Assessment of Radon Emanation Rate from Various Building Materials in Malaysia Using Tight Chamber Method

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ABSTRACT

Radon gas has been known as one of the main factors that cause breathing complications which lead to lung cancer, second only after smoking habit. As one of the most commonly found Naturally Occurring Radioactive Materials (NORM), its contribution to background radiation is immense, and its contributors, Uranium and Thorium are widely available on Earth and have been in existence for such a long time with long half-lives. Indoor radon exposure contributed by building materials worsens the effects. The probability of inhaling radon-polluted air and being surrounded by it in any buildings is very high. This research is focused on the detection of radon emanation rate from various building materials which are commonly being used in Malaysia. Throughout this research, common building materials used in constructions in Malaysia were collected and indoor radon exposure from each material was measured individually using Tight Chamber Method coupled to a Continuous Radon Monitor, CRM 1029. It has been shown that sand brick is the biggest contributor to indoor radon compared to other samples such as sand, soil, black cement, white cement, and clay brick. From the results, materials which have high radon emanation could be reconsidered as building materials and mitigation action can be chosen, suitable to its application.

Keywords: *Indoor Radon, Building Materials, Radon Emanation Rate, Continuous Radon Monitor, Radon Mitigation.*

INTRODUCTION

Health hazards posed to humans and environment due to radon and its decay products have created an awareness amongst the public over the past decade [1]. Being inert and having gaseous properties make Radon-222 easily inhaled by human beings [2] and hence, it is said to be the second cause of lung cancer after smoking habit [3]. Radon and its progeny, which inherit short half-lives ranging from μs to minutes, could be dangerous due to their high level of radioactivity which can reach Pb-210 with a half-life of 22.3 years [1,2,3]. Being the most dangerous radioactive gaseous element in the science of environmental radioactivity, Radon-222 behaves as an alpha emitter which produces alpha particles with energy of 5.48 MeV [4].

This radioactive material naturally exists in almost all types of soils, sand, rocks, bricks, and cement, from which most of the building materials are made [4]. The findings on the concentrations of Radon-222 in various types of soil, water [5] and building materials [4] and its contribution to indoor air pollution have led to many researches being conducted all around the world [4]. The long duration of time people normally spend indoor – be it in the office, at the school, or even at home - increases the exposure to the radiation dose from the inhaled decay products of Radon-222 [2].The main mechanism through which high level of radon enters a building is the pressure-driven flow of soil gas found in floor cracks. Given the fact that the air inside a building is slightly of lower pressure as compared to the pressure outdoor, the flow of gas could happen through any openings available [2].

Buildings, where humans normally take shelter from the sun and the rain, are mostly made of common types of building materials such as soil, sand, cement, and bricks. The quality selection of the type of building material is hence very important in order to curb the continuous danger of indoor inhalation by its residents. This research is focused on the common building materials used in construction site in Malaysia, and the measurement was conducted individually using continuous radon monitor. Each sample was measured a few times for long hours, and the average reading was taken to ensure the reliability of the data. The result could be used to compare radon emanation rate individually by each sample with the general measurement inside a readily-constructed building which will be done in the next research. From the result, indoor radiation level in Malaysia could be measured, and further mitigation action could be taken or at least suggested mitigation action could be given to the resident, and more awareness could be created.

EXPERIMENTAL

This particular study focuses on the indoor radon emanation rate from various building materials. The selection of these materials was based on common materials being used to construct a building in Malaysia, specifically in rural area. Most of the materials were obtained from material stores as well as from construction sites upon permission of the site workers. All samples were weighed, and later dried in the oven for at least 72 hours at 60 °C to ensure no humidity had been stored before measurements were taken. Physical descriptions and densities of the samples are summarized in Table 1.

