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Health Risk Implications of High Background Radiation Dose Rate in Kampung Sungai Durian, Kinta District, Perak, Malaysia

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Abstract

Terrestrial gamma radiation dose rate measurement has been conducted around Kampung Sungai Durian (Kg. Sg. Durian), Kinta District, Malaysia. The mean value of outdoor terrestrial gamma radiation (TGR) dose rate and indoor in the area are 458 nGy h^{-1} and 286 nGy h^{-1}, respectively. It causes fatal cancer risk of about 9.90 x 10^{-5} per year to each individual. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil samples were measured by gamma spectrometry. It ranged from 32 Bq kg^{-1} to 554 Bq kg^{-1}, 64 Bq kg^{-1} to 1 806 Bq kg^{-1} and 21 Bq kg^{-1} to 2 522 Bq kg^{-1}, respectively. Activity concentration of uranium and thorium ranged from <0.49 mBq kg^{-1} to 996.38 mBq kg^{-1}, and <0.21 mBq kg^{-1} to 1 274 mBq kg^{-1} in plant samples respectively, which cause fatal cancer risk of about 4.7 x 10^{-8} per year. The activity concentration in water samples ranged from <0.24 mBq L^{-1} to 31.96 mBq L^{-1}, and <0.21 mBq L^{-1} to 5.69 mBq L^{-1} for uranium and thorium respectively. It causes fatal cancer risk of 2.70 x 10^{-8} per year. The terrestrial gamma radiation, activity concentration from soil, leafy plants and water contribute fatal cancer risk per capita of 9.91 x 10^{-5} per year

Keywords: Gamma radiation, Health risk, Dose assessment

1. Introduction

A radiation survey was conducted throughout the State of Perak, Malaysia, to assess the environmental impact of *amang* deposits (*amang* being the local name for tin tailings that is a tin mining by product) (to be published). As a result of the survey, areas around Kg. Sg. Durian in the Kinta District of Perak, was identified as having the highest background radiation in the state. In the context of determining the significance of a critical pathway, an assessment on health physics implications of the high radiation dose in the area was carried out. The results obtained for this area can be used to determine the natural radiological status of Perak state and then be used as one of the baseline data in the assessments of the environmental impact of *amang* deposits in Perak State.

The concentration of uranium and thorium in high radiation area is associated with soil originating from igneous rocks (Kogan et al., 1969). Background terrestrial gamma radiation dose rate is influenced by soil type, geological feature and geographical condition (Florou & Kritidis, 1992; Ramli, 1997).

The world average values for terrestrial gamma radiation dose rate outdoor and indoor are 57 nGy h^{-1} and 75 nGy h^{-1} respectively (UNSCEAR, 2000). The highest concentrations of radioactive minerals in soil are found in Brazil and India (Radhakrishna et al., 1993). The abnormally high terrestrial gamma radiation in Brazil is due to the presence of monazite sand along the Atlantic coast and volcanic intrusion in the state of Minas Gerias. Dose rate in this area ranged up to 2.1 μGy h^{-1} (Malanca et al., 1993; Roser and Cullen, 1964; the Brazilian Academy of Science, 1977).

The study area as shown in figure 1 is located between the latitudes 4°15' to 4°21' North, and the longitudes 101°00' to 101°04' East (Director of National Mapping Malaysia, 1996). The area is situated in the South East of Kinta district, Perak, Malaysia. The climate is tropical with temperature between 28°C to 32°C. The area is 40 m to 70 m above sea level. It has a population of 1 643, within an area of 71 km^2. Kampung Sungai Durian is underlying by two geological formations (Director General of Geological Survey, 1985) (i) Carboniferous, with limestone and sedimentary rocks in the western part, and (ii) Acid undifferentiated with igneous acidic rocks, these are mostly granitic rocks and are found in the eastern part. The soil types present according to FAO/UNESCO classification (Director General of Agriculture Peninsular Malaysia, 1973) are dystric histosols (peat), gleyic acrisols (*Lunas*), haplic acrisols (*Rengam*), ferric acrisols (*Bukit Temian*g) and disturbed land (urban and mining land).

2. Materials and Methods

The samples were taken randomly along the longitudinal and latitudinal grid line. Figure 2 shows Kg Sg Durian with its soil types and geological background and where the samples were taken. The measurement of terrestrial gamma radiation dose rate was done from September 2004 to April 2006.

2.1 Terrestrial gamma radiation (TGR) dose rates

The measurements were carried 1 m above the ground. The detector used was model 19, micro roentgen (μR) meter, manufactured by Ludlum, USA. It uses 1″ × 1″ (2.54 × 2.54 cm^2) sodium iodide (NaI) crystal doped with thallium (Tl). The instrument was calibrated by Malaysia Nuclear Agency; it is a Secondary Standard Dosimetry Laboratory (SSDL). The measurement indoor in concrete houses and outdoor for TGR dose rates were done on the same sites. The terrestrial gamma radiation dose rate measured from 270 outdoor locations and 70 indoor locations. For indoor measurement was done in living room, with 1 m from the surface and 1.5 m from the wall. Figure 3 shows a correlation between indoor and outdoor measurements, the linear correlation is good with R = 0.98. The Intercept of 114 on the y-axis indicates the presence of intrinsic gamma radiation from the building materials.

