Assessment of ^{137}Cs Activity Concentration In Soil From Tea Plantantion Areas In Cameron Highlands

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ABSTRACT

^{137}Cs is well known man-made radionuclide produced from nuclear industry. Nuclear weapon tests and nuclear accidents had contributed to presence of ^{137}Cs into the worldwide environment including Malaysia. It has spread out to the entire world through the air and water current. Since Cameron Highlands is located at high altitude, there is a better chance of the ^{137}Cs to settle down on the trees and later the soil underneath. In this study, the soil samples were taken at the slopes of two different tea plantation areas namely A and B. The soil samples were oven dried, ground, sieved and packed and sealed properly in plastic containers before measurement. Each plastic container contains around 450 g of sample. The measurement of ^{137}Cs activity concentration was done using HPGe detector gamma spectrometer. The spectrum was analyzed using Gamma Vision software to calculate the activity concentration of ^{137}Cs with energy peak of 661.66 keV. The activity concentration of ^{137}Cs found in the samples ranged from 0.23 to 1.90 and 0.11 to 3.01 Bq/kg for tea plantation A and tea plantation B, respectively. From the activity concentration of ^{137}Cs result, it was comparable to the others research regarding to ^{137}Cs in the soil around Asian.

ABSTRAK

^{137}Cs dikenali sebagai radionuklid buatan manusia hasil dari industri nuklear. Senjata nuklear dan kemalangan nuklear telah menyumbang kepada peningkatan jumlah ^{137}Cs ke persekitaran di seluruh dunia termasuk persekitaran Malaysia. Ia telah merebak ke seluruh dunia melalui arus udara dan air. Disebabkan Cameron Highlands terletak di kawasan yang tinggi, ^{137}Cs mempunyai peluang yang lebih tinggi untuk jatuh menetap di pohon dan kemudian jatuh ke tanah dibawahnya. Dalam kajian ini, sampel tanah diambil pada lereng bukit dari dua kawasan ladang teh yang berbeza iaitu A dan B. Sampel tanah tersebut kemudiannya dikeringkan didalam ketuhar, ditumbuk, diayak dan dimasukkan ke dalam bekas plastik serta disalut kemas sebelum pengukuran. Setiap bekas plastik mengandungi berat sekitar 450 g sampel. Pengukuran kepekatan aktiviti ^{137}Cs dilakukan dengan menggunakan spektrometer gama dengan pengesan HPGe. Spektrum dianalis dengan menggunakan perisian 'Gamma Vision' untuk mengira kepekatan aktiviti ^{137}Cs pada puncak tenaga 661.66 keV. Kepekatan aktiviti ^{137}Cs di dalam sampel masing-masing menunjukkan julat 0.23-1.90 dan 0.11-3.01 Bq/kg untuk ladang teh A dan ladang teh B. Daripada keputusan kepekatan aktiviti ^{137}Cs, ianya sebanding dengan lain- lain kajian mengenai ^{137}Cs di dalam tanah di sekitar Asia.

Keywords: *^{137}Cs, Atmospheric fallout, Gamma spectrometer, Cameron Highlands, Tea Plantation*

INTRODUCTION

^{137}Cs is an artificial radionuclide and introduced into the atmospheric environment from testing of thermonuclear weapons during a period extending from the mid-1950s to the mid-1970s (Collins *et al.,* 2001). The Chernobyl accident in 1986 also was an additional source of radioactive ^{137}Cs in the environment. It provided a new source of ^{137}Cs deposition in

Europe and Western Asia (Pelt *et al*., 2007). In 1963 before Limited Nuclear Test Ban Treaty, the majority of nuclear test were carried out on earth surface, which injected great, quantity of trash into troposphere and stratosphere. Nuclear explosion radioisotopes will be formed and contaminated with the trash, and when these contaminated particles reach troposphere and stratosphere, it is detached by atmospheric winds are droplets gradually fall back to earth. This effect is referred to as fallout. Although the nuclear plants accidents have contributed to radioisotopes contamination, it is only formed as local fallout in the nearest regions (Andrello and Appoloni, 2004).

