

Estimation of Radon Concentration in Soil Samples from Cameron Highlands, Malaysia

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Abstract: Concentrations of radon have been estimated in agricultural soil in Cameron Highlands in Pahang, Malaysia. CR-39 plastic track detectors are used to measure concentration of radon rate in the soil samples. Results reveal that the mean radon concentrations in agricultural soil collected from Cameron Highlands are 198.44 ± 59.44 Bq m⁻³. These concentrations are below than the action levels of 200 - 600 Bq m⁻³ as recommended by ICRP. According to the results, the areas of study are safe and do not pose health risks to the population in those areas, and thus the soil can be used for construction materials.

Keywords: CR-39, Radon, Cameron Highlands

1. Introduction

Radon measurements are crucial in monitoring human health and safety. Exposure to radon and its daughters contributes to more than 50% of the total radiation dose received from natural sources by human beings (UNSCEAR, 2000). ²²²Rn is produced by the alpha decay of ²²⁶Ra. It comes from the natural decay of uranium that is found in nearly all types of soil although the concentrations vary widely (NCRP, 1984). It typically moves up from the ground to the air. Radon decays with a half-life of 3.8 days which produces short daughters namely, ²¹⁸Po, ²¹⁴Pb, ²¹⁴Bi and ²¹⁴Po. Some atoms leave the soil and enter the surrounding air or water. As a result, radon is available indoor and outdoor. Emission of alpha particles takes place within the lungs as they inhale radon progenies. The most important and dominant contributors to the inhalation dose are the decay products of radon. Radon and its decay products in the air form the main natural sources of irradiation in human. Radon concentrations are higher indoors, but there is a substantial concentration outdoors as well. Besides affecting the public, it is responsible for many cancer deaths among uranium miners

[UNSCEAR, 2000, Adams, 1991]. In this concern, studies on soil have been carried out in different parts of the world, and much data is available in the literature (Rafique et al., 2011; Saad et al., 2013; Al-Nafiey et al., 2014). The Kinta district has many tin mining sites and is expected to have high background radiation from minerals, such as monazite and zircon. Granite bodies form the Main Range on the east and the Kledang Range on the west of the Kinta District. Higher radiation levels are associated with igneous rocks such as granite. The main objective of this study is to assess the levels of radon in the soil samples collected from Cameron Highlands region of Pahang, as well as the results are compared with the allowable levels worldwide.

2. Materials and Methods

Study area

Cameron Highlands, which is a district in the state of Pahang, has a total area of 71,218 ha. Cameron Highlands is located between Kelantan and part of Kinta District (Perak) and is situated in a part of the northwestern tip in Pahang as showed in Figure 1. Furthermore, Cameron Highlands is a popular tourist

and recreational area in addition to its being a key agricultural area for vegetables, flowers, and tea (Aswood *et al.*, 2013).

