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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.

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Abstract: Accumulation of radioactive trace elements in soils is accelerated by industrial and other human activities such as mining, smelting, cement-pollution, energy and fuel production, power transmission, traffic activities, intensive agriculture, sludge dumping and melting operations. The aim of this work is to assess the contamination factor (CF) of radioactive traces like ^{40}K, ^{226}Ra and ^{232}Th. The results showed that the soil in Barkin Ladi, has mean CF decreased in the order of ^{232}Th (1.064) > ^{40}K (0.812) > ^{226}Ra (0.758). The soil in Mangu, has mean CF decreased in the order of ^{232}Th (0.922) > ^{226}Ra (0.878) > ^{40}K (0.809). The water in Barkin Ladi, has mean CF decreased in the order of ^{232}Th (1.033) > ^{40}K (0.783) > ^{226}Ra (0.719). The water in Mangu, has mean CF based on sample points decreased in the order of ^{232}Th (0.874) > ^{226}Ra (0.826) > ^{40}K (0.749). The edible plants in Barkin Ladi, has mean CF decreased in the order of ^{232}Th (0.961) > ^{40}K (0.737) > ^{226}Ra (0.614). The edible plants in Mangu, has mean CF decreased in the order of ^{226}Ra (0.883) > ^{232}Th (0.797) > ^{40}K (0.782). Based on the findings of this study, 75 % of the area under study has its contamination factor ratio "> 1" which implies higher contamination of trace element in soil, plant and water. It can 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 geo-accumulation index 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

Accumulation of radioactive trace elements in soils is accelerated by industrial and other human activities such as mining, smelting, cement-pollution, energy and fuel production, power transmission, traffic activities, intensive agriculture, sludge dumping and melting operations [1,2,3,4,5,6]. Plants received these radioactive trace elements from soils through ionic exchange, redox reactions, precipitation-dissolution, and so on [7]. This implies that the solubility of trace elements based on factors like minerals in the soil (carbonates, oxide, hydroxide etc.), soil organic matter (humic acids, fulvic acids, polysaccharides and organic acids), soil pH, redox potential, content, nutrient balance, other trace elements concentration in soil, physical and mechanical characteristics of soil, soil temperature and humidity, and so on. [8,9,10,11,12]. The bioavailability of metals in soil is a variable process which is based on specific combinations of chemical, biological, and environmental parameters [13]. Metals distribution in plants is very heterogeneous and is governed by genetic, environmental and toxic factors. The variation of heavy metals in plant-soil association is based mainly on the levels of soil contamination and plant species [14,15]. Plants traps heavy metals from the soil through the root and from the atmosphere through over ground vegetative organs [16,17,18]. Some plants species have lower tolerance to toxic radioactive trace elements

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absorption in polluted mine soil as they accumulate high concentrations of ^{40}K, ^{226}Ra and ^{232}Th [19]. More so, different plant species grown in the same soil may have different concentration of the same element [20,21]. Some authors have reported the existence of differences in accumulation of radioactive trace elements in plant cultivars, age of plants, plant organs and tissues [22,23,24]. The same radioactive trace elements can contaminate water through erosion, where radioactive trace elements are flushed to our rivers and streams and we consume them [25]. Transmission of radioactive trace elements from soil to plant tissues and from soil to water is studied using an index called Contamination Factor (CF) as recommended in a previous study (transfer factor) by same authors. Also, similar research was conducted in the same study area by the same authors, but the research was focused to contamination factor (CF) of heavy metals like Cd, As, Cr, Pb and Ni, while the present study focused on contamination factor (CF) of radioactive traces like ^{40}K, ^{226}Ra and ^{232}Th.

2 Materials and Method

2.1 Materials

The materials that was 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 (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 [26].

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 [27].

