LAPORAN AKHIR PROJEK PENYELIDIKAN

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LEMBAGA PERLESENAN TENAGA ATOM MALAYSIA

TAJUK PROJEK PENYELIDIKAN

KAJIAN RADIOLOGI KE ATAS KESAN AMANG DI NEGERI PERAK

Disediakan oleh

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KANDUNGAN

BAHAGIAN C KERTAS KERJA DAN DERAF KERTAS KERJA.

RINGKASAN EKSEKUTIF

Kajian ini telah dilakukan untuk meletakkan kesan radiologi industri amang dalam konteks persekitaran radiologi alam sekitar yang terdapat di negeri Perak. Untuk tujuan tersebut satu tinjauan terhadap sifat radiologi alam sekitar telah dilakukan di negeri Perak untuk mendapatkan data dasar radiologi alam sekitar negeri Perak. Tinjauan ini telah menghasilkan peta isodos sinar gama daratan tabi'i bagi negeri Perak. Peta isodos ini sesuai digunakan sebagai data dasar untuk kerja-kerja penguatkuasaan polisi perlindungan dan kesihatan radiologi di negeri Perak. Didapati bahawa nilai dos gama daratan di negeri Perak berada dalam julat 38 nGy $^{j-1}$ sehingga 1039 nGy j^{-1}, dengan nilai minnya (214 ± 145) nGy j^{-1}. Nilai purata dunia ialah 57 nGy j^{-1}.

Kajian ini mengaitkan aras dos sinar gama daratan dengan jenis tanah dan latar belakang geologi, dan mengemukakan kemungkinan untuk menggunakan maklumat kaitan ini untuk menganggarkan aras dos sinar gama daratan tabi'i.

Kajian juga telah melakukan pengukuran untuk menentukan kepekatan keradioaktifan ^{238}U, ^{232}Th dan ^{40}K bagi sampel tanah dari seluruh negeri Perak. Julat nilai yang didapati ialah 7 Bq kg^{-1} – 426 Bq kg^{-1}, 23 Bq kg^{-1} – 1390 Bq kg^{-1}, dan 6 Bq kg^{-1} – 2204 Bq kg^{-1}. UNSCEAR 2000 memberikan nilai berikut sebagai nilai rujukan ^{238}U, 35 Bq kg^{-1}; ^{232}Th, 30 Bq kg^{-1} ; dan ^{40}K, 400 Bq kg^{-1}.

Di kawasan dos sinar gama daratan tinggi, khususnya di sekitar Kampung Sungai Durian pengukuran terhadap aras kepekatan keradioaktifan juga dilakukan terhadap sampel air dan tumbuh-tumbuhan. Di sini juga dilakukan pengukuran terhadap aras radon dan toron. Didapati penduduk yang berada di lokasi dos sinaran gama daratan yang tertinggi, iaitu 1039 nGy j^{-1} berkemungkinan terdedah kepada dos berkesan akibat radon dan toron sebesar sehingga 10 mSv setahun. Dicadangkan supaya kajian lanjutan impak dos yang agak tinggi ini terhadap kesihatan radiologi penduduk tempatan dilakukan.

Oleh kerana kebanyakan kilang amang berada di daerah Kinta, kajian ini juga memberikan tumpuan khusus kepada pengukuran dos sinaran radiologi alam sekitar di daerah Kinta, walaupun nilai min aras dos sinaran gama daratannya, (220 ± 191) nGy j^{-1} hampir tidak berbeza dari nilai min untuk negeri Perak, (214 ± 145) nGy j^{-1}. Pengukuran aras dos sinaran dan keradioaktifan telah turut dilakukan di kilang-kilang amang. Setakat ini kajian mendapati bahawa kesan dari industri amang merupakan kesan setempat dan tidak meningkatkan aras dos sinaran dan keradioaktifan latar belakang di alam sekitar secara signifikan, kecuali di kawasan kilang itu sendiri atau jiran terdekatnya. Aras dos sinaran dan keradioaktifan yang terdapat di kawasan kilang amang adalah jauh melebihi aras yang lazimnya dapat diterima bagi kawasan kerja sinaran.

