The Malaysian Journal of ANALYTICAL SCIENCES ISSN 1394-2506

ASSESSMENT OF RADIATION HEALTH RISK IN CAMERON HIGHLANDS TEA PLANTATIONS

(Risiko Penilaian Kesihatan di Ladang Teh Cameron Highlands)

Zaini Hamzah[1], Seh Datul Riduan[1*] and Ahmad Saat[2]

[1]*Faculty of Applied Sciences,*
[2]*Institute of Science,*
Universiti Teknologi MARA, 40450 Shah Alam, Selangor

**Corresponding author: sehdatulriduan@yahoo.com*

Abstract

Exposure to the natural radiation is quite common except that the level varies from one place to another. The level of radiation will depend on the type of rocks and soil on that particular area, where the granitic rocks tend to contribute more to the background radiation. The present study was conducted in two of the Tea Plantations in Cameron Highlands, where it has been in operation for more than 50 years. The landscape is hilly type and the workers have to pluck the tea leaves manually. Practically, there are spending long hours in the plantation area. There were thirteen locations for soil sampling and surface dose in-situ measurement. Soil samples were taken back to the UiTM laboratory in Shah Alam for further analysis. Samples were clean, dried, ground and sieve to obtain homogenous samples before analysis. Samples were packed in a plastic container around 400 g, sealed and leave it for 3 weeks to allow radionuclides to reach secular equilibrium, before counting using gamma spectrometer with HPGe detector. The spectrum was analysed using gamma vision software to calculate the activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K. From the radium equivalent values, one can estimate the external hazard index, the absorb dose and cumulative effective dose received by the person who spend their time in the study area. The results show the external hazard index more than one for one of the tea plantation, but the cumulative effective dose is still below the recommended level.

Keywords: gamma spectrometer, radium equivalent, external hazard index, surface dose, intermediate igneous rock

Abstrak

Pendedahan kepada radionuklid semulajadi sentiasa ada kecuali kadar radiasi adalah berbeza daripada satu tempat kepada tempat yang lain. Kadar radiasi adalah bergantung kepada jenis batu dan tanah di sesuatu kawasan itu dimana batuan granit memberikan kadar bacaan radiasi yang tinggi. Kajian yang terbaru telah dijalankan di dua ladang teh bertempat di Cameron Highland yang telah beroperasi lebih daripada 50 tahun. Bentuk muka bumi yang berbukit dan para pekerja perlu memetik daun teh secara manual. Secara pratikalnya, mereka menghabiskan masa lebih lama di kawasan ladang. Tiga belas lokasi pengambilan sampel dan juga kadar dos di permukaan telah diambil di kawasan tersebut. Semua sampel telah dibawa ke makmal UiTM di Shah Alam untuk analisa seterusnya. Kesemua sampel tersebut telah dibersihkan, dikeringkan, disimpan dan diayak bagi menghasilkan sampel yang sebati sebelum dianalisa. Sampel telah dimasukkan kedalam bekas plastik dalam anggaran 400g sampel telah dimasukkan, kemudian ditutup dan disimpan selama 3 minggu bagi membiarkan sampel mencapai keseimbangan sekular. Spectrum telah dianalisa dengan menggunakan perisian GammaVision untuk mengira aktiviti kepekatan ^{226}Ra, ^{228}Ra dan ^{40}K. Daripada nilai keseimbangan radium, kadar serapan dan indeks radiasi berbahaya, dos serapan dan dos efektif terkumpul yang diterima oleh orang yang menghabiskan masa di kawasan kajian. Hasil kajian menunjukkan kadar serapan dan indeks radiasi berbahaya melebihi daripada satu di salah satu lokasi ladang teh tetapi dos efektif terkumpul masih dibawah tahap yang dicadangkan.