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

Table 1: 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"

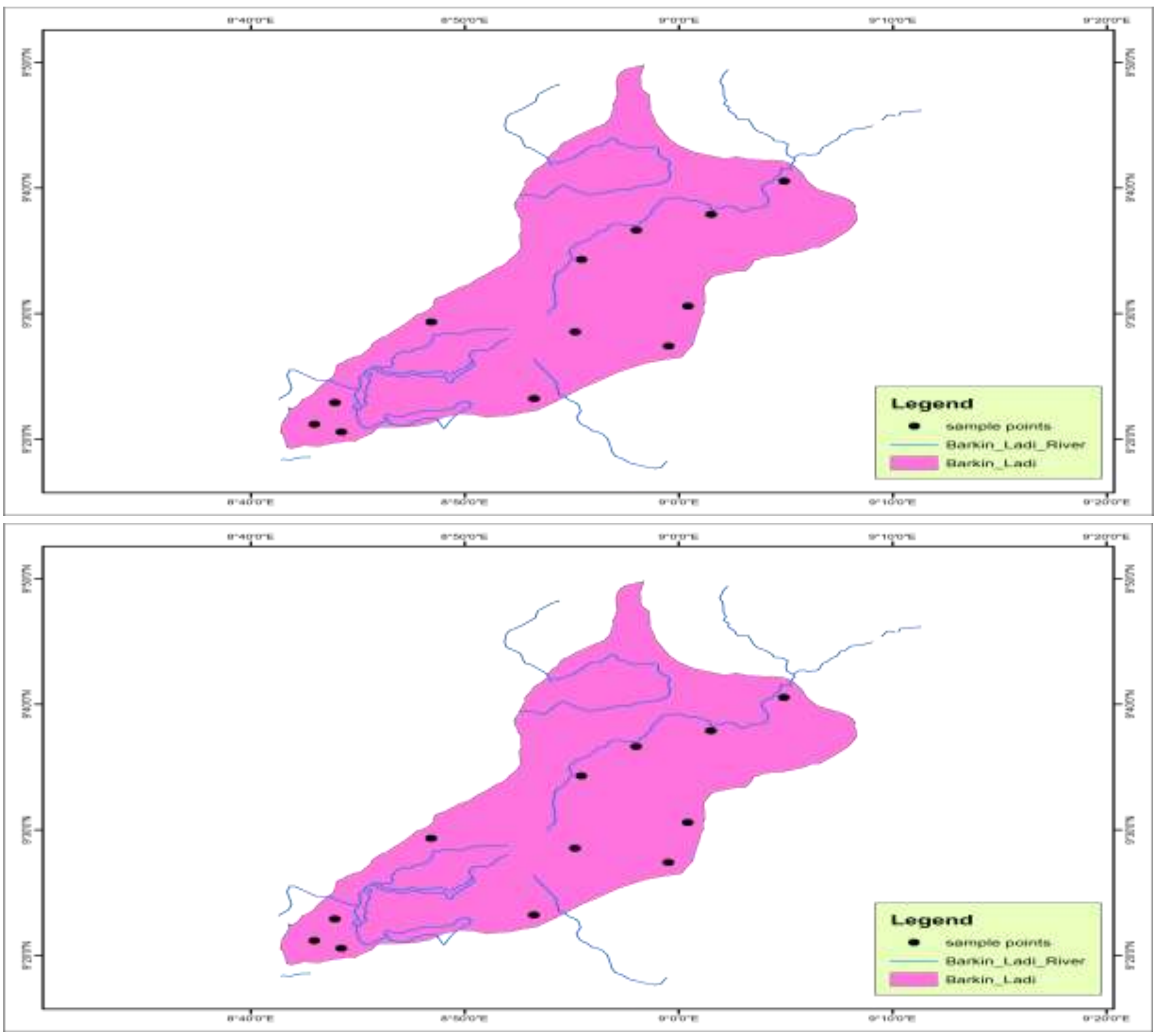

Fig. 1: Map of the Study Area Showing Sample Points in Barkin Ladi.

