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^{222}Rn activity concentration in outdoor air of Johor, Malaysia

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Abstract: *Radon is a radioactive element which has a great potential to cause cancer, in addition to other impacts on the environment. In this study, investigation was conducted to establish a reference data for outdoor concentration of ^{222}Rn in air around Johor state in Malaysia. The ^{222}R activity in outdoor air was measured using RAD7 solid-state alpha detector. The measured values vary from MDA to 3.85 Bq/L with a mean value of 0.15 ±0.04 Bq/L, which is approximately ten times the maximum permissible range specified by WHO (2016) of 0.005-0.015 Bq/L. A map of the spatial distribution of ^{222}Rn in outdoor air was produced which indicates that higher values of ^{222}Rn in outdoor air were measured in the north western part of this study area.*

Keywords: *Radon, outdoor air concentration, Johor, and Malaysia, geological impact,*

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1.0 Introduction

Radon (^{222}Rn) is a naturally occurring, alpha-emitting, colourless, tasteless and odourless and chemically inert radioactive gas. It is formed from spontaneous disintegration of ^{226}Ra that belongs to the ^{238}U decay series that is found in trace quantity in the soils and rocks of the earth's crust. ^{222}Rn, is the most stable of its isotope, with a half-life of 3.825 days. (Srinivasa, Rangaswamy, & Sannappa, 2015).

The worldwide average value of annual effective dose from natural sources is estimated to be 2.4 mSv/y, of which more than 50 % (1.26 mSv/y) is due to ^{222}Rn exposure (UNSCEAR, 2008) Measurement of ^{222}Rn in the environment is of great interest due to its alpha-emitting characteristic and negative health impact to human. The most significant cause of lung cancer is exposure to radon (^{222}Rn), which depends on the average radon level and smoking frequency in a country (WHO, 2016). Therefore, the international agency for research on cancer and world health organisation classified ^{222}Rn as group one carcinogen (Mehra & Bala, 2014; WHO, 2009).

Radon in the outdoor air is generally low and pose no problem , according to WHO (2016) radon level in the outdoor air varies from 5–15 Bq/m^3, However, radon in the outdoor air may also contribute to indoor radon levels, as in some geographical locations, outdoor radon levels are higher than indoors (Vaupotič, Kobal, & Križman, 2010) Therefore assessment of radon in the outdoor air is necessary.

In Johor state 27 % of the total land area is underlain with geological formation of granitic rocks (Saleh *et al.*, 2015), which serve as the parent material upon which most of the soil within the study area is derived from. Granitic igneous rocks has been consider to have high concentration of natural radionuclides (UNSCEAR, 2000).Previously Sulaiman *et al*. (1994) measures indoor and outdoor radon in 178 houses in the entire Malaysian peninsular, however, the number of sampling points covered by their research did not seems to be a good representative sample size that matches the deduction made

for the cannot provide good representative data for Johor state. Therefore, this research was conducted to establish a baseline data for Johor state based on a total of 111 point in outdoor air of Johor state.

2.0 Materials and methods

2.1 Study area

Johor state is located in between latitudes 1˚ 16´ to 2° 50´ north, and longitude 102° 28.5´ to 104° 18´ east, in the southern part of Peninsular Malaysia. The state covers a total land area of 19,210 km^2. It has a tropical climate (Saleh *et al*., 2015). The entire state is overlain by seven soil types, classified according to their parent material. Fig. 1 shows the various soil classes in Johor state.