Kata kunci: spektrometer gamma, keseimbangan radium, index radiasi berbahaya, dos permukaan, batuan igneus pertengahan

Introduction

Radiation health risk now has been concern by public and they have a right know the hazard risks of the area there are visited. The natural radiation is contributed from the radionuclides materials that occur naturally from the earth crush also known as Naturally Occur Radionuclides Material (NORM). The high radiation of NORM was occurring at the location where the granite rock were enriching with radionuclides occur [1]. Soil is one of the major contributions of continuous radiation exposure to human and soil can be used as radiological indicator in environment [2]. The radioactivity in soil are primary comes from U, Th and their progenies and also from the natural K [3, 4]. The gamma radiation emit from ^{40}K, ^{238}U, ^{232}Th and their decays series represent the main external exposure to the environment [5]. NORM which also called as terrestrial background radiation is the main present of the external sources of irradiation to the human body [6]. These radionuclides can enter human body through ingestion of water and food, and inhalation of the air [7].

The major radionuclides that widely used for estimating the radiation health assessment are ^{226}Ra, ^{228}Ra and ^{40}K [8, 9, 10]. ^{226}Ra were come from series of ^{238}U which will decays to ^{222}Rn and ^{222}Rn are in gas state which can transfer trough the environment. ^{222}Rn is an alpha particle emitter and when ^{222}Rn enter human body through the air, it can initiate the cancer for example is lung cancer. ^{228}Ra represent the ^{232}Th and ^{40}K come from natural K that emit γ-rays to the environment.

The objective of this study is to determine the activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K at tea plantation Cameron Highlands by using gamma rays spectrometer with HPGe detector. This study will also calculate the radium equivalent and then estimate the external hazard index of the study area. This study will give the information about the annual effective dose receive by the public and workers at the study area and also to provide baseline data for future assessment reference. The activity of ^{226}Ra, ^{228}Ra and ^{40}K was analyzed at γ-rays energy peak of 609 KeV for ^{226}Ra, 911 KeV for ^{228}Ra and ^{40}K at 1460 KeV[11].

Experimental

Samples collection and preparation

Cameron Highlands tea plantations areas were chosen to determine the health risk because of the usage of fertilizer and also as one of the tourism attraction. In order to determine NORM in soil, thirteen location of soil were taken at different slope with composite and profile of the soil taken. The samples was taken at two tea plantation place label as Plantation A and B. Table 1 shows the samples label at the study area and the position of the sampling point that was taken by using Global Positioning System (GPS) with elevation higher than 1100 m. There are 2 categories of samples taken which are composite soil samples and profile soils samples for all location by using hand auger. Composite samples consist of the top layer of the soil which about 10 cm from the surface of soil and profile soil samples was taken according to the depth of samples which is the samples was divided into 2 cm each for 20 cm depth soil. In-situ measurement of radiation dose was measured by using survey meter Model 2241 from LUDLUM Measurement Incorporations was taken for surface and 1 meter above the surface. All the samples were taken to the laboratory for oven dried at 60^{o}C until constant weight achieve. Then the samples were grind to pass through 250 micron sieve. About 400 g of sample was kept and sealed in the plastic container and the samples were grounded for 3 weeks to let the samples achieve secular equilibrium before been measured using gamma rays spectrometer.

Measurement of ^{226}Ra, ^{228}Ra and ^{40}K

The samples was counted using gamma rays spectrometer with ORTEC® HPGe detector with resolution 1.84 keV, 25% relative efficiency at 1332 KeV ^{60}Co gamma ray and couple to Multi Channel Analyser (MCA). Because of ^{226}Ra is an alpha emitter the measurements of ^{226}Ra are base on radon daughter which known as ^{214}Bi and ^{214}Pb [12]. ^{228}Ra was measured based on activity of ^{228}Ac by assuming secular equilibrium between parent and daughter. The efficiency calibration was made by using secondary standard made up by mixing UO_3 and KCl in the same container as samples and counted for 43200 second. Figure 1 shows the efficiency of the gamma rays spectrometer used for calculation of individual radionuclides activity in samples. Because of the energy of radionuclides interested is higher than 200 keV, equation (A) were used to calculate the detection efficiency at energy of each radionuclides.

