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Characteristics of radionuclides in soil and tea plant (*Camellia sinensis*) in Hoa Binh, Vietnam

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Abstract
Understanding concentration and mobility behavior of radionuclides in soil and plant plays an important role and application. In this study, radionuclides in 28 soil layers and tea plant parts samples at Hoa Binh, Vietnam were investigated by gamma spectrometry. The results showed that the ^{137}Cs concentration significantly decreased with the depth, while other radionuclides was almost unchanged. The transfer factor (TF) for ^{137}Cs from soil to tea root was highest, followed by that from soil to trunk and from soil to leaf. By contrast, for the natural radionuclides, the highest transfer factor was recorded from soil to leaf, followed by the transfer factor from soil to trunk and the lowest one was observed from soil to root. Regarding the trending bioaccumulation (BFA) for tea plant decreased as the solubility and mobility of radionuclides decreased BFA (^{40}K > ^{137}Cs > ^{226}Ra > ^{228}Ra).

Keywords Radionuclides · Tea plant · Heavy elements · Transfer factor · Bioaccumulation

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Introduction

Radionuclides (^{40}K, ^{137}Cs, ^{226}Ra, and ^{228}Ra) existing on surface soil of the Earth's crust originate from various sources, such as from bedrock formations, fertilizer materials, mining activities, processing of radioactive ore, and nuclear disasters [1–9]. The presence of these radionuclides with low or high concentrations can be a potential risk to the health of humans and animals. They can be transferred from soil to plant and get accumulated at high concentrations in plants and then transferred to the body through the food-chain/drinking [10]. Thus, understanding the behavior and accumulated concentration of radionuclides in different soil depths and parts of plant is necessary for providing information to protect human and animal health.

The characteristic and transfer of radionuclides from soil to plants has been widely investigated for most common plants such as for vegetable crops [2, 11–18]; for rice [15, 19, 19–23]; for tobacco leaves [24–26]; and for grass [13, 27–29]. Besides these plants, the concentration and transfer of radionuclides from soil to tea plants also attracted many researchers around the world. For tea leaves in Taiwan NPP, China, the research results of Lu et al. [30] indicated that the concentrations of ^{137}Cs and ^{90}Sr were 0.27 and 3.0 Bq/kg, respectively. In Turkey, Keser et al. [31] showed that the concentrations of ^{232}Th, ^{238}U, ^{40}K, and ^{137}Cs in tea leaves were 36.3, 23.1, 688.4, and 20.9 Bq/kg, respectively, and the soil to tea leaves transfer factors for these radionuclides were 0.56, 0.44, 3.63, and 0.09, respectively. Zehringer [32] reported that the concentration of ^{137}Cs and ^{90}Sr in tea leaves in Turkey was 34 and 31 Bq/kg, respectively. In tea leaves in Ramsar, Iran, the concentration of ^{226}Ra was reported to be 725 mBq/kg [33]. Moreover, the radionuclides in tea leaves were also examined in different manners, especially for artificial radionuclides (^{137}Cs, ^{90}Sr) regarding the Chernobyl and Fukushima nuclear accidents [34–42]. Recently, the transfer of radionuclides from soil to tea leaves and estimation of committed effective dose in Bangladesh has been reported [43]. In general, the study on the activity concentration and transfer factor for radionuclides from soil to tea plants have been investigated at different locations in the world. However, most of these investigations focus on the radionuclides in soil and tea leaves. The concentration of radionuclides in other parts of tea plants such as root and trunk has rarely been concerned. A tea plant species grown in different local environments and conditions will have different concentration and transfer factors. Therefore, the radionuclides in different parts of tea plants and transfer factor from soil to these parts at local environment in Vietnam (tropical monsoon) should be extensively investigated to understand the transferring behavior of radionuclides from soil to tea plants. The radioactivity of the tea plants will provide activity and domestic transfer as accurate base information for better predictive dose assessment as well as health risk also. In addition, studying the variation in studied radionuclides at different soil depths to find those behaviors, could be a useful information for further soil geochemical studies at this study area and similar location.