^{137}Cs fallout reaches the earth's surface mostly as a result of deposition and is strongly and quickly adsorbed by fine soil colloidal particles such as clay minerals and organic matter in topsoil. The chemical or biological removal of ^{137}Cs from soil particles is limited, and it is assumed that only physical processes of moving soil particles such as soil erosion and tillage practice are involve in the ^{137}Cs transport (Afshar *et al.,* 2010). Strong absorption of ^{137}Cs in most soils occurs close to the surface. Hence, its subsequent redistribution will be mostly sediment-associated. With a half life of 30.2 year, ^{137}Cs is suitable for tracing sediment redistribution since the onset of fallout accumulation (Lu and Higgitt, 2000).

The ^{137}Cs concentration in the surface soil decreases under several influence processes such as decay, mechanical removing with rain water, vertical migration and diffusion into deeper layers of soil. The migration of fallout in the undisturbed soil column undergoes two basics processes which are the particles can percolate downwards with rain water and the solvable phase is subject to convection and diffusion with the soil solution and sorption to the soil matter described by the convection-diffusion model equation (Ajayi and Raji, 2010). Therefore, these two types of migrations and resulting profile redistribution differ from area to area and depend strongly on landscape position (Al-Masri, 2006).

Cameron Highlands that is situated at the north-western tip of Pahang, is one of the famous eco-tourism location with tea plantation has been planted more than 50 years ago, before the intensive nuclear weapons testing period. Therefore, this location is suitable for the study of ^{137}Cs because during the period of time, it is assumed that there are no changes of the landscape of the tea plantation and the soil was undisturbed over that period of time. The present study embarked on the determination of ^{137}Cs activity concentration in the study areas and profiling the related vertical distribution of the radionuclide. A comparison between the two study areas and other country were also carried out.

EXPERIMENTAL METHOD

Sampling and sample preparation

Samples were collected within tea plantation areas A and B in Cameron Highlands, 1200 meter above the sea level. The sampling locations (six from each area) are shown in Table 1. Each of the samples was collected in the middle of the hilly slope. For each of the sampling point top soil and profile samples were taken using hand auger. Top soil sample represent soil down to 15 cm from surface, while for profiling samples were collected at 2 cm interval for 20 cm depth. The samples was taken to the laboratory for oven dried at 60^{o}C until constant weight, then ground and sieved through 250 µm sieve. Around 450 g of samples was kept and sealed properly in the plastic container.

Table 1: The soil samples locations

Code	Location	Code	Location
A1	N4" 27.254' E101" 22.043'	B1	N4" 26.909' E101" 24.855'
A2	N4" 27.204' E101" 22.108'	B2	N4" 26.991' E101" 24.969'
A3	N4" 27.143' E101" 21.982'	B3	N4" 26.992' E101" 24.744'
A4	N4" 27.543' E101" 21.844'	B4	N4" 26.886' E101" 24.926'
A5	N4" 27.248' E101" 21.999'	B5	N4" 26.091' E101" 25.115'
A6	N4" 27.340' E101" 21.074'	B6	N4 26.956' E101" 24.953'

Instrumentation

Gamma measurement was carried out using low background hyper pure coaxial germanium (P-type) detector. It is linked to gamma spectrometer with a multi-channel digital analyzer system from EG & G, ORTEC. The gamma peak resolution at 1332 keV ^{60}Co was 1.86 keV and relative efficiency of 25 % with energy range from 40 keV to 10 MeV. The ORTEC Gamma Vision^{TM} Version 6.07 software was used for the spectra analysis and processing (Saat *et al*., 2010).

Each of the samples was counted at 43200 second and the spectrum was analyzed using Gamma Vision software for energy peak at 661.66 keV of ^{137}Cs. The efficiency calibration of the detector was made using secondary standard made up of UO_3 and KCl matrix in the same geometry as the sample (Saat *et al*., 2011). The spectrometer efficiency at 661.66 keV obtained was used to calculate the activity concentration of ^{137}Cs in the soil using the equation,

$$A_{Ei} = \frac{N_{Ei}}{\varepsilon_E \times t \times \gamma_d \times M_s} \quad \text{Eq. 1}$$

$A_{Ei} =$ Activity concentration (in Bq/kg)
$N_{Ei} =$ Net peak area of a peak at energy E
$\varepsilon_E =$ Detection efficiency at energy E
$t =$ Counting live time
$\gamma_d =$ Number of gammas per disintegration of this nuclide for a transition at energy E
$M_s =$ Mass in kg of the measured sample

