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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.

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Abstract: 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. The aim 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. The results showed that the soil in Barkin Ladi, has the mean I_{geo} decreasing in the order of ^{40}K (7.744) > ^{232}Th (4.642) > ^{226}Ra (3.886). The soil in Mangu, has the mean I_{geo} decreasing in the order of ^{40}K (7.705) > ^{232}Th (4.382) > ^{226}Ra (4.128). The water in Barkin Ladi, has the mean I_{geo} decreasing in the order of ^{232}Th ^{40}K (7.685) > ^{232}Th (4.598) > ^{226}Ra (3.804). The water in Mangu, has the mean I_{geo} decreasing in the order of ^{40}K (7.575) > ^{232}Th (4.303) > ^{226}Ra (4.037). The edible plants in Barkin Ladi, has the mean I_{geo} decreasing in the order of ^{40}K (7.582) > ^{232}Th (4.496) > ^{226}Ra (3.540). The edible plants in Mangu, has the mean I_{geo} decreasing in the order of ^{40}K (7.520) > ^{232}Th (4.122) > ^{226}Ra (3.817). Based on the findings of this study, 100 % of the area under study has its geo-accumulation index ratio "> 1" which implies higher accumulation of trace element in soil, plant and water. It can therefore be concluded that the water, soil and edible plants in the study area are issue of health concern which on high consumption without regulatory control can lead to cancer effects, even though, researches of contamination factor and pollution load index of the radioactive trace elements in the study areas are recommended.

Keywords: Radioactive Trace Element; Soil; Plant; Water; Contamination Factor.

1 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 [1]. Carcinogens are classified as either genotoxic or nongenotoxic depending on their modes of action [2]. 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 [3]. 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 [4]. Substances that induce tumors in animals are also considered human carcinogens until proven otherwise [5].

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 [6]. Other studies have demonstrated a strong correlation between carcinogenic potencies estimated from epidemiological data and those

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from animal carcinogenesis bioassays [7,8]. These observations have been used as guidelines to avoid human exposure to such chemicals found to be carcinogenic in laboratory animals [9]. 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 [10] 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 [11].

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 [12]. 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 [13]. 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 [14]. 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 [15]. It has been estimated that approximately 29104 DNA damaging events occur in every cell per day [16]; 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 [17]. 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 [18]. 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 [19]. This may result in occurrence of aging effect and cancer infection.

1.1. 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 [20] as follows:

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

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 are presented in Table 1.

Table 2.2. 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	Uncontaminated to moderately contaminated
0	0	Uncontaminated

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.

2 Materials and Methods

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. Masking tape
vi. Permanent marker and Jotter
vii. 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 [21,22].

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 [23,24,25,26,27].

The coordinates of the study areas are presented in Table 2 and were further used to design a map of the study areas as presented in Figure 1 and Figure 2.

Table 2: Geographical Coordinates of the Study Areas.

Village	Sample Points	Geographical Coordinates	
		East	North
Barkin Ladi	PT01	9° 4' 55.2"	9° 40' 33.6"
	PT02	9° 1' 30"	9° 37' 55.2"
	PT03	8° 58' 1.2"	9° 36' 39.6"
	PT04	8° 55' 26.4"	9° 34' 19.2"
	PT05	9° 0' 25.2"	9° 30' 36"
	PT06	8° 59' 31.2"	9° 27' 25.2"
	PT07	8° 55' 8.4"	9° 28' 33.6"
	PT08	8° 48' 25.2"	9° 29' 20.4"
	PT09	8° 53' 13.2"	9° 23' 13.2"
	PT10	8° 43' 55.2"	9° 22' 55.2"
	PT11	8° 42' 57.6"	9° 21' 10.8"
	PT12	8° 44' 13.2"	9° 20' 34.8"
Mangu	PT01	9° 9' 57.6"	9° 42' 21.6"
	PT02	9° 6' 21.6"	9° 34' 19.2"
	PT03	9° 13' 8.4"	9° 33'
	PT04	9° 11' 52.8"	9° 31' 30"
	PT05	9° 12' 36"	9° 29' 34.8"

