KERADIOAKTIFAN TABII TANAH DI SABAH DAN SARAWAK

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ABSTRACT

Soil samples were collected from 40 locations throughout Sabah and Sarawak and were analysed for natural radionuclides concentration. The mean soil concentrations of ^{238}U, ^{226}Ra, ^{232}Th, ^{228}Ra and ^{40}K in Sabah were 22, 18, 28, 24 and 216 Bq kg^{-1} respectively while corresponding values in Sarawak were 25, 25, 38, 32 and 305 Bq kg^{-1} respectively. This study showed that the concentration of natural radionuclides (except ^{40}K) in soil in Sabah and Sarawak were about one third of the respective values in Peninsular Malaysia. The results of the study can be used as baseline data of natural radioactivity for East Malaysia.

ABSTRAK

Sampel tanah telah diambil di 40 lokasi di seluruh Sabah and Sarawak. Keradioaktifan tabii sampel tanah telah diukur. Min kepekatan ^{238}U, ^{226}Ra, ^{232}Th, ^{228}Ra dan ^{40}K dalam tanah di Sabah masing-masing adalah 22, 18, 28, 24 dan 216 Bq kg^{-1} manakala di Sarawak pula masing-masing adalah 25, 25, 38, 32 and 305 Bq kg^{-1}. Kajian menunjukkan keradioaktifan tabii tanah (kecuali ^{40}K) di Sabah dan Sarawak adalah lebih kurang satu pertiga daripada nilai di Semenanjung Malaysia. Hasil kajian ini boleh digunakan sebagai data asas keradioaktifan tabii di Malaysia Timur.

Keywords: Natural, radioactivity, radiation, terrestrial

INTRODUCTION

Naturally occuring radionuclides of terrestrial origin exist since the creation of the earth and are ubiquitous in the environment. The main radionuclides from terrestrial sources are ^{238}U decay series, ^{232}Th decay series and ^{40}K. They exist in various concentrations in all media in the environment, including human body itself. Even though these radionuclides are widely distributed, their concentrations have been found to depend on the local geological condition and as such they vary from one place to another. High level of natural radiation and radioactivity is normally associated with igneous rock area while low level with sedimentary rock. ^{238}U decays by emitting alpha particle to produce daughter radionuclides ^{234}Th followed by other decays to produce radionuclide such as ^{226}Ra. Similarly, ^{232}Th decays to produce ^{228}Ra followed by other radionuclide. These radionuclides and their decay products that emit gamma radiation, alpha and beta particles could contribute to external and internal exposure. Some other natural terrestrial radionuclides such as ^{235}U and ^{87}Rb have not been

given much attention probably due to their low abundances in nature, and thus their contributions to the dose in human are insignificant.

A number of studies on natural radiation and radioactivity has been conducted all over the world (Abbady *et al.,* 2006; Abe *et al.*, 1984; Bradley *et al.,* 1993; Chu *et al.,* 1989; Deworm *et al.*, 1988; El-Arabi *et al.,* 2006; Green *et al.,* 1988; Lai *et al.,* 1999; McAulay, 1980 & 1988; Mjones, 1988; Miller, 1992; Omar *et al.,* 1991, 2000; Rannou *et al.,* 1988; Stuardo, 1996; Sulaiman *et al.,* 2008; Wrixon, 1988). UNSCEAR (2000) has reported that radiation from terrestrial source is the main component from all natural sources of exposure to human. As for Malaysia, the baseline data of soil radioactivity (Omar *et al.*, 1991) and outdoor radiation level (Omar *et al.*, 2000) for the Peninsula and the environmental radiation level for Sabah and Sarawak (Sulaiman *et al.*, 2008) have been reported. As the previous study (Omar *et al.*, 1991) was more focused on the Peninsula and only a small number of location, i.e. 6 and 4 in Sabah and Sarawak respectively, a new and systematic study covering a representative populated areas in the East Malaysia (Sabah and Sarawak) has been carried out. The purpose of the study is to establish baseline data of natural radioactivity in East Malaysia. This paper describes the results of the study.

MATERIALS AND METHODS

Undisturbed top soil (to a depth of 10cm) samples were collected from 20 locations each in Sabah and Sarawak. The locations were randomly selected and mainly in major towns or populated areas due to easy transportation and accessibility. Sampling locations are shown in Fig 1.

