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Contamination Factor of Radioactive Trace Elements (^{40}K, ^{226}Ra and ^{232}Th) due to Mining Activities in Bassa, Plateau State, Nigeria

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Abstract: Plants received these radioactive trace elements from soils through ionic exchange, redox reactions, precipitation-dissolution. The same trace elements can contaminate water through erosion, where radioactive trace elements are flushed to our rivers and streams and we consume them. Contamination factor of soil, water and edible plants is studied using an index called Contamination Factor (CF). The result revealed that, the total CF for different trace elements in soil based on sample points decreased in the order P06 (1.66)>P09 (1.65)>P11 (1.61)>P10 (1.55)>P08 (1.46)>P01 (1.43)>P03 (1.42)>P02 (1.34)>P07 (1.21)>P12 (1.20)>P05 (0.86)>P04 (0.75), considering the individual trace elements, the total CF decreased in the ^{232}Th (1.90) > ^{40}K (1.21) > ^{226}Ra (0.92). The total CF for different trace elements in water based on sample points decreased in the order P06 (1.33)>P11 (1.29)>P10 (1.23)>P08 (1.14)>P01 and P03 (1.09)>P02 (1.02)>P07 (0.97)>P12 (0.87)>P04 (0.65)>P09 (0.58)>P05 (0.54), considering the individual trace elements, the total CF decreased in the order: ^{232}Th (1.59) > ^{40}K (0.79) > ^{226}Ra (0.58). The total CF for different trace elements in edible plant based on sample points decreased in the order of Shuwaka (1.01)>Water Leaf (0.98)>Rogo (0.92)>Zogale (0.89)>Karkashi (0.83)>Kuka (0.81)>Kabeji (0.79)>Rama (0.77)>Yakuwa (0.75)>Ugu (0.58)>Alayyahu (0.47)>Yateya (0.46), considering the individual trace elements, the total CF decreased in the order ^{232}Th (1.28) > ^{40}K (0.55) > ^{226}Ra (0.48).

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

1 Introduction

Aggregation of radioactive trace elements in soils is instigated 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 [1,2,3,4,5,6,7]. Plants received these radioactive trace elements from soils through ionic exchange, redox reactions, precipitation-dissolution, and so on. 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

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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 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 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. X-Ray Fluorescence Spectrometry System (XRF)

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 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 [26].
Though situated in the tropical zone, a higher altitude means that Plateau State has a near temperate climate with an average temperature of between 13 and 22 °C. Harmattan winds cause the coldest weather between December and February. The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies between 131.75 cm (52 in) in the southern part to 146 cm (57 in) on the Plateau. The highest rainfall is recorded during the wet season months of July and August. The average lower temperatures in Plateau State have led to a reduced incidence of some tropical diseases such as malaria. The Jos Plateau makes it the source of many rivers in northern Nigeria including the Kaduna, Gongola, Hadeja and Damaturu rivers. The Jos Plateau is thought to be an area of younger granite which was intruded through an area of older granite rock, making up the surrounding states. These "younger" granites are thought to be about 160 million years old. This creates the unusual scenery of the Jos Plateau. There are numerous hillocks with gentle slopes emerging from the ground like mushrooms scattered with huge boulders. Also, volcanic activity 50 million years ago created numerous volcanoes and vast basaltic plateaus formed from lava flows. This also produces regions of mainly narrow and deep valleys and pediments (surfaces made smooth by erosion) from the middle of rounded hills with sheer rock faces. The phases of volcanic activities involved in the formation of Plateau State have made it one of the mineral rich states in the country. Tin is still mined and processed on the plateau [27].

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].

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 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 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 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 1000ml 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]:

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

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 [29] as:

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

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 1: Concentration of ^{40}K, ^{226}Ra and ^{232}Th 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 contamination factors as presented in Table 2.

Table 2: Contamination Factor of ^{40}K, ^{226}Ra and ^{232}Th in Soil, Water and Edible Plants for Bassa.