	PT06	9° 17' 20.4"	9° 28' 22.8"
	PT07	9° 15' 21.6"	9° 25' 40.8"
	PT08	9° 11' 20.4"	9° 25' 58.8"
	PT09	9° 4' 1.2"	9° 25' 12"
	PT10	9° 8' 6"	9° 7' 55.2"
	PT11	9° 16' 30"	9° 6' 57.6"
	PT12	9° 12' 18"	9° 4' 1.2"

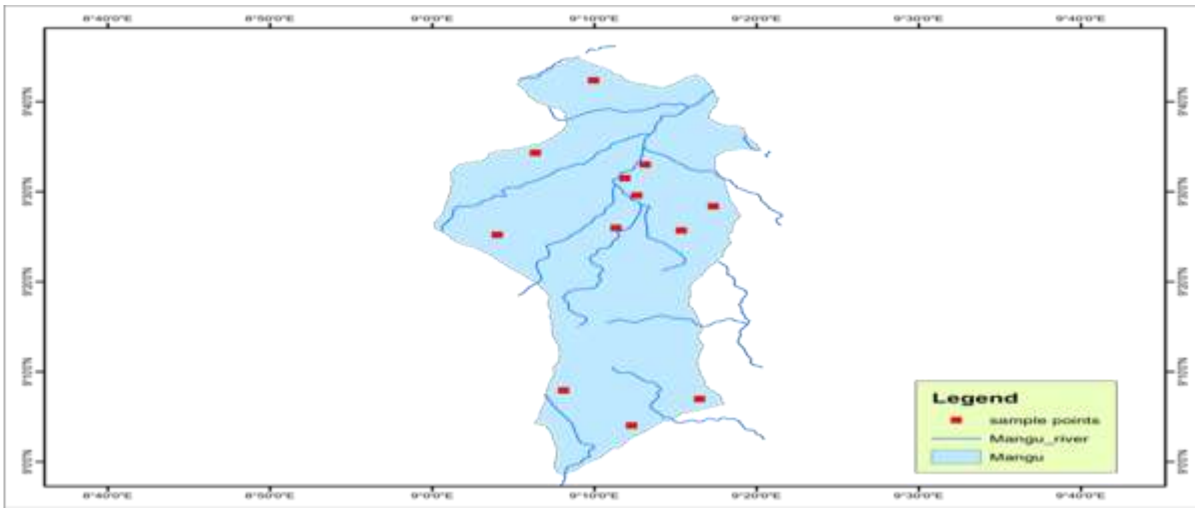

Fig. 1: Map of the Study Area Showing Sample Points in Barkin Ladi.

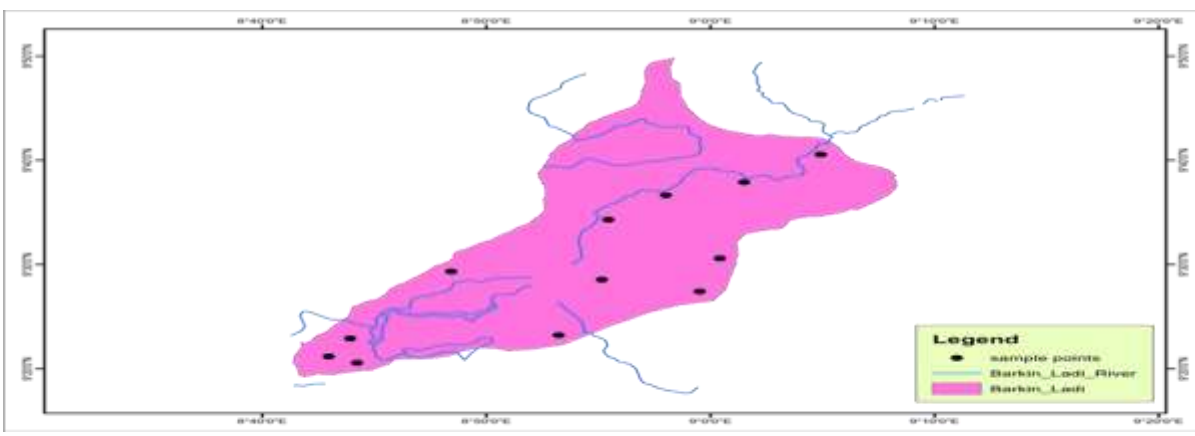

Fig. 2: Area Showing Sample Points in Mangu.