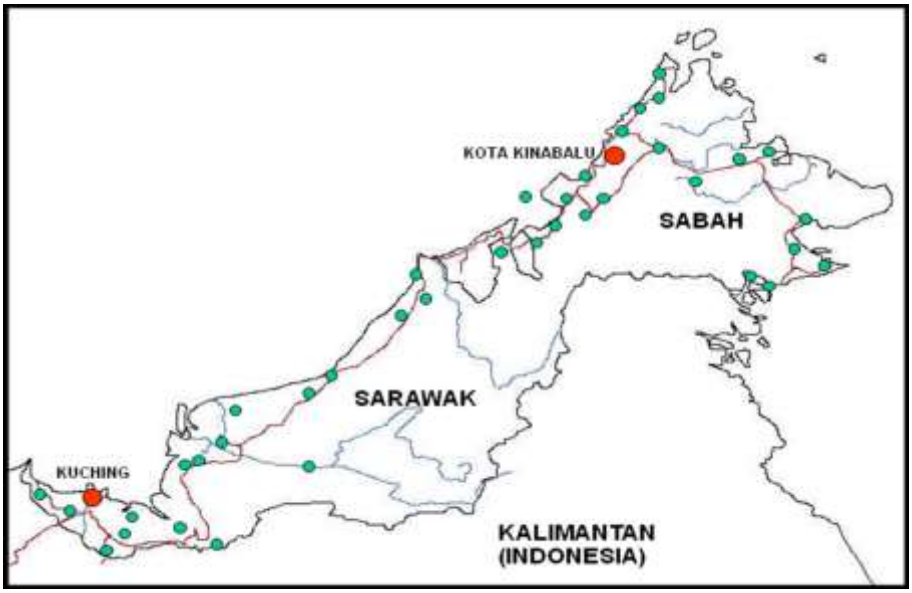

Figure. 1: Locations of towns for soil sampling in Sabah and Sarawak

The samples were dried, weighed, packed and sealed in 1-L Marinelli beakers and stored for at least three weeks. Storage is to allow radioactive equilibrium between ^{226}Ra and ^{222}Rn (thus radon daughters, ^{214}Pb and ^{214}Bi) to be attained. Samples were analysed for ^{226}Ra, ^{228}Ra and ^{40}K concentrations using gamma spectrometers and Genie 2000 analysis software (Canberra, USA). ^{226}Ra was determined using the concentration of ^{214}Pb (295, 352 keV) and ^{214}Bi (609 keV) while ^{228}Ra was measured through its daughter (^{228}Ac) concentration based on 911

keV and ^{40}K was based on 1461 keV. A similar method of efficiency calibration and measurements as reported earlier (Omar *et al.*, 2004) was used.

The uranium and thorium concentrations in samples were determined by neutron activation analysis (NAA) technique. The analysis was based on comparative method using uranium and thorium standards. The IAEA-312 certified reference material (CRM) was used for analytical control. The samples together with CRM were then irradiated in the PUSPATI TRIGA Mark II 1-MW reactor for 6 hours. Uranium and thorium were measured from ^{238}U(n,β)^{239}Np (after three-day decay) and ^{232}Th(n,β)^{233}Pa (after three-week cooling) reactions, respectively. In NAA, gamma spectrometers with high-resolution HpGe detector (1.9 keV at 1333 of ^{60}Co) was used to measure uranium (via the detection of 228 and 278 keV gamma energies of ^{239}Np) and thorium (via the detection of 312 keV gamma energy of ^{233}Pa). The concentrations of ^{238}U and ^{232}Th in µg g^{-1} were then converted into Bq kg^{-1} using conversion factors of 0.012 and 0.004 Bq µg^{-1} for ^{238}U and ^{232}Th respectively.