2.2 Soil, water and plant samples preparation

Twenty eight of soil samples were collected about 15 cm depth from the soil surface. The sample were dried by placing them in an oven at 110°C for 24 hours then crushed and ground to fine powder by using a grinding mill (Herzog-D4500/type HSM 100, No. 62B/529, German-made). The samples were sieved by passing through a 200 mm test sieve/150 microns to be homogenized in size. Samples were placed and sealed in marinelli beaker for at least one month, before gamma spectrometric analysis, to ensure secular equilibrium (Mollah et al., 1987; Ibrahim et al., 1993).

Twelve of water samples were collected from ground water, fish ponds, stream, and river. Two liters of water from each sampling point was taken and filtered using 4.5 mm pore size filter paper to eliminate impurities from soil, plant, sandstone, and other materials. 2 ml nitrite acid ($HN0_3$) was added to a liter of the sample, so that the water pH became less than 2 (IAEA, 1989). Water samples were evaporated by boiling to a volume of about 20 ml. continuing evaporated by boiling in a polyethylene vial to a volume about 2 ml for NAA analysis.

Fourteen of plant samples were collected from moss, tapioca, oil palm, banana, jack fruit, rambutan and water spinach. Distilled water was used to clean and remove soil contaminants to the plant samples. The samples were dried by placing them in an oven at 60°C for 24 h. Their dry weights were determined. The samples were turned into ashes in a furnace at 450°C for 24 h. The ashes were powdered and homogenized to a 0.2 g sample and packed in a polyethylene vial for NAA analysis

2.3 Samples analysis

Soil samples were prepared to determine ^{236}U, ^{232}Th and ^{40}K concentration by using gamma ray spectrometry with a coaxial high purity germanium (HPGe) detector. The radionuclide considered was determined the peak at ^{212}Pb (239 keV), ^{208}Tl (583 keV) and ^{228}Ac (911 keV) for ^{232}Th, the peak at ^{214}Pb (352 keV) and ^{214}Bi (609 keV) for the ^{238}U and the peak at 1 460 keV for ^{40}K. The standard samples IAEA SL-14 and IAEA SL-2 were used as reference materials and were mixed with SiO_2 in Marinelli beakers. For calibration, the IAEA reference materials ^{133}Ba, ^{22}Na, ^{137}Cs, ^{60}Co and ^{152}Eu, were used. The minimum detectable activity for counting time 10 800 s were estimated to be 4 Bq kg^{-1}, 9 Bq kg^{-1} and 19 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively.

Plants and water samples were prepared to determine ^{238}U and ^{232}Th concentration by using NAA method in the TRIGA Nuclear Reactor available at Malaysian Nuclear Agency. Quality assurance and control procedure used have been described elsewhere Ramli et al., (2005).

2.4 Estimation of health risk.

To estimate the fatal cancer risk to an individual, $\hat{R}_i$. The equation below is used (Alvarez, 1997):

$$\hat{R}_i = a\sum H_E \quad \text{or} \quad \hat{R}_i = a\,(H_{E\,in} + H_{Eout}), \qquad (1)$$

Where a is the risk factor, that uses the value of 0.05 per sievert (public) for terrestrial gamma radiation dose (ICRP 1990), H_{Ein} and H_{Eout} are effective dose rates indoor and outdoor respectively. Dose factor for intake rate is 4.50 $\times 10^{-8}$ Sv Bq^{-1} and 2.30 $\times 10^{-7}$ Sv Bq^{-1} for ^{238}U and ^{232}Th respectively for adult members of the public (UNSCEAR 2000).

3. Results and Discussion

The terrestrial gamma radiation dose rate outdoor locations, ranged from 78 nGy h^{-1} to 1 039 nGy h^{-1} with the mean value of (458 ± 295) nGy h^{-1}, Figure 4 shows the isodose of terrestrial gamma radiation dose rate at Kg Sg Durian, Perak. This value is about 9 times the world average value of 57 nGy h^{-1} and 5 times the Malaysian average value of 92 nGy h^{-1} (UNSCEAR 2000). For indoor values, TGR dose rates were measured at 70 locations inside concrete houses, the value obtained ranged from 195 nGy h^{-1} to 390 nGy h^{-1}. For all data, using the indoor mean value was estimated to be (286± 95) nGy h^{-1}. The corresponding annual effective dose equivalent average for TGR dose rates indoor and outdoor are (1.39 ± 0.72) mSv and (0.59 ± 0.21) mSv respectively. The TGR annual effective equivalent dose for this area is 1.98 mSv that is 4 times higher than the reference value of 0.48 mSv (UNSCEAR 2000). This value, by using equation (1) cause fatal cancer risk of about 9.90 x 10^{-5} per year to each individual in the area.

Table 1 shows the value of TGR dose rates from different soil types and geological features in the study area. The highest TGR dose rate outdoor of 1 039 nGy h^{-1} were found at locations with soil type haplic acrisols - ferric acrisols (*Rengam Bukit Temiang*) that originate mainly from granitic rock. The annual effective dose in the area with 100% outdoor occupancy is 6.37 mSv. This value will cause fatal cancer risk of about 3.19 x 10^{-4} per year.