S/P	^{40}k	^{226}Ra	^{232}Th	Total	^{40}k	^{226}Ra	^{232}Th	Total	S/P	^{40}k	^{226}Ra	^{232}Th	Total
Soil					Water				Edible Plants				
PT01	1.42	0.61	2.26	**1.43**	1.14	0.20	1.94	**1.09**	Zogale	0.87	0.17	1.62	**0.89**
PT02	1.34	0.79	1.90	**1.34**	1.06	0.42	1.58	**1.02**	Kuka	0.78	0.39	1.27	**0.81**
PT03	1.33	1.09	1.83	**1.42**	1.05	0.72	1.52	**1.09**	Rama	0.78	0.35	1.20	**0.77**
PT04	0.60	0.18	1.48	**0.75**	0.60	0.18	1.17	**0.65**	Yateya	0.32	0.15	0.91	**0.46**
PT05	0.67	0.72	1.19	**0.86**	0.39	0.35	0.87	**0.54**	Alayyahu	0.11	0.68	0.61	**0.47**
PT06	1.61	1.15	2.21	**1.66**	1.34	0.78	1.89	**1.33**	Shuwaka	1.06	0.41	1.58	**1.01**
PT07	0.12	1.46	2.04	**1.21**	0.09	1.10	1.72	**0.97**	Yakuwa	0.06	0.73	1.46	**0.75**

PT08	1.40	1.08	1.89	**1.46**	1.13	0.71	1.58	**1.14**	Karkashi	0.85	0.38	1.26	**0.83**
PT09	2.56	0.57	1.82	**1.65**	0.04	0.20	1.50	**0.58**	Ugu	0.01	0.54	1.19	**0.58**
PT10	1.34	1.23	2.07	**1.55**	1.06	0.86	1.76	**1.23**	Rogo	0.79	0.52	1.44	**0.92**
PT11	0.71	1.79	2.35	**1.61**	0.43	1.42	2.03	**1.29**	Water Leaf	0.15	1.08	1.72	**0.98**
PT12	1.38	0.42	1.79	**1.20**	1.10	0.05	1.47	**0.87**	Kabeji	0.83	0.38	1.16	**0.79**
Total	**1.21**	**0.92**	**1.90**	**1.34**	**0.79**	**0.58**	**1.59**	**0.98**	**Total**	**0.55**	**0.48**	**1.28**	**0.77**

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

It was observed from Table 2 that the contamination factor of soil; water; edible plants; for ^{40}K, ^{226}Ra and ^{232}Th has the total of 1.21, 0.92 and 1.90; 0.79, 0.58 and 1.59; 0.55, 0.48, and 1.28; respectively.

It was also observed from Table 2 that the contamination factors of soil have the total values in trend with P06 (1.66) > P09 (1.65) > P11 (1.61) > P10 (1.55) > P08 (1.46) > P01 (1.43) > P03 (1.42) > P02 (1.34) > P07 (1.21) > P12 (1.20) > P05 (0.86) > P04 (0.75).

It was similarly observed from Table 2 that the contamination factors of water have the total values in trend with P06 (1.33) > P11 (1.29) > P10 (1.23) > P08 (1.14) > P01 and P03 (1.09) > P02 (1.02) > P07 (0.97) > P12 (0.87) > P04 (0.65) > P09 (0.58) > P05 (0.54).

It was similarly observed from Table 2 that the contamination factors of edible plants have the total values in trend with Shuwaka (1.01) > Water Leaf (0.98) > Rogo (0.92) > Zogale (0.89) > Karkashi (0.83) > Kuka (0.81) > Kabeji (0.79) > Rama (0.77) > Yakuwa (0.75) > Ugu (0.58) > Alayyahu (0.47) > Yateya (0.46).

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, 2 and 3.

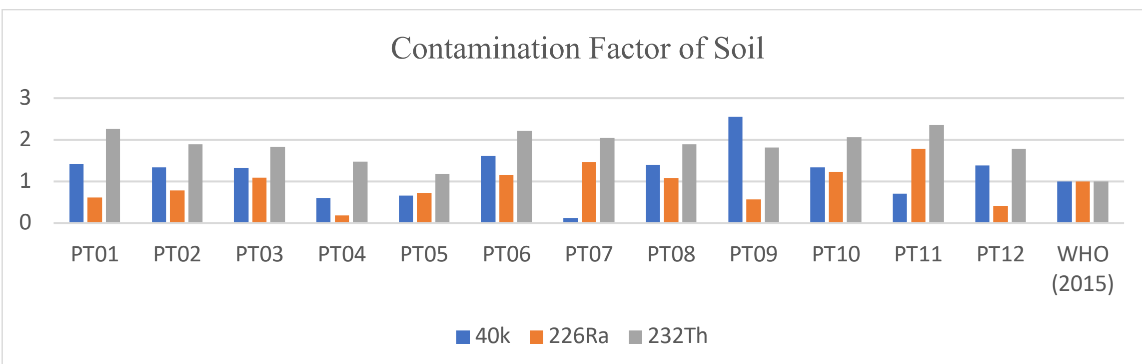

Fig.1: Comparison of Contamination Factor of Soil with World Health Organization.