Aras dos sinaran dan keradioaktifan seperti yang diukur dalam kajian ini adalah terlalu kecil untuk menyebabkan kesan deterministik, tetapi nilai di beberapa kawasan dos sinaran gama daratan tinggi (>400 nGy j^{-1}), mempunyai aras nilai kebarangkalian yang signifikan untuk meningkatkan kebarangkalian kejadian kesan-kesan stokastik sinaran. Kawasan sebegini terdapat di sekitar Tanjung Tualang (khususnya di Kampung Sungai Durian, di Mukim Hulu Selama, ke Selatan dari Bandar Lumut dan beberapa kawasan di Banjaran Gunung Keledang. Pemantauan mungkin sesuai dilakukan di kawasan ini.

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Lembaga Perlesenan Tenaga Atom, Malaysia

Tuan Haji Ahmad bin Bakar

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BAHAGIAN A.

KAJIAN RADIOLOGI NEGERI PERAK

BAHAGIAN B.

SURVEY OF NATURAL BACKGROUND RADIATION AND ANALYSIS OF AMANG SAMPLES IN KINTA DISTRICT

RINGKASAN

Dalam kajian ini pengukuran dos sinaran gama daratan dilakukan berdasarkan kepada maklumat jenis tanah, latar belakang geologi di negeri Perak dan peta survei udara. Pengukuran juga dilakukan di dalam bangunan, bagi menganggarkan kebarangkalian kesan kesihatan. Peta isodos bagi taburan dos sinar gama daratan telah dibina berdasarkan kaedah Kriging dengan menggunakan perisian Mapinfo/Arc View, dan diselaraskan secara manual dengan maklumat jenis tanah dan latar belakang geologi dan bacaan sebenar.

Analisis variansi (ANOVA) dan ujian t boleh digunakan bagi menjangkakan dos sinaran gama daratan dan untuk melihat perbezaan dos yang terdapat bagi berbagai jenis tanah. Pengukuran kepekatan keradioaktifan untuk sampel tanah telah dilakukan menggunakan spektrometer gama germanium hipertulen. Pengukuran kepekatan radionuklid uranium dan torium bagi tumbuh-tumbuhan dan air telah dilakukan dengan menggunakan kaedah Analisis Pengaktifan Neutron.

Hasil kajian, dos sinaran gama daratan di negeri Perak didapati berada pada julat nilai 38 nGy j^{-1} sehingga 1039 nG j^{-1}. Nilai minnya (214 ± 145) nGy j^{-1} di luar bangunan dan (219 ± 131) nGy j^{-1} di dalam bangunan. Bacaan ini merupakan 4 kali ganda bacaan purata dunia iaitu 57 nGy j^{-1} (UNSCEAR 2000). Nilai julat kepekatan keradioaktifan ^{238}U, ^{232}Th dan ^{40}K masing-masingnya ialah 7 Bq kg^{-1} – 426 Bq kg^{-1}, 23 Bq kg^{-1} – 1390 Bq kg^{-1}, dan 6 Bq kg^{-1} – 2204 Bq kg^{-1}. Nilai min didapati (123 ± 94) Bq kg^{-1} bagi ^{238}U, (305±137) Bq kg^{-1} bagi ^{232}Th, dan. (295±108) Bq kg^{-1} bagi ^{40}K. UNSCEAR 2000 memberikan nilai berikut sebagai nilai rujukan bagi kepekatan keradioaktifan ^{238}U, ^{232}Th dan ^{40}K, 35 Bq kg^{-1} , 30 Bq kg^{-1} dan 400 Bq kg^{-1} Di kawasan dos sinaran gama daratan tinggi di Kampung Sungai Durian di dapati bacaan radon dan toron masing-masing berada dalam julat 0.70 mWL (3.3 Bq m^{-3}) hingga 47 mWL (220.1 Bq m^{-3}) dan 0.30 mWL (1.4 Bq m^{-3}) hingga 16 mWL (75.4 Bq m^{-3}). UNSCEAR 2000 memberikan nilai 46 Bq m^{-3} dan 12 Bq m^{-3} sebagai nilai rujukan bagi radon dan toron,

BAB A.I

PENGENALAN

A.1.1. Latar Belakang Kajian

Setiap manusia tidak terlepas daripada menerima dedahan dos sinaran dari berbagai sumber sinaran samada buatan manusia atau pun semula jadi. Secara purata manusia menerima dos sinaran berpunca daripada sumber semula jadi berjumlah 2.4 mSv setahun (UNSCEAR, 2000), atau 77 % dari dedahan keseluruhan (Gonzales, 1993).