Vietnam has favorable conditions for growing green tea (*Camellia sinensis*) throughout the whole country. Tea is planted in 34 provinces with an estimated total area of 125 000 hectares in Vietnam [44]. Drinking tea is one of the most traditional customs of Vietnamese and popular in many other countries. Vietnamese tea products have been exported to more than 100 countries and territories worldwide [44]. In this study, the partitioning of natural and artificial radionuclides of ^{40}K, ^{137}Cs, ^{226}Ra and ^{228}Ra (^{232}Th) in different soil layers and, in different parts of tea plants including root, trunk and leaf, together with soil-to-plant transfer factors, bioaccumulation and annual committed effective dose and lifetime cancer risk of these radionuclides has been extensively examined in a tea farm, Hoa Binh, Vietnam.

Materials and methods

Study area

A tea farm in Hoa Binh province was chosen for this study. This is a quite flat area with a slope of about 2–3 %. The soil in this area was formed by the weathering of igneous rocks, limestone and terrigenous sediment. The study area is located in the monsoon tropical climate of North Vietnam, with a high annual rainfall of about 1760 mm [45]. The study area and sampling points for this investigation are shown in Fig. 1. In this study, the soil and tea plant samples were collected from 28 locations. The physical properties and chemical composition of the soil samples from 28 locations are listed in Table 1 with Min/Max/Average/SD/SE values. As shown in this table, the collected soil samples are clay soils.

Sampling methods

The soil and tea plant samples including roots, mature leaves, and trunks were collected from 28 different locations in spring season 2019. The mature leaves sample with a length of about 8 to 12 cm and a width of about 3 to 5 cm were collected from tea tree with about 1 m in height. The distance between sampling locations is about 500–800 m. In each position, the soil samples were taken at 5 points within an area of 1 m^2 around the tea tree zone (the zone is related