The gamma dose rates at soil sampling location involving different soil types and geological background are given in Table 2. The activity concentration for the 28 soil samples ranged of 32 Bq kg^{-1} to 554 Bq kg^{-1}, the mean value is (196 ± 43) Bq kg^{-1} for ^{238}U; 69 Bq kg^{-1} to 1 806 Bq kg^{-1}, with mean value of (628 ± 169) Bq kg^{-1} for ^{232}Th.; and 21 Bq kg^{-1} to 2 522 Bq kg^{-1}, with mean value of (475 ± 89) Bq kg^{-1} for ^{40}K. These values are higher than the world average as given by UNSCEAR. The most abundant radionuclide was thorium (^{232}Th). Thorium to uranium ratio is and thorium to potassium is 3.20 and 1.32 respectively, they are higher than reference value. The highest level of concentration was found in haplic-ferric acrisols (Rengam Bukit Temiang) soil type which originates mainly from granitic rock.

Table 3 shows the activity concentration of uranium and thorium in plants. The mean activity concentration of uranium and thorium in oil palms sample are (64 ± 41) mBq kg^{-1} and (60 ± 33) mBq kg^{-1} respectively. The mean activity concentration of uranium and thorium in leafy vegetable samples are (30 ± 13) mBq kg^{-1} and (19 ± 12) mBq kg^{-1}, respectively. The mean activity concentration of uranium and thorium in fruits samples are (3.7 ± 1.8) mBq kg^{-1} and (2.1 ± 1.5) mBq kg^{-1} respectively. Those values are higher than the reference values for uranium and thorium in leafy vegetables, fruit and grain (UNSCEAR 2000). If the annual consumption rates of oil palm, leafy vegetables and fruit respectively are used, which are 30 kg, 60 kg, and 170 kg, respectively, the resulting annual intake for uranium and thorium will be 1.9 Bq and 1.8 Bq in oil palm samples, 1.8 Bq and 1.1 Bq in leafy vegetables, and 0.6 Bq and 0.3 Bq in fruits, respectively. This will contribute to annual effective doses of 0.19 μSv and 0.74 μSv for uranium and thorium, respectively. The plant annual effective dose for uranium and thorium of 0.93 μSv is higher than the reference values of 0.63 μSv for adult (UNSCEAR 2000). The annual intake due to the consumption of plant is low. Activity concentration in plant contributes only insignificant small risk towards fatal cancer that is 4.7 x 10^{-8} per year. Moss samples were collected for comparing uranium and thorium concentration with plant samples. Moss is a nonvascular plant and is a good absorber of uranium and thorium compared to other plants. Uranium activity in moss samples varies from 355 mBq kg^{-1} to 996 mBq kg^{-1}, and thorium activity varies from 464 mBq kg^{-1} to 1274 mBq kg^{-1}, with the mean value of (599 ± 346) mBq kg^{-1} and (820 ± 413) mBq kg^{-1} for uranium and thorium, respectively. These values indicated that

moss is a more efficient absorber of uranium and thorium compared to oil palms, leafy vegetables and the fruit, as similarly reported by Say and Whitton (1983), Mouvet (1984), Tremolieres et al. (1994) and Ramli (2005)

The concentrations of uranium and thorium in water samples are shown in Table 4. The mean activity concentration of uranium and thorium in all water samples is (9.6 ± 7.0) mBq l^{-1} and (2.5 ± 1.6) mBq l^{-1} respectively. These values are higher than the reference values of drinking water in the word of 1 mBq l^{-1} and 0.05 mBq l^{-1} for uranium and thorium respectively (UNSCEAR, 2000). The estimated annual intake of radioactivity due to the consumption of water is calculated using water ingestion rate of 500 l y^{-1} (UNSCEAR 2000). The value will contribute to annual intake of 4.8 Bq and 1.3 Bq for uranium and thorium, correspondingly. The annual effective dose for water sample is 0.21 μSv for uranium and 0.33 μSv for thorium. It will cause fatal cancer risk of about 2.70 x 10^{-8} per year.

4. Conclusions

The mean natural terrestrial gamma radiation dose rate in Kg. Sg. Durian is about 5 times higher than the Malaysian average and about 9 times higher than the world average value (UNSCEAR 2000). The population does receive relatively higher background TGR exposures, however the increase in fatal cancer risk of about 9.90 x 10^{-5} y^{-1} per capita is not high enough to cause for alarm.

The results indicate that the radionuclide contribution to annual effective dose rate from plant and water are higher than the reference values provided by UNSCEAR, nevertheless their contribution of 4.7 x 10^{-8} y^{-1} for plant and 2.70 x 10^{-8} y^{-1} for water per capita towards fatal cancer risk is relatively insignificant from health physics point of view. It might be a good policy to institute basic and simple radiological health monitoring for the affected area but probably nothing more than that.

The results obtained indicate that the most critical natural radiation area in Perak does not pose significant health physics risk, therefore the overall natural radiological status of Perak state is not out of norm.

References

Alvarez, JL. (1997). Ionizing Radiation Risk Assessment, in: Molak., V (eds.), *Fundamental of Risk Analysis and Risk Management.* CRC Press, pp. 163-175.

Brazillian Academy of Sciences. (1997). *International Symposium on Areas of High Natural Radioactivity.* Acad. Brazil de Ciencias ed.

Derector of National Mapping Malaysia. (1996). Kampar. L7030 series. 1-PPNM edition.