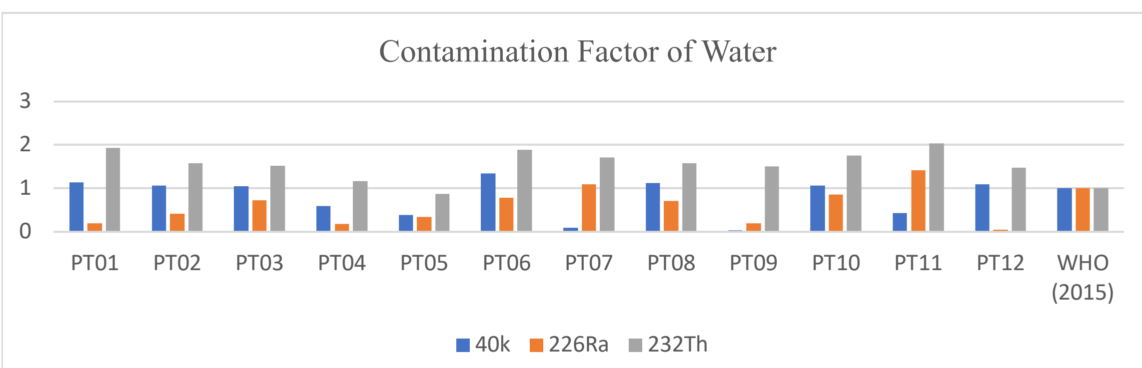

Fig.2: Comparison of Contamination Factor of Water with World Health Organization.

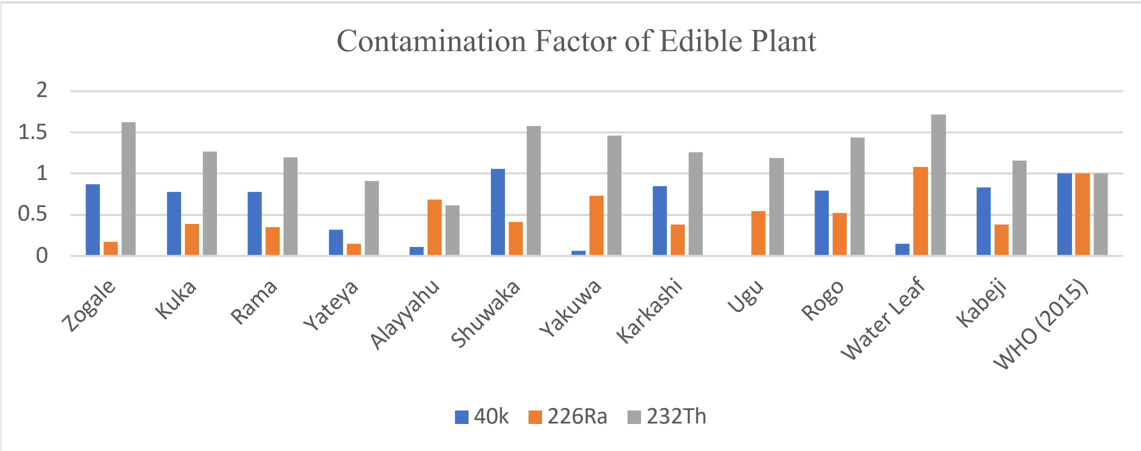

Fig.3: Comparison of Contamination Factor of Edible Plant with World Health Organization.

Based on the chart presented in figure 1, the soil is moderately contaminated with most of the radioactive traces (^{40}K, ^{226}Ra and ^{232}Th) except for ^{226}Ra in P01, ^{226}Ra in P02, ^{40}K and ^{226}Ra in P04, ^{40}K and ^{226}Ra in P05, ^{40}K in P07, ^{226}Ra in P09, ^{40}K in P11 and ^{226}Ra in P12 which are less contaminated considering the World Health Organization recommended value of CF < 1 as low contamination, 1 < CF < 3 as moderate contamination, 3 < CF < 6 as considerable contamination and CF > 6 as very high contamination.