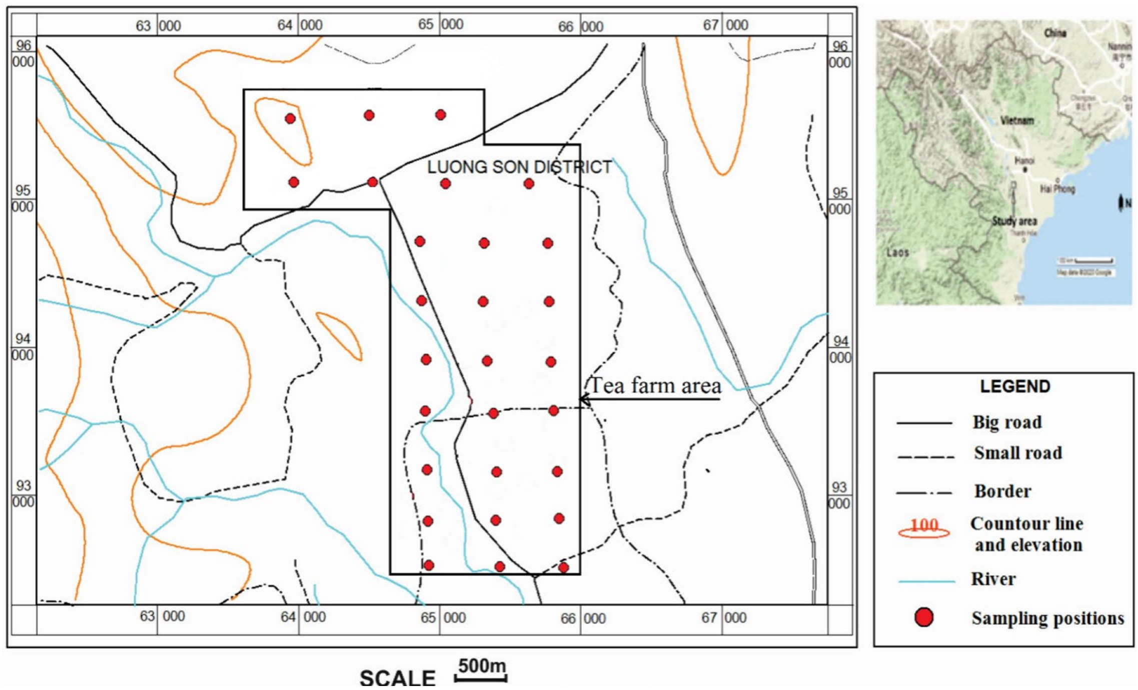

Fig. 1 Sampling locations in a tea farm, Hoa Binh, Vietnam (The numbers in two axes are coordinate system WGS84 (World Geodetic System 1984))

Table 1 Physical properties and chemical compositions of soil in the study area

Values (n-28)	Sand (%)	Silt (%)	Clay (%)	Organic content (%)	Ca^{2+} (m_e/100 g soil)	Mg^{2+} (m_e/100 g soil)	Fe^{3+} (mg/kg)	pH
Min	17.6	4.0	38.9	2.00	4.0	2.3	60.9	5.23
Max	28.6	46.7	48.1	3.78	6.8	4.2	85.0	6.35
Average	22.2	37.2	42.9	2.93	4.8	3.1	75.2	5.99
Standard deviation-SD	2.94	7.54	2.51	0.52	0.82	0.45	6.21	0.24
Standard error-SE	0.56	1.43	0.47	0.10	0.16	0.09	1.17	0.04

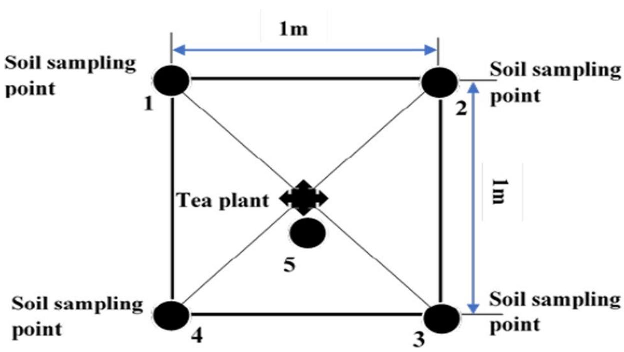

Fig. 2 Schema of soil sampling

to the presence of the root of study tea trees) and in 5 depths of 10 cm, 20 cm, 30 cm, 40 cm, and 50 cm by a special AMS (US) soil sampling tool, diameter 57.15 mm, a connecting rod of 15.88 mm in diameter, the tool could sample up to 3.6 m in depth [45] (Fig. 2). These depths were chosen for understanding the distribution of study radionuclides in different depths since the feeder roots of mature tea trees were mostly found at the depth from 0 to 45 cm below the soil surface [46]. Soil sample was put into plastic bags after removing large objects, such as stones and tree roots. The tea tree part samples, including leaves, trunks, and roots were washed (to be sure that any contaminants removed) before being put into plastic bags. A total of 140 soil samples (at

5 depths) and 84 tea plant samples (root, leaf, and trunk) at 28 positions were collected for investigation.

Sample processing

The sample processing followed previous studies [9, 17, 47]. The soil samples were dried in an oven at 110 °C to a constant weight and then were milled to powder. Plant samples were chopped into small pieces and then dried in an oven at 85 °C to a constant weight and then were milled. All the studied samples of soil and plants were carefully packed in cylindrical boxes (121.2 cm^3 cylindrical geometries with a diameter of 70 mm, a height of 31.5 mm) and stored for 4 weeks to establish the secular equilibrium between ^{226}Ra and its daughters before measurement [47].