2.2.2 *Method of Sample Collection*

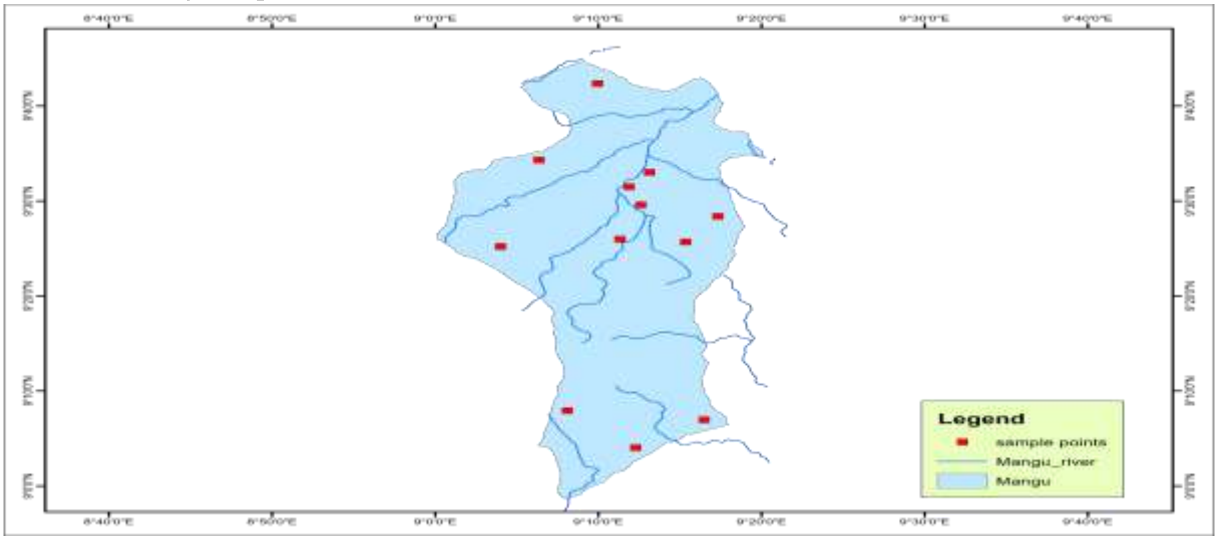

Fig. 2: Map of the Study Area Showing Sample Points in Mangu.

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.

2.2.3 *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 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 collected water Sample Preparation at the instrumentation laboratory, the beakers will be properly washed and rinsed with distil water, after which they will be sterilized using Acetone. Each beaker will again be rinsed twice with a little quantity of the water sample to be analyzed, then 1000 ml of the water sample will be poured into the beaker, which will in turn set on a hot plate in a fume cupboard and allowed to evaporate at a temperature of 50^0C to 60^0C. The beaker will be left open without stirring to avoid excessive loss of the residue. When the water in each beaker remained about 50ml, it will be transferred to a pre-weighed ceramic dish where the sample will be finally evaporated to dryness using a hot plate. The ceramic dish will be weighed again after cooling and the weight of the residue will be obtained by subtracting the previous weight of the empty dish. A few drops of Acetone will be added to the dry residue in order to sterilize it. It will then be 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 [28,29]:

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

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

2.2.5 Method of Results Analysis

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

2.2.5.1Contamination factor (CF)

The level of contamination by metals is expressed in terms of a contamination factor (CF) according to [30,31] as:

$$CF = \frac{C_m \text{Sample}}{C_m \text{Background}} \qquad 2$$

Where C_m = Concentration of sample from the flooded farm, C_m Background = Concentration of sample from the control area.
If CF < 1: indicates low contamination
1 < CF < 3: indicates moderate contamination.
3 < CF < 6: indicates considerable contamination.
CF > 6: indicates very high contamination.

3 Results and Discussion

3.1 Results

Table 2: Contamination Factor of Soil Samples for Barkin Ladi and Mangu.

T/E	^{40}K	^{226}Ra	^{232}Th	Total	^{40}K	^{226}Ra	^{232}Th	Mean
S/P	**Barkin Ladi**				**Mangu**			
P01	1.076	0.637	1.063	**0.925**	1.094	0.910	1.091	**1.032**
P02	1.000	0.813	1.037	**0.950**	0.634	0.973	0.731	**0.779**
P03	0.794	0.903	1.026	**0.906**	0.816	0.923	0.851	**0.864**
P04	0.776	0.520	1.014	**0.770**	0.791	0.607	0.674	**0.691**
P05	0.856	0.473	1.069	**0.799**	0.916	1.270	0.780	**0.989**
P06	0.776	0.890	1.003	**0.890**	0.808	0.807	0.643	**0.752**
P07	0.928	0.837	1.011	**0.925**	1.109	0.840	1.120	**1.023**
P08	0.786	0.753	0.923	**0.821**	0.606	0.890	1.191	**0.896**
P09	0.488	1.017	0.986	**0.830**	0.566	0.720	0.731	**0.672**
P10	0.653	1.113	1.089	**0.952**	0.334	0.840	0.634	**0.603**
P11	1.075	0.603	1.431	**1.037**	1.163	0.840	1.606	**1.203**
P12	0.533	0.540	1.120	**0.731**	0.868	0.920	1.006	**0.931**

