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Original Article

Transfer of ^{238}U and ^{232}Th from Soils to Tea Leaves on Luong My Farm, Hoa Binh Province, Vietnam

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Abstract: This paper studies the soil-to-plant transfer factors of natural occurring radioisotopes (^{238}U and ^{232}Th) on Luong My Tea farm, Tan Thanh district, Luong Son commune, Hoa Binh province. The activity concentrations in leaves, trunk and roots of the tea tree at no harvest period (winter break) were determined. The measurements were carried out using gamma spectroscopy with high puritygermanium detector HP(Ge). The research results show that the activity of ^{238}U and ^{232}Th is higher in the tea tree's leaves than in its trunk and roots. The soil-leave transfer factors (TF) for ^{238}U and ^{232}Th were determined as follows: TF_{U-238} = 0.52 – 0.87; TF_{Th-232} = 0.25 – 0.43.

Keywords: Luong My Tea farm, transfer factors, soil-leave, trunk.

1. Introduction

Transfer of artificial radionuclides along terrestrial food chainshas been studied extensively since thesecond part of the last century,with understandable emphasis on ^{137}Cs since 1986.

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Naturallyoccurring radionuclides have not been studied to the same extent.In the course ofthe last years, however, the interest intheassessment other impacts of these radioactive elements on arable soils, soil microbiota, edible plants and humans has been increasing constantly. Many investigations have been carried out in differentcountries, especially in those where concentrations of naturallyoccurring radionuclides in soils are particularly high [1-3].

The most common terrestrial radioisotopes are ^{238}U, ^{232}Th, and ^{40}K. In this paper, we will discuss the transfer soil to tea tree of two of them: uranium and thorium. Uranium and thorium are major energy sources, which drive the evolution of Earth and Planets. Both these radionuclides are components of the biosphere, and thus occur naturally in all soils and plants, though their concentrations in plants may be rather low.

There are numerous reports in literature on biogeochemistry of U and Th. Unfortunately, a large part of available publications refers to the studies performed either in highly contaminated areas or in nutrient solutions that have been artificially 'spiked' with radionuclides. Meanwhile, it would be more important to assessthe effects of background levels of natural radioactivity in soil, plants and humans [4-10].

The study of U and Th transfer from soil to edible vegetation through root uptake is very important, especially considering theaccumulation of these radionuclides in the food chains. An understanding of the mobility of U and Th in soils and their transfer to different plants requires a detailed knowledge of U and Th interactions with soil composed of abiotic and biotic components. Despite numerous studies on U and Th contents in vegetation, there is little information yet related to the rate of their uptake and storage by different plant species. Previous experimental results demonstrated that distribution of U and Th in soil is highly variable. For example, activity concentrations of ^{238}U in soil can vary by around three orders of magnitude depending on various factors [10]. Therefore, an assessment of the radionuclide distributions in the soil–plant system may be rather complicated.Many studies haveshown that soil-plant transfer factor for ^{232}Th is smaller than that of ^{238}U [10,11]. In addition, the correlation of concentration of these two radionuclides in soil and plants was assessed by using the Spearman's rank correlation coefficient. This quantity has a value between -1 and 1. A correlation coefficient of 0 (or near 0) means that the two variables have no relation to each other; conversely, if a coefficient of -1 or 1 means the two variables have an absolute relationship. If the value of the correlation coefficient is negative ($\rho<0$), that means that when one variable increases, the other decreases (and vice versa); If the correlation coefficient value is positive ($\rho> 0$), it means that when this variable increases, the other variable increases, and when it decreases, the other variable decreases.

The purpose of this work is to determine the TF coefficients of ^{238}U and ^{232}Th, the distribution of concentration activities on the parts of tea plants in Luong My farm.

2. Research object and method

2.1. Sampling area

Luong My tea farm was selected for our study. This is a low semi-mountainous area having attitude above sea level of 50-80 m, with slope is about 2-3 %. It has low mountain band which was formed by macma stone, limestone and terrigenous sediment. Climate of this area is typically monsoon tropical. Winter usually is since November to March and summer is from April to October and average rain level is about 1.760 mm. The sampling area is quite flat, height difference between sampling position in comparison to sea level is ignorable. (see Fig.1).