Methods

Physical and chemical analysis The soil sample is air-dried at room temperature, and sieved through a 2 mm sieve to analyze the physical and chemical properties of the soil by the following methods: The soil texture including sand (2-0.02 mm), silt (0.02–0.002 mm) and clay (< 0.002 mm) were analyzed by the pipette method based on sedimentation of the particles by gravity according to the law of Stokes [48]; soil organic carbon is based on the Walkley & Black chromic acid wet oxidation method [49]; the pH_{KCl} value in 1 M KCl solution is measured by the pH-meter [48]; the exchangeable Ca^{2+} and Mg^{2+} by complex metric titration with EDTA; and iron (III) by colorimetric method with sunfoxalixilic acid [50].

Gamma spectrometry After equilibrium was reached, activity concentration measurements were performed using gamma spectrometry with a low background and high-resolution HPGe GEM50P4 detector (ORTEC™) and the spectrum analysis was performed using Gamma Vison software. The detector efficiency, energy resolution and high voltage are 50 %, 1.9 keV at 1.33 MeV of ^{60}Co gamma-ray peak and 3.2 kV respectively. To reduce the radiation at the laboratory, the detector was shielded by a 10 cm thick HPLBS1F lead shield cylinder. The instrument specifications were presented in published articles [17, 47, 51, 52]. The measurement time for soil samples was 172,000 s, while that for plant samples was 259,200 s to avoid statistical counting errors. Activity calculation and calibration were carried out based on standard reference materials (IAEA-375; IAEA-446 and IAEA RG standard materials).

The gamma lines of 609.3 keV, 1120.3 keV and 1764.5 keV were used to determine the activity concentration of ^{226}Ra, while that of 911.2 keV, 969.0 keV, and 583.0 keV were used for ^{228}Ra; 1460 keV for ^{40}K; and 662 keV for ^{137}Cs. The Minimum Detection Limit (MDA) of gamma-ray system based on the equation taken from [53, 54].

Analytical methods The transfer factor (TF) for radionuclides from soil (which were used for average of radionuclides in all of five depths) to tea plant can be calculated by the following Eqs. [17, 18, 52]:

$$\mathrm{TF} = \frac{\text{Activity concentration of nuclide of interest per kg dry plant mass}}{\text{Activity concentration of that nuclide in dry soil within the rooting area}} \quad (1)$$

Bioaccumulation factor (BAF) for radionuclides from soil to tea plant was calculated as follows [55, 56]:

$$\mathrm{BAF} = \frac{\text{Activity concentration in plant (root + trunk + leaf)}}{\text{Activity concentration in soil}} \quad (2)$$

The annual committed effective dose (ACED) due to the drinking of tea leaves can be calculated using the following Eqs. [43, 57]:

$$\mathrm{ACED}\,(\mu\mathrm{Sv/y}) = C_r \times (0.28 \times A_{Ra} + 0.22 \times A_{Th} + 0.0062 \times A_K) \quad (3)$$

where A_{Ra}, A_{Th}, A_K are activity concentration of ^{226}Ra, ^{232}Th, ^{40}K respectively.

0.28; 0.22; 0.0062 are ingestion dose conversion for ^{226}Ra, ^{232}Th, ^{40}K respectively.

C_r is the consumption rate. In Vietnam, an average of 20 g (7.2 kg/year) of tea leaves is consumed everyday by adults. This rate is classified as high consumption rate which proposed by Zehringer et al. [32].

Lifetime cancer risk can be estimated based on the following formula [43]:

$$\mathrm{LCR} = \mathrm{ACED} \times \mathrm{LE} \times \mathrm{RFSE} \quad (4)$$

where AEDE is the annual committed effective dose (μSv/y); LE represents the cumulated time of tea consumption. In Vietnam, the average time of tea consumption is assumed about 50 years. RFSE stands for the risk factor of stochastic effects the common population is exposed to (0.05 Sv^{-1}).