Mean	**0.812**	**0.758**	**1.064**	**0.878**	**0.809**	**0.878**	**0.922**	**0.870**

It was seen from Table 2 that the contamination factor of ^{40}K, ^{226}Ra and ^{232}Th in Barkin Ladi and Mangu has the mean of 0.0.812, 0.758 and 1.064 respectively for Barkin Ladi, while in Mangu, the soil-water transfer factor of ^{40}K, ^{226}Ra and ^{232}Th has the total values of 0.809, 0.878 and 0.922 respectively.

Moreover, the contamination factor of Barkin Ladi has its trend in descending order based on sample points with P11 (1.037) > P10 (0.952) > P02 (0.950) > P01 and P07 (0.925) > P03 (0.906) > P06 (0.890) > P09 (0.830) > P08 (0.821) > P05 (0.799) > P04 (0.770) > P12 (0.731). On the other hand, that of Mangu has its trend in descending order with P11 (1.203) > P01 (1.032) > P07 (1.023) > P05 (0.989) > P12 (0.931) > P08 (0.896) > P03 (0.864) > P02 (0.779) > P06 (0.752) > P04 (0.691) > P09 (0.672) > P10 (0.603).

Table 3: Contamination Factor of Water Samples for Barkin Ladi and Mangu.

T/E	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Total**	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Mean**
S/P	Barkin Ladi				Mangu			
P01	1.025	0.600	1.031	**0.885**	1.067	0.873	1.060	**1.000**
P02	0.998	0.777	1.006	**0.927**	0.606	0.937	0.700	**0.747**
P03	0.763	0.867	0.994	**0.875**	0.788	0.887	0.820	**0.832**
P04	0.753	0.483	0.983	**0.737**	0.763	0.570	0.643	**0.659**
P05	0.828	0.437	1.037	**0.767**	0.861	1.200	0.717	**0.926**
P06	0.754	0.853	0.971	**0.859**	0.753	0.703	0.577	**0.678**
P07	0.900	0.800	0.980	**0.893**	1.028	0.807	1.091	**0.975**
P08	0.758	0.717	0.891	**0.789**	0.525	0.857	1.163	**0.848**
P09	0.433	0.947	0.954	**0.778**	0.503	0.687	0.703	**0.631**
P10	0.626	1.077	1.057	**0.920**	0.253	0.807	0.606	**0.555**
P11	1.050	0.567	1.400	**1.006**	1.058	0.737	1.489	**1.094**
P12	0.505	0.503	1.089	**0.699**	0.788	0.843	0.914	**0.848**
Mean	**0.783**	**0.719**	**1.033**	**0.845**	**0.749**	**0.826**	**0.874**	**0.816**

It was seen from Table 3 that the contamination factor of ^{40}K, ^{226}Ra and ^{232}Th in has the mean of 0.783, 0.719 and 1.033 respectively for Barkin Ladi, while in Mangu, the soil-water transfer factor of ^{40}K, ^{226}Ra and ^{232}Th has the total values of 0.749, 0.826 and 0.874 respectively.

Moreover, the contamination factor of Barkin Ladi has its trend in descending order based on sample points with P11 (1.006) > P02 (0.927) > P10 (0.920) > P07 (0.893) > P01 (0.885) > P03 (0.875) > P05 (0.859) > P08 (0.789) > P09 (0.778) > P05 (0.767) > P04 (0.737) > P12 (0.699). On the other hand, that of Mangu has its trend in descending order with P11 (1.094) > P01 (1.000) > P07 (0.975) > P05 (0.926) > P08 and P12 (0.848) > P03 (0.832) > P02 (0.747) > P06 (0.678) > P04 (0.659) > P09 (0.631) > P10 (0.555).

Table 4: Contamination Factor of Edible Plant Samples for Barkin Ladi and Mangu.