Table 1: Origins and Descriptions of Selected Building Materials

SAMPLE	ORIGIN	DESCRIPTION	
		Type	Density ($kg\ m^{-3}$)
Sand	Batu 3, Kuantan, Pahang	Powdery	1666.67
Soil 1	Bukit Goh, Kuantan, Pahang	Powdery	1428.57
Soil 2	Batu 3, Kuantan, Pahang	Powdery	1250.00
Black Cement	Portland Rawang, Selangor	Powdery	1000.00
White Cement	A Stopping ASG, Setapak KL	Powdery	909.09
Clay Brick	Kuantan, Pahang	Solid	1749.29
Sand Brick	Kuantan, Pahang	Solid	2147.69

The Continuous Radon Monitor is a device patented specifically to measure radon concentration rate. It is suitable for radon indoor measurement due to its high sensitivity. It also measures the temperature, humidity and pressure of measured environment. The setting for this particular experiment is done for the interval of every one hour for the total of 72 hours of exposure. Container for this experiment is made of plastic material in order to avoid any electrostatic charges effect. The dimension of the container is of length 48.3 cm x width 34.0 cm x height 24.8 cm. For every test, the container is ensured to be sealed tightly using masking tape to make sure no leakage of radon gas from inside of the container to outside or vice versa. Background radiation was taken every time the samples were changed. The reading of each sample was taken three times over three days to ensure its accuracy. The schematic diagram of the experimental setup is shown in Figure 1.

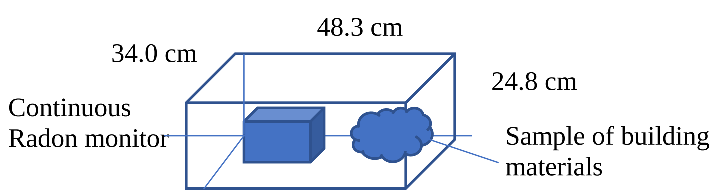

Figure 1: Schematic diagram of the radon chamber

Environmental Protection Agency (EPA) Average reading was taken directly from the data produced by the monitor. It gave the reading of average radon emanation for every hour for the whole duration of 72 hours of measurement. From the setup, radon concentration was measured using Continuous Radon Monitor 1029. Results were then subtracted to the background reading to ensure data accuracy. The corrected Radon activity concentration was obtained by using Equation 1.

$$C_{Rn} = C_{ave} - C_b \tag{1}$$

Where:

C_{Rn} = Corrected Radon activity concentration
C_{ave} = Average measured concentration
C_b = Background concentration

From corrected values of Radon activity concentrations, Radon concentration in secular equilibrium, C_{eq}, Radon Exhalation rate, E_m, and the materials' Radon content, C_{Ra} can be obtained using the equations suggested by Hussein et. al [7]:

Rn-222 activity at secular equilibrium is:

$$C_{eq} = \frac{C_{Rn}}{1 - e^{-\lambda_{Rn} t}} \quad (2)$$

Radon Emanation Rate (E_m):

$$E_m = \frac{\frac{C_{eq}\lambda_{Rn}V_{eff}}{m}}{t} \quad (3)$$

Radium Content (C_{Ra}):

$$C_{Ra} = \frac{E_m}{\lambda_{Rn}} \quad (4)$$

where:

λ_{Rn} = Radon decay constant = 7.567 x 10^{-3} hr^{-1}
t = time of the Radon activity build-up in the container
V_{eff} = air volume inside the air-tight container
m = mass of the sample.

RESULTS AND DISCUSSION

From the results, the indoor radon contributor from the samples of common building in Malaysia being measured from its radon concentration, radon emanation rate as well as the radium concentration. Figure 2 shows the results calculated for radon concentration in secular equilibrium for various samples of building materials taken in this experiment. From the figure, it shows that sand brick gives the highest radon concentration which is 203.73 Bq/m^3 as compared to other samples ranging only between 26.03 to 57.79 Bq / m^3. Sand however, shows the lowest reading of radon concentration in secular equilibrium at 26.03 Bq/m^3. The huge differences between sand brick and loose sand sample could be due to the effect of drying and firing to high temperatures in its process of becoming mould for the sand brick. It could also be contributed by the composition in the sand brick that enhances the radon concentration.