Results and discussions

Results

The results of activity concentration of radionuclides in soil and tea plant parts (dry weight) are shown in Table 2, including min, max, arithmetic mean (AM), mode, median, standard deviation (SD), geometric mean (GM), and geometric standard deviation (GSD). The results show that the concentration of studied radionuclides in the study area have a slight variation and standard deviation (SD). This indicates

Table 2 Activity concentration of radionuclides in soil and at different tea plant parts

Values	Concentration (Bq/kg dry.wt)			
	Soil ($n=28$)	Root ($n=28$)	Trunk ($n=28$)	Leaf ($n=28$)
^{40}K				
Min	184	51.8	67.6	171
Max	286	90.8	98.3	220
AM	221	73.2	78.7	189
Mode	215	80.6	77.5	188
Median	218	74.8	78.0	187
SD	22	9.21	6.56	13.8
GM	220	72.6	78.5	188
GSD	1.10	1.14	1.08	1.07
^{137}Cs				
Min	1.49	0.93	0.34	0.24
Max	1.90	1.55	0.89	0.66
AM	1.66	1.12	0.59	0.46
Mode	1.82	1.12	0.49	0.43
Median	1.66	1.10	0.59	0.47
SD	0.12	0.13	0.14	0.08
GM	1.66	1.12	0.57	0.45
GSD	1.07	1.12	1.28	1.22
^{226}Ra				
Min	29.1	2.36	3.03	17.1
Max	39.6	6.17	7.02	27.6
AM	33.3	4.08	4.30	21.5
Mode	34.9	4.12	4.10	22.1
Median	32.6	4.12	4.15	20.3
SD	2.94	0.96	0.93	2.91
GM	33.2	3.97	4.21	21.3
GSD	1.09	1.26	1.22	1.13
^{228}Ra				
Min	37.8	1.49	1.54	12.7
Max	52.9	4.22	9.67	18.9
AM	43.5	2.58	4.26	15.8
Mode	42.1	2.10	3.40	12.7
Median	42.2	2.30	4.05	16.6
SD	3.55	0.76	2.01	1.84
GM	43.3	2.48	3.85	15.7
GSD	1.08	1.32	1.56	1.12

that the soil and tea plant samples collected from 28 locations could be a baseline data as representative information for study area.

The concentration of radionuclides in soil at different depths is shown in Table 3. The data in this table includes min, max, AM, GM, and GSD values.

Table 3 Concentration of radionuclides in soil at different depths

Depth (cm)	Values	^{40}K	^{137}Cs	^{226}Ra	^{228}Ra
10 ($n=28$)	Min	179	3.83	22.1	33.8
	Max	300	5.62	44.2	58.2
	AM	227	4.8	32.3	43.0
	GM	224	4.8	31.9	42.7
	GSD	1.15	1.09	1.17	1.13
20 ($n=28$)	Min	172	1.74	26.1	37.1
	Max	268	2.98	41.3	52.0
	AM	217	2.1	33.5	44.4
	GM	215	2.1	33.3	44.3
	GSD	1.13	1.14	1.14	1.09
30 ($n=28$)	Min	161	0.49	27.0	34.9
	Max	279	1.19	48.3	58.7
	AM	220	0.8	34.3	43.0
	GM	217	0.8	34.0	42.7
	GSD	1.15	1.22	1.15	1.13
40 ($n=28$)	Min	181	0.12	22.1	32.1
	Max	299	0.88	43.3	54.6
	AM	222	0.4	32.4	44.8
	GM	220	0.3	32.1	44.4
	GSD	1.13	1.70	1.15	1.14
50 ($n=28$)	Min	172	0.01	20.8	32.5
	Max	299	0.37	45.7	55.2
	AM	219	0.2	34.1	42.0
	GM	217	0.2	33.6	41.8
	GSD	1.13	2.37	1.17	1.11