Director General of Agriculture Peninsular Malaysia. (1973). Map of Soil Types in Peninsular Malaysia. 1st Edition. Kuala Lumpur.

Director General of Geological Survey. (1985). Map of Geological Features in Peninsular Malaysia. Ipoh.

Florou, H., & Kritidis, P. (1992). Gamma radiation measurements and dose rate in the coastal areas of a volcanic island, Aegean Sea, Greece. *Journal of Radiation Protection Dosimetry*, 45, 277–279.

Ibrahim, N.M., Abd El Ghani, A.H., Shawky, E.M., Ashraf, E.M., Farouk, M.A. (1993). Measurement of radioactivity levels in soils in the Nile Delta and Middle Egypt. *Journal of Health Phyics,* 64, 620–627.

International Atomic Energy Agency. (1989). *Measurement of Radionuclides in Food and the Environment*. Technical Report Series No. 295, IAEA Publication, Vienna.

International Atomic Energy Agency. (2005). N*atural activity concentrations and fluxes as indicators for the safety assessment of radioactive waste disposa.* IAEA-TECDOC-1464, IAEA Publication, Vienna

International Commission on Radiological Protection. (1990). *Recommendations of the International Commission on Radiological Commission*. ICRP Publication 60. Pergamon Press, New York.

Kogan, R.M., Nazarov, I.M., & Fridman, S.D. (1969). *Gamma Spectrometry of Natural Environments and Formation: Theory of the Method Application to Geology dan Geophysics*. Jerusalem: Keter Press.

Malanca, A., Pessina, V., & Dallara, G. (1993). Assessment of the natural radioactivity in the Brazillian state of Rio Grende Do Norte. *Journal of Health Physics*. 65, 298–302.

Mollah, S., Rahman, N.M., Kodlus, M.A., & Husain, S.R. (1987). Measurement of high natural background radiation level by TLD at Cox and Bazar coastal areas in Bangladesh. *Journal of Radiation Protection Dosimetry*, 18, 39 – 41.

Mouvet, C. (1984). Accumulation of chromium and copper by the aquatic moss. *Environmental Technology Letters 5*, 542–548.

Pietrzak-Flis, Z., Rosia,L., Suplinska.,M.M., Chrzanowski.,E., Dembinska., S. (2001). Daily intakes of ^{238}U, ^{234}U, ^{232}Th, ^{230}Th, ^{228}Th and ^{226}Ra in the adult population of central Poland. *Journal of the Science of the Total Environment,* 273, 163-169

Radhakrishna, A.P., Somashekarappa , H.M., Narayana. Y., & Siddappa, K. (1993). A new natural background radiation area on the southwest coast of India. *Journal of Health Physics*. 65, 390-395.

Ramli, A.T. (1997). Environmental Terresterial Gamma Radiation Dose and its Relationship with Soil Type and Underlying Geological Formation in Pontian District, Malaysia. *Journal of Applied Radiation and Isotops,* 48, 407-412.

Say, P.J., & Whitton, B.A. (1983). *Accumulation of heavy metals by aquatic mosses.* Hydrobiologica 100, 19–36.

Ramli, A.T., Abdel Wahab, M.A., & Wood, A.K. (2005). Environmental ^{238}U and ^{232}Th concentration measurements in an area of high level natural background radiation at Palong, Johor, Malaysia. *Journal of Environment Radioactivity*, 80, 287-304.

Roser FX, Cullen TL. (1964). External Radiation Levels in High Background Region of Brazil. In: *Natural Radiation Environment*. University of Chicago Press, III: 855 – 872

Tremolieres, M.U., Roeck, J.P.K., & Carbiener, R. (1994). *The exchange process between river and groundwater on Central Alsace Floodplain*, France. Hydrobiologica 273, 19–36.

United Nations Scientific Committee on the Effect Atomic Radiation. (2000). Sources and Effects of Ionizing Radiation. *UNSCEAR Report 2000*.

Table 1. Terrestrial gamma radiation dose rate from different soil types and geological background around Kg Sg Durian

Soil type and Geology features	**N**	**Mean**	**Std Dev**	**95% Confidence Interval for Mean**		**Min**	**Max**
				Lower Bound	**Upper Bound**		
Soil types							
Disturbed Land	32	266	192	197	335	104	780
Gleyic Acrisols	41	300	277	213	388	91	909
Dystric Histosols	19	256	159	179	332	117	747
Haplic Acrisols, Ferric Acrisols	178	550	283	508	592	78	1 039
Geological background							
Acid Undifferentiated (granitoid)	194	530	281	490	570	117	1 039
Carboniferrous	76	274	244	218	329	78	974
Overlayer between soil type and geological background							
Disturbed Land and Granitoid	9	316	187	172	460	169	780
Gleyic Acrisols and Granitoid	7	473	353	147	800	130	909
Dystric Histosols and Granitoid	19	256	159	179	332	117	747
Haplic Acrisols, Ferric Acrisols and Granitoid	159	577	271	535	620	117	1 039
Disturbed Land and Carboniferrous	23	247	194	163	331	104	747
Gleyic Acrisols and Carboniferrous	34	265	251	177	352	91	909
Haplic Acrisols, Ferric Acrisols and Carboniferrous	19	322	288	183	461	78	974
Present study		458	295	422	493	78	1 039
Malaysian average (UNSCEAR 2000)		92					
World median (UNSCEAR 2000)		57					

Table 2. Concentration of uranium and thorium in soil samples collected from different soil types and geological background around Kg. Sg. Durian, Perak, Malaysia.