Aras keradioaktifan semula jadi luar biasa telah ditemui di beberapa tempat di dunia contohnya Brazil di pantai Guarapari (90,000 nGy j^{-1}), China (370 nGy j^{-1}), Perancis (10.000 nGy j^{-1}), India (1800 nGy j^{-1}), Mesir (400 nGy j^{-1}), Itali (560 nGy j^{-1}) (UNSCEAR, 2000). Hasil kajian Agensi Nuklear Malaysia telah mengenal pasti beberapa kawasan di Semenanjung Malaysia yang mempunyai kandungan unsur keradioaktifan semula jadi yang tinggi. Kawasan tersebut terdapat di pantai Pasir Hitam di Langkawi, pantai Batu Feringgi di Pulau Pinang, Genting Highland di Pahang, Taiping di Perak, Lebuh Raya Timur Barat di Sempadan Perak dan Kelantan, dan Sik di Kedah (Omar et al, 1991). Negeri Perak, khususnya daerah Kinta merupakan kawasan penyimpanan amang (IAEA, 2003., Ichihara dan Harding, 1995) yang mengandungi mineral berat berkeradioaktifan tinggi seperti ilmenit, monazit, zirkon dan xenotim (Hewson, 1993).

Keradioaktifan semula jadi di suatu kawasan berpunca daripada kepekatan radionuklid yang wujud samaada dalam tanah, batuan, air, tumbuhan, haiwan, dan udara (Kogan et. al, 1969), tanah liat (Roessler et al., 1993), dan komposisi mineral (Klein dan Hurlbut, 1985). Terdapat hubungan diantara jenis tanah, struktur geologi dan taburan dos sinar gama semulajadi (Ramli, 1997; Quindos et al., 1994; Malanca et al, 1993). Kepekatan keradioaktifan daratan di Semenanjung Malaysia disumbang terutamanya oleh uranium, torium, dan kalium. Nilai tipikal masing-masingnya ialah 66 Bq kg^{-1}, 82 Bq kg^{-1} dan 310 Bq kg^{-1} (UNSCEAR, 2000). Dos daratan di Malaysia berdasarkan laporan UNSCEAR di luar bangunan ialah 92 nGy j^{-1} dan di dalam bangunan ialah 96 nGy j^{-1} (UNSCEAR, 2000). Sumbangan terbesar adalah dari radionuklid siri torium iaitu sebanyak 51% (Omar et al, 1991).

Keradioaktifan juga wujud di dalam tubuh manusia akibat pengambilan makanan dan mineral keperluan harian, terutamanya makanan laut, sayur-sayuran dan bijirin yang menyumbang kepada pengambilan radionuklid ^{232}Th dan ^{238}U (Shiraishi, 1992; Fisenne, 1987). Di China contohnya purata sayur-sayuran menyumbang kepekatan keradioaktifan 24 mBq kg^{-1} untuk ^{238}U, dan 23 mBq kg^{-1} untuk ^{232}Th (UNSCEAR, 2000). Sumbangan keradioaktifan yang berasal dari pada sayur-sayuran dan bijirin berhubung rapat dengan nilai dos semulajadi gama daratan. Beberapa kajian telah dilakukan berkaitan faktor pemindahan keradioaktifan daripada tanah kepada tumbuh-tumbuhan, contohnya Hamilton, 1972 ; Kobashi dan Tominaga 1985, Fisenne et al 1987 ; Yu dan Mao, 1995; Ibrahim dan Whicker, 1988 ; Pietrzak-Flis et al, 2001., Ekdal et al, 2006, Bolcaa et al, 2007. Berdasarkan UNSCEAR jumlah keradioaktifan dalam tumbuh-tumbuhan yang tertelan se hari bernilai dalam julat 8 mBq - 156 mBq bagi ^{238}U, 2 mBq - 25 mBq bagi ^{232}Th, 24 mBq - 109 mBq bagi ^{226}Ra, 44 mBq - 301 mBq bagi ^{210}Pb, dan 36 mBq - 180 mBq bagi ^{228}Ra (UNSCEAR, 2000). Di kawasan bacaan luar biasa di Rio de Janeiro, Brazil, nilai kepekatan radinuklid yang tertelan se hari ialah 1.9 mBq ^{232}Th (0.47 µg), 2.0 mBq ^{238}U (0.17 µg), 19 mBq ^{226}Ra, 26 mBq ^{210}Pb dan 47 mBq ^{228}Ra. Dos berkesan tahunan yang diterima penduduk berpunca dari tumbuh-tumbuhan dianggarkan bernilai 14.5 µSv (Santos et al., 2002). Kajian di kawasan bacaan dos sinaran semula jadi tinggi di Palong Johor mendapati bahawa kepekatan uranium dan torium pada sampel kelapa sawit masing-masing bernilai dalam julat 0.005 mg kg^{-1} – 0.031 mg kg^{-1} dan 0.011 mg kg^{-1} – 0.23 mg kg^{-1} (Ramli et al., 2005).