Discussions

Variation of radionuclide concentration in different soil layer and depths

The variation of the respective radionuclide concentrations (AM values) in soil at different depths are plotted in Table 3. As shown in Table 3, the activity concentrations of ^{40}K, ^{226}Ra, ^{228}Ra are independent of depth from 10 to 50 cm. This result agrees with the findings of Ramzaev et al. [58] and Belivermiş [59]. In contrast, the activity concentration of ^{137}Cs tends to decrease as the depth increases with $R^2 \sim 1$. Reaching to the depth of 50 cm, the ^{137}Cs concentration in soil is insignificant. The variation of ^{137}Cs concentration in soil with depth in this study is similar to that reported in some previous studies at other locations [60–63]. In those previous studies, at the depth of about 40 cm, the concentration of ^{137}Cs was also negligible. This can be attributed to the characteristic of ^{137}Cs. The ^{137}Cs is a human induced radionuclide, which comes from the atmospheric nuclear weapon tests and nuclear power plant accidents, such as the Chernobyl and Fukushima Daiichi accidents, with a long half-life of 30.17 year [59]. It is non-exchangeable and firmly binds with soil particles. It is highly insoluble in the soil solution and its migration and uptake by plants is relatively slight [63]. In the study area, the soil has a high content of clay particles with a low permeability. Thus, the ^{137}Cs finds it very difficult to migrate into lower depths. In addition, this study area is quite flat, so the soil erosion process is insignificant. Therefore, the distribution of ^{137}Cs in soil could be interpreted as being an immobile radionuclide on surface soil with a slow dynamic for reaching to lower depths.

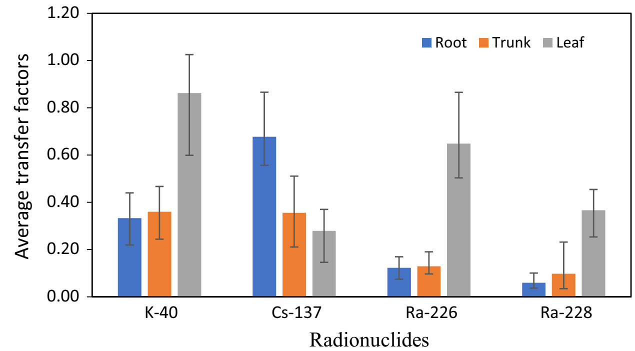

Fig. 3 Transfer factors (TFs) for different radionuclides

Transfer factors

Based on the results of radionuclide concentrations as shown in Table 2, the TF for radionuclides from soil to different plant tissues (root, trunk, leaf) was calculated and shown in Table 4, including min, max, arithmetic mean (AM), mode, median, standard deviation (SD), geometric mean (GM), and geometric standard deviation (GSD). GM and GSD are preferred to the AM and SD in order to reflect the general log-normal distribution of the TF values. The normality of the data was evaluated by the Shapiro Wilk's and Kolgomorov-Smirnov tests. Only the log-transformed data had normal distribution.

Table 4 Soil-to-tea plant tissue transfer factors

Values	Transfer factors		
	TF_{root}	TF_{trunk}	TF_{leaf}
^{40}K ($n = 28$)			
Min	0.22	0.24	0.60
Max	0.44	0.47	1.03
AM	0.33	0.36	0.86
Mode	0.33	0.38	0.83
Median	0.34	0.37	0.87
SD	0.05	0.05	0.09
^{137}Cs ($n = 28$)			
Min	0.56	0.21	0.15
Max	0.87	0.51	0.37
AM	0.68	0.36	0.28
Mode	0.73	0.43	0.29
Median	0.66	0.37	0.29
SD	0.08	0.09	0.05
^{226}Ra ($n = 28$)			
Min	0.07	0.10	0.50
Max	0.17	0.19	0.87
AM	0.12	0.13	0.65
Mode	0.11	0.10	0.52
Median	0.12	0.13	0.63
SD	0.03	0.03	0.10
^{228}Ra ($n = 28$)			
Min	0.04	0.03	0.25
Max	0.10	0.23	0.45
AM	0.06	0.10	0.37
Mode	0.05	0.09	0.40
Median	0.05	0.09	0.38
SD	0.02	0.05	0.06