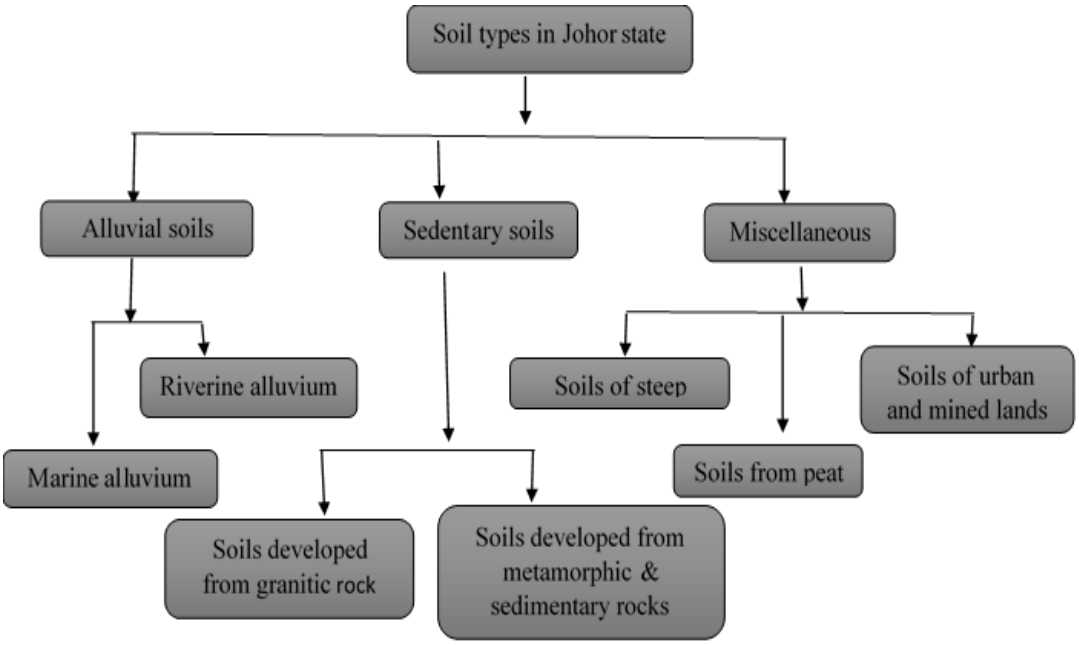

Fig. 1 Classification of soil types in Johor state

2.2 In situ measurement

^{222}Rn activity concentration in outdoor air was measured in situ using Rad7 alpha detector coupled to a laboratory drying unit. The equipment has an in-built pump that collects ^{222}Rn samples from the ambient air via the tubing and desiccant ($CaSO_4$) through an inlet filter to the detector sample volume. The measurement was done in sniff mode in a 10 minutes cycles and 3 recycle periods. The average of the last two cycles was considered for data analysis (Durridge, 2015). The measured concentrations of ^{222}Rn in outdoor air, the internal temperature of the detector, and relative humidity were downloaded to the software CAPTURE for analysis.

A total of 111 sampling points was measured, in each of the sampling points, the geographical coordinates were also recorded while the sampling sites were selected based on the type of geology.

3.0 Results and Discussion

Fig. 2 presents data for the distribution of the measured ^{222}Rn in outdoor air, it can be seen from the results that, the distribution is asymmetric with a high frequency and low values. The measured ^{222}Rn activity concentration varies from MDA to 3.84 Bq/L with a mean and median value of 0.15 ± 0.04 and 0.07 Bq/L, respectively while the standard deviation was 0.39 Bq/L. The results also shows that 50 % of the measured ^{222}Rn activity concentration in outdoor air is below the recommended WHO (2016) limit of 0.15 Bq/L.), Also, the average level of ^{222}Rn in outdoor air range from 0.005 to 0.015 Bq/L, which indicate a tenfold increment over the WHO (2016) limit.

Fig. 3 presents the data distribution for each administrative district, while, the summary statistics for the measured ^{222}Rn activity concentration in outdoor air (for each administrative district together with the

average values, of relative humidity and temperature inside the detector) are presented in Table 1. The results shown in the table indicates that the Muar district has the highest median value of ^{222}Rn in outdoor air. The high median value in Muar district can be attributed the fact that 57 % of measured point belongs to the soil that developed from granitic igneous rocks that seems to have a significant link to a high concentration of natural radionuclides (UNSCEAR, 2000) The table also indicates that 50 % of the measured data in Mersing district record values below the detection limit of the measuring instrument, this is the reason why the Mersing district has a median value of zero. The mean value of ^{222}Rn in outdoor air in all the district is found to be higher than the maximum value in WHO (2016) range.