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. 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 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.

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 (2) as pointed out by [28]:

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

Where Vw is the volume of water evaporated, TR is the total residue obtained, RP is the residue transferred to the planchet [29].

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. The results obtained was used to assess 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 [20,30,31,32] in equation (1).

3 Results and Discussion

3.1 Results

Table 3: Geo-Accumulation Index of Soil Samples for Barkin Ladi and Mangu.

H/M	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Total**	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Mean**
S/P	Barkin Ladi				Mangu			
P01	8.192	3.683	4.648	**5.508**	8.217	4.200	4.687	**5.701**

P02	8.087	4.038	4.613	**5.579**	7.426	4.298	4.107	**5.277**
P03	7.752	4.190	4.597	**5.513**	7.792	4.221	4.327	**5.447**
P04	7.719	3.390	4.580	**5.230**	7.747	3.613	3.989	**5.116**
P05	7.861	3.254	4.656	**5.257**	7.960	4.683	4.200	**5.614**
P06	7.720	4.168	4.564	**5.484**	7.777	4.026	3.920	**5.241**
P07	7.978	4.079	4.576	**5.544**	8.236	4.084	4.724	**5.682**
P08	7.737	3.927	4.444	**5.369**	7.361	4.168	4.813	**5.447**
P09	7.047	4.361	4.539	**5.316**	7.261	3.861	4.107	**5.077**
P10	7.470	4.492	4.683	**5.548**	6.499	4.084	3.901	**4.828**
P11	8.192	3.605	5.079	**5.625**	8.305	4.084	5.245	**5.878**
P12	7.176	3.445	4.724	**5.115**	7.881	4.216	4.568	**5.555**
Mean	**7.744**	**3.886**	**4.642**	**5.424**	**7.705**	**4.128**	**4.382**	**5.405**

It was seen from Table 3 that the geo-accumulation Index of soil for ^{40}K, ^{226}Ra and ^{232}Th has the total of 7.744, 3.886 and 4.642 respectively for Barkin Ladi, while Mangu has the total values of 7.705, 4.128 and 4.382 respectively.

Moreover, the geo-accumulation index of soil in Barkin Ladi has its trend in descending order based on sample points with P11 (5.625) > P02 (5.579) > P10 (5.548) > P07 (5.544) > P03 (5.513) > P01 (5.508) > P06 (5.484) > P08 (5.369) > P09 (5.316) > P05 (5.257) > P04 (5.230) > P12 (5.115). On the other hand, that of Mangu has its trend in descending order with P11 (5.878) > P01 (5.701) > P07 (5.682) > P05 (5.614) > P12 (5.555) > P03 and P08 (5.447) > P02 (5.277) > P06 (5.241) > P04 (5.116) > P09 (5.077) > P10 (4.828).

Table 4: Geo-Accumulation Index of Water Samples for Barkin Ladi and Mangu.

H/M	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Total**	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Mean**
S/P	Barkin Ladi				Mangu			
P01	8.122	3.597	4.605	**5.441**	8.180	4.141	4.644	**5.655**
P02	8.083	3.971	4.568	**5.541**	7.361	4.242	4.044	**5.216**
P03	7.695	4.130	4.552	**5.459**	7.742	4.163	4.273	**5.392**
P04	7.675	3.284	4.535	**5.165**	7.695	3.523	3.920	**5.046**
P05	7.813	3.137	4.613	**5.188**	7.869	4.601	4.079	**5.516**
P06	7.677	4.107	4.518	**5.434**	7.675	3.827	3.764	**5.089**
P07	7.934	4.014	4.531	**5.493**	8.127	4.026	4.687	**5.613**
P08	7.685	3.854	4.394	**5.311**	7.154	4.113	4.778	**5.348**
P09	6.873	4.257	4.492	**5.208**	7.091	3.793	4.049	**4.978**
P10	7.407	4.444	4.640	**5.497**	6.098	4.026	3.834	**4.653**
P11	8.157	3.515	5.047	**5.573**	8.168	3.894	5.136	**5.733**
P12	7.098	3.343	4.683	**5.041**	7.741	4.090	4.430	**5.420**
Mean	**7.685**	**3.804**	**4.598**	**5.363**	**7.575**	**4.037**	**4.303**	**5.305**