T/E	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Total**	**^{40}K**	**^{226}Ra**	**^{232}Th**	**Mean**
Edible Plants	Barkin Ladi				Mangu			
Zogale	0.975	0.420	0.891	**0.762**	1.033	0.723	1.034	**0.930**
Kuka	0.930	0.670	0.997	**0.866**	0.533	0.810	0.606	**0.649**
Rama	0.753	0.780	0.897	**0.820**	0.753	0.710	0.663	**0.709**
Yateya	0.718	0.357	0.917	**0.664**	0.750	0.450	0.551	**0.584**

Alayyahu	0.775	0.377	1.006	**0.719**	0.780	1.180	0.609	**0.856**
Shuwaka	0.728	0.713	0.946	**0.796**	0.745	0.600	0.443	**0.596**
Yakuwa	0.853	0.760	0.917	**0.843**	1.005	0.677	1.037	**0.906**
Karkashi	0.695	0.607	0.831	**0.711**	0.525	0.737	1.097	**0.786**
Ugu	0.354	0.873	0.863	**0.697**	0.496	0.640	0.609	**0.581**
Rogo	0.605	1.003	1.031	**0.880**	0.250	0.713	0.551	**0.505**
Water Leaf	1.031	0.470	1.200	**0.900**	1.028	0.667	1.383	**1.026**
Kabeji	0.423	0.340	1.037	**0.600**	0.753	0.670	0.811	**0.745**
Mean	**0.737**	**0.614**	**0.961**	**0.771**	**0.782**	**0.838**	**0.797**	**0.806**

It was seen from Table 4 that the contamination factor of ^{40}K, ^{226}Ra and ^{232}Th in has the mean of 0.737, 0.614 and 0.961 respectively for Barkin Ladi, while in Mangu, the soil-water transfer factor of ^{40}K, ^{226}Ra and ^{232}Th has the total values of 0.782, 0.838 and 0.797 respectively.

Moreover, the contamination factor of Barkin Ladi has its trend in descending order based on sample points with Water Leaf (0.900) > Rogo (0.880) > Kuka (0.866) > Yakuwa (0.843) > Rama (0.820) > Shuwaka (0.796) > Zogale (0.762) > Alayyahu (0.719) > Karkashi (0.711) > Ugu (0.697) > Yateya (0.664) > Kabeji (0.600). On the other hand, that of Mangu has its trend in descending order with Water Leaf (1.026) > Zogale (0.930) > Yakuwa (0.906) > Alayyahu (0.856) > Karkashi (0.786) > Kabeji (0.745) > Rama (0.709) > Kuka (0.649) > Shuwaka (0.596) > Yateya (0.584) > Ugu (0.581) > Rogo (0.505).

3.1.1 Comparison of Results with World Health Organization (WHO)

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

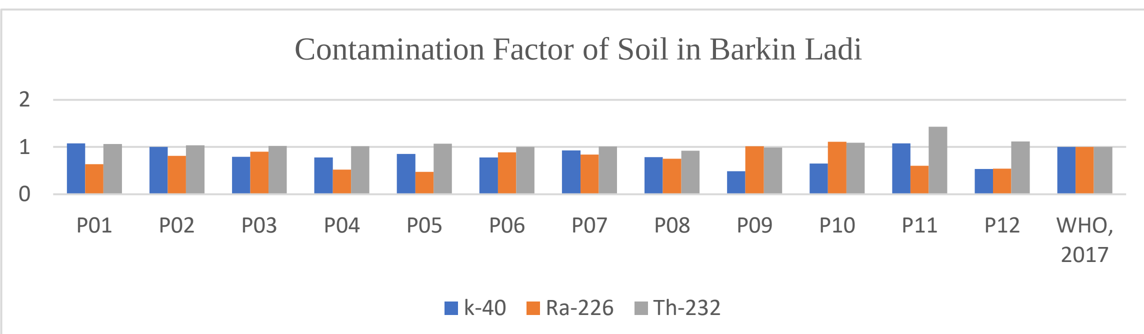

Fig. 3: Chart of Contamination Factor of Soil in Barkin Ladi with World Health Organization.