Table 1: Sample locations collection

Location	North	East	Elevation (m)
A1	4° 27.254"	101° 22.043"	1216
A2	4° 27.204"	101° 22.108"	1219
A3	4° 27.143"	101° 22.982"	1199
A4	4° 27.543"	101° 21.844"	1190
A5	4° 27.248"	101° 21.999"	1214
A6	4° 27.340"	101° 21.074"	1200
A7	4° 27.314"	101° 21.133"	1220
B1	4° 26.909"	101° 24.855"	1350
B2	4° 26.991"	101° 24.969"	1360
B3	4° 26.992"	101° 24.744"	1320
B4	4° 26.886"	101° 24.926"	1340
B5	4° 26.091"	101° 25.115"	1380
B6	4° 26.956"	101° 24.953"	1340

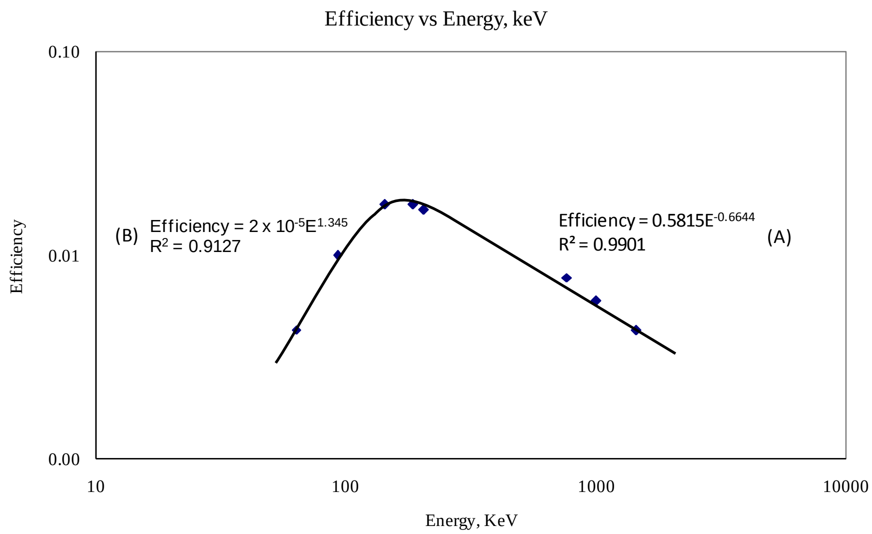

Figure 1**:** Efficiency Calibration using UO_3 and KCl by Gamma Rays Spectrometer

Energy peak 1461 keV for ^{40}K, 609 keV of ^{214}Bi for ^{226}Ra and 911 keV for ^{228}Ra were used for the laboratory measurement of activity concentration potassium, radium and thorium. The counting time for measuring each sample was 43200 second and the spectrum obtained was analyzed by using GammaVision software provided by ORTEC®. After the peak was analyzed, the activity per unit mass was calculated. The calculation of the individual radionuclides was calculated using the Equation (1),

$$A_{Ei} = \frac{N_{Ei}}{\varepsilon_E \times t \times \gamma_d \times M_s} \quad (1)$$

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

By considering Radium equivalent as external exposure that is widely used by the international parameter in radiological protection and radiological risk assessment is the effective equivalent dose which is originated by gamma emitters [13]. Radium equivalent was calculated using Equation (2) and absorbed dose rate Equation (3),

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K \tag{2}$$

$$D = 0.461C_{Ra} + 0.623C_{Th} + 0.0414C_K \tag{3}$$

The external hazard index (H_{ex}) is an evaluation of potential hazards due to the radiological effect and it should be less than unity. The maximum value of H_{ex} is depending to the upper limit of Ra_{eq} which is 370 Bq/kg [6]. The H_{ex} can be calculated using equation (4) and annual effective dose Equation (5).

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} < 1 \tag{4}$$

$$Annual\ effective\ Dose(mSv.y^{-1}) = D\ (nGy/h) \times 8760\ (h/y) \times 0.2 \times 0.7(Sv/Gy) \times 10^{-6} \tag{5}$$

C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively

Results and Discussion

The result from Table 2 shows that the activity of ^{226}Ra, ^{228}Ra and ^{40}K is higher than global average value provided by UNSCEAR 2008 report. Also the External Hazard Index is higher than unity for plantation B. This is because of different in location may result different activity concentration of radionuclides in soil [14, 15]. The ratio of ^{228}Ra/^{226}Ra in table 2 varied from 1.23 to 2.62. Ratios more than 1 concludes that ^{228}Ra is more enriched in the soil compare to ^{226}Ra may be due to the external sources that have not been identified.