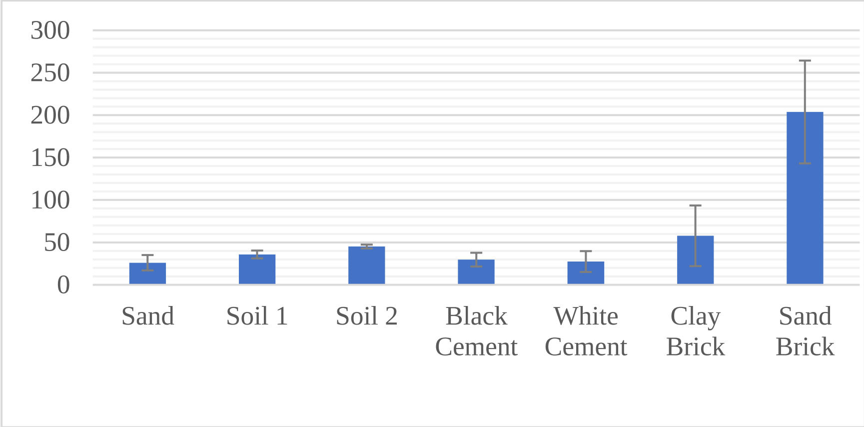

Figure 2: Radon Concentration (Bq / m^3) in Secular Equilibrium for Various Building Materials

Figure 3 represents the radon emanation rate calculated from equation (3) for the samples. It shows that the highest radon emanation rate released from the sand brick at 22.51 mBq / kg.hr while the lowest radon emanated rate released from sample of clay brick at 7.28 mBq / kg.hr. The value calculated from sand brick however high compared to other samples which ranged from 7.28 until 13.92 mBq / kg.hr. The difference in the structure of sand brick and clay brick give effect to the radon emanation rate. The porosity of sand brick as compared to clay brick give way to the radon emanation rate to increase.

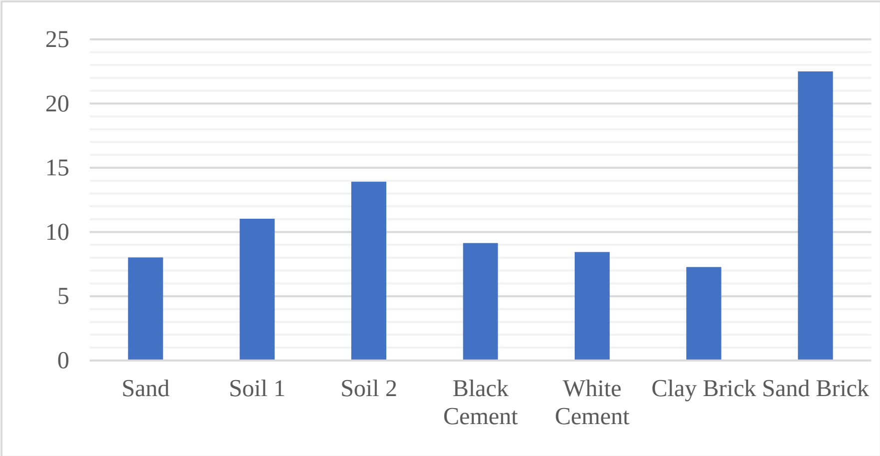

Figure 3: Radon Emanation Rate (mBq / kg hr) for Various Building Materials

With the fact that most of the radon gas emanated from the decay of radium, equation (4) was applied to calculate the radium content in each sample. From the calculation, it has been shown in Figure 4 that sand brick contains the most radium content from other samples taken in this experiment at 2.97 Bq / kg. The least radium content was calculated from the sample of clay brick at 0.96 Bq / kg. This is comparable to the result of radon emanation rate where most of its contributor could be from the radium content in the sample.