Air juga memberikan sumbangan yang signifikan terhadap kemasukan radionuklid ke dalam tubuh manusia. Di Palong Johor, kepekatan uranium dan torium dalam air sungai masing-masing bernilai 0.33 µg l^{-1} – 1.40 µg l^{-1} dan 0.012 µg l^{-1} – 0.66 µg l^{-1} (Ramli et al, 2005). Di kawasan bekas kilang amang yang dikaji di Malaysia didapati kepekatan uranium dan torium di dalam air kolam masing-masing bernilai 27.7 µg l^{-1} - 110.5 µg l^{-1} dan 41.8 µg l^{-1} – 297.2 µg l^{-1} (Yusof et al, 2001). Nilai rujukan bagi air ialah 1 mBq kg^{-1}, 0.05 mBq kg^{-1} masing-masing untuk ^{238}U dan ^{232}Th (UNSCEAR, 2000).

Gas radon (^{220}Rn) dan gas toron (^{222}Rn) merupakan sumber sinaran alfa semulajadi yang terbesar. Satu pertiga daripada dos sinaran yang diterima manusia berpunca dari gas radon dan progeninya (Iacob, 2005). Di Malaysia nilai purata kepekatan radon di dalam rumah adalah 14 Bq m^{-3} dengan nilai maksimumnya 20 Bq m^{-3}, dan kepekatan setara keseimbangan (EEC) bagi toron adalah 0.5 Bq m^{-3} dalam julat 0.3 Bq m^{-3} – 1.8 Bq m^{-3} (UNSCEAR, 2000). Had yang dibenarkan oleh Lembaga Pelesenan Tenaga Atom (LPTA) bagi masing-masing radon dan toron adalah 400 mWL thn^{-1} dan 1200 mWL thn^{-1} (Akta, 1984).

Dos sinaran berpotensi mendatangkan kesan kesihatan terhadap penduduk setempat (Wilson, 1993). Sekecil mana dos sinaran mempunyai kebarangkalian untuk menyebabkan mudarat (Martin, et.al. 1986, Peterson, 1993). Tubuh secara tabii mempunyai toleransi terhadap dos sinaran berjumlah kecil yang terdapat di alam ini. Walau bagaimanapun ada aktiviti manusia seperti pelepasan sisa radioaktif, pemrosesan amang, dan aktiviti dalam bidang penjanaan tenaga nuklear yang dapat meningkatkan aras dos sinaran sehingga berpotensi menimbulkan kesan terhadap kesihatan. Kesan yang mungkin timbul bergantung kepada jumlah dos sinaran yang diterima (Ramli, 1993).

Dalam penyelidikan ini, dos sinaran gama daratan dianggarkan secara statistic berdasarkan kepada hubungan diantara dos sinar gama daratan dengan jenis tanah dan latar belakang geologi di suatu kawasan berdasarkan kesahihan hasil data secara statitik. Penyelidikan ini akan menganggarkan kesan dos sinar gama daratan terhadap kesihatan penduduk di kawasan dos sinaran tinggi di Negeri Perak. Aras keradioaktifan semulajadi pada tumbuh-tumbuhan, di dalam air dan di udara umumnya dilakukan secara rawak. Kajian yang lebih terperinci dilakukan di kawasan dos sinaran gama daratan yang tinggi, seperti kawasan Kampung Sungai Durian yang mempunyai bacaan tertinggi 1039 nGy j^{-1}, atau lebih dari 18 kali ganda bacaan purata dunia iaitu 57 nGy j^{-1} Dos berkesan kepada manusia dianggarkan berdasarkan kepada dedahan yang meliputi dos sinaran luar (daratan dan kosmik) dan dos sinaran dalam (air, tumbuh-tumbuhan dan udara) di dalam dan di luar rumah.