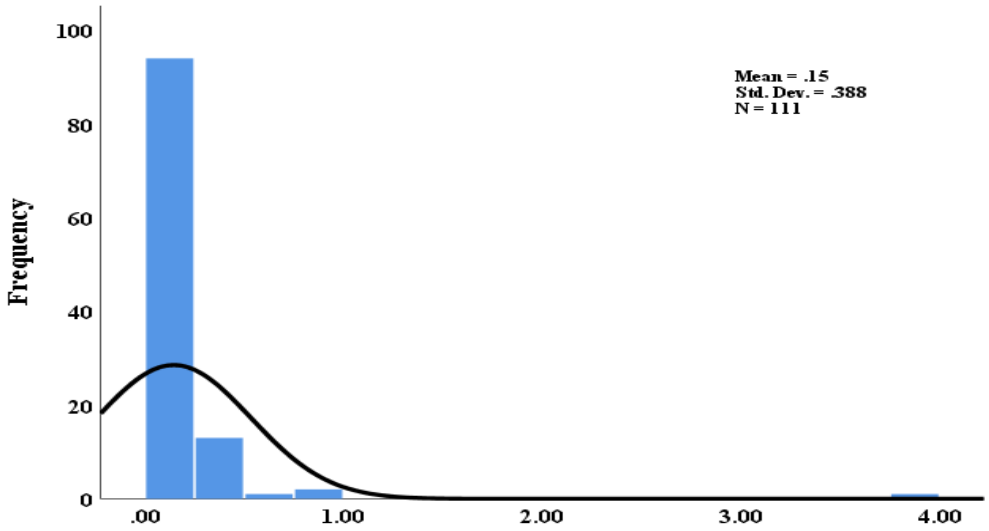

Fig. 2 Frequency distribution of ^{222}Rn in outdoor air

Table 1 Summary statistic of ^{222}Rn activity concentration in outdoor air of Johor state

District	Tem (℃)	RH (%)	Activity concentration of ^{222}Rn in outdoor air (Bq/L)							
			Mean	Std. D	Std. Error	Min	Max	Q1	Median	Q3
Batu Pahat	35	5	0.11 ± 0.02	0.16	0.05	MDA	0.45	0	0.04	0.13
Johor Bahru	37	5	0.14 ± 0.04	0.16	0.04	MDA	0.53	0	0.1	0.2
Kluang	36	5	0.06 ± 0.04	0.05	0.02	MDA	0.15	0.02	0.07	0.1
Kota Tinggi	37	5	0.34 ± 0.04	1.01	0.27	MDA	3.85	0.05	0.06	0.1
Muar	36	5	0.25 ± 0.04	0.3	0.11	0.06	0.92	0.13	0.15	0.18
Mersing	36	6	0.06 ± 0.03	0.13	0.04	MDA	0.42	0	0	0.05
Pontian	36	6	0.06 ± 0.03	0.08	0.03	MDA	0.25	0	0.02	0.08
Segamat	37	5	0.13 ± 0.03	0.15	0.04	MDA	0.42	0	0.08	0.21
Ledang	33	5	0.18 ± 0.06	0.22	0.06	MDA	0.85	0.07	0.1	0.25
Kulai Jaya	35	6	0.06 ± 0.04	0.03	0.01	0.02	0.1	0.04	0.05	0.08
Johor State	36	5	0.15 ± 0.04	0.39	0.04	MDA	3.85	0	0.07	0.15

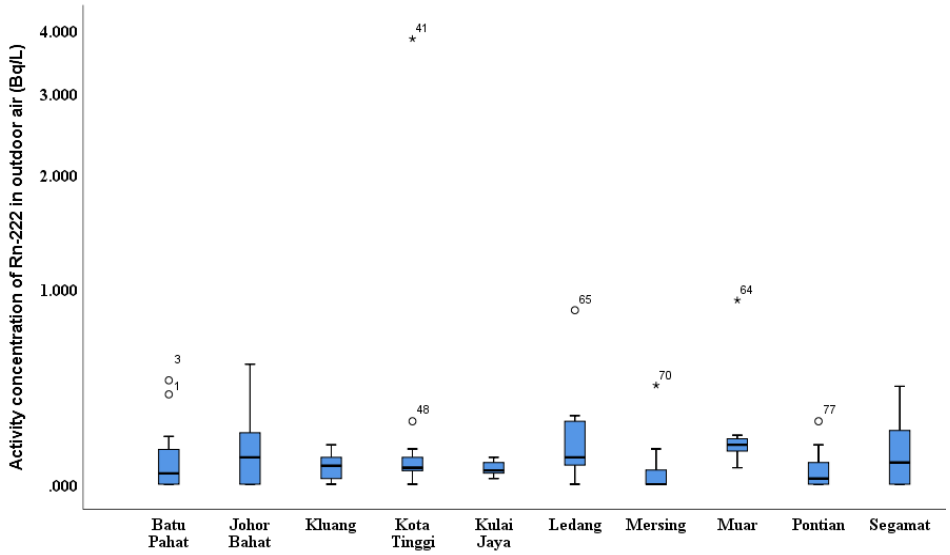

Fig. 3: Distribution of ^{222}Rn activity concentration in outdoor air for each district

