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ASSESSMENT OF RADON CONCENTRATIONS ON HIGHLAND AREAS IN MALAYSIA

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ABSTRACT

The indoor and outdoor radon concentrations in Cameron Highlands (Peninsular Malaysia) and Ranau (East Malaysia) were measured. The measurements were carried out using passive method based on CR-39 solid state nuclear track detector (SSNTD) (for indoor measurements in Cameron Highlands) and active method using continuous radon/thoron progeny monitor (for indoor and outdoor measurements in Ranau and outdoor measurements in Cameron Highlands). The mean indoor radon concentrations in Cameron Highlands and Ranau were 50 Bqm^{-3} and 1.5 Bqm^{-3}, respectively. The mean indoor radon concentration in Cameron Highlands was slightly higher compare to the world average. The maximum value recorded was 97 Bqm^{-3} which is almost similar to WHO reference level. The mean outdoor radon concentrations in Cameron Highlands and Ranau were 7.4 Bqm^{-3}and 1.7 Bqm^{-3}, respectively. The outdoor concentrations were low and comparable to world outdoor average.

Keywords: DosemanPro, CR-39, indoor, outdoor, radon, SSNTD,

INTRODUCTION

Naturally occurring radioactive material (NORM) which occurs everywhere pose radiation exposure risks to people throughout the world. The important radionuclides are those from ^{238}U and ^{232}Th decay series. The main components of radiation exposure are inhalation of radon (and thoron) and their progenies and external gamma radiation. Radon (and thoron) and their decay products have been known as a potential health hazard as they can cause a significant inhalation radiation dose to the respiratory tract and other tissue. The exposure to indoor radon is the most significant contributor to natural radiation dose (Tanner, 1980; Akerblom et al., 1993). According to UNSCEAR (2000) report, radon (including thoron) contributed about 52% to the natural radiation dose received by the public.

Radon is released into the atmosphere mainly from soil, underlying rocks and ground water. For indoor environment it also includes building materials. Generally, as radium, the levels of radon in rock and soil also vary markedly. Certain rock type, predominantly granites has been documented as having elevated radium. Besides geological factors like radium content of the underlying bedrock soil, the concentration of radon emitted from materials is also determined by emanation coefficients, moisture content, porosity, permeability and weather conditions (Nazaroff et al., 1988; Schumann and Gundersen, 1996; Varley and Flowers, 1998).
The Levels of radon in the open atmosphere and its spatial variation not only depend on the geological conditions but also governed by the balance between the exhalation rate and the atmospheric dilution processes. Radon which emanates from soil grain and exhales from the soil surface into the free atmosphere is rapidly dispersed and diluted by natural convection and turbulence. Radon levels in indoor environment are influenced by building material, building

construction characteristics (e.g. insulation and finished surfaces), and the degree of exchange with outdoor air, the entry rate of radon rich air from the underlying soil and rocks and also the life style of the occupants.

Generally, the indoor radon can reach considerably high levels if the building was built on ground that contains high radium radioactivity, the underlying soil that allows easy movement of radon gas, cracks or other openings below the ground surface that allow radon gas from soil to infiltrate the building and air pressure inside is lower than in the soil around the foundation. In some areas which associated with granite rocks, groundwater can have high radon concentrations (Choubey et al., 2000). Therefore, radon dissolved in water can also contribute to indoor radon concentration in buildings when water is used in different domestic activities involving heat and turbulence, due to its volatile character and its efficient transfer from water to air (NRC, 1999; UNSCEAR, 2000).

The objectives of this study were to measure radon concentrations indoor and outdoor on the highland areas ɨ.e. Cameron Highlands in Pahang (Peninsular Malaysia) and Ranau in Sabah (East Malaysia) and to estimate the dose receive by the people in those areas. This paper describes the results of radon measurements and their associated risk of exposure. Thoron concentration and its dose contribution were not discussed due to lack of data available.