It was seen from Table 4 that the geo-accumulation index of water for ^{40}K, ^{226}Ra and ^{232}Th has the total of 7.685, 3.804 and 4.598 respectively for Barkin Ladi, while Mangu has the total values of 7.575, 4.037 and 4.303 respectively.

Moreover, the geo-accumulation index of water in Barkin Ladi has its trend in descending order based on sample points with P11 (5.573) > P02 (5.541) > P10 (5.497) > P07 (5.493) > P03 (5.459) > P01 (5.441) > P06 (5.434) > P08 (5.311) > P09 (5.208) > P05 (5.188) > P04 (5.165) > P12 (5.041). On the other hand, that of Mangu has its trend in descending order with P11 (5.733) > P01 (5.655) > P07 (5.613) > P05 (5.516) > P12 (5.420) > P03 (5.392) > P08 (5.348) > P02 (5.216) > P06 (5.089) > P04 (5.046) > P09 (4.978) > P10 (4.653).

Table 5: Geo-Accumulation Index of Edible Plant Samples for Barkin Ladi and Mangu.

H/M	^{40}**K**	^{226}**Ra**	^{232}**Th**	**Total**	^{40}**K**	^{226}**Ra**	^{232}**Th**	**Mean**
Edible Plants	Barkin Ladi				Mangu			
Zogale	8.050	3.081	4.394	**5.175**	8.134	3.868	4.609	**5.537**
Kuka	7.982	3.757	4.556	**5.432**	7.175	4.032	3.834	**5.014**
Rama	7.675	3.977	4.403	**5.352**	7.676	3.841	3.965	**5.161**
Yateya	7.606	2.844	4.435	**4.962**	7.671	3.181	3.698	**4.850**
Alayyahu	7.718	2.923	4.568	**5.070**	7.727	4.576	3.841	**5.382**
Shuwaka	7.627	3.848	4.479	**5.318**	7.661	3.597	3.381	**4.880**
Yakuwa	7.856	3.939	4.435	**5.410**	8.094	3.771	4.613	**5.493**
Karkashi	7.560	3.613	4.293	**5.155**	7.154	3.894	4.694	**5.247**
Ugu	6.582	4.141	4.346	**5.023**	7.070	3.691	3.841	**4.867**
Rogo	7.360	4.342	4.605	**5.435**	6.081	3.848	3.698	**4.542**
Water Leaf	8.130	3.244	4.824	**5.399**	8.126	3.750	5.029	**5.635**
Kabeji	6.840	2.775	4.613	**4.743**	7.675	3.757	4.257	**5.230**
Mean	**7.582**	**3.540**	**4.496**	**5.206**	**7.520**	**3.817**	**4.122**	**5.153**

It was seen from Table 5 that the geo-accumulation index of ^{40}K, ^{226}Ra and ^{232}Th in has the total of 7.582, 3.540 and 4.496 respectively for Barkin Ladi, while in Mangu of ^{40}K, ^{226}Ra and ^{232}Th has the total values of 7.520, 3.817 and 4.122 respectively.