Table 2**:** ^{226}Ra, ^{228}Ra and ^{40}K of composite soil samples

Location	**^{226}Ra Bq/kg**	± ±	**^{228}Ra Bq/kg**	±	**^{40}K Bq/kg**	±	**Ratio ^{228}Ra/^{226}Ra**
A1	75.90	1.55	102.55	2.38	230.20	2.49	1.35
A2	65.97	1.42	80.99	2.11	84.91	4.34	1.23
A3	50.94	1.34	104.68	2.44	491.43	1.61	2.05
A4	54.66	1.27	105.04	2.35	329.17	1.96	1.92
A5	64.44	1.51	168.85	3.01	117.89	4.11	2.62
A6	80.58	1.76	132.68	2.75	219.43	2.77	1.65
A7	61.78	1.53	100.64	2.41	79.07	5.20	2.59
B1	117.28	2.10	202.21	3.48	282.00	7.05	1.72
B2	104.16	1.94	241.06	3.54	238.26	6.27	2.31
B3	118.72	1.98	201.55	4.31	203.09	6.21	1.70
B4	118.36	2.14	222.43	3.63	348.29	7.56	1.88
B5	137.08	2.18	233.96	3.77	407.35	8.11	1.71
B6	131.34	2.30	246.67	4.32	656.91	10.90	1.88

Table 3**:** Radiation surface doses in situ measurement

Location	**Surface (µSv/h)**	**1 Meter Above Surface (µSv/h)**
A1	0.30	0.23
A2	0.25	0.18
A3	0.25	0.19
A4	0.25	0.19
A5	0.28	0.19
A6	0.24	0.17
A7	0.23	0.16
B1	0.32	0.31
B2	0.36	0.32
B3	0.32	0.31
B4	0.34	0.31
B5	0.36	0.34
B6	0.34	0.29

Table 3 shows the radiation surface dose for study area on the surface and 1 meter above the surface. The higher radiation dose for surface and 1 meter above the surface is at location B2 and the lowest is at location A7. The Pearson correlation calculated shows that ^{226}Ra and ^{228}Ra has a strong correlation with surface dose measurement at surface and 1 meter above surface with correlation coefficient more than 0.88 but ^{40}K shows weak correlation with correlation coefficient 0.4 respectively.

Table 4 shows the calculated results for External Hazard Index, Radium Equivalent, Absorbed Dose Rate and Annual Effective Dose. This calculation is based on composite soil measurement.

Table 4: External Hazard Index, Radium Equivalent, Absorbed Dose Rate and Annual Effective Dose at tea Plantation A and B

Location	**Radium Equivalent Bq/kg**	**Absorbed Dose Rate nGy/h**	**External Hazard Index**	**Annual Effective Dose**	
				Public	**Workers**
A1	238.66	108.41	0.65	0.13	0.16
A2	187.74	84.39	0.51	0.10	0.12
A3	235.04	109.05	0.64	0.13	0.16
A4	227.91	104.27	0.62	0.13	0.15
A5	314.14	139.78	0.85	0.17	0.21
A6	285.67	128.89	0.78	0.16	0.19
A7	211.24	94.46	0.57	0.12	0.14
B1	426.17	191.72	1.16	0.24	0.28
B2	465.56	208.06	1.26	0.26	0.31
B3	421.15	188.70	1.14	0.23	0.28
B4	460.81	207.55	1.25	0.25	0.31
B5	500.16	225.81	1.36	0.28	0.33
B6	530.06	241.42	1.44	0.30	0.36

From the Table 4, location B6 has the highest calculation value for External Hazard Index, Radium Equivalent, Absorbed Dose Rate and Annual Effective Dose compared to others and the lowest is at location A2. Radium equivalent for plantation A is bellow limit but for plantation B, the value is exceed the upper limit for radium equivalent (370 Bq/kg) [8].