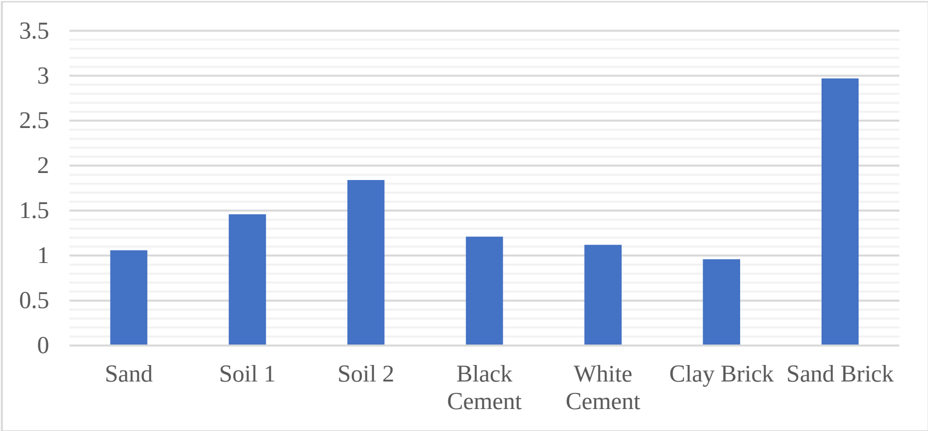

Figure 4: Radium Content (Bq / kg) in Various Building Materials

Table 2 summarizes the experimental findings compared to the radon emanation rate conducted by other researchers from many locations around the world. It shows that the present study of radon emanation rate in Malaysia is comparable to other countries except for the results taken from Iraqi Kurdistan. The variation in the data were seen which may be contributed by the individual country's climate and raw materials composition used as the raw materials in constructing the building material samples. It also may be affected by the techniques used in the constructing the samples as well as the variation in ratio composition of raw materials used.

Table 2: The comparative values of radon concentration between this research with other researchers conducted around the world.

	Radon emanation rate (mBq kg^{-1} hr^{-1})					
	Sand	Soil	Black Cement	White Cement	Clay Brick	Sand Brick
Present Study (Malaysia)	8.02 ± 2.79	13.92 ± 0.69	9.15 ± 2.50	8.45 ± 3.79	7.28 ± 4.50	22.51 ± 6.69
Zakariya A. Hussein et al (Iraqi Kurdistan)	88.66 ± 2.42	NA	72.31 ± 1.54	NA	NA	NA
B. K. Sahoo et al (India)	6.5 ± 4.3	23.5 ± 11.8	2.3 ± 1.6	12.3 ± 5.6	6.1 ± 3.4	72.8 ± 15.3
M. Y. Shoeib et al (Egypt)	10.76	NA	19.50	18.40	22.73	29.34
Rafat M. Amin (Saudi Arabia)	16.7	NA	3.3	1.9	NA	NA
Amit Kumar et al (India)	27.6 ± 5.7	68.4 ± 3.9	3.74 ± 0.56	NA	NA	NA

CONCLUSIONS

From the study, sand brick shows the highest radon emanation rate of 22.51 mBq/kg.hr. when exposed to CRM-1029 for 72 hours in sealed environment. Clay brick, on the other hand, shows the lowest reading of 7.28 mBq/kg.hr. The results were comparable with other results obtained by other researchers while some shows variation due to the climate change in each country involved. The radon emanation rate contributed much from the radium content in each sample and it is proven that sand brick gives the highest reading of 2.97 Bq/kg radium content compared to clay brick of 0.96 Bq/kg.

In conclusion, radon assessment using tight chamber method and CRM-1029 detector is time consuming, but it has the repeatability that can increase its accuracy. In terms of cost, it is also inexpensive compared to other detection instruments. CRM-1029 also requires simple sample preparation and analytical procedures.

For further investigations, more samples should be taken from different locations around Malaysia. From the results also, we can find a way to shield the radon from emanating out by painting effect. The difference between bare, and different layers of shielding may contribute to the decrement of indoor radon level.

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