The average values of transfer factors for radionuclides from soil to different tea plant tissues are shown in Fig. 3. It can be seen that for ^{40}K, ^{226}Ra, and ^{228}Ra radionuclides, the transfer factors (TFs) for these radionuclides from soil to leaf are significantly higher than that from soil to trunk and root. The finding was similar with transfer factor from soil to leaf of flooded water spinach but was not for unflooded water spinach [18]; and met the results for transfer factor from soil to leaf of leafy vegetables in Iraq and Vietnam [17]. This could be attributed to the variation in the different vegetable metabolic characteristics as well as different local environmental conditions. It was clear that the TFs of ^{40}K, ^{226}Ra, and ^{228}Ra showed the trend TF_{leaf} (from soil to leaf) > TF_{trunk} (from soil to trunk) > TF_{root} (from soil to root). In contrast, for ^{137}Cs, the TF from soil to leaf was the lowest and the trend was the inverse of TFs of ^{40}K, ^{226}Ra, and ^{228}Ra ($TF_{leaf} < TF_{trunk} < TF_{root}$) (Fig. 3). It should be noted here that the ^{137}Cs may be mainly concentrated in root, which can lead to a high concentration of this radionuclide in roots (Fig. 3) and this phenomenon was similarly reported by Topcuoğlu [41]. The TF of ^{137}Cs from soil to leaf was the lowest in comparison to other radionuclides. For TF from soil to root and from soil to trunk, the lowest TFs were observed for ^{228}Ra. From soil to trunk, the highest TF were found for both ^{40}K and ^{137}Cs.

Bioaccumulation factor

The bioaccumulation factor (BAF) can be used to evaluate the transfer of radionuclides from soil to plant biomass. In this study, BAF is calculated based on the activity

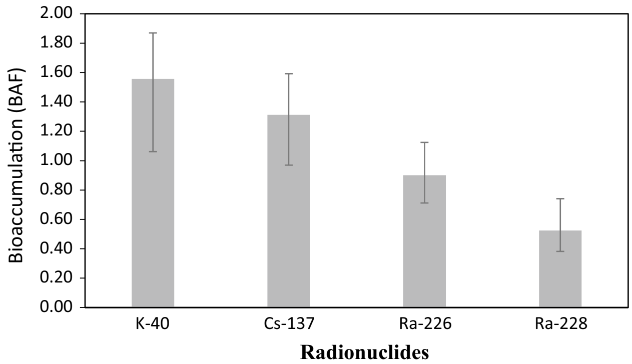

Fig. 4 Average bioaccumulation factor for different radionuclides

concentration of radionuclide in soil, root, trunk, and leaf of tea plant. It is the ratio of radionuclide concentration in tea plant (root + trunk + leaf) to that in soil. The calculated results of average BAF in tea plant is plotted in Fig. 4. It can be seen that the highest BAF is found for ^{40}K and followed by ^{137}Cs, ^{226}Ra and ^{228}Ra in that order (^{40}K > ^{137}Cs > ^{226}Ra > ^{228}Ra). This indicates the concentration of ^{40}K in tea plants is the highest amongst the studied radionuclides, while that of ^{228}Ra is the lowest. The high concentration of ^{40}K in tea plants attributes to higher absorption of potassium by plants as it serves as an essential element for their metabolism [64]. Moreover it is one of the principal nutrient elements for vegetable crops [65, 66]. Furthermore, since potassium is a light element and highly soluble in water [67–69], it easily migrates to tea plant tissues. In contrast, since the ^{137}Cs, ^{226}Ra and ^{228}Ra radionuclides have heavier and larger ions than ^{40}K, they have lower mobility than ^{40}K and lower concentration in tea plants. ^{228}Ra, the heaviest element and a progeny of ^{232}Th is highly insoluble among other studied radionuclides [67, 68]. It can note here that the high mobility and solubility of ^{40}K radionuclide will lead to an increase of its concentration in tea plant, especially coupled to high metabolic demand. This phenomenon was also observed for other plants in the world such as date pits in Saudi Arabia [69]; grass in Bangladesh [28]; non-leafy vegetables in Iraq [2] and mushrooms in China [16]; leafy vegetables in Vietnam [17]. Thus, the BAF in tea plants in this study not only depends on the atomic mass but also relates to mobility and solubility of radionuclides.