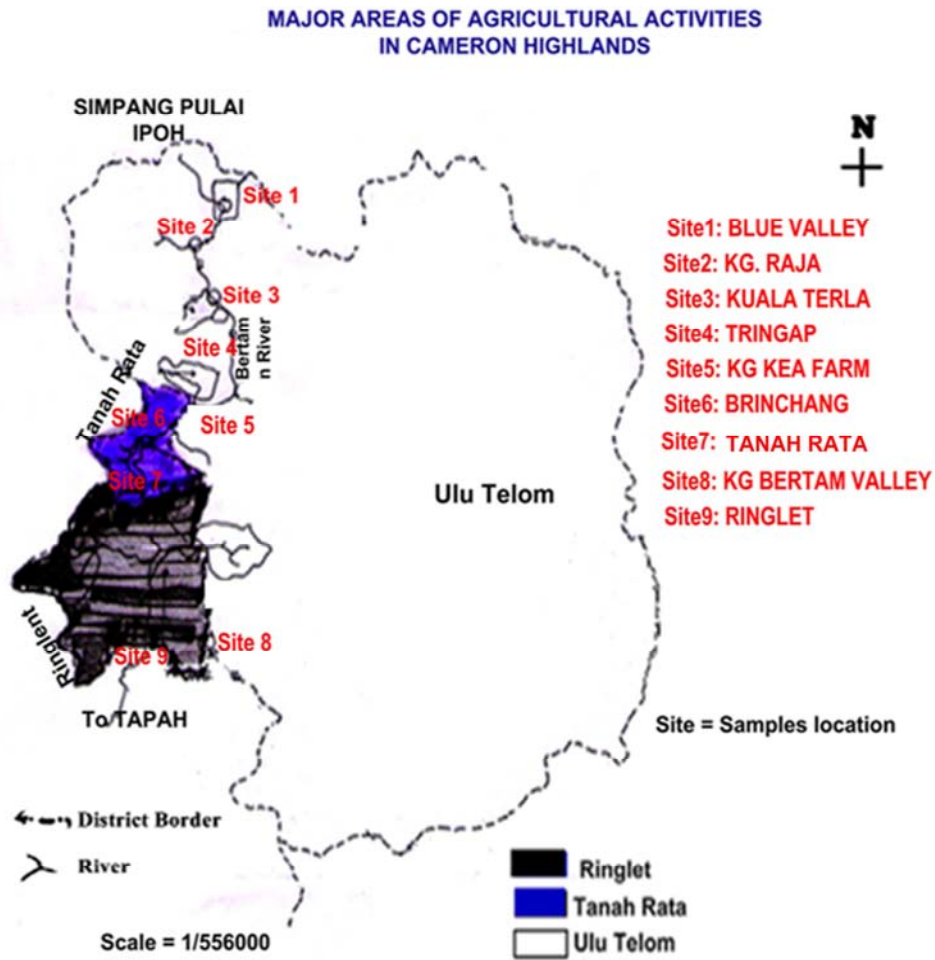


Figure 1. Map of Cameron highlands, Malaysia with sampling sites.

Collection and preparation of samples

Soil samples were collected from different parts of agricultural and non-agricultural areas in the Cameron Highlands. Samples were collected from the surface soil to a depth of 15 cm as showed in Figure 2. One kg of soil sample

was cleaned, and stones, pebbles, and root parts were removed. Soil samples were oven-dried at 110°C for 24 h to remove moisture. Then, the soil samples were grinded and sieved through a 2 mm nylon mesh to remove large debris, stones, and pebbles.



Figure 2. Illustration of use of hand corer for soil sampling.

CR-39 Detector

The present research used the standard grade CR-39 solid state track detectors (SSTD) having thickness of 500 μm produced by the Track Analysis Systems Ltd., Napier House, Meadow Grove, Bristol, UK. Large sheets of CR-39 were cut into small pieces, with each size of 1.5 cm \times 1.5 cm. For measuring the radon concentration, the CR-39 detector was fixed inside the cans lid before closed the cans. The size of the cans used was 10 cm in height and a 5.5 cm inner diameter as shown in Figure 3. The CR-39s were stored in the cans for three months with the samples. After 90 days of exposure, the detectors from all the cans were retrieved. The CR-39 detectors were etched at several conditions. The optimum condition for the etching of the CR-39 detectors was 6.25% N - NaOH at 70°C with accuracy of $\pm 0.1^\circ\text{C}$ and an etching time of 6 h. After etching, the detectors were washed in distilled water and were then dipped for a few seconds in 3% acetic acid solution. After that, the detectors were washed again and allowed to dry in air. The numbers of track in 40 fields were scanned for each detector using an optical microscope (400X objective lens) which was used to determine the track density per cm^2 (Aswood et al., 2014). The CR-39 detector records the tracks of alpha particles emitted by radon gas. The track density ρ (track cm^{-2}) was determined from the formula below.

$$\rho = \frac{A_n}{N_v} \quad (1)$$

where A_n is the average number of total tracks and N_v is the fields of view. The radon concentration C_{Rn} (Bq m^{-3}) was calculated using the formula given by (Ramu et al., 1988).

$$C_{Rn} = \frac{\rho}{K \times T} \quad (2)$$

where K is the calibration factor (tr.cm^{-2} per $\text{Bq.m}^{-3}.\text{d}$) and T is the exposure time (d). In this formula, K is the calibration factor of CR-39 and has a value of 0.024 (tr.cm^{-2} per $\text{Bq.m}^{-3}.\text{d}$) (Al-Nafey et al., 2012).