Fig.1. Mapping of the sampling location, Luong Son, Hoa Binh, Viet Nam.

2.2. Tea tree of Luong My farm

As mentioned, theobject of our research is tree tea, its leaf is popularly used to make a drink in Vietnam. Tea tree is usually found in tropical and near tropical climate. It is a neutral one in the young stage while an adult tea tree adapts very well with sunshine. Under shadow, tea leaveshave dark green color and less shoot due to weak photosynthesis. The scattered light in high mountain area has a good influence to tea quality that direct light. In the foggy, wet and cool weather together with temperature difference between day and night are good condition for having high quality tea leaf. Usually, most suitable rainfall for growing up of tea tree is about 1500-2000 mm, air humidity is about 80-85 % is good for tee root growth. For tea trees planted by seed, it normally has tap-root, lateral and absorbed. Tap-root usually has alength of 1 m, depending on the soil character and processing method, manured manner, tea tree age and its species. Tap-root does not exist in tea tree which is planted by using tea branch. The lateral and absorbed root are distributed mainly in the depth from 5 to 50 cm and their horizontal distribution is about two times of tree shadow area. For the tea tree, which is planted by using branches, lateral root is well developed. In the natural growth condition, tea trunk is a single and straight, its branches are arised continuously to form a branch and shot system. In our work, tea trees selected for study are over 20 years (see Fig.2)old which were planted in the period from 1981 to 1995. In this farm, tea tree branches are cutted and tree are fertilized twice per years, one in early season about on February and other on November, at the last of season.

Fig.2. Mature tea tree.

2.3. Sampling method and position

In this work, 14 tea trees and corresponding 14 surrounded soil samples were collected from 14 different positions. Distance between sampling positions is about 700-1500m. Soil wassampledat4 points within area of 1 m^2 around the tea tree and in 5 depth layers of 10 cm, 20 cm, 30 cm, 40 cm and 50 cm by using special sampling tool (see Figure 3) then removed stone, tree root and putted into plastic boxes. Tea tree samples with full three parts as root, trunk and leaf were washed and then putted in the plastic bag. In 14 sampling positions, 42 samples of the tea tree parts and 70 soil samples in 5 different depth layers were collected. The information about samples and their labels are shown in Table 1.

Table 1. Information of the collected samples

Position	Sample label									
	Tree				Soil					
	Leaf	Trunk	Root	Whole tree	10cm	20cm	30cm	40cm	50cm	Average of 5 soil layers
1	L1	T1	R1	C1	D1-10	D1-20	D1-30	D1-40	D1-50	D1
2	L2	T2	R2	C2	D2-10	D2-20	D2-30	D2-40	D2-50	D2
3	L3	T3	R3	C3	D3-10	D3-20	D3-30	D3-40	D3-50	D3
4	L4	T4	R4	C4	D4-10	D4-20	D4-30	D4-40	D4-50	D4
5	L5	T5	R5	C5	D5-10	D5-20	D5-30	D5-40	D5-50	D5
6	L6	T6	R6	C6	D6-10	D6-20	D6-30	D6-40	D6-50	D6
7	L7	T7	R7	C7	D7-10	D7-20	D7-30	D7-40	D7-50	D7
8	L8	T8	R8	C8	D8-10	D8-20	D8-30	D8-40	D8-50	D8
9	L9	T9	R9	C9	D9-10	D9-20	D9-30	D9-40	D9-50	D9
10	L10	T10	R10	C10	D10-10	D10-20	D10-30	D10-40	D10-50	D10
11	L11	T11	R11	C11	D11-10	D11-20	D11-30	D11-40	D11-50	D11
12	L12	T12	R12	C12	D12-10	D12-20	D12-30	D12-40	D12-50	D12
13	L13	T13	R13	C13	D13-10	D13-20	D13-30	D13-40	D13-50	D13
14	L14	T14	R14	C14	D14-10	D14-20	D14-30	D14-40	D14-50	D14