The External Hazard Index for location B is higher than unity and this is because the activity of the ^{226}Ra and ^{228}Ra is higher than recommendation value and the recommendation value is below than 1. Even through all the location is higher than recommendation value except for ^{40}K, external hazard index for location A still below unity. Only two location of ^{40}K that higher than recommendation value. According to the soil map of peninsular Malaysia, the soils at Cameron Highlands were originated as an intermediate igneous rock [16]. This explained the higher value of radionuclides in the soil. The higher value of External Hazard Index is maybe due to the location where igneous rocks were exist in Cameron Highland which make the activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K is higher than global average value. The global average value for ^{226}Ra, ^{228}Ra and ^{40}K were set to be 32 Bq/kg, 45 Bq/kg and 412 Bq/kg [17]. The worldwide outdoor dose rates proposed by the UNSCEAR 2008 were 58 nGy/h but when compared with this study, there are 3 to 4 times higher than proposed value. Study by El-Arabi, 2007 on igneous rock give a higher value of external hazard index and annual dose above the global average value [18].

In this study, the annual effective doses are divided into two categories which are for worker doses and for public doses. For public it is well known that 0.2 occupancy fraction is for outdoor exposure in a year reported by UNSCEAR 2008. For workers, in my study area, the worker spend around 8 hour per day and 22 day per month in the tea plantation. They expose more to the radiation of the study area which is 2112 hour per year and for public is 1752 hour per year. Therefore for workers, the annual effective dose is higher than the public exposure but annual effective dose is still in the range proposed by the UNSCEAR 2008 is 0.3-1.0 mSv/y.

Activity profile for ^{226}Ra, ^{228}Ra and ^{40}K at Plantation A and B

Figures 2, 3 and 4 shows the activity profile for ^{226}Ra, ^{228}Ra and ^{40}K at plantation A and B. This profile shows the activity concentration behaviour in the soil and also can be used to monitor the change in concentration with depth. From Figure 2, it shows the profile for activity ^{226}Ra in a depth of 20cm for location A and B. the similarities between these profiles is the activity of ^{226}Ra show monotonic pattern trough the depth. There is no observable trend is shown at the study area depth profile. Range concentration of ^{226}Ra for location A is 44.76-86.31 Bq/kg and Location B 70.20-142.89 Bq/kg. The mean concentration of A is 63.90 Bq/kg and B is 112.78 Bq/kg respectively.