The minimum detectable activity (MDA) of this low background Gamma spectrometer at 661.66 keV was 0.0875 Bq/kg was calculated using the equation (Taha and Morsi, 2009);

$$MDA = \frac{(4.65\sqrt{N} + 3)}{ET} \quad \text{Eq. 2}$$

N = background count
T = counting time
E = counting efficiency

RESULTS AND DISCUSSIONS

The activity concentrations of ^{137}Cs for top soil and profile for Locations A and B are shown in Table 2 and Table 3 respectively. The top soil at Location A, shows a range from 0.37 to 1.52 Bq/kg with a mean activity concentration of 1.11 Bq/kg. While at Location B the corresponding mean is 1.84 Bq/kg, with a range from 1.22 to 2.75 Bq/kg. In general, the activity concentration of ^{137}Cs at Location B is higher than at Location A. The presence of ^{137}Cs is due to atmospheric deposition over a long period of time. At least there were two major sources indentified namely nuclear bomb test in the 60's and Chernobyl reactor accident in 1985. ^{137}Cs had slowly dispersed from its original sites and was distributed all over the world with the help of wind and rain.

Table 2: Activity concentration of ^{137}Cs in tea plantation A

Layer (cm)	Activity concentration (Bq / kg)					
	A1	**A2**	**A3**	**A4**	**A5**	**A6**
Top soil	1.06± 0.10	1.23± 0.10	1.41± 0.11	1.06± 0.09	1.51± 0.12	0.37± 0.06
00 - 02	1.24± 0.21	1.22 ± 0.20	1.90± 0.25	1.67± 0.23	1.12± 0.20	1.54± 0.24
02 - 04	0.85± 0.17	1.34± 0.21	1.48± 0.23	1.14± 0.19	1.37± 0.22	1.62± 0.24
04 - 06	0.95± 0.18	0.97± 0.18	1.02± 0.19	1.26± 0.20	1.66± 0.24	1.18± 0.20
06 - 08	1.25± 0.21	1.33± 0.22	1.65± 0.23	1.79± 0.24	1.37± 0.22	0.37± 0.11
08 - 10	0.42 ± 0.12	1.14± 0.21	0.73± 0.15	1.39± 0.22	1.12± 0.19	0.87± 0.17
10 - 12	1.21± 0.20	0.98± 0.19	1.16± 0.21	1.07± 0.19	1.56± 0.23	1.63± 0.26
12 - 14	0.70± 0.15	0.90± 0.18	0.94± 0.18	1.50± 0.23	0.90± 0.18	1.09± 0.20
14 - 16	0.63± 0.15	0.85± 0.17	0.85± 0.17	1.20± 0.20	0.82± 0.17	1.21± 0.20
16 - 18	0.53± 0.14	0.49± 0.14	0.25± 0.10	1.31± 0.21	0.81± 0.16	0.70± 0.15
18 - 20	0.85± 0.18	0.70± 0.15	1.04± 0.18	0.67± 0.14	0.23± 0.09	0.38± 0.12

Table 3: Activity concentration of ^{137}Cs in tea plantation B

Layer (cm)	Activity concentration (Bq / kg)					
	B1	**B2**	**B3**	**B4**	**B5**	**B6**

Top soil	1.60 ± 0.13	1.37 ± 0.11	1.22 ± 0.11	2.29 ± 0.15	1.82 ± 0.13	2.75 ± 0.17
00 - 02	2.01 ± 0.14	1.59 ± 0.13	2.29 ± 0.15	1.31 ± 0.11	1.27 ± 0.11	2.35 ± 0.15
02 - 04	1.49 ± 0.12	2.16 ± 0.15	2.06 ± 0.14	1.58 ± 0.12	1.67 ± 0.13	3.01 ± 0.17
04 - 06	1.99 ± 0.14	2.08 ± 0.14	1.21 ± 0.11	1.44 ± 0.12	2.49 ± 0.16	1.31 ± 0.11
06 - 08	0.19 ± 0.04	1.19 ± 0.11	1.64 ± 0.13	0.60 ± 0.08	2.02 ± 0.14	1.12 ± 0.10
08 - 10	0.11 ± 0.03	2.00 ± 0.14	1.43 ± 0.12	0.60 ± 0.08	2.03 ± 0.15	1.28 ± 0.11
10 - 12	2.08 ± 0.14	1.35 ± 0.12	1.26 ± 0.11	1.10 ± 0.10	1.64 ± 0.13	1.83 ± 0.13
12 - 14	0.83 ± 0.09	1.71 ± 0.13	2.01 ± 0.14	0.49 ± 0.07	1.73 ± 0.13	1.35 ± 0.12
14 - 16	1.37 ± 0.12	1.17 ± 0.11	1.32 ± 0.11	1.56 ± 0.12	1.13 ± 0.11	1.24 ± 0.11
16 - 18	0.66 ± 0.08	0.77 ± 0.09	1.39 ± 0.11	0.71 ± 0.08	1.47 ± 0.12	0.61 ± 0.08
18 - 20	1.41 ± 0.12	0.27 ± 0.05	1.11 ± 0.11	0.95 ± 0.11	1.16 ± 0.11	0.26 ± 0.05