RESULTS AND DISCUSSION

Radioactivity level

The natural radionuclides concentrations in soil are shown in Table 1 and 2. Their distribution patterns are shown in Fig. 2 to 4. The histograms showed the frequency (in percentage) of radionuclide concentration in soil found in the study. Generally, the concentration of radionuclides (U, Th, Ra) in the East Malaysia were <40 Bq kg^{-1} and <60 Bq kg^{-1} respectively. The ^{40}K concentration in the East Malaysia were generally <500 Bq kg^{-1}. The mean concentrations of ^{238}U, ^{226}Ra, ^{232}Th, ^{228}Ra and ^{40}K in Sabah were 22, 18, 28, 24 and 216 Bq kg^{-1} respectively, while in Sarawak were 25, 25, 38, 32 and 305 Bq kg^{-1} respectively. The mean natural soil radioactivity in Sabah and Sarawak were less than the world median values reported by UNSCEAR i.e. 35, 30 and 400 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively. Although ^{40}K concentration of soil in the East Malaysia was comparable to values in the Peninsula, the concentrations of uranium and thorium series were much lower, i.e. only about one-third. The difference is probably due to geological factors, being granite (of the igneous) and sedimentary as the major rock type in Peninsular Malaysia and the East Malaysia respectively. Granite is known to contain significant amount of natural radionuclides. The radium concentration of granite in Peninsular Malaysia has been reported earlier (Omar *et al.*, 1999). The radioactivity levels of ^{238}U, ^{226}Ra, and ^{40}K in the East Malaysia were lower than the values reported by McAulay *et al.* (1988) i.e. 37, 60 and 350 Bq/kg respectively. UNSCEAR reported that the ^{40}K concentrations in soil is an order of magnitude higher than that of ^{238}U or ^{232}Th (UNSCEAR, 2000). It seems that the ^{40}K concentration in the East Malaysia also followed the same pattern. There was no area showing significantly high level of soil radioactivity in the East Malaysia (even near Gunung Kinabalu – the highest mountain in South East Asia) compared to Peninsular Malaysia which has highlands with considerably high level of natural radioactivity (Omar *et al*, 1991) and beaches with abnormally high concentration of natural radionuclides (Omar *et al*, 1991; Omar and Hassan, 2002). The results of the study can be used as baseline data of natural radioactivity for East Malaysia. The data can be used as reference for comparison in future should there be any activities involving enhancement of natural occurring radioactive materials (NORM) in the environment. An example of the usage of such data is in the radiological impact assessment of treated sludge disposal or operation of mineral processing plant in order to ensure that people living nearby the site will not receive additional dose more than 1 mSv per year as stipulated by the Atomic Energy Licensing Board (AELB) regulation.

Table 1: Radioactivity of soil in Sabah

Location	Activity Concentration, Bq kg^{-1} dry weight				
	^{238}U	^{226}Ra	^{232}Th	^{228}Ra	^{40}K
K.Kinabalu	23	16	27	23	106

Papar	32	26	27	44	107
Keningau	14	11	13	12	58
Tenom	20	19	23	23	155
Beaufort	18	16	27	23	283
Sipitang	19	18	23	21	121
Ranau	23	22	33	34	333
Tawau	21	21	21	23	30
Merotai	36	17	42	26	274
Lahad Datu	13	12	16	15	126
Semporna	31	27	25	25	110
Kunak	10	4	21	5	29
Sandakan	17	12	20	13	81
Beluran	32	24	60	43	445
Kudat	16	15	36	21	332
Kota Marudu	4	17	32	26	474
Kota Belud	28	20	32	27	373
Tuaran	26	20	30	27	354
Telupid	31	18	36	26	271
WP Labuan	17	16	22	24	248
Mean ± σ	22 ± 8	18 ± 5	28 ± 10	24 ± 9	216 ± 140

Table 2: Radioactivity of soil in Sarawak

Location	Activity Concentration, Bq kg^{-1} dry weight				
	^{238}U	^{226}Ra	^{232}Th	^{228}Ra	^{40}K
Kuching	18	18	25	28	232
Tebedu	22	30	42	25	304
Serian	26	36	46	52	253
Bintulu	24	24	39	35	288
Tatau	28	28	44	44	588
Miri	10	7	12	8	66
Niah	23	22	34	28	369
Beluru	31	26	37	37	443
Limbang	19	18	17	19	139
Lawas	39	21	51	34	446
Kota	58	31	74	53	585
Sri Aman	17	22	26	27	198
Lubuk Antu	21	33	12	21	30
Sibu	20	25	27	30	369
Dalat	19	15	22	25	102
Bintangor	8	5	30	13	160
Sarikei	35	33	48	47	345
Kapit	30	31	93	42	605
Bau	21	31	34	28	451
Lundu	30	43	52	47	125
Mean ± σ	25 ± 11	25 ± 9	38 ± 20	32 ± 13	305 ± 177