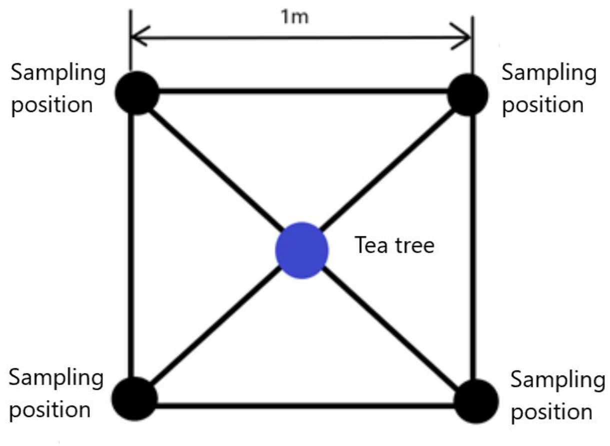

Fig. 3. Soil sampling scheme.

2.4. Sample preparation

The collected soil samples were exposed under sunshine for naturally drying. After that, these samples were dried at 110^0C in the oven until weight changing less than 1%. The dried soil samples were removed remaining stone by using a sieve with a hole diameter of 1 mm and then ground to achieve the particle dimension of 0.25 mm. Full part tea tree samples were washed carefully to remove the soil and dust by clean water and distilled which then were dried at 110^0C and also finely ground to obtain particle dimension of 0.5 mm. The processed samples were mixed carefully to ensure homogeneity and packed in a cylinder box with diameter of 74 mm and height of 30 mm. Weight of soil samples are 180 g and that of tea tree ones are 100 g. All these samples were sealed for 4 week to establish secular equilibrium before measurement.

2.5. Sample measurement and data analysis

Samples were measured by the CANBERRA lead shielded-low background gamma spectrometer with high purity germanium detector HPGehaving resolution of 1.86 keV at 1332.49 keV photo-peak of ^{60}Coand relative efficiency is 15 %. In order to accumulate enough statistics and reduce statistical error, measurement time for soil samples was 100.000 second while that for plant were 150.000 seconds. In addition to that, background measurement time was 100.000 seconds. The Geniee 2000 softwarewas used for data acquisition and spectrum analysis. The activities of ^{238}U and ^{232}Th contained in the samples were deduced by mean of our own developed method using only one absolute value of the efficiency at energy of 1460.82 keVcorresponding to characteristics gamma ray of ^{40}K and relative efficiency curve [12]. For each sample, the relative efficiency curve F(E) is constructed based on 295.57 keV and 351.9 keV gamma peaks of ^{214}Pb and 609.31 keV, 1120 keV , 1764.49 keV peaks of ^{214}Bi . The activity of ^{232}Th was extracted by 911.1 keV gamma rays of ^{228}Ac and 583.19 keV gamma ray of ^{208}Tl, respectively.

The typical measured gamma spectra of the soiland tea tree samples are shown in Figure 4 and 5.

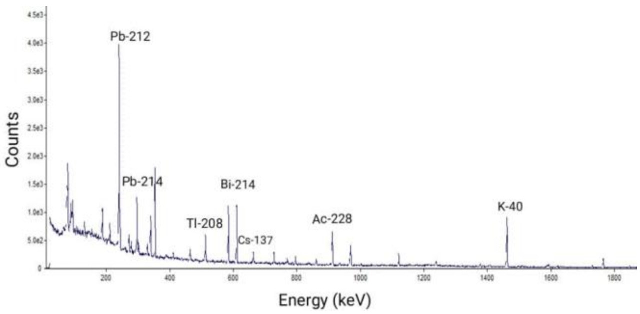

Fig.4. Gamma spectrum of soil sample at position 1 (layer 0-10cm)

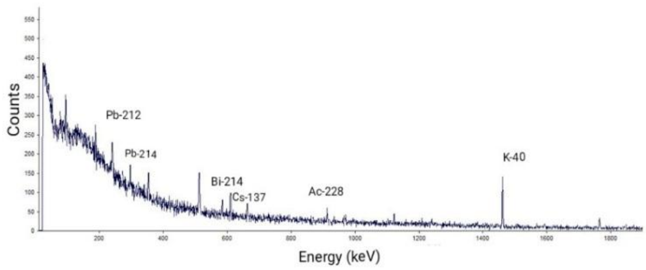

Fig.5. Gamma spectrum of tea leaf sample at position 1.