In Figure 1 the mean activity concentration for each layer of the locations were plotted against depth to show the mean depth distribution of ^{137}Cs in the soils.

The depth profile distributions for sampling points at Location A and B showed some what similar pattern, however at B the activity concentrations are consistently higher. Two distribution patterns are observable for depth of 0 – 10 cm and another for 12 – 20 cm, as obviously can be seen in Table 2, Table 3 and also Figure 1. The presence of two distribution patterns for depth profiles indicates the existence of two sources of ^{137}Cs. The two sources could be attributed to the Chernobyl accident in 1986 represented by the 0 – 10 cm distribution pattern that begins from the surface of soil and atmospheric testing of nuclear weapon during the period between 1950s and the 1970s (Osvaldo *et al.*, 2002) as indicated by the 12 – 20 cm distribution pattern.

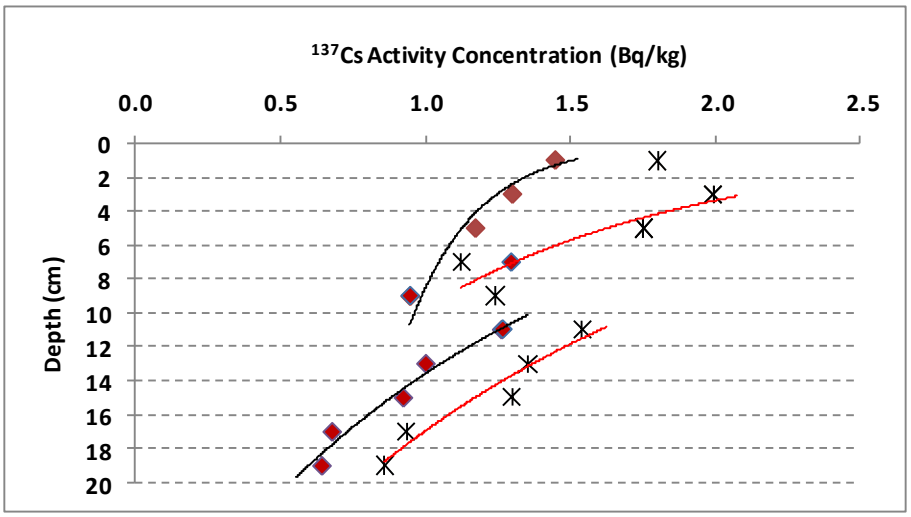

Figure 1: Mean depth profile of ^{137}Cs at Location A (kite) and Location B (crosses)

A careful observation showed the ^{137}Cs activity concentrations decrease exponentially with depth from each maximum values as shown in Figure 1. The presence of the two slopes of different gradients (Figure 1) obviously showed the occurrence of two sources of ^{137}Cs as mentioned earlier. These suggest that there are runoffs, and soil redistribution effect on ^{137}Cs concentration with depth and ^{137}Cs was transferred vertically. For the top pattern, the rate of decrease for Location B is higher, however both locations showed a similar rate of decrease for the lower distribution pattern. This could be explained due to the different degree of disturbance on top soils in both locations. The consistently higher concentration at Location B may be explained by the fact that Location B is situated at higher altitude than Location A hence may receive more ^{137}Cs fallout.