Soil Samples	Soil Type (FAO/UNESCO)	Geology	Concentration (Bq kg^{-1}) ± σ			TGR dose rate at the point sampling (nGy h^{-1})
			^{238}U	^{232}Th	^{40}K	
S1	Haplic-Ferric Acrisols	Acid Undifferentiated	174 ± 39	138 ± 32	210 ± 21	780
S3	Disturbed Land	Carbonifferous	87 ± 7	160 ± 27	356 ± 123	157
S4	Haplic-Ferric Acrisols	Acid Undifferentiated	295 ± 24	1 286 ± 187	177 ± 17	974
S5	Gleyic Acrisols	Carbonifferous	72 ± 5	126 ± 11	85 ± 5	130
S6	Disturbed Land	Acid Undifferentiated	197 ± 19	1 298 ± 212	210 ± 37	1039
S7	Haplic-Ferric Acrisols	Acid Undifferentiated	181 ± 15	732 ± 35	226 ± 41	611
S8	Haplic-Ferric Acrisols	Acid Undifferentiated	426 ± 24	399 ± 82	1940 ± 177	812
S9	Haplic-Ferric Acrisols	Acid Undifferentiated	554 ± 87	1 806 ± 276	1014 ± 137	1039
S2	Haplic-Ferric Acrisols	Carbonifferous	137 ± 12	729 ± 78	414 ± 69	487
S10	Haplic-Ferric Acrisols	Acid Undifferentiated	267 ± 41	203 ± 23	101 ± 19	780
S11	Gleyic Acrisols	Carbonifferous	384 ± 67	880 ± 29	413 ± 48	909
S12	Dystric Hystosols	Acid Undifferentiated	44 ± 5	69 ± 9	95 ± 14	117
S13	Haplic-Ferric Acrisols	Acid Undifferentiated	167 ± 21	1 209 ± 216	147 ± 31	974
S14	Haplic-Ferric Acrisols	Carbonifferous	355 ± 50	707 ± 29	2 522 ± 101	747
S15	Dystric Hystosols	Acid Undifferentiated	75 ± 6	153 ± 21	237 ± 24	156
S16	Gleyic Acrisols	Carbonifferous	255 ± 31	812 ± 121	522 ± 54	650
S17	Gleyic Acrisols	Acid Undifferentiated	248 ± 23	244 ± 38	1 539 ± 203	325
S18	Dystric Hystosols	Acid Undifferentiated	79 ± 6	142 ± 23	105 ± 4	143
S19	Disturbed Land	Carbonifferous	60 ± 7	97 ± 13	132 ± 28	148
S20	Haplic-Ferric Acrisols	Acid Undifferentiated	225 ± 27	1 400 ± 154	486 ± 49	1039
S21	Haplic-Ferric Acrisols	Acid Undifferentiated	394 ± 19	1 629 ± 156	631 ± 93	1039
S22	Gleyic Acrisols	Acid Undifferentiated	233 ± 35	1 037 ± 78	674 ± 51	909
S23	Gleyic Acrisols	Carbonifferous	52 ± 7	83 ± 12	97 ± 14	104
S24	Gleyic Acrisols	Carbonifferous	38 ± 8	95 ± 13	85 ± 11	117
S25	Gleyic Acrisols	Carbonifferous	32 ± 9	78 ± 23	21 ± 18	104
S26	Gleyic Acrisols	Carbonifferous	61 ± 5	123 ± 18	78 ± 8	130
S27	Haplic-Ferric Acrisols	Acid Undifferentiated	308 ± 25	1 752 ± 216	326 ± 30	974
S28	Disturbed Land	Carbonifferous	90 ± 9	193 ± 19	451 ± 87	169
Present study mean			196 ± 43	628 ± 169	475 ± 89	458 ± 295
Malaysia average (UNSCEAR, 2000)			66 (49 - 86)	82 (63 - 110)	310 (170 - 430)	92 (55 - 130)
World median (UNSCEAR, 2000)			35 (16 - 110)	30 (11 - 64)	400 (140 - 850)	57 (18 - 93)

Table 3. Concentration of uranium and thorium in plant samples (dry weight)

Plant Samples	Plant	Scientific name	Concentration (mBq kg^{-1})		Th to U ratio	TGR dose rate at the sampling point (nGy h^{-1})
			Uranium	Thorium		
P 1	Moss	*funaria hygrometrica*	355.21	464.48	1.31	156
P 2	Moss	*funaria hygrometrica*	446.91	722.16	1.62	780
P 3	Moss	*funaria hygrometrica*	996.38	1 274.24	1.28	1 039
P 4	Oil Palm (seed)	*Elaeis guineesis*	17.23	50.99	2.96	325
P 5	Oil Palm (seed)	*Elaeis guineesis*	95.75	73.47	0.77	974
P 6	Oil Palm (seed)	*Elaeis guineesis*	79.61	55.27	0.69	974
P 7	Tapioca (leafy)	*Manihot esculenta*	44.81	36.95	0.82	909
P 8	Tapioca (leafy)	*Manihot esculenta*	36.02	18.88	0.52	487
P 9	Tapioca (leafy)	*Manihot esculenta*	25.78	11.51	0.45	143
P10	Water spinach (leafy)	*Ipomoea aquatici*	13.28	8.96	0.67	117
P11	Banana (fruit)	*Musa sapientum*	< 0.49	< 0.21	-	130
P12	Rambotan (fruit)	*Nephelium lappaceum*	2.80	1.25	0.45	650
P13	Jack fruit (fruit)	*Artocarpus heterophyllus*	5.44	4.26	0.78	812
P14	Papaya (fruit)	*Carica papaya*	6.22	2.33	0.37	974
Reference value (UNSCEAR, 2000)						
Root vegetables and fruits			3	0.5	0.17	
Leafy vegetables			20	15	0.75	
Grain product			20	3	0.15	