MATERIALS AND METHODS

Study Area

The first selected area for the study was Cameron Highlands in Pahang. Cameron Highlands is located on the highlands and lies on the Main Range of Peninsular Malaysia. It is a tourist's destination as well as a major area for agriculture activities. More than 30% of the land area lies more than 1400 m above sea level. The geological formation of Cameron Highlands made from igneous rocks (mainly granite). Granite form is one of the most important rock types in Peninsular Malaysia. The second selected area was Ranau in Sabah (East Malaysia). The geology of Sabah is dominated by sedimentary formations. About 70% of this underlying geology is made of sedimentary rocks. The sedimentary rocks form the mountain and hill ranges along the east and west coast of Sabah (ECD, 2001). Ranau is located at 1,176 m above sea level and noted for its hilly geographical structure. Tourism and agriculture are the major industries. It has many tourist attractions including Mount Kinabalu (highest point of 4095 m above sea level).

Radon Measurement

The radon measurement locations are shown in Figure 1. The measurements have been conducted involving 30 and 10 houses in Cameron Highlands and Ranau, respectively. In Cameron Highlands, the indoor radon measurements were carried out in brick houses while in Ranau which are involved brick, partially-brick (wooden + brick) and also wooden houses. Most measurements were conducted in the living room. There are various methods available for the measurements of radon/thoron and their decay products. In Cameron Highlands, indoor radon concentrations were measured using passive method based on CR-39 solid state nuclear track detector (SSNTD) that was made and calibrated by Landauer Nordic, Sweden. Principle of detection and measurement procedures has been described by Sulaiman et al. (2017). An exposure period was 3 months. It has been suggested that for nationwide survey of radon concentrations in air, long-term measurement (3 months and above) should be performed. The average radon concentrations were given in Bqm^{-3}.

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Figure 1: Locations of radon measurements

For outdoor radon concentrations, short-term measurements based on active method were performed using continuous radon progeny monitors model DosemanPro (Sarad, Germany). The monitors were calibrated by the manufacturer. The monitor is equipped with alpha spectroscopy system which capable of discriminating alpha energy peaks emitted by radon/thoron progenies. The equipment consists of a membrane pump, a USB interface, a semiconductor detector, a filter paper holder and a rechargeable battery. The sampling of radon progenies was performed by pumping the air through the filter paper. The monitor was placed on a tripod stand at a height of 1 m above the ground. As far as possible, the measurement was conducted for a period of about 24 hours in order to obtain a representative average radon concentration for one day. The advantage of using this type of equipment can record radon concentrations variation against time of the day. The radon concentrations are normally high or maximum in the early morning and low or minimum in the afternoon. The radon progenies concentrations in term of Equilibrium Equivalent Concentration (EEC) in Bqm^{-3} were then converted to radon gas concentration using appropriate equilibrium factor (UNSCEAR, 2000). Whilst in Ranau, due to logistic problems, the measurements for both indoor and outdoor radon concentrations were performed based on active method using the same type of equipment used in Cameron Highlands. For indoor measurement, the monitor was normally placed on a table or cupboard at least 30 cm from the wall.

RESULTS AND DISCUSSION

Concentrations of Radon

The mean indoor and outdoor radon concentration in Cameron Highlands and Ranau are shown in Table 1 while their frequency distributions are shown in Figure 2 and 3. The mean indoor radon concentration in Cameron Highlands was 50 Bqm^{-3}. This value was higher than the average world indoor radon concentration of 39 Bqm^{-3} (UNSCEAR, 2000). There were also about 50% of the measured houses have indoor radon concentrations above the world average concentration. The highest indoor radon concentration measured was 97 Bqm^{-3}which is very close to the World Health Organization (WHO) indoor radon reference level of 100 Bqm^{-3} (WHO, 2009). The mean indoor radon concentration in Cameron Highlands was also slightly higher than indoor radon in Ipoh (Kinta Valley - another radon high risk area) of 45 Bqm^{-3} (Sulaiman *et al.*, 2017). Based on the present results and local geology, Cameron Highlands is probably the area which has the highest indoor radon concentration in Malaysia. It is suggested that more houses in Cameron Highlands to be measured their radon concentrations to find out if there are any houses exceed the reference level before any suggestion or action can be taken.