A.1.2. Sinaran Daratan

Sumber sinaran tabii dipermukaan bumi berasal dari bahan radioaktif semulajadi yang disebut radionuklid primordial. Keradioaktifan ini dapat ditemui pada lapisan tanah atau batuan, air serta udara. Ada terdapat sekitar 60 jenis radionuklid semula jadi dengan 25 daripadanya mempunyai tempoh setengah hayat yang setara umur bumi (Enge, 1966). Salah satu daripada radionuklid primodial ialah uranium. Uranium wujud sebagai mineral dalam kerak bumi dengan kadar 3-4 gram dalam 1 ton batuan. Kepekatan uranium dalam batuan granit adalah paling tinggi berbanding dengan batuan lainnya. Ini menyebabkan tingginya bacaan dos sinaran pada kawasan ber batuan granit.

Anggota siri uranium terutamanya ^{226}Ra dan ^{238}U dan siri torium ^{228}Th mempunyai taburan yang paling meluas di alam sekitar. Selain daripada anggota siri radioaktif di atas ^{40}K juga merupakan radionuklid semulajadi yang mempunyai taburan yang meluas di alam sekitar. Kepekatan purata kalium dalam batuan bumi adalah 27 mg kg^{-1}, dilautan sekitar 380 mg l^{-1}, dan dalam tanaman dan haiwan termasuk manusia 1.7 g kg^{-1} (Cember, 1983).

A.1.3. Keradioaktifan di kerak bumi

Bumi (Stokes *et al*. 1978), terdiri dari 3 bahagian, iaitu: teras, mantel, dan kerak bumi. Kerak bumi ber ketebalan 5 hingga 50 km. Kerak bumi berhubungan terus dengan litosfera. Litosfera adalah bahagian yang pejal, rapuh dan secara relatifnya sejuk, dimana ketebalannya adalah 50 hingga 100 km di bawah kerak bumi. Kajian yang telah dilakukan menunjukan bahawa keradioaktifan tersebar secara tidak merata di seluruh isi padu kerak bumi dan litosfera. Keadaan ini berkaitan dengan struktur dan latar belakang geologi bumi (Kogan et al. 1969)

A.1.4 Keradioaktifan pada batuan igneus.

Batuan igneus adalah batuan yang terbentuk oleh haba (Holmes, 1965; Stokes *et al*., 1978). Ketika letupan gunung berapi berlaku, cecair panas yang dikenal sebagai magma melintasi permukaan bumi semakin lama semakin menyejuk dan segara membeku sehingga membentuk batuan igneus. Batuan igneus diklasifikasikan berdasarkan kepada komposisi mineral. Termasuk ke dalam klasifikasi ini antara lain ialah : granit, riolit, sianit, trakit, fonolit, monsonit, latit, granodiorit, diorit kuarza, andesit, gabro, basalt, diolerit, peridotite, obsidian, dan batu apung.
Kepekatan unsur radioaktif pada batuan igneus bergantung kepada kuantiti silikatnya. Kepekatan uranium, torium, dan kalium di dalam batuan berbeza disebabkan oleh faktor di atas. Batuan berapi yang lebih dikenal secara umum sebagai batuan granit memiliki kandungan ^{238}U yang tinggi (Wedepohl, 1969 dan Levesque *et al*. 1997). Disamping uranium batuan ini diperkayakan pula oleh torium, sehingga akibatnya terjadi peningkatan kepekatan keradioaktifan yang disebabkan oleh pereputan siri uranium dan siri torium (Yasuaka and Shinogi, 1997).

A.1.5. Keradioaktifan pada batuan mendapan.

Batuan mendapan terdiri dari butiran halus yang merupakan hasilan dari pecahan dan penghuraian batuan igneus (Stokes *et al*., 1978). Butiran halus ini biasanya dipindahkan oleh air, angin, atau ais ke lokasi baru, kemudian diendapkan dalam struktur yang baru sebagai kerikil, pasir, atau tanah lempung. Salah satu sifat dari batuan mendapan adalah terdapatnya pelapisan. Pengendapan bahan batuan sedimen berlaku melalui dua cara, iaitu pengendapan dengan cara pengelompokan mineral dan proses kimia. Mineral paling banyak terdapat pada batuan mendapan ialah kuarza, feldspar, kalsit, dan tanah lempung.