Table 4. Specific activity of uranium and thorium in water samples

Samples	Water Sources	Specific Concentration (mBq L^{-1})		Th to U ratio	TGR dose rate close to the sampling point (nGy h^{-1})
		Uranium	Thorium		
W1	Tumboh River	7.05	1.34	0.19	130
W2	Tumboh River	4.59	2.51	0.55	909
W3	Tumboh River	1.39	< 0.21	-	104
W4	Pond	6.96	3.54	0.51	325
W5	Pond	16.25	0.62	0.04	130
W6	Ground water	< 0.24	< 0.21	-	974
W7	River	2.36	1.70	0.72	1039
W8	pond	16.16	3.69	0.23	117
W9	Ground water	31.96	5.69	0.18	143
W10	Pond	1.18	0.72	0.61	1039
W11	Ground water	8.56	3.22	0.38	487
W12	Stream	9.62	2.54	0.26	974
Reference value					
River, China (IAEA, 2005)		21.61	1.26		
Surface water, Japan (IAEA , 2005)		0.31	0.01		
Central Poland (Pietrzak-Flis, 2001)		8.32	0.02		
Ground water dug well, Finland (IAEA, 2005)		<0.12-446.89	<0.08-6.11		

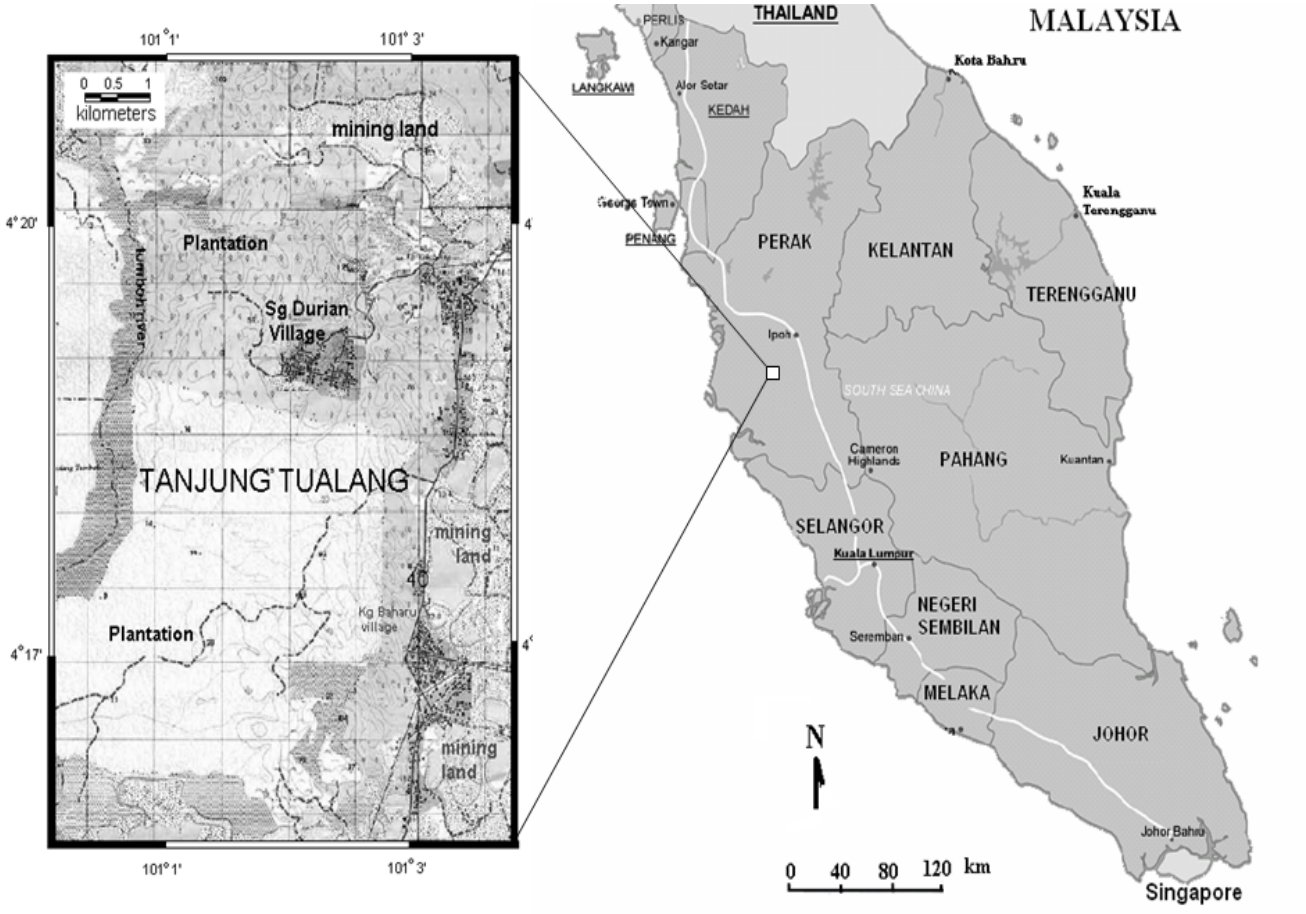

Figure 1. Study location at Kg Sg Durian, Malaysia

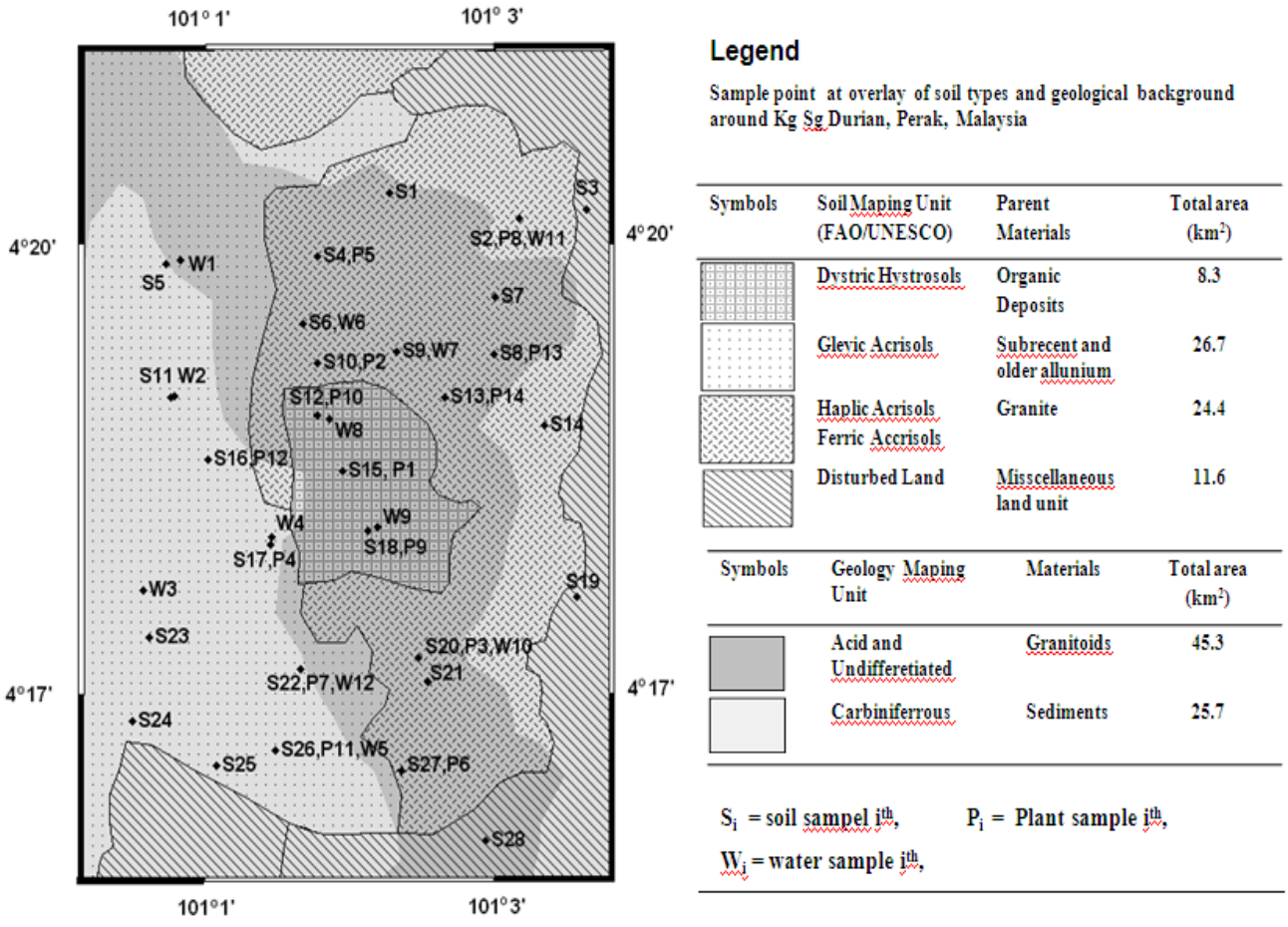

Figure 2. Sample point at overlay of soil types and geological backgrounds around Kg. Sg. Durian