Table 1: Radon concentrations in Cameron Highlands and Ranau

Location		Indoor (Bqm^{-3})	Outdoor (Bqm^{-3})
Cameron Highlands	Mean	50 $\pm$ 25	7.4 $\pm$ 2.6
	Minimum	28	5.6
	Maximum	97	9.3
	Mean	1.5 $\pm$ 1.1	1.7 $\pm$ 1.4
Ranau	Minimum	1.0	0.7
	Maximum	3.7	3.7

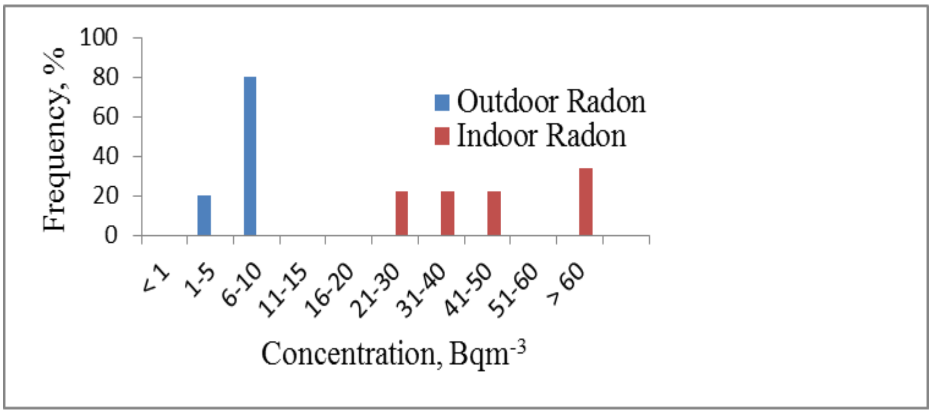

Figure 2: Distribution of radon concentrations in Cameron Highlands

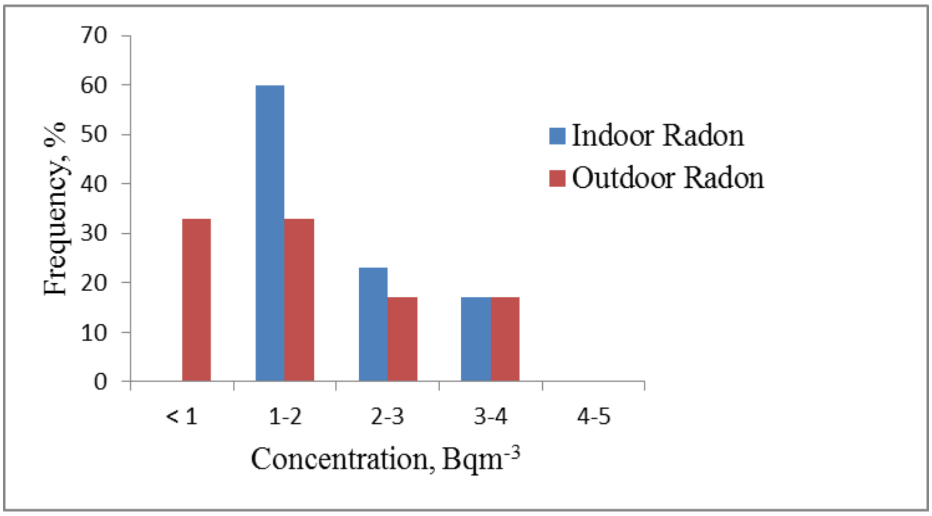

Figure 3: Distribution of radon concentrations in Ranau

While in Ranau, the mean indoor radon concentration (based on progenies measurement) was very low i.e. 1.5 Bqm^{-3} which is similar with the average value for Sabah i.e. 1.7 Bqm^{-3} (Sulaiman and Omar, 2010). Statistically, by using t-test analysis, it was found that there was no significant difference of indoor radon concentrations for different types of houses in Ranau. The mean indoor radon concentration in Cameron Highlands is more than 30 times higher than in Ranau.