CONCLUSION

The activity concentration of ^{137}Cs soil collected from tea plantation A and B was in range of 0.23 – 1.90 Bq/kg and 0.11 – 3.01 Bq/kg respectively. The effect from nuclear tests and Chernobyl accident is still observable in Malaysia. It has been shown after 50 years the major deposition of ^{137}Cs had diffused into the soil depth of 20 cm and can be expected to still diffuse into deeper layers of soils. It was comparable with other Asian country such as Indonesia with activity concentration of ^{137}Cs in the range 2.19 – 8.13 Bq/kg (Suhartini, 2006), Thailand with 11.23 – 16.4 Bq/kg (Malika, 2010)

and Vietnam with 0.5 – 18 Bq/kg (Hien *et al*., 2002). In the future, it is necessary to study more places in Malaysia regarding this ^{137}Cs radionuclide.

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REFERENCES

Al-Masri, M, S., (2006). Vertical distribution and inventories of ^{137}Cs in the Syrian soils of the eastern Mediterranean region. *Journal of Environmental Radioactivity*, 86, 187-198.

Afshar, F, A., Shamsollah, A. and Ahmad, J., (2010). Soil redistribution rate and its relationship with soil organic carbon and total nitrogen using ^{137}Cs technique in a cultivated complex hill slope in western Iran. *Journal of Environmental Radioactivity*, 101, 606-614.

Ajayi, I, R. and Raji, A, T., (2010). Evaluation of the ^{137}Cs activity-depth profiles by the diffusion-convection model. *International journal of the physics sciences*, 5(2), 154-157.

Andrello, A, C. and Appoloni, C, R., (2004). Spatial variability and cesium-137 inventories in native forest. *Brazillian journal or physics*, 34, no.3A. 800-803.

Collins, A, L., D. E. Walling, H. M. Sichingabula. and G. J. L. Leeks., (2001). Using ^{137}Cs measurements to quantify soil erosion and redistribution rates for areas under different land use in the Upper Kaleya River basin, southern Zambia. *Geoderma*, 104, 299–323.

Hien, P, D., Hiep, H, T., Quang, N, H., Huy, N, G., Binh, N, T., Hai, P, S., Long, N, Q. and Bac, V, T., (2002). Derivation of ^{137}Cs deposition density from measurements of ^{137}Cs inventories in undisturbed soils. *Journal of Environmental Radioactivity*, 62, 295–303.

Lu, X, X. and Higgit, D, L., (2000). Estimating erosion rates on sloping agricultural land in the Yangtze Three Gorges, China, from cesium-137 measurements. *Catena*, 39, 33-51.

Mallika, S., (2010). Application of ^{137}Cs Accumulation In Soil In Predicting Soil Erosion From Different Land Uses In Haui Raen-Klongpid Watershed, Eastern Thailand. 19th World Congress of Soil Science, Soil Solutions for a Changing World. 5-7.

Osvaldo, B, F., Julio, G, B., Adelmo, M, E. and Aldo, B, C., (2002). Estimating soil erosion using fallout cesium-137 in cultivated land at the watershed of Maximo River, Cuba. *Transactions of the 17th World Congress of Soil Science.* 1-10.

Pelt, R. S. V., Ted, M. Z., Jerry, C. R. and Thomas, E. G., (2007). Validating the use of ^{137}Cs measurements to estimate rates of soil redistribution by wind. *Catena*, 70, 455–464.

Saat, A., Hamzah, Z., Yusop, M, F. and Zainal, A., (2010). Experimental Determination of the HPGe Spectrometer Efficiency Calibration Curves for Various Sample Geometry for Gamma Energy from 50 keV to 2000 keV. *AIP Conference Proceedings, 1250*, 39-42.

Saat, A., Hamzah, Z., Jamaluddin, H., Muda, H, M. (2011). Assessment of Outdoor Radiation Hazard of Natural Radionuclides in Tourism Beach Areas, *2011 Proceedings 3rd International Symposium & Exhibition in Sustainable Energy & Environment*, 1-3 June 2011, Melaka, Malaysia123-127 (ISBN 978-1-4577-0342-3)

Suhartini, N., (2006). Perbandingan Profil Distribusi Vertikal ^{137}Cs Di Lapisan Tanah Hasil Pengukuran Terhadap Simulasi. *Makara, Sains.* 2, 89 – 95.

Taha, T, M. and Morsi T, M., (2009). Calibration of single high purity germanium Detector for whole body counter. *Radiation Protection Department, Nuclear Research Center, Atomic Energy.* Proceedings of the 7th Conference on Nuclear and Particle Physics. 485-492.