Moreover, the geo-accumulation index of edible plants in Barkin Ladi has its trend in descending order based on sample points with Rogo (5.435) > Kuka (5.432) > Yakuwa (5.410) > Water Leaf (5.399) > Rama (5.352) > Shuwaka (5.318) > Zogale (5.175) > Karkashi (5.155) > Alayyahu (5.070) > Ugu (5.023) > Yateya (4.962) > Kabeji (4.743). On the other hand, that of Mangu has its trend in descending order with Water Leaf (5.635) > Zogale (5.537) > Yakuwa (5.497) > Alayyahu (5.382) > Karkashi (5.247) > Kabeji (5.230) > Rama (5.161) > Kuka (5.014) > Shuwaka (4.880) > Ugu (4.867) > Yateya (4.850) > Rogo (4.542).

3.1.1 Comparison of Results with World Health Organization (WHO)

The results presented on Table 3, Table 4 and Table 5 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, Figure 6, Figure 7 and Figure 8.

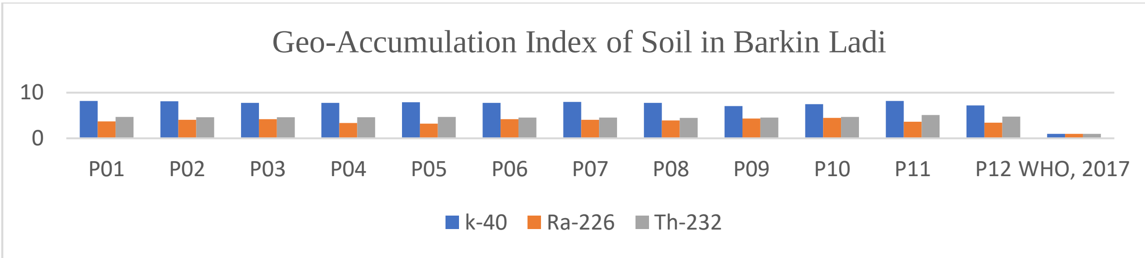

Fig.3: Chart of geo-accumulation index of Soil in Barkin Ladi with World Health Organization.

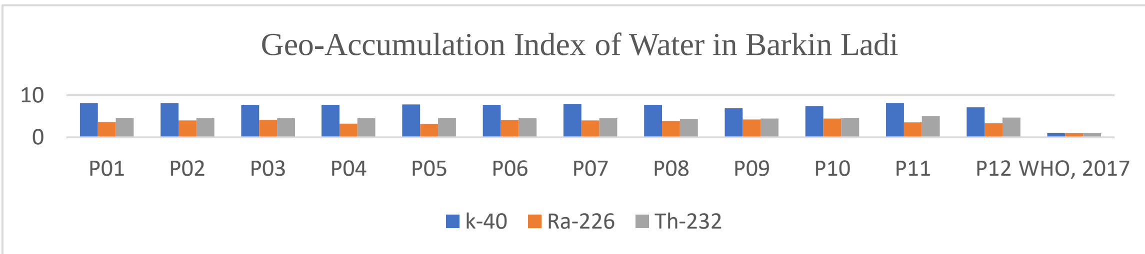

Fig.4: Chart of geo-accumulation index of Water in Barkin Ladi with World Health Organization.

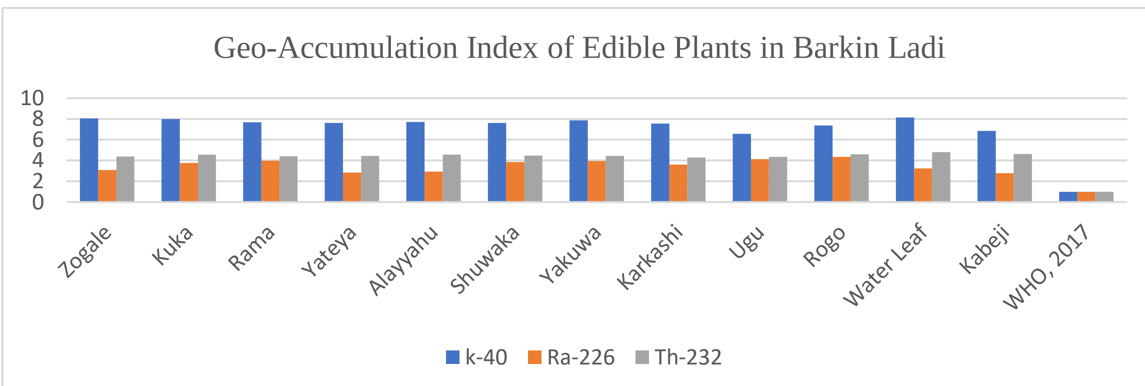

Fig. 5: Chart of geo-accumulation index of Edible Plants in Barkin Ladi with World Health Organization.

