Identification of Medical and Industrial Used Radionuclides in Dumpsites across Lafia Town, Nasarawa State, Nigeria. *Journal of Radiation and Nuclear Application, an International Journal.*, **7**, 15-19, (2022).

[13]. Rilwan Usman, Umar Ibrahim, Samson Dauda Yusuf, Idris Muhammad Mustapha, Emmanuel Ifeanyi Ugwu, Olatunji Samuel Ayanninuola, Identification of Medical and Industrial Used Radioisotopes in Mining Sites of Nasarawa, Nasarawa State, Nigeria. *Journal of Oncology Research*., **4**, 27-33, (2022).

[14]. Rilwan U, Rufai AM and Yahaya I., Assessment of radiation levels and radiological health hazards in Keffi Dumpsite, Nasarawa State, Nigeria Using Inspector Alert Nuclear Radiation Monitor (Dose to Organs (Dorgan) Approach). *Journal of Chemical Research Advances.*, **2**, 13-19, (2021).

[15]. Dawdall, M., Vicat, K., Frearso, I., Geland, S., Linda, B. & Shaw, G., Assessment of the Radiological Impacts of Historical Coal Mining Operations in the Environment of Ny-Alesund, Svalbard. *Journal of environmental radioactivity*., **71**, 101-114, (2004).

[15]. Farai, I. P. & Vincent U.E., Outdoor Radiation Level Measurement in Abeokuta, Nigeria, by Thermoluminescent Dosimetry. *Nig. Journ. Phys*., **18**,121-126, 2006.

[16]. Felix, B. M., Robert, R. D. & Emmanuel, W. M., Assessment of Indoor and Outdoor Background Radiation Levels in Plateau State University Bokkos, Jos, Nigeria. *J. Environ. Ear*. Sci., **5**, 67-99, (2015).

[17]. United Nation Scientific Committee on the Effects of Atomic Radiations (UNCSEAR), *Report to the General Assembly Scientific Annexes*, New York; United Nations, (1988).

[18]. Huyumbu, P., Zaman, M.B., Lababa, N.H.C., Munsanje, S. S. & Meleya, D., Natural Radioactivity in Zambian Building Materials Collected from Lusaka. *Journal of radioactivity nuclear chemistry*., **11**, 299, (1995).

[19]. James, I. U., Moses, I. F., Vandi, J. N.&Ikoh, U. E., Measurement of Indoor and Outdoor Background Ionizing Radiation Levels of Kwali General Hospital, Abuja. J. Appl. Sci. Environ. Manage., **19**, 89 – 93, (2015).

[20]. Maria S., Gael, P.H., Michael, K., Anne. M. T & Bernd, G., Accounting for Smoking in the Radon Related Lung Cancer Risk among German Uranium Miners. Result of nested case control study, *Health Phys*., **98**, 20-28, (2010).

[21]. Nisar A., Mohamad S. J., Muhammad B. & Muhammad R., "An overview on measurements of natural radioactivity in Malaysia", Journal of radiation research and applied sciences., **1**, 136-141, (2015).

[22]. O.O. Galadima, Chikwendu E. Orji, U. Rilwan, Peter E. Ojike, Efe Omita, 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**, 29-38, (2022).

[23]. U. Rilwan, M. Jafar, M. Musa, M.M. Idris and J. Waida, Transfer of Natural Radionuclides from Soil to Plants in Nasarawa, Nasarawa State, Nigeria. *Journal of Radiation and Nuclear Applications, An International Journal*., **7**, 81-86, (2022).

[24]. O.G. Onuk, Chikwendu E. Orji, U. Rilwan, Peter E. Ojike and Efe Omita, 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**, 60-68, (2022).

[25]. U. Rilwan, I. Yahaya, M. Musa, O.O. Galadima J. Waida and M. M. Idris, Investigation of Radon-222 in Water from Loko Town in Nasarawa, Nasarawa State, Nigeria. *Journal of Oncology and Cancer Screening*., **4**, 1-7, (2022).

[26]. Galadima, O. O., Ayagi, M. D., Rebecca, R., Rilwan, U., and Dauda, M. A., Analysis and Assessment of Gross Alpha and Beta in Drinking Water of Some Selected Areas of Gashua, Yobe State, Nigeria. A*dvances in Theoretical and Computational Physics*., **5**, 485-491, (2022).

[27]. Rilwan, U., Ugwu, E. I. and Alkasim A., Environmental Impact of Radiation Emitted from Radionuclide Across Southern Borno, Nigeria Using Inspector Alert Nuclear Radiation Monitor. *Advances in Theoretical and Computational Physics*., **5**, 492-507, (2022).

[28]. Chad-Umoren, Y. E., Adekanmbi, M. & Harry, S.O., Evaluation of Indoor Background Ionizing Radiation Profile of a Physics Laboratory. Facta Universitis series: Working and living, *Environmental Protection*., **3**, 1-7, (2007).

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