Soil-plant transfer of radionuclides is evaluated using transfer factor (TF) which is defined as theratio betweenthe activity of radionuclides in plant C_P(in Bq.kg^{-1}dry plant) and activity of radionuclide in soil C_S (in Bq.kg^{-1}dry soil) [13,14]and is calculated as:

$$TF = \frac{C_P}{C_S}$$

In addition to that, we have analyzed, including investigation the distribution of U and Th in soil layers, the distribution of U and Th in the tea tree parts (see next session).

To evaluate the relationship between U and Th activity in soil and tea, Spearman's rank correlation coefficient was calculated.

Uncertainties of all measurements were calculated taking into account random and systematic components of uncertainty, i.e. uncertainties due to sample preparation, efficiency calibration, measurement of sample and nuclear data [15]. The total uncertainty was calculated by uncertainty propagation equation.The uncertainties were presented at the 95% confidence level.

3. Results and discussion

Many experimental studies shown that the soil-plant transfer of radionuclide depends very much on the physical and chemical properties of the soil. Therefore, we have first analyzed soil to evaluate the soil character by the laboratory of the University of Science, Vietnam National University, Hanoi and the obtained results are shown in Table 2.

Table 2. The physical and chemical properties of the soil at tea farm Luong My

	Physical and chemical characteristics of research land							
Sample notation	Sand (%)	Limon (%)	Clay (%)	Humus (%)	Ca^{2+} ($^{m_e}/_{100g\ soil}$)	Mg^{2+} ($^{m_e}/_{100g\ soil}$)	Fe^{3+} (mg/kg)	pH
D1	22.7	36.5	46.2	3.48	4.04	2.87	84.1	5.86
D2	23.7	38.2	48.1	3.57	4.05	2.98	85	6.21
D3	28.6	46.1	45.3	2.0	6.79	4.23	62	5.96
D4	26.1	46.7	45.1	2.1	6.68	4.13	63.1	6.05
D5	25.6	34.0	40.4	2.11	4.72	3.28	70	6.12
D6	23.3	32.1	41.1	2.0	4.67	3.36	69.2	5.97
D7	18.9	36.5	43.1	2.36	4.34	3.02	79	5.85
D8	19.7	37.1	43.2	2.35	4.2	3.05	78	6.08
D9	26.4	35.2	43.3	3.10	4.02	2.99	80.2	5.89
D10	22.1	34.9	39.1	3.22	4.1	2.89	78.9	6.14
D11	19.8	4.01	40.2	3.41	4.13	2.78	80.2	6.23
D12	20.1	46.2	38.9	3.0	3.98	3.02	75.1	5.75
D13	25.6	39.8	44.5	3.55	4.51	3.1	76.8	5.92
D14	18.8	37.5	46.1	3.05	4.46	3.14	77.8	6.03

With these results, we could conclude that tea tree collected from 14 different positions were grown in the same condition.

The activity range in the soil layers of ^{238}U is 20.81 - 48.34 Bq/kg dry. This value of ^{232}This higher, with the activity range: 32.14 - 58.74 Bq/kgdry. U and Th are two radioactive isotopes that have naturally existed in the earth since the formation of the earth. The measured activities of ^{238}U together with ^{232}Th in soil are shown in Fig.6 and as can be seen, these two isotope's concentration are scattered, it means that there isn't any dependence between them in the soil.This is especially evident when the spearman coefficient is close to zero (ρ = 0.23).

The concentration depth profile analyzing shown that ^{238}U and ^{232}Th aredistributed quite uniformly in different soil layers (see Fig. 7 and Fig. 8).