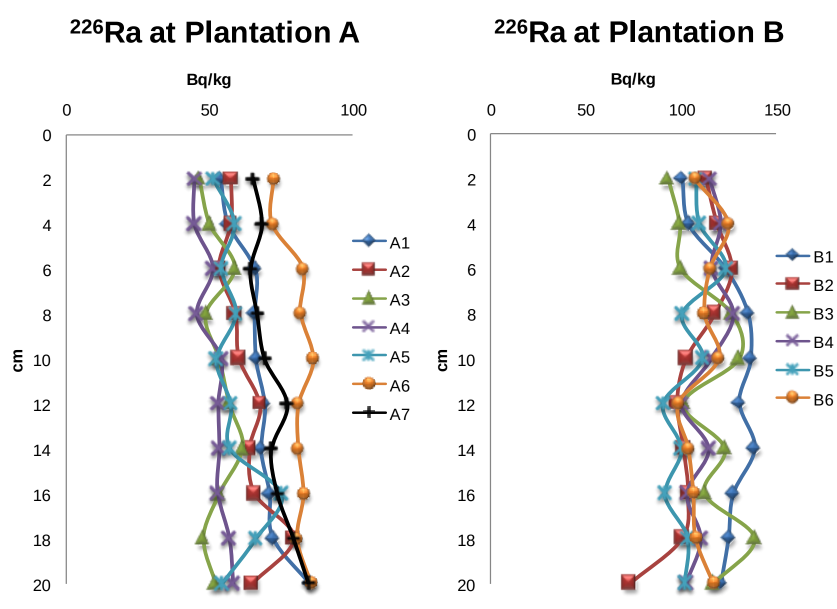

Figure 2: ^{226}Ra profile

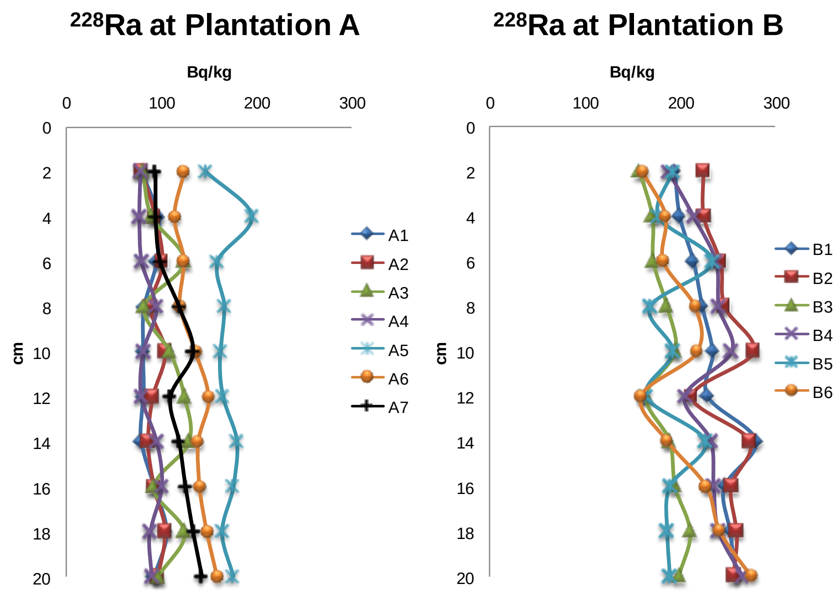

Figure 3: ^{228}Ra profile

The activity profile for ^{228}Ra were also same as ^{226}Ra, there is no observable trend was shown in Figure 3. When compare between location A and B, the average activity concentration ^{228}Ra at B is higher than location A. The range concentration of ^{228}Ra is 77.04-195.53 Bq/kg for A and 157.11-280.11 Bq/kg for B. The mean concentration of ^{228}Ra is 113.55 Bq/kg for A and 217.41 Bq/kg for B respectively.

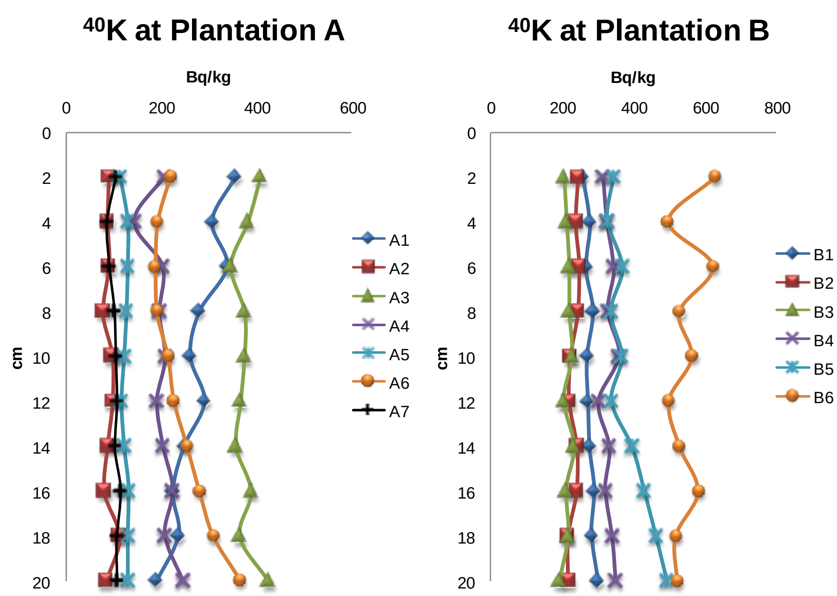

Figure 4: ^{40}K profile

There is one locations profile for ^{40}K is increasing through the depth which is for location A6and B5. Also only one location is decreasing through the depth which is A1 .It seems that there is also no observable pattern for ^{40}K. The decreasing pattern at location A1 and B5 is maybe due to the external sources of K which is from fertilizer may occur which enrich the top layer and decreasing through the depth. The range concentration of ^{40}K for location A and B is 78.67-491.43 Bq/kg and 192.08-689.09 Bq/kg. Mean concentration is for A is 204.55 Bq/kg and B 337.31 Bq/kg respectively.

As overall estimation of the external hazard index of this study, the annual effective dose for public and workers is still in the range proposed by the UNSCEAR 2008 except for location B. This place is considered still under global average value.

