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An overview of radon concentration in Malaysia

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ABSTRACT

It is known that the inhalation and ingestion of radon gas could lead to the primary health risks for lung and stomach cancers. Besides the health hazards of radon gas, it has different geological applications. In this context, numerous studies have been reported all over the world. Different research groups in Malaysia have also conducted and reported numerous studies since several decades. However, these studies are scattered and need to be compiled for future studies in Malaysia. The main emphasis is to overview and compiles these articles that will work as baseline data for the level of radon gas in Malaysia.

1. Introduction

In the last decade, radon gas is considered one of the major concerns of radiation exposure. Radon is a naturally occurring radioactive noble gas, comes from the decay of uranium in rocks, soil and groundwater. The progenies of radon ^{218}Po and ^{214}Po emits highly ionizing alpha particles. After inhalation and ingestion of radon gas, the highly ionizing alpha particles emitted by the deposited short lived progenies of radon gas interact with the biological tissue in the lungs leading to damage of DNA (Aswood, Jaafar, & Bauk, 2014; WHO, 2008). It is considered as a second leading cause of lung cancer among the nonsmokers and can cause a serious public health problem. It is reported that radon gas in dwellings causes about 21,100 lung cancer deaths per years in USA (WHO, 2008). Another study showed that radon is responsible for about 1100 deaths per year in UK (Gray, Read, McGale, & Darby, 2009). A very small exposures to radon gas can cause lung cancer and no evidence exist that gives the minimum permissible level of exposure to radon gas. Many smokers will get lung cancer due to their radon exposure who otherwise would not have gotten lung cancer. This is because of the synergistic relationship between radon and cigarette smoking in causing lung cancer (Almayahi, Tajuddin, & Jaafar, 2013). Cancer (lung, breast, stomach, thyroid, leukaemia and liver) is one of the most important issues. In this contest, a survey conducted in 1998 in Penang Malaysia revealed that the age standardized incidence rate was 199.3 per 100,000 for all type of cancers. In Penang, Malaysia, a total 19,692 cases were diagnosed during a period of 2004–2008. In a study carried out by Almayahi, Tajuddin, and Jaafar (2012) concluded that high concentration of natural radioactivity is the main cause of cancer in Penang, Malaysia. In Malaysia, numerous research groups have been involved in the measurement of radon concentrations in different materials since 1994 to 2017. The data published by different researchers have been overviewed and compiled in this article for future studies.

2. Summary of the results

This section presents the studies conducted by different researchers in Malaysia and summarized in Table 1. Sulaiman, Omar, and Hassan (1994) measured radon concentration in Peninsular Malaysia. Indoor and outdoor air born radon was measured in air in 178 houses. The average value of indoor radon was found 0.6 pCi/l (22 Bq/m^3) with the maximum value of indoor radon of 196 Bq/m^3.

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Table 1
Measurement of radon concentration in Malaysia from 1994 to 2017.