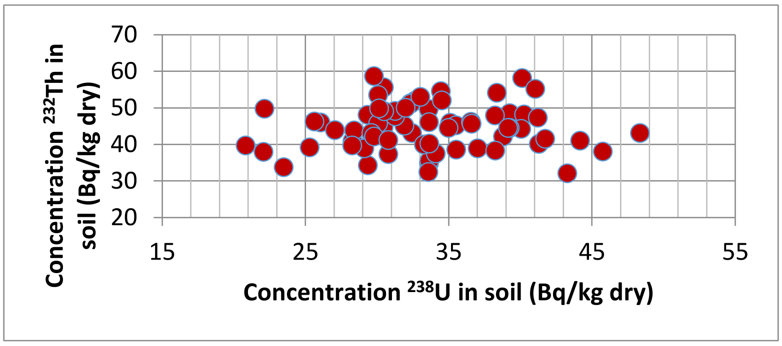

Fig. 6. Scatterplot of ^{238}U versus ^{232}Th concentration in soil (Bq/kg dry).

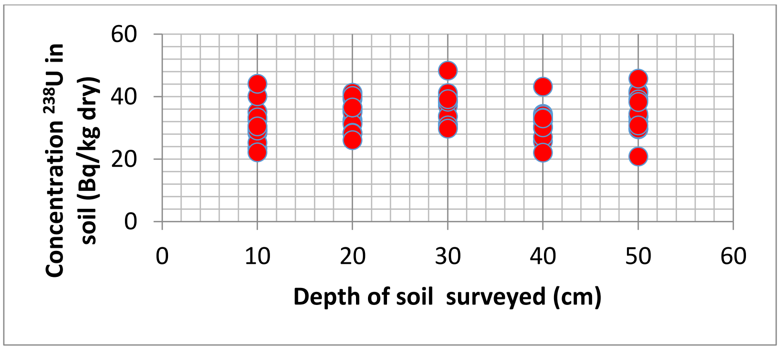

Fig. 7. Concentration of ^{238}U in soil layers.

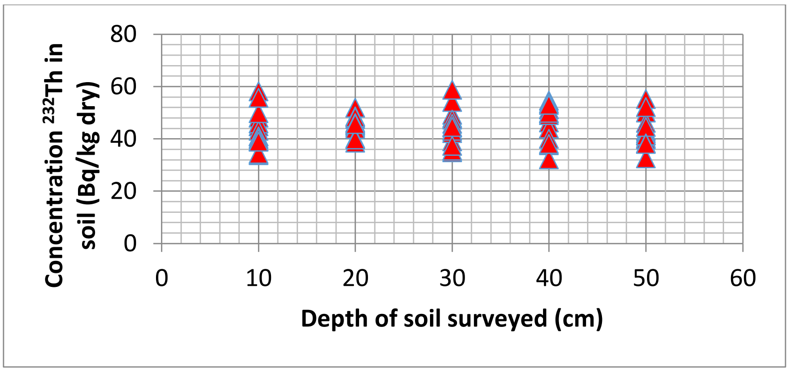

Fig. 8. Concentration of ^{232}Th in soil layers.

The concentration of plant radioactive isotopes is usually not linearly related to their concentration in the soil [7, 16, 17]. When analyzing and determining the activity of U and Th in tea leaves, this is clearly seen. While the activity of U in soil is lower than Th, but in tea leaves U is higher (Table 3).

Table 3.^{238}U and ^{232}Th activity in tea trea (Bq/kg dry)