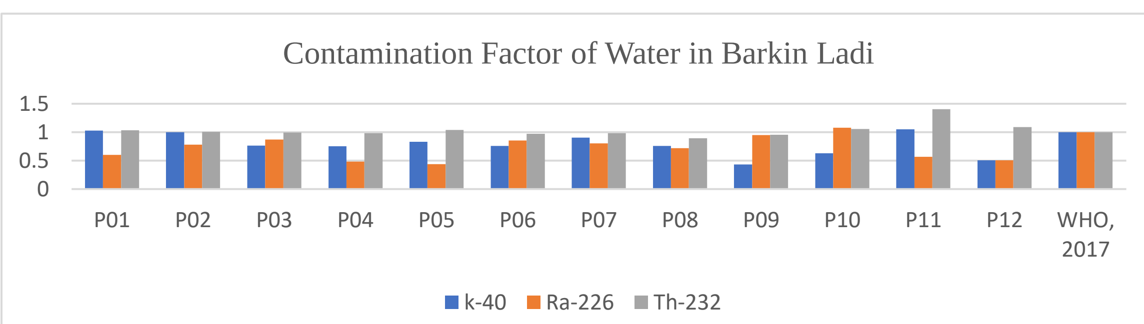

Fig. 4: Chart of Contamination Factor of Water in Barkin Ladi with World Health Organization.

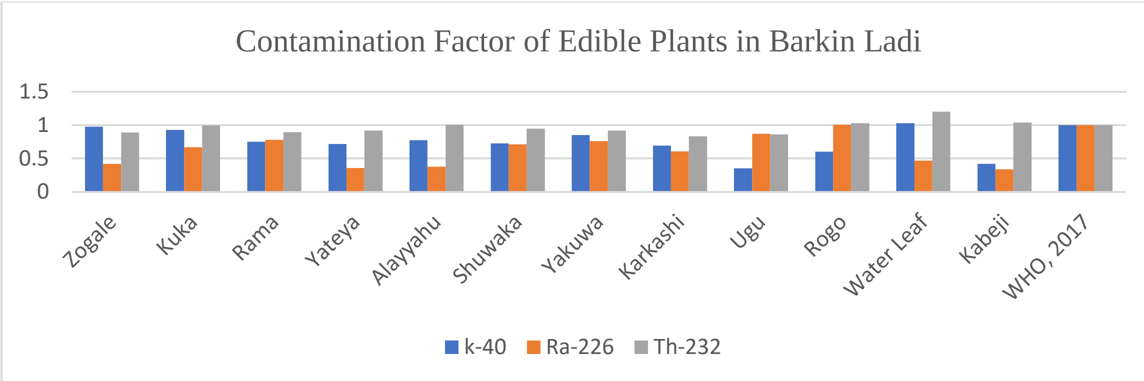

Fig. 5: Chart of Contamination Factor of Edible Plants in Barkin Ladi with World Health Organization.

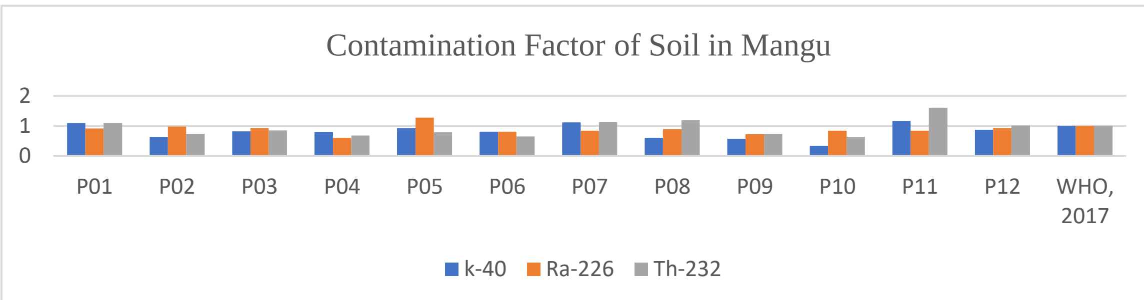

Fig. 6: Chart of Contamination Factor of Soil in Mangu with World Health Organization.

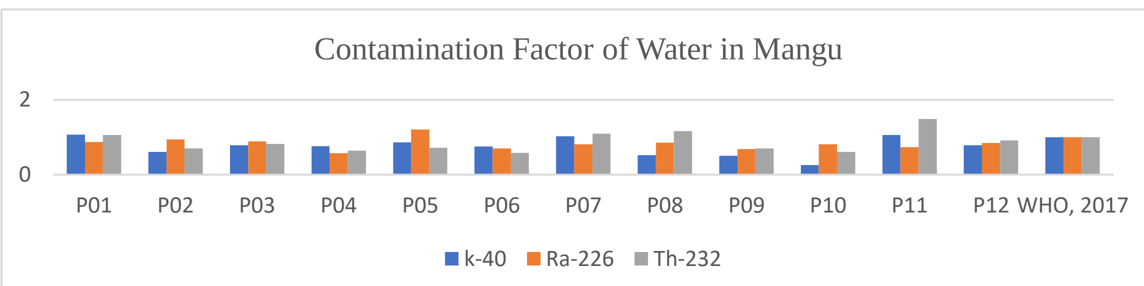

Fig. 7: Chart of Contamination Factor of Water in Mangu with World Health Organization.