S. no	Study area	Type of sample	Radon concentration	Sample size/Technique used	References
1	Peninsular Malaysia	Indoor radon concentration	Average: 22 Bq/m^3	178 houses	(Sulaiman et al., 1994)
2	Niah, Sarawak	Indoor radon concentration in Great Cave	Range: 100–3075 Bq/m^3	CR-39 track detector	(Gillmore et al., 2005)
3	Peninsular Malaysia	Indoor and outdoor radon concentration	Indoor: 0.30–1.54 pCi/l Outdoor: 0.23–1.11 pCi/L Indoor annual effective dose: 0.28–1.42 mSv/y	Continuous Radon Monitor	(Saat et al., 2007)
4	Malaysia	Building materials	Average: 303.7 Bq/m^3 for bricks, Average: 436.6 Bq/m^3 for concrete brick with cement coating and 410.7 Bq/m^3 for concrete brick with cemented coating and paint. Average: For brown clay brick, brown clay brick with cemented coatings and brown clay brick with cemented coatings and painting are 166.5, 166.5 and 148 Bq/m^3, respectively.	Continuous Radon Monitor	(Ahmed & Jaafar, 2010)
5	Sarawak, Sabah	Indoor and outdoor radon concentration	Indoor and outdoor radon in Sarawak was found 1.2 and 1.5 Bq/m^3 while that for Sabah were found 0.4 and 0.3 Bq/m^3, respectively	Radon monitors (Alphadosimeter model 560, Alphanuclear, Canada)	(Sulaiman & Omar, 2010)
6	Kelantan, Pahang and Perak	River Water	Range: 0.156–1.876 Bq/l	Gamma Spectrometry and Liquid Scintillation Counter	(Hamzah et al., 2011b)
7	Perak, Selangor, Sembilan, Pahang and Kelantan	Water	Range: 0.29–1.41 Bq/l	HPGe	(Hamzah et al., 2011a)
8	Northern Malaysia Peninsular	Soil	Range: 2.23–375.42 kBq/m^3	CR-39 NTDs	(Almayahi et al., 2011)
9	Penang	Water	Range: 7.49–26.25 Bq/l, 0.49–9.72 Bq/l and 0.58–2.54 Bq/l in raw, treated and bottled water, respectively. Committed effective doses ranged from 0.003 to 0.048, 0.001 to 0.018 and 0.002–0.023 mSv/y for age group 0–1, 2–16 and > 16 year, respectively.	RAD-7	(Muhammad et al., 2012)
10	Cameron Highlands	Ground water	Range: 0.09–0.48 Bq/l	Continuous Radon Monitor	(Saat et al., 2012)
11	Northern Malaysia Peninsular	Soil	Range: 3.04–306.05 kBq/m^3	CR-39 NTDs	(Almayahi et al., 2012)
12	Malaysia	Foamed Light Concrete	1.9 pCi/l	Continuous Radon Monitor	(Saidi et al., 2013)
13	Northern Malaysia Peninsular	Soil	Range: 6–79 Bq/m^3 for surface air and 133 to 143,059 Bq/m^{3}at a depth of 50 cm	Continuous Radon Monitor and RAD-7	(Almayahi et al. 2013)
14	Malaysia	Fabricated concrete	111 Bq/m^3 before remediation and 14.8 Bq/m^3 after waterborne epoxy resin coating	Continuous Radon Monitor	(Al-janabi et al., 2013)
15	Penang, Kedah and Perlis	Soil and water	Range: 2225 to 9950 and 12 to 1002 Bq/m^3 in soil and water, respectively	RAD-7 AND CR-39 NTDs	(Almayahi et al., 2014)
16	Cameron Highland	Irrigation water	Range: 0.21–0.297 Bq/l	RAD-7	(Al-Nafiey et al., 2014)
17	Cameron Highland	Fertilizer	Range: 79.25–634.01 Bq/m^3	CR-39 NTDs	(Aswood et al., 2014)
18	Kedah	Soil	Average: 532.3, 668.1 and 809.7 Bq/m^3 for grain size of 0.249, 0.5 and 1 mm, respectively. Average exhalation rate: 4.1, 5.1 and 6.1 Bq/m^2 h^1 for grain size of 0.249, 0.5 and 1 mm, respectively.	Continuous Radon Monitor	(Ahmad et al., 2014)
19	Sungai Petani	Water	5.37 and 14.7 Bq/l in tap and well water	RAD-7	(Ahmad et al., 2015)
20	Malaysia	Fabricated light foamed concrete	0.2–1.7 pCi/l	Continuous Radon Monitor	(Saidi et al. 2016)
21	Pulau Penang	Blood and Urine	570.25 Bq/m^3 and 734.50 Bq/m^3, respectively	RAD-7	Salih et al., 2016
22	Baling	Water	5.7 Bq/l	RAD7	Ahmad et al., 2017
23	Cameron Highland	Soil	198.44 Bq/m^3	CR-39	Aswood et al., 2017

Indoor and outdoor radon daughters were also measured and were found same (1.5 mML) for indoor and outdoor (Sulaiman et al., 1994). Gillmore et al. (2005) reported the concentration of radon in Great Cave of Niah in Sarawak using CR-39 track detector (Gillmore et al., 2005). The concentration of radon in cave was ranged between minimum and maximum values of 100–3075 Bq/m^3 and was found below the world standards. Saat, Hamzah, Kadir, and Abu (2007) reported the indoor and outdoor radon concentrations at various locations in Peninsular Malaysia using Continuous Radon Monitor (CRM) (Saat et al., 2007). The maximum average value for indoor radon was found 1.54 pCi/l in Kampung Gajah while minimum was found 0.30 pCi/l in Shah Alam, Selangor. The maximum average value for outdoor radon was found 1.11 pCi/l in Ampang, Selangor while minimum was found 0.23 pCi/l in Shah Alam, Selangor. Hourly variation of radon in all locations shows the maximum radon concentration during early to late morning and minimum in afternoon till evening. Indoor annual effective dose ranged 0.28–1.42 mSv/y in Shah Alam, Selangor and Kampong Gajah, respectively. The values for indoor radon concentration and annual effective dose were found below the action levels of USEPA and ICRP, respectively. Ahmed and Jaafar (2010) measured radon concentration in selected building materials in Malaysia using

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