Annual committed effective dose and lifetime cancer risk

Based on the activity concentration of radionuclides in tea leaves, the calculated annual committed effective dose (ACED) and the lifetime cancer risk (LCR) are listed in Table 5.

Table 5 Calculated hazard indices due to consumption of tea leaves

Index	Max	Min	Average	Limitation
ACED (μSv/y)	95.5	62.1	76.8	290 [70]
LCR	2.4×10^{-4}	1.6×10^{-4}	1.9×10^{-4}	2.5×10^{-3} [71]

The annual committed effective dose (ACED) due to the intake of studied radionuclides in tea leaves ranged from 62.1 μSv/y to 95.5 μSv/y with an average of 76.8 μSv/y (Table 5). The average of AECD from ingestion of tea leaves in this study is lower than the average dose value worldwide with 290 μSv/y contributing from both food and water consumption [70]. Figure 5 shows the contribution of individual studied radionuclides in the total ACED. As shown, the highest contribution to ACED is observed for ^{226}Ra (56.4 %), followed by ^{232}Th (32.6 %) and ^{40}K (11.0 %). Regarding cancer risk, the estimated LCR (for a period of 50 years) was found to be in the range from 1.6×10^{-4} to 2.4×10^{-4} with an average value of 1.9×10^{-4}. It can be seen that the mean LCR in this study is lower than the limitation value of 2.5×10^{-3} given by ICRP [71].

Conclusions

In the current investigation, a comprehensive study on the activity concentration of ^{40}K, ^{137}Cs, ^{226}Ra and ^{228}Ra radionuclides in soil and different tea plant parts in Hoa Binh, Vietnam has been conducted. Based on the results, the following conclusions can be drawn as follows:

The concentration of ^{137}Cs in soil decrease as the soil depth increases (with $R^2 \sim 1$, $p < 0.05$) while the other

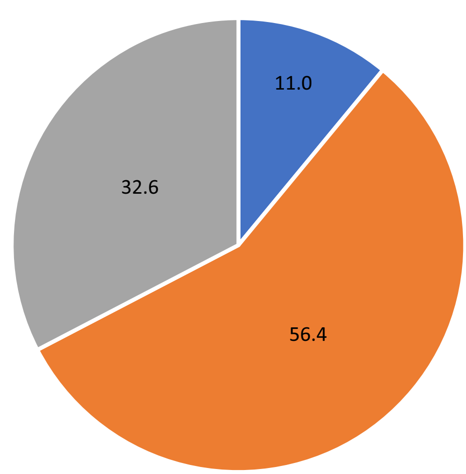

Fig. 5 Contribution of individual studied radionuclides to ACED

radionuclides were almost unchanged at different depths. The ^{137}Cs concentration was negligible when the depth reached to greater than 50 cm.

The TFs of ^{40}K, ^{226}Ra and ^{228}Ra from soil to leaf were higher than those from soil to trunk and from soil to root with the following order $TF_{leaf} > TF_{trunk} > TF_{root}$. In contrast, for ^{137}Cs radionuclide, the highest transfer factor was found from soil to root followed by from soil to trunk and soil to leaf.

Regarding the bioaccumulation factor (BAF), the highest BAF was found for ^{40}K, and followed by ^{137}Cs, ^{226}Ra, and ^{228}Ra ($^{40}K > {}^{137}Cs > {}^{226}Ra > {}^{228}Ra$). In other words, the highest capacity of accumulation in tea plants was observed for ^{40}K.

Regarding the hazard assessment, the average ACED and LCR due to tea consumption in the study area for adult in Vietnam are lower than the worldwide average dose and limitation values.

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