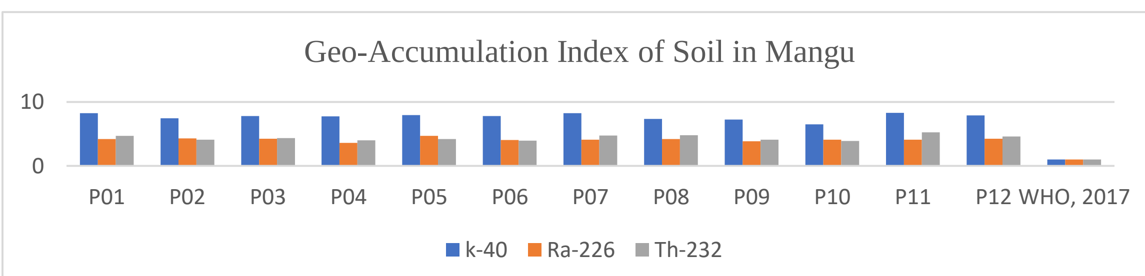

Fig. 6: Chart of geo-accumulation index of Soil in Mangu with World Health Organization.

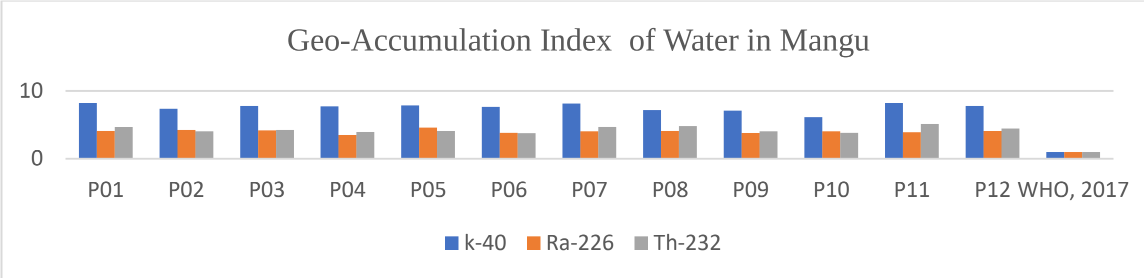

Fig.7: Chart of geo-accumulation index of Water in Mangu with World Health Organization.

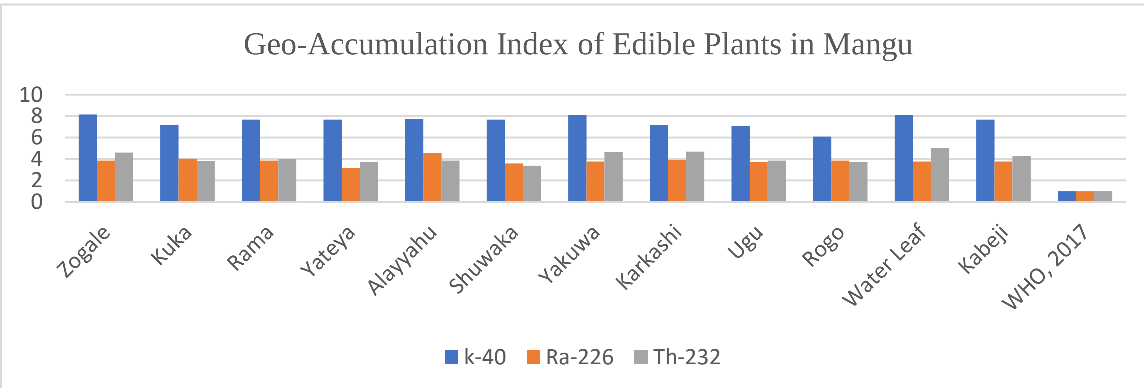

Fig.8: Chart of geo-accumulation index of Edible Plants in Mangu with World Health Organization.