Conclusion

In the present study the external hazard index (H_{ex}) for the study area is higher than unity for location B but the annual effective dose is still in the global average range for workers and public. The higher activity of NORM in the study area due to the location which is Cameron highlands is located at Titiwangsa range where the origin of the soil is intermediate igneous rock.

Acknowledgement

Thanks to District Officer of Cameron Highlands for giving permission doing research at Cameron Highlands. Also thanks to Institute of Science UiTM and Faculty of Applied Sciences UiTM for providing research facility and fund.

References

1. Abbady A., (2005). Assessment of the natural radioactivity and its radiological hazards in some Egyptian rock phosphates. Indian Journal of Pure and Applied Physics. 43(7): 489-493.
2. Al-Hamarneh I.F. and Awadallah M.I., (2009). Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan. Radiation Measurements. 44(1): 102-110.
3. Mehra R., Singh S., and Singh K., (2009). Analysis of ^{226}Ra, ^{232}Th and ^{40}K in soil samples for the assessment of the average effective dose. Indian Journal of Physics. 83(7): 1031-1037.
4. Singh S., Rani A., and Kumar Mahajan R., (2005). ^{226}Ra, ^{232}Th and ^{40}K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gamma ray spectrometry. Radiation Measurements. 39(4): 431-439.
5. UNSCEAR, 2008. Sources and Effects of Ionizing Radiation. 1: 223-439.
6. Alaamer A., (2008). Assessment of human exposures to natural sources of radiation in soil of Riyadh, Saudi Arabia. Turkish Journal of Engineering & Environmental Sciences. 32(4): 229-234.
7. Alias M., Hamzah Z., Saat A., Omar M., and Z. T., (2005). Determination Of ^{226}Ra, ^{228}Ra And ^{40}K In Soil From Felda Jengka-15 Oil Palm Plantation. Malaysian Journal of Analytical Sciences. 9(1): 126 - 132.
8. Alias M., Hamzah Z., Saat A., Omar M., and Wood A.K., (2008). An Assessment of Absorbed Dose And Radiation Hazard Index From Natural Radioactivity. Malaysian Journal of Analytical Sciences. 12(1): 195-204.
9. Banzi F.P., Kifanga L.D., and Bundala F.M., (2000). Natural radioactivity and radiation exposure at the Minjingu phosphate mine in Tanzania. Journal of Radiological Protection. 20: 41-51.
10. Msaki P. and Banzi F., (2000). Radioactivity in products derived from gypsum in Tanzania. Radiation protection dosimetry. 91(4): 409-412.
11. Hamzah Z., Ahmad S., Noor H., and Seh D., (2008). Surface Radiation Dose and Radionuclide Measurement in Ex-Tin Mining Area, Kg Gajah, Perak. The Malaysian Journal of Analytical Sciences. 12(2): 419-431.
12. El-Aydarous A., (2007). Gamma Radioactivity Levels and Their Corresponding External Exposure of Some Soil Samples from Taif Governorate, Saudi Arabia. Global Journal of Environmental Research. 1(2): 49-53.
13. Júnior J.A.S., Amaral R.S., Silva C.M., and Menezes R.S.C., (2010). Radium equivalent and annual effective dose from geological samples from Pedra - Pernambuco - Brazil. Radiation Measurements. 45(7): 861-864.
14. Wang Z., (2002). Natural radiation environment in China. International Congress Series. 1225: 39-46.
15. Martínez-Aguirre A., García-Orellana I., and García-León M., (1997). Transfer of natural radionuclides from soils to plants in a marsh enhanced by the operation of non-nuclear industries. Journal of Environmental Radioactivity. 35(2): 149-171.
16. Division of Agriculture Ministry of Agriculture and Fisheries M., Generelized Soil Map Peninsular Malaysia 1970. 1970, Derectorat Pemetaan Negara, Malaysia No-137-1976: Kuala Lumpur.
17. UNCEAR, 2008. Sources and Effects of Ionizing Radiation. 1: 223-439.
18. El-Arabi A.M., (2007). ^{226}Ra, ^{232}Th and ^{40}K concentrations in igneous rocks from eastern desert, Egypt and its radiological implications. Radiation Measurements. 42(1): 94-100.