Kepekatan uranium dan torium pada batuan mendapan berbeza-beza. Serpihan batu dan lempung memiliki keradioaktifan yang tinggi, sementara batu pasir memiliki keradioaktifan yang lebih rendah. Torium adalah bahan yang tidak mudah larut, bahan ini tertinggal pada batuan debrit atau menjadi mineral tambahan (monazit, zirkon, apatit, xenotim, dan lain-lain), atau dipindahkan oleh aliran air. Pengumpulan endapan seperti di atas kadang kala menyebabkan tingginya kepekatan torium pada bijih aluvial. Kepekatan unsur radioaktif pada batuan endapan bergantung kepada jarak dari sumber basuhan (Kogan *et al*., 1971). Jadual A.1.1. menunjukkan konsentrasi tersebut dari U, Th, dan K pada batuan endapan.

Jadual A.1.1 Kepekatan uranium, torium dan kalium pada batuan endapan (Kogan et al., 1971)

Jenis batuan	U 10^{-4} %	Th 10^{-4} %	K, %	Th/U
Syal dan tanah liat	4.0	11.0	3.2	2.8
Batu pasir	3.0	10.0	1.2	3.3
Batu kapur	1.4	1.8	0.3	1.3
Evaporites (halite, anhydrite, gipsum)	0.1	0.4	0.1	4.0

A.1.6. Keradioaktifan di dalam Tanah

Tanah dibentuk oleh pengaruh tenaga matahari di lapisan permukaan bumi melalui saling tindak dengan bahan organik yang mereput dan hilangnya butiran mineral dari batuan induk akibat kesan iklim. Berbagai jenis tanah yang sama terdapat di kawasan yang memiliki iklim yang sama walaupun berasal dari sumber batuan yang berbeza (Rich dan Kunze, 1964).

Keradioaktifan di tanah bergantung kepada komposisi mineral (Klein dan Hurlbut 1985). Proses formasi tanah menentukan kepekatan keradioaktifan pada tanah. Nilai purata dos sinaran latar belakang di permukaan bumi dinyatakan oleh Suruhanjaya Antarabangsa untuk Perlindungan Radiologi (ICRP, 1991) sebagai bernilai 80 nGy j^{-1}. Terdapat beberapa kawasan yang mempunyai aras latar belakang dos sinaran yang tinggi walaupun jenis tanah secara amnya sama dengan kawasan lain.

Tanah yang mempunyai aras dos sinaran yang tinggi biasanya disebabkan oleh beberapa mineral seperti monazit (Radhakrishna *et al.*, 1993, Brazilian Academy of Science, 1977, Narayana et al., 1995). Bacaan yang tinggi mungkin juga disebabkan oleh sumbangan bahan dari gunung berapi sebagaimana yang terdapat di wilayah Minas Gerias, Brazil (Roser dan Cullen, 1964), aras dos sinaran di sisni mungkin setinggi 2.1 μGy j^{-1}.

Keradioaktifan di dalam tanah akan tersebar pada tumbuh-tumbuhan, air dan udara dan seterusnya memasuki tubuh manusia melalui penyedutan udara dan penelanan makanan (Simon, 1998). Untuk melindungi manusia dari kesan dos sinaran aras tinggi maka perlu dilakukan kajian dos sinaran semulajadi pada pelbagai jenis tanah. Bonazzola *et al*. (1993) telah mengkaji proses pemindahan endapan ^{137}Cs dan Ruthenium ^{106}Ru pada tanah di Italy, selepas tragedi Chernobyl. Hasil kajian mendapati lebih dari 95% kontaminasi tanah oleh radionuklid berlaku pada ketebalan 5 cm.

Di Malaysia telah dilakukan kajian mengenai hubung kait di antara jenis tanah dan bacaan dos sinar gama daratan semulajadi. Dari kajian tersebut didapati bahawa jenis tanah nitosol yang berasal dari batuan igneus mempunyai bacaan dos sinaran yang secara relatifnya tinggi, dan tanah gambut pula mempunyai bacaan yang umumnya lebih rendah dari bacaan bagi tanah jenis-jenis lain.

A.1.7. Pernyataan Masalah

Berdasarkan jenis tanah dan geologi yang terdapat di negeri Perak di jangkakan beberapa kawasan akan mempunyai bacaan dos sinar gama daratan yang tinggi. Kawasan-kawasan ini perlu dikenal pasti dan potensi kesannya terhadap kesihatan perlu ditinjau. Kajian ini juga dilakukan dalam konteks untuk melihat secara perbandingan kemungkinan kesan industri amang yang terdapat terutamanya di daerah Kinta berbanding dengan dos sinaran yang terdapat secara tabii.