Based on the results presented in Figure 3, Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8, Barkin Ladi has geo-accumulation index of both soil, water and edible plants for all the investigated trace elements to be higher than the World Health Organization limits of unity.

4 Discussions

Trace elements concentration in plants and water strongly depends on their relative exposure level to the contaminated soil. In this research work, the geo-accumulation index (I_{geo}) showed slight difference with locations.

On soil in Barkin Ladi, the total I_{geo} based on sample points decreased in the order of P11 (5.625) > P02 (5.579) > P10 (5.548) > P07 (5.544) > P03 (5.513) > P01 (5.508) > P06 (5.484) > P08 (5.369) > P09 (5.316) > P05 (5.257) > P04 (5.230) > P12 (5.115) with radioactive trace elements decreasing in the order of ^{40}K (7.744) > ^{232}Th (4.642) > ^{226}Ra (3.886).

On soil in Mangu, the mean I_{geo} based on sample points decreased in the order of P11 (5.878) > P01 (5.701) > P07 (5.682) > P05 (5.614) > P12 (5.555) > P03 and P08 (5.447) > P02 (5.277) > P06 (5.241) > P04 (5.116) > P09 (5.077) > P10 (4.828) with radioactive trace elements decreasing in the order of ^{40}K (7.705) > ^{232}Th (4.382) > ^{226}Ra (4.128).

On water in Barkin Ladi, the mean I_{geo} based on sample points decreased in the order of P11 (5.573) > P02 (5.541) > P10 (5.497) > P07 (5.493) > P03 (5.459) > P01 (5.441) > P06 (5.434) > P08 (5.311) > P09 (5.208) > P05 (5.188) > P04 (5.165) > P12 (5.041) with radioactive trace elements decreasing in the order of ^{232}Th ^{40}K (7.685) > ^{232}Th (4.598) > ^{226}Ra (3.804).

On water in Mangu, the mean I_{geo} based on sample points decreased in the order of P11 (5.733) > P01 (5.655) > P07 (5.613) > P05 (5.516) > P12 (5.420) > P03 (5.392) > P08 (5.348) > P02 (5.216) > P06 (5.089) > P04 (5.046) > P09 (4.978) > P10 (4.653) with radioactive trace elements decreasing in the order of ^{40}K (7.575) > ^{232}Th (4.303) > ^{226}Ra (4.037).

On edible plants in Barkin Ladi, the mean I_{geo} based on sample points decreased in the order of Rogo (5.435) > Kuka (5.432) > Yakuwa (5.410) > Water Leaf (5.399) > Rama (5.352) > Shuwaka (5.318) > Zogale (5.175) > Karkashi (5.155) > Alayyahu (5.070) > Ugu (5.023) > Yateya (4.962) > Kabeji (4.743) with radioactive trace elements decreasing in the order of ^{40}K (7.582) > ^{232}Th (4.496) > ^{226}Ra (3.540).

On edible plants in Mangu, the mean I_{geo} based on sample points decreased in the order of Water Leaf (5.635) > Zogale (5.537) > Yakuwa (5.497) > Alayyahu (5.382) > Karkashi (5.247) > Kabeji (5.230) > Rama (5.161) > Kuka (5.014) > Shuwaka (4.880) > Ugu (4.867) > Yateya (4.850) > Rogo (4.542) with radioactive trace elements decreasing in the order of ^{40}K (7.520) > ^{232}Th (4.122) > ^{226}Ra (3.817).

5 Conclusion

The findings of this study revealed that 100 % of the area under study has its geo-accumulation index ratio "> 1" which implies higher accumulation of trace element in soil, plant and water. It can therefore be concluded that the water, soil and edible plants in the study area are issue of health concern which on high consumption without regulatory control can lead to cancer effects, even though, researches of contamination factor and pollution load index of the radioactive trace elements in the study areas are recommended.

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