	^{238}U		
	Root	Trunk	Leaf
C1	3.02±0.30	3.68±0.50	20.86±1.2
C2	4.25±0.40	4.64±0.41	22.1±1.6
C3	4.46±0.48	5.51±0.61	26.8±1.2
C4	2.36±0.20	5.63±0.30	19.7±2.1
C5	4.4±0.3	4.91±0.44	20.3±2.3
C6	6.17±0.8	5.23±0.60	19.01±1.4
C7	3.94±0.71	4.31±0.21	25.8 ± 1.2
C8	5.17±0.22	4.44±0.26	24.0± 1.1
C9	5.15±0.40	3.39±0.25	20.1±1.1
C10	3.18±0.26	3.95±0.29	18.8±1.4
C11	4.12±0.42	3.39±0.25	26. 9±1.7
C12	3.21±0.34	4.49±0.36	27.6±2.1
C13	3.01±0.31	3.03±0.25	19.8±2.1
C14	5.69±0.42	7.02±0.51	27.2±2.3
	^{232}Th		
	Root	Trunk	Leaf
C1	2.84±0.22	5.11±0.31	14.76±0.91
C2	1.85±0.14	4.34±0.34	12.88±0.87
C3	1.55±0.18	5.82±0.32	16.5±1.2
C4	1.49±0.19	6.51±0.50	15.01±0.89
C5	1.81±0.36	3.42±0.27	16.75±0.77
C6	3.02±0.35	1.54±0.25	17.02±0.79
C7	3.49±0.45	5.21±0.28	13.40±0.59
C8	4.22±0.42	6.10 ±0.29	12.7±1.0
C9	4.11±0.56	9.67±0.24	17.1±1.0
C10	2.26±0.25	3.38±0.21	17.3±1.1
C11	1.98±0.18	4.56±0.22	18.3±1.1
C12	2.13±0.16	8.10±0.25	16.9±1.1
C13	3.11±0.47	4.20±0.19	14.40±0.98
C14	2.56±0.26	8.17±0.14	12.70±0.76

Results showed that the ^{232}Th combination in leaves varied from 12.70 to 18.30 Bq/kg dry, while ^{238}U changed from 18.77 to 27.64 Bq/kg dry. The average activity of ^{238}U in leaves is about 3-5 times higher than that of trucks and roots. Similar to ^{238}U, ^{232}Th is also concentrated mainly in leaves, in trucks and lower in roots. The average activity of ^{232}Th in leaves is about 4 times higher than that in trucks and 6 times higher than that in roots.Thus, the ability to accumulate radioactive isotopes ^{238}U and ^{232}Th on different parts of plants is very different.The research results obtained are consistent with the study results presented in [18, 19], ^{238}U tends to move towards the outer extremities of the tree and accumulates the most in new leaves and sprouts.It however, in order to evaluate the soil-plant transfer of ^{238}U in comparison to ^{232}Th in these tea leaves, we calculated transfer factor (TF), the results are shown in Table 4.

The same tree, same growing conditions, but it is clear that the soil to tea leaves transfer of U and Th varies over a wide range. The TF(^{238}U) is 0.52 - 0.87 and TF(^{232}Th) is 0.25 – 0.43.Considering the whole survey area, TF(^{238}U) is 2 times higher than TF(^{232}Th).These research results are consistent with many other research ones [6].

Table 4. Transfer factor of ^{238}U and ^{232}Th fromsoilto tea leaves

Position	TF(^{238}U)	TF(^{232}Th)	Position	TF(^{238}U)	TF(^{232}Th)
1	0.61 ± 0.07	0.31± 0.04	8	0.77± 0.08	0.30± 0.04
2	0.69± 0,07	0.26± 0.02	9	0.58± 0.06	0.41± 0.03
3	0.82± 0,08	0.43± 0.07	10	0.51± 0.05	0.38± 0.04
4	0.62± 0,09	0.37± 0.03	11	0.77± 0.06	0.43± 0.04
5	0.67± 0,08	0.40± 0.03	12	0.87± 0.09	0.40± 0.04
6	0.52± 0,05	0.38± 0.03	13	0.67± 0.09	0.30± 0.03
7	0.71± 0,08	0,25± 0.03	14	0.74± 0.09	0.27± 0.03
Average				**0.68**	**0.35**

3. Conclusions

In our study, concentration of ^{238}U and ^{232}Th in soil and different parts of tea tree at 14 different positions of Luong My tea tree farm and these isotope's soil-leaves transfer factor were first time determined. We can conclude that there is no correlation between ^{238}U and ^{232}Th in the soil, both U and Th are uniformly distributed in different soil layers. As many other researches, soil-tea leaves transfer of U and Th varies in a wide range and that of U is greater than that of Th twice.

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