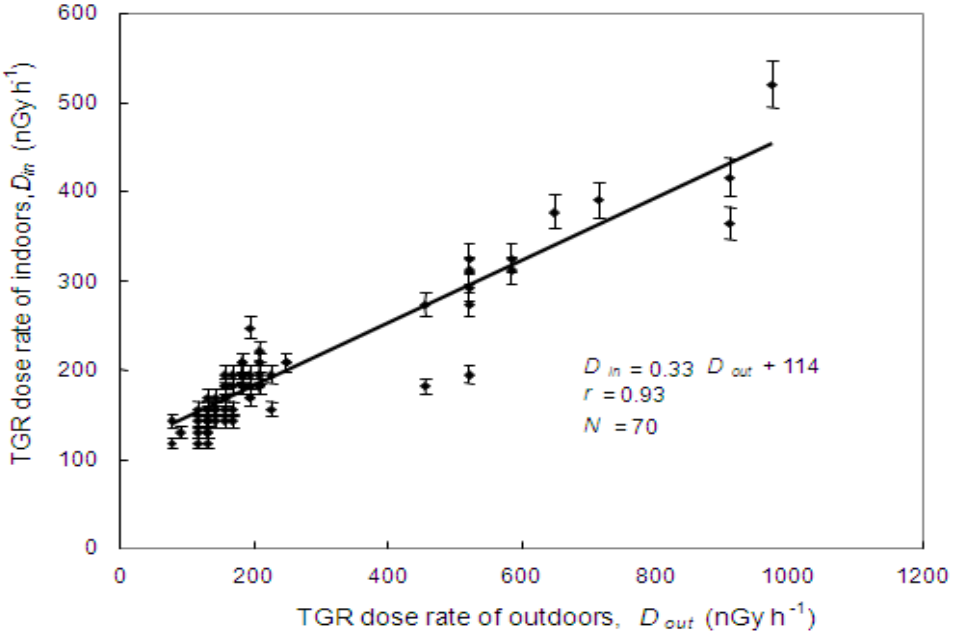

Figure 3. Correlation between Terrestrial Gamma Radiation (TGR) dose rates outdoor and indoor

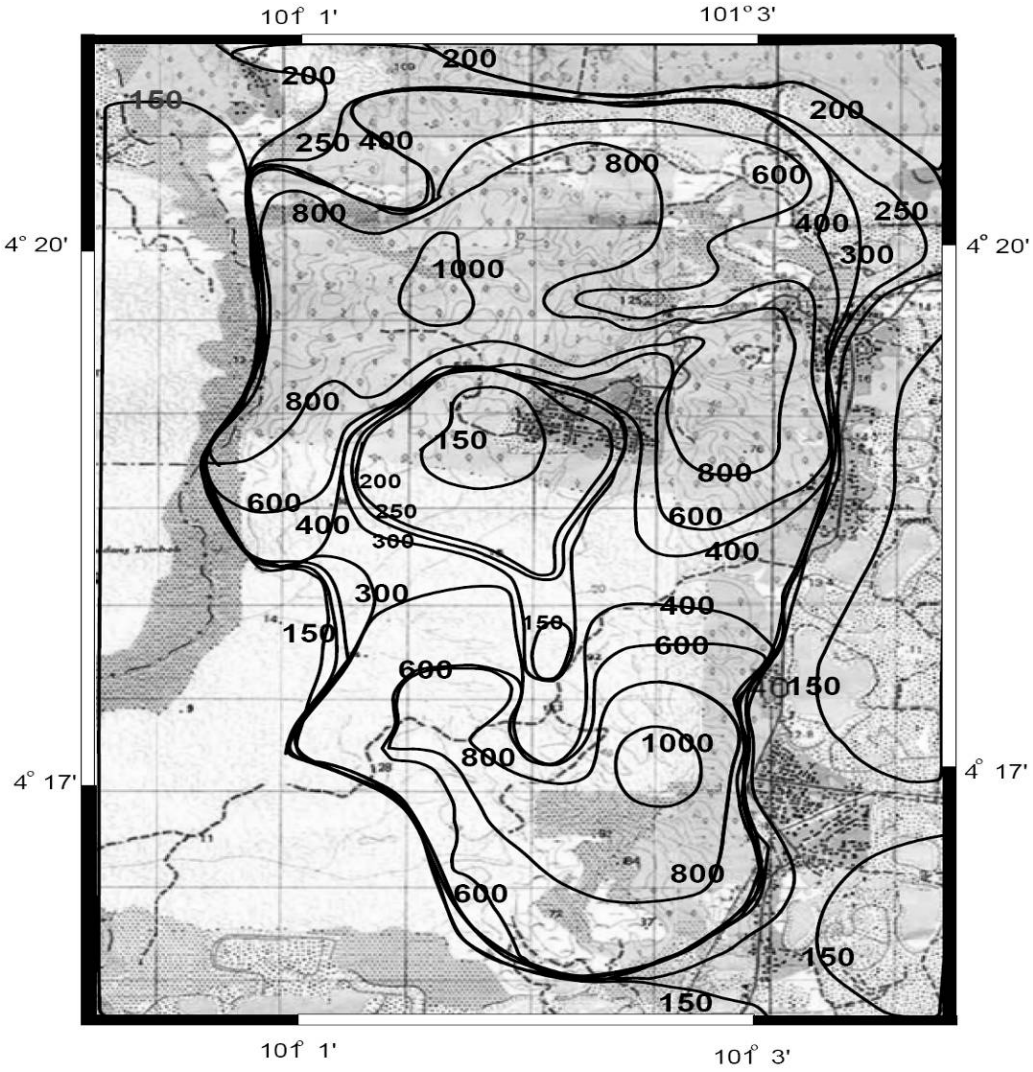

Figure 4. Isodose map of TGR dose rate around Kg. Sg. Durian, Perak. The dose rate unit is in nGy h^{-1}