Fig. 4 presents the distribution of the measured ^{222}Rn activity concentration in outdoor air for each soil type in Johor state. The presented results indicates that the highest value of ^{222}Rn activity concentration in outdoor air was measured in the soil of urban and mined land, however, the high value appears as an outlier. The results obtained, also revealed that soils of steep lands have the highest median value of ^{222}Rn activity concentration, this soil type is developed from granitic igneous rocks which account for the higher values measured in regions overlain by this soil type.

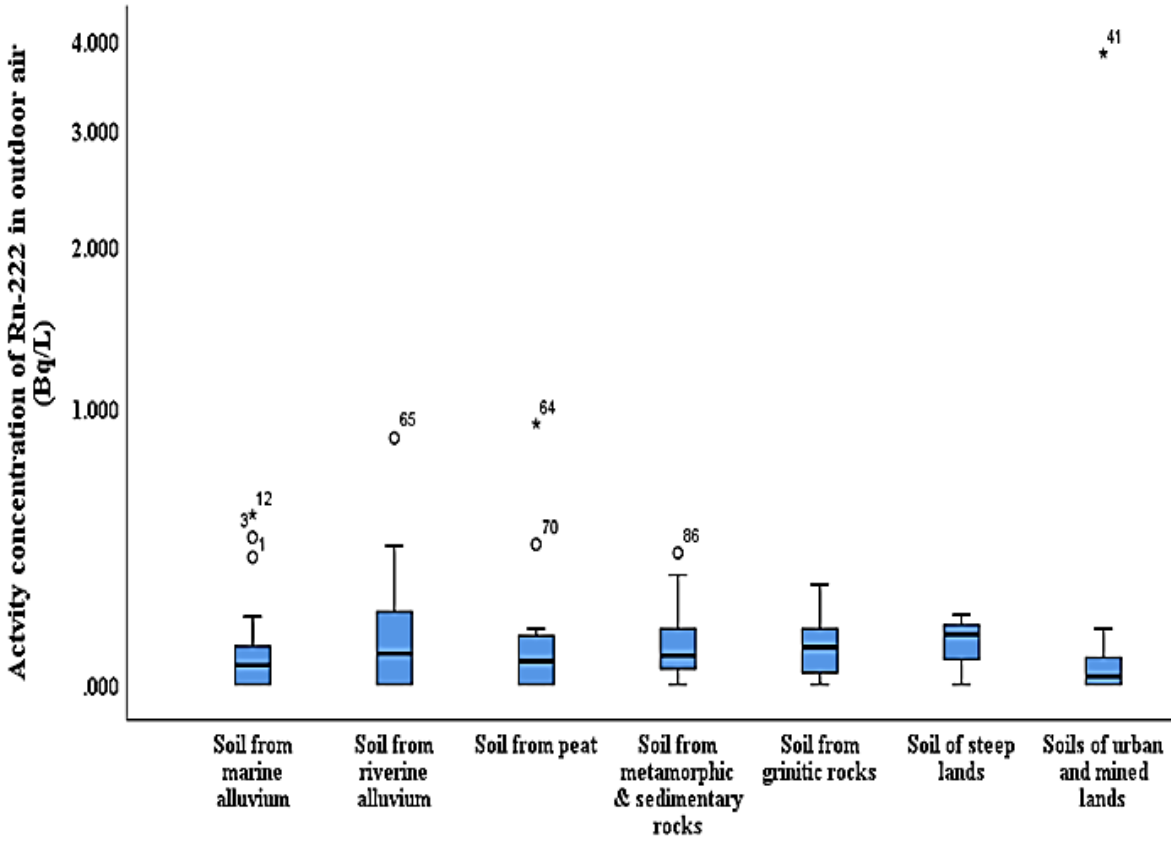

Fig. 4: Distribution of ^{222}Rn activity concentration in outdoor air for each soil type

A Spearman's correlation between measured ^{222}Rn activity concentration and relative humidity inside the detector shows a weak negative correlation r=.-195 and p-value of .040. While a correlation between ^{222}Rn activity concentration and temperature inside the detector shows a negligible correlation r=.015 and a p-value of .875.