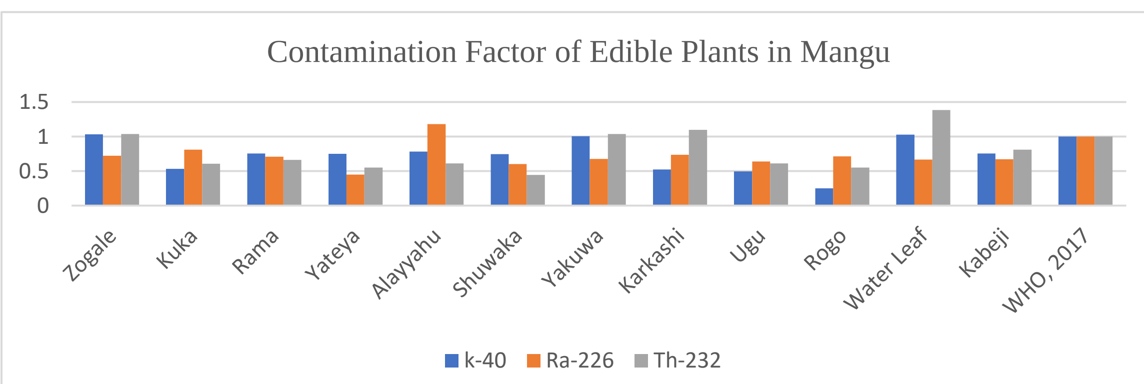

Fig. 8: Chart of Contamination Factor of Edible Plants in Mangu with World Health Organization.

Based on the results presented in Figure 3, Barkin Ladi has contamination factor of soil for ^{40}K in P01, P02 and P11 higher than the World Health Organization limits of unity, whereas other points are found to be lower. The contamination factor of soil for ^{226}Ra in Barkin Ladi was found to be high in P09 and P10, whereas other points are found to be lower compare to World Health Organization limits of unity. Lastly in Figure 3, Barkin Ladi was seen to have P08 and P09 for ^{232}Th lower than the World Health Organization limits of unity, whereas other points are found to be higher.

According to the results presented in Figure 4, Barkin Ladi has contamination factor of water for ^{40}K in P01 and P11 higher than the World Health Organization limits of unity, whereas other points are found to be lower. The contamination factor of water for ^{226}Ra in Barkin Ladi was found to be high in P10, whereas other points are found to be lower compare to World Health Organization limits of unity. Lastly in Figure 4, Barkin Ladi was seen to have P03, P04, P06, P07, P08 and P09 lower for ^{232}Th than the World Health Organization limits of unity, whereas other points are found to be higher.

Based on the results presented in Figure 5, Barkin Ladi has contamination factor of edible plants for ^{40}K in water leaf higher than the World Health Organization limits of unity, whereas other points are found to be lower. The contamination factor of edible plants for ^{226}Ra in Barkin Ladi was found to be high in Rogo, whereas other points are found to be lower compare to World Health Organization limits of unity. Lastly in Figure 5, Barkin Ladi was seen to have Alayyahu, Rogo and Kabeji for ^{232}Th higher than the World Health Organization limits of unity, whereas other points are found to be lower.

According to the results presented in Figure 6, Mangu has contamination factor of soil for ^{40}K in P01, P07 and P11 higher than the World Health Organization limits of unity, whereas other points are found to be lower. The contamination factor of soil for ^{226}Ra in Mangu was found to be high in P05, whereas other points are found to be lower compare to World Health Organization limits of unity. Lastly in Figure 6, Mangu was seen to have P01, P07, P08, P11 and P12 higher for ^{232}Th than the World Health Organization limits of unity, whereas other points are found to be lower.