High indoor radon concentration measured in Cameron Highlands was attributable to high radium and uranium concentration in soil, rocks and building materials. The radium concentration of granite in Peninsular Malaysia has been reported by Omar et al. (1999) while radioactivity of soil at two tea plantations in Cameron Highlands has been reported by Hamzah et al. (2011). Low radon concentration in Ranau was due to low radioactivity content of radium in soil (Omar et al., 1991; Sulaiman et al., 2007), rocks and also building materials. Although studies on radium concentration of building materials in Sabah have not been found, the local bricks are expected (based on local soil radioactivity) to contain lower radium concentration and hence contribute to lower radon concentration. The mean outdoor radon concentration (also based on progenies measurement) in Cameron Highlands and Ranau were low i.e 7.4 Bqm^{-3} and 1.7 Bqm^{-3}, respectively. The outdoor radon concentrations in Cameron Highlands was about 4 times higher than in Ranau but comparable to the world average value of 10 Bqm^{-3} (UNSCEAR, 2000).

Wind and ventilation play important role in influencing the radon concentrations in air. Furthermore, it also depends on many other factors such as changes in air pressure, temperature and moisture. There was a significantly huge difference between indoor and outdoor radon concentrations in Cameron Highlands. The changed of occupants activities by closing doors and windows (especially at night) will reduce ventilation and allowing the accumulation of radon in the houses. While in outdoor air, radon exhaled from the soil and rock surface rapidly dispersed and diluted in the free atmosphere. In Ranau, there was no significantly difference between radon concentrations indoor and outdoor probably due to good air exchange between indoor and outdoor air for houses involved in the measurement (especially wooden and half-brick houses). The ratio of indoor to outdoor radon concentration in Cameron Highlands and Ranau were 6.7 and 1.1, respectively.

Limited ground surface radon concentrations measurements were also conducted at Poring Hotspring and Malaysian Meteorological Department (MMD) station near Ranau. The radon concentrations at the respective areas were also generally low i.e. 9.8 Bqm^{-3} and 12.3 Bqm^{-3}, respectively but higher than outdoor radon concentrations in Ranau. In this situation radon emitted from the ground will immediately be detected by the monitor before dispersed and diluted by natural convection and turbulence in the air. These results have confirmed that the radon concentration in Ranau is generally low.

It is obvious that the indoor radon concentration in Cameron Highlands was much higher than in Ranau even though Ranau is also located on highland and near Mount Kinabalu. The huge differences of radon concentrations between these two highland areas were due to differences in geological formations (granite rocks in Cameron Highlands compare to sedimentary rocks in Ranau), radioactivity of soil and building materials in the respective areas. Radioactivity in granite rocks is relatively high compared to sedimentary rocks (Nagaratnam, 1994). Variation of indoor radon levels (from low/normal to high concentrations) in different parts of Himalayan regions in India has been reported (Choubey et al., 2010; Ramola et al., 1997; 2000; 2005). The variation was mainly due to different geological formation of soil and rocks.

Effective Dose

For the assessment of the annual effective dose received by the public living on those two highland areas, it was assumed that peoples were exposed for 24 hours per day and 365 days per year and using the UNSCEAR's established factors such as equilibrium factor of 0.4 (indoor) and 0.6 (outdoor), occupancy factor of 0.8 (indoor) and 0.2 (outdoor) and dose conversion factor of 9 $nSvBq^{-1}h^{-1}m^{-3}$. The estimated annual effective dose was 1.38 mSv and 0.13 mSv in Cameron Highlands and Ranau, respectively. The annual effective dose in Cameron Highlands was very much higher than in Ranau but slightly higher than world average reported by UNSCEAR (i.e. 1.25

mSv). However both the study areas are safe and do not pose health risks to the peoples in those areas.

CONCLUSIONS

Even though both Cameron Highlands and Ranau are located on highland areas, radon concentrations in Ranau were very much lower. The huge difference between radon concentrations on both highlands were attributable to different in geological formation especially type of rocks and their radioactivity content. People in Cameron Highlands and Ranau were received annual effective dose from radon of 1.38 mSv and 0.13 mSv, respectively. These dose levels are still safe and do not pose health risks to the peoples in those areas.

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