A contour map was constructed, based on the measured ^{222}Rn activity concentration in the outdoor air (Fig. 5). The region with a higher value of ^{222}Rn activity concentration is seen around the central area of the state that is mostly covered with soils developed from granitic rocks. Higher values, although not expected, were also seen in region overlain with soil from peat at the northwestern part of the state in Muar district. The higher values obtain from Muar district can be associated with the stability of the relative humidity during measuring which in response to the local metrological condition during measurement.

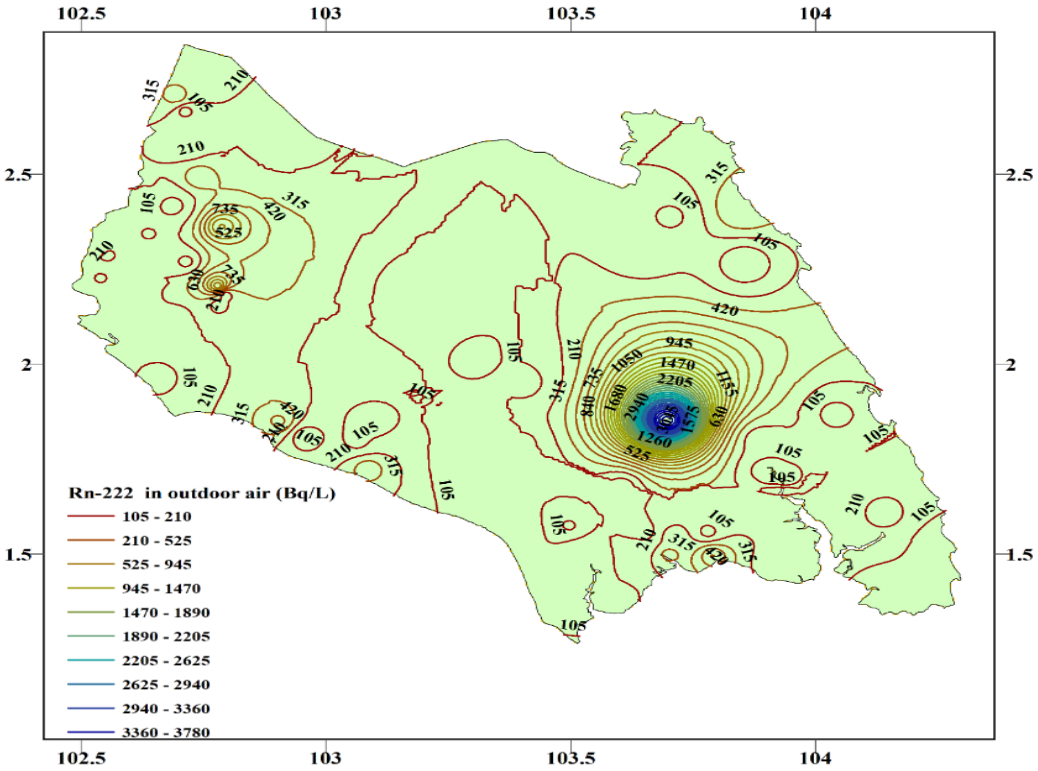

Fig. 5 : Spatial distribution of ^{222}Rn in outdoor air

4.0 Conclusion

A total of 111 locations were measured for ^{222}Rn activity concentrations in outdoor air across Johor state. The measured data have a mean value of 0.15 Bq/L, with a standard of 0.39 Bq/L. The measured data categorised according to the soil types in Johor state, indicates that, the highest median value is found in the soil of steep lands (median = 0.13 Bq/L) near the central area of the state at Kota Tinggi district. ^{222}Rn values greater than 900 Bq/L were also measured in the northwestern part of Johor state. Based on this finding it is recommended that a long-time measurement of ^{222}Rn in the outdoor and indoor air should be conducted as ^{222}Rn concentration is affected by metrological parameter to cater for temporal variations.

5.0 Acknowledgement

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Consent for publication

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