According to the results presented in Figure 7, Mangu has contamination factor of water for ^{40}K in P01, P07 and P11 higher than the World Health Organization limits of unity, whereas other points are found to be lower. The contamination factor of water for ^{226}Ra in Mangu was found to be high in P05, whereas other points are found to be lower compare to World Health Organization limits of unity. Lastly in Figure 7, Mangu was seen to have P01, P07, P08 and P11 higher for ^{232}Th than the World Health Organization limits of unity, whereas other points are found to be lower.

Based on the results presented in Figure 8, Mangu has contamination factor of edible plants for ^{40}K in water leaf, Zogale and Yakuwa higher than the World Health Organization limits of unity, whereas other points are found to be lower. The contamination factor of edible plants for ^{226}Ra in Mangu was found to be high in Alayyahu, whereas other points are found to be lower compare to World Health Organization limits of unity. Lastly in Figure 8, Mangu was seen to have Zogale, Yakuwa, Karkashi and Water Leaf for ^{232}Th higher than the World Health Organization limits of unity, whereas other points are found to be lower.

4 Discussion

Radioactive trace elements concentration in plants and water strongly depends on their relative exposure level to the contaminated soil. In this work, the contamination Factor (CF) showed slight variation with locations.

On soil in Barkin Ladi, the total CF based on sample points decreased in the order of P11 (1.037) > P10 (0.952) > P02 (0.950) > P01 and P07 (0.925) > P03 (0.906) > P06 (0.890) > P09 (0.830) > P08 (0.821) > P05 (0.799) > P04 (0.770) > P12 (0.731) with radioactive trace elements decreasing in the order of ^{232}Th (1.064) > ^{40}K (0.812) > ^{226}Ra (0.758).

On soil in Mangu, the total CF based on sample points decreased in the order of P11 (1.203) > P01 (1.032) > P07 (1.023) > P05 (0.989) > P12 (0.931) > P08 (0.896) > P03 (0.864) > P02 (0.779) > P06 (0.752) > P04 (0.691) > P09 (0.672) > P10 (0.603) with radioactive trace elements decreasing in the order of ^{232}Th (0.922) > ^{226}Ra (0.878) > ^{40}K (0.809).

On water in Barkin Ladi, the total CF based on sample points decreased in the order of P11 (1.006) > P02 (0.927) > P10 (0.920) > P07 (0.893) > P01 (0.885) > P03 (0.875) > P05 (0.859) > P08 (0.789) > P09 (0.778) > P05 (0.767) > P04 (0.737) > P12 (0.699) with radioactive trace elements decreasing in the order of ^{232}Th (1.033) > ^{40}K (0.783) > ^{226}Ra (0.719).

On water in Mangu, the total CF based on sample points decreased in the order of P11 (1.094) > P01 (1.000) > P07 (0.975) > P05 (0.926) > P08 and P12 (0.848) > P03 (0.832) > P02 (0.747) > P06 (0.678) > P04 (0.659) > P09 (0.631) > P10 (0.555) with radioactive trace elements decreasing in the order of ^{232}Th (0.874) > ^{226}Ra (0.826) > ^{40}K (0.749).

On edible plants in Barkin Ladi, the total CF based on sample points decreased in the order of Water Leaf (0.900) > Rogo (0.880) > Kuka (0.866) > Yakuwa (0.843) > Rama (0.820) > Shuwaka (0.796) > Zogale (0.762) > Alayyahu (0.719) > Karkashi (0.711) > Ugu (0.697) > Yateya (0.664) > Kabeji (0.600) with radioactive trace elements decreasing in the order of ^{232}Th (0.961) > ^{40}K (0.737) > ^{226}Ra (0.614).

On edible plants in Mangu, the total CF based on sample points decreased in the order of Water Leaf (1.026) > Zogale (0.930) > Yakuwa (0.906) > Alayyahu (0.856) > Karkashi (0.786) > Kabeji (0.745) > Rama (0.709) > Kuka (0.649) > Shuwaka (0.596) > Yateya (0.584) > Ugu (0.581) > Rogo (0.505) with radioactive trace elements decreasing in the order of ^{226}Ra (0.883) > ^{232}Th (0.797) > ^{40}K (0.782).

5 Conclusions

The findings of this study revealed that 75 % of the area under study has its contamination factor ratio "> 1" which implies higher contamination 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 geo-accumulation index and pollution load index of the radioactive trace elements in the study areas are recommended.

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