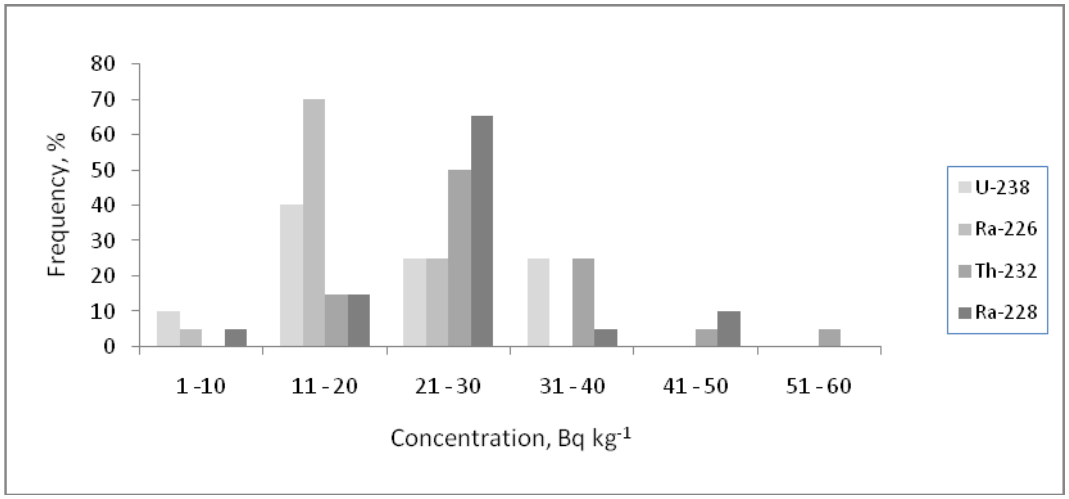

Figure 2: Distribution of uranium, thorium and radium in soil in Sabah

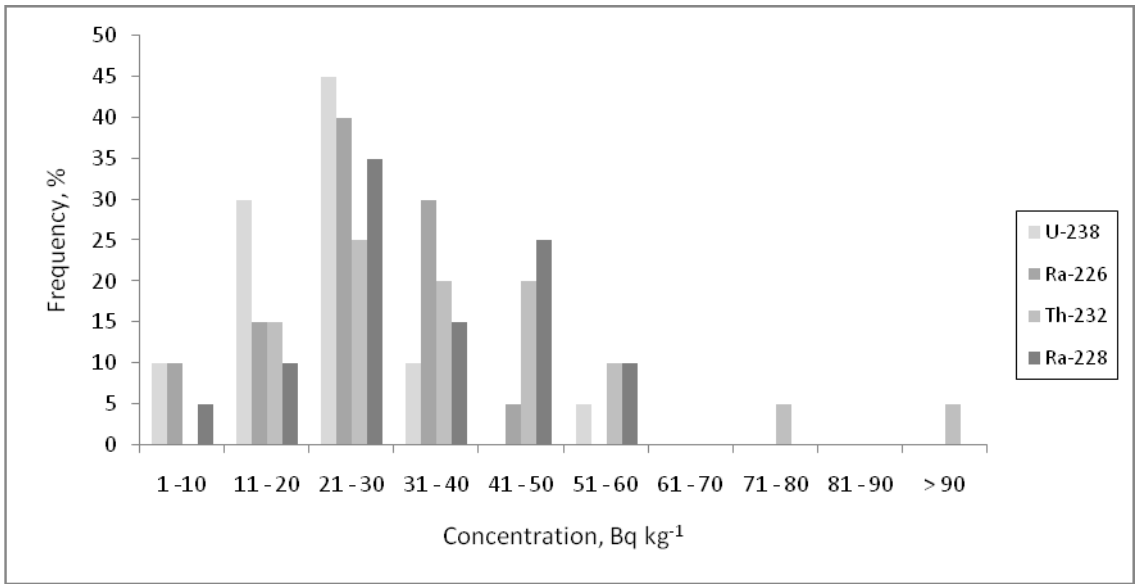

Figure 3: Distribution of uranium, thorium and radium in soil in Sarawak

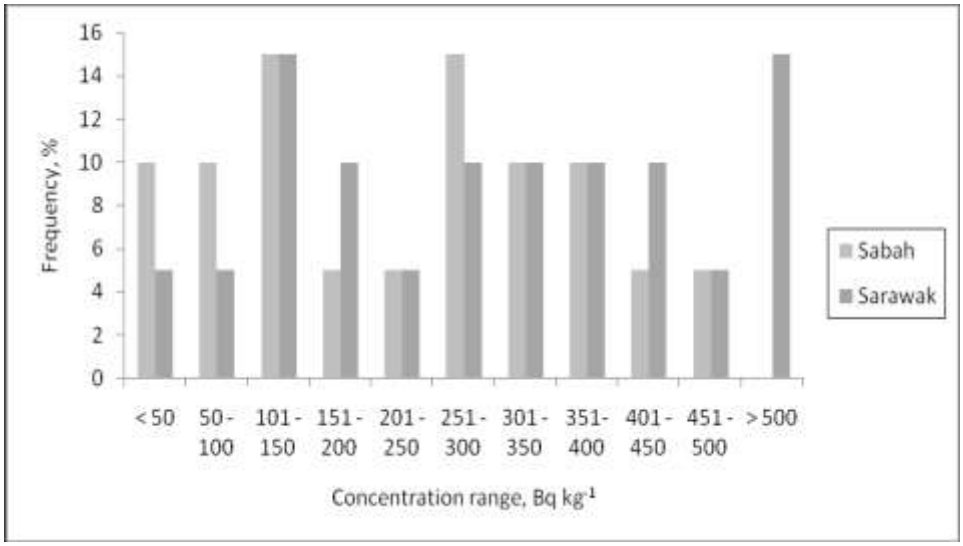

Figure 4: Distribution of ^{40}K in soil in Sabah and Sarawak

Absorbed dose rate and annual effective dose

The outdoor absorbed dose rate (D_r in nGy h^{-1} at 1m above the ground) based on radionuclide activity concentration of soil was calculated using Formula 1 derived from UNSCEAR's conversion factors (UNSCEAR, 2000).

$$D_r = 0.462A_U + 0.604A_{Th} + 0.0417A_K \quad (1)$$

where A_U, A_{Th} and A_K are the activity concentration (in Bq kg^{-1} wet weight basis) of ^{238}U, ^{232}Th and ^{40}K respectively.

The uranium and thorium series are considered to be in equilibrium and thus the concentration of ^{226}Ra and ^{228}Ra can also be used in place of ^{238}U and ^{232}Th respectively in the formula. The formula also uses the activity concentration of radionuclides based on wet weight, representing the actual condition of soil in the environment. In this study, the radionuclide concentrations were corrected for soil moisture content. The absorbed dose rate based on soil radioactivity for Sabah and Sarawak were 29 and 38 nGy h^{-1} respectively. These values were found to be lower compared to results of direct measurement of 47 and 42 nGy h^{-1} in Sabah and Sarawak respectively, using portable mini spectrometer (Sulaiman *et al.*, 2008). The contribution from structures (e.g. building materials, road surface, concrete drain etc.) in the surrounding might have added to the radiation level during direct measurement. It should be noted that the purpose of the measurement using portable mini spectrometer was to measure the general outdoor radiation exposure from all sources.

In order to estimate the annual effective dose from terrestrial radiation received by the public, the outdoor occupancy factor of 0.2 throughout 365 days a year and the quotient of effective dose to absorbed dose rate in air of 0.7 $SvGy^{-1}$ (UNSCEAR, 2000) were used. The mean annual effective dose (outdoor) from terrestrial radiation (from soil) in Sabah and Sarawak were 36 and 47 µSv respectively, i.e. lower than the Peninsular Malaysia (Omar *et al.*, 1991).

CONCLUSION

The concentrations of natural radionuclides from the uranium and thorium series in soil of the East Malaysia are lower than the Peninsular Malaysia and the world average values (UNSCEAR, 2000). The terrestrial radiation levels calculated from soil radioactivity in Sabah and Sarawak were 29 and 38 nGy h^{-1} respectively. The estimated annual doses from terrestrial radiation sources received by the population in Sabah and Sarawak were 36 and 47 µSv, i.e. lower than the Peninsular Malaysia. The data from this study can be used for future reference.

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