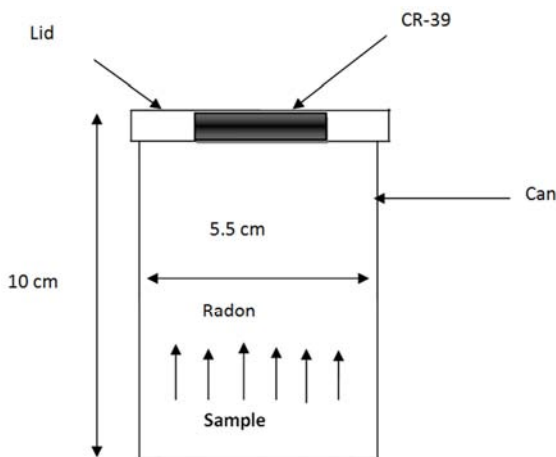


Figure 3. The experimental can for the measurement of radon.

3. Results and Discussion

Radon concentrations in agricultural soil samples collected from Cameron Highlands are presented in Table 1. The radon concentrations varied from 67.22 to 295.07 Bq m^{-3} , with a mean and standard deviation of $198.44 \pm 59.44 \text{ Bq m}^{-3}$. Based on the results, it can be seen that the radon concentration varies significantly among the samples of both regions. As previously mentioned, it is clearly expected that the radon concentration due to the uranium and radium concentrations are present in these samples. On the other hand, the concentration of radon in soil and air varies over time, and the variations are associated with the physical nature of the soil and the environment although it also depends on many other parameters such as changes in air pressure, temperature, wind and moisture. Other most important factors that control the emanation of radon in soil are the grain size and shape. The UNSCEAR (2000) found that the relation between the grain size and emanation of radon is inversely proportional to grain size. The results exhibited normal levels of radon concentration from agricultural soil.

Table 1. Concentrations of ^{222}Rn in agricultural soil samples collected from Cameron Highlands.

Location	Rn-222 (Bq m^{-3})
Ulu Telom	
Blue Valley	278.58
Kg. Raja	126.67
Kg. Kuala Terla	149.47
Kg. Tringkap	245.54
Kg. Kea Farm	220.80
Tanah Rata	
Brinchang	210.86
Tanah Rata	202.61
Ringle	
Ringle	245.54
Kg. Bertam Valley	133.26
Mean	198.44
Std. Dev	59.44
Std. Error	12.13

Table 2, shows the comparison between radon concentrations in the present study with those elsewhere. The concentrations of radon in this area of study are remarkably lower than those for Pakistan, India, Egypt and Libya; whereas the values of radon are higher than those reported for Brazil (Rafique et al., 2011, Binns et al., 1998, Abd-Elzaher, 2012, Mahur et al., 2013, Saad et al., 2013). Based on the comparison, it has been observed that there is also a variation in the values of radon levels among countries. This variation is due to the difference in the nature of the samples and the uranium content in the samples. However, these concentrations are found below than the action levels of 200 - 600 Bq m^{-3} recommended by ICRP (1993). In general, the results are within the worldwide range values found in soil and are within the safety level. According to the results, the areas of study are safe and do not pose health risks to the population in those areas, and thus the soil can be used for construction materials.

Table 2. A comparison between the radon concentrations in agricultural soil samples with the values reported for other countries.

Country	²²² Rn (Bq m ⁻³)			References
	Min	Max	Mean	
Pakistan	-	-	261.67	Rafique et al., 2011
Brazil	4	404	69	Binns et al., 1998
Egypt	3130	6970	5110	Abd-Elzaher, 2012
India	177.5	583.4	330.5	Mahur et al., 2013
Libya (Benghazi)	31.1	469	220.3	
Libya (Al-Marj)	59.3	515.8	325.5	Saad et al., 2013
Malaysia (Cameron Highlands)	67.219	295.068	198.442	Present Study

4. Conclusion

The mean radon concentrations in agricultural soil collected from Cameron Highlands are 198.44 ± 59.44 Bq m⁻³. These concentrations are below than the action levels of 200 - 600 Bq m⁻³ as recommended by ICRP (1993). In general, the results are within the worldwide average values found in soil; these results are within the safe limit.

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