Similarly, the chart presented in figure 2 showed that, the water is moderately contaminated with most of the radioactive traces (^{40}K, ^{226}Ra and ^{232}Th) except for ^{226}Ra in P01, ^{226}Ra in P02, ^{226}Ra in P04, ^{40}K and ^{226}Ra in P05, ^{40}K in P07, ^{40}K and ^{226}Ra in P09, ^{40}K in P11 and ^{226}Ra in P12 which are less contaminated considering the World Health Organization recommended value of CF < 1 as low contamination, 1 < CF < 3 as moderate contamination, 3 < CF < 6 as considerable contamination and CF > 6 as very high contamination.

Finally, the chart presented in figure 3 revealed that, the edible plant is moderately contaminated with most of the radioactive traces (^{40}K, ^{226}Ra and ^{232}Th) except for ^{226}Ra in Zogale, ^{226}Ra in Kuka, ^{226}Ra in Rama, ^{40}K and ^{226}Ra in Yateya, ^{40}K in Alayyahu, ^{226}Ra in Shuwaka, ^{40}K in Yakuwa, ^{226}Ra in Karkashi, ^{40}K in ugu, ^{226}Ra in Rogo, ^{40}K in Water Leaf and ^{226}Ra in Kabeji which are less contaminated considering the World Health Organization recommended value of CF < 1 as low contamination, 1 < CF < 3 as moderate contamination, 3 < CF < 6 as considerable contamination and CF > 6 as very high contamination.

4 Discussions

Concentration of different elements in plants depends on the relative level of exposure of plants to the contaminated soil as well as the deposition of toxic elements in the polluted air by sedimentation. In this study, the Contamination Factor (CF) for various trace elements showed that the CF values differed slightly between the locations.

On the contamination factor (CF) of soil, the total CF for different trace elements in soil based on sample points decreased in the following order: P06 (1.66) > P09 (1.65) > P11 (1.61) > P10 (1.55) > P08 (1.46) > P01 (1.43) > P03 (1.42) > P02 (1.34) > P07 (1.21) > P12 (1.20) > P05 (0.86) > P04 (0.75). Meanwhile, considering the individual radioactive trace elements, the total CF decreased in the following order: ^{232}Th (1.90) > ^{40}K (1.21) > ^{226}Ra (0.92).

On the contamination factor (CF) of water, the total CF for different trace elements in water based on sample points decreased in the following order: P06 (1.33) > P11 (1.29) > P10 (1.23) > P08 (1.14) > P01 and P03 (1.09) > P02 (1.02) > P07 (0.97) > P12 (0.87) > P04 (0.65) > P09 (0.58) > P05 (0.54). Meanwhile, considering the individual radioactive trace elements, the total CF decreased in the following order: ^{232}Th (1.59) > ^{40}K (0.79) > ^{226}Ra (0.58).

On the contamination factor (CF) of edible plants, the total CF for different trace elements in edible plant based on sample points decreased in the following order: Shuwaka (1.01) > Water Leaf (0.98) > Rogo (0.92) > Zogale (0.89) > Karkashi (0.83) > Kuka (0.81) > Kabeji (0.79) > Rama (0.77) > Yakuwa (0.75) > Ugu (0.58) > Alayyahu (0.47) > Yateya (0.46). Meanwhile, considering the individual radioactive trace elements, the total CF decreased in the following order: ^{232}Th (1.28) > ^{40}K (0.55) > ^{226}Ra (0.48).

5 Conclusions

Based on the results presented, the soil, water and edible plant in the study area is moderately contaminated with ^{40}K, ^{226}Ra and ^{232}Th except for few points as discussed in Table 2 which are less contaminated considering the World Health Organization recommended value of CF < 1 as low contamination, 1 < CF < 3 as moderate contamination, 3 < CF < 6 as considerable contamination and CF > 6 as very high contamination.

Based on the findings of this study, it can be concluded that the soil, water and plants in the study area are moderately contaminated and call for serious concern and regulatory control.

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