A.1.8. Hipotesis

Ramli, 1997; Quindos. et al, 1994; Malanca, et al, 1993, telah mengkaji hubungan diantara dos sinaran gama daratan semula jadi dengan jenis tanah dan latar belakang geologi. Berdasarkan kaedah adanya suatu kesamaan struktur geologi dan jenis tanah di Semenanjung Malaysia (H_o: μ_o=μ_x) maka dos sinaran gama daratan semula jadi bagi berbagai jenis tanah dan latar belakang geologi dapat dianggarkan. Penjangkaan dan penganggaran dos ini dapat menjimatkan masa kajian terutama bagi kawasan yang sukar untuk dicapai.

Dos sinaran gama daratan mempunyai potensi untuk memberi kesan kesihatan kepada penduduk. Kajian ini juga coba meramalkan kesan kesihatan akibat dari sinar gama daratan semula jadi yang bernilai tinggi.

A.1.9. Skop Kajian

Penyelidikan merangkumi seluruh negeri Perak yang mempunyai keluasan 21,005 km^2 terletak di antara garis lintang (longitud) 100^o 22' T sehingga 101^o 45' T dan di antara garis membujur (latitud) 3^o 40' U hingga 5^o 56' U. Negeri Perak terbagi kepada 10 daerah (Jabatan Perangkaan Malaysia, 2003) iaitu Batang Padang (keluasan 2,712 km^2), Manjung (1,171 km^2), Kinta (1,958 km^2), Kerian (958 km^2), Kuala Kangsar (2,541 km^2), Larut dan Matang (1,349 km^2), Hilir Perak (1,728 km^2), Hulu Perak (6,563 km^2), Perak Tengah (746 km^2) dan Selama (795 km^2).

Kajian ini mengkhusus kepada tinjauan dos sinaran gama daratan semula jadi berdasarkan kepada jenis tanah dan latar belakang geologi. Analisis perbandingan dan ujian kesahihan dilakukan secara statistik berdasarkan cerapan terhadap beberapa sampel di lokasi kajian. Kajian sumbangan dos sinaran semulajadi yang meliputi dos sinaran luaran dan dos sinaran dalaman serta kajian terhadap keradioaktifan di dalam air, tumbuh-tumbuhan, radon dan toron dilakukan bagi kawasan yang mempunyai bacaan dos sinaran gama daratan yang tinggi.

A.1.10. Objektif Kajian

Penyelidikan ini bertujuan membina pengkalan data taburan dos sinar gama daratan semula jadi untuk rujukan bagi tujuan kesihatan dan keselamatan radiologi bagi negeri Perak. Kajian juga meliputi perkara berikut :

1. Membina data jangkaan dos sinar gama daratan berdasarkan maklumat jenis tanah dan latar belakang geologi.
2. Mengenal pasti kawasan yang mempunyai aras dos sinar gama daratan yang tinggi.
3. Menguji kesahihan data jangkaan secara statistik, dan dengan melakukan pencerapan di lapangan.
4. Membina sebuah peta isodos bagi sinar gama daratan sebagai rujukan untuk tujuan kesihatan dan keselamatan radiologi alam sekitar.
5. Mengenal pasti kepekatan radionuklid bagi jenis tanah dan latar belakang geologi di kawasan kajian.
6. Menganggarkan kesan kesihatan terhadap penduduk di kawasan yang mempunyai dos sinar gama daratan yang tinggi.

A.1.11. Kepentingan Kajian

Diantara kepentingan kajian ini ialah :

a. Menghasilkan kaedah baru yang dapat mengurangkan masa kerja lapangan dengan menggunakan kaedah statistik.
b. Menyediakan data rujukan kandungan radionuklid dan hubungannya dengan jenis tanah dan latar belakang geologi di negeri Perak.
c. Hasil survei dos sinaran gamma juga boleh digunakan bagi tujuan carigali mineral.

BAB A. II

LATAR BELAKANG STATISTIK

A.2.1. PENGENALAN

Analisis statistik dapat menghasilkan maklumat berkaitan dengan hubungan diantara jenis tanah, latar belakang geologi dan aras dos sinaran semulajadi. (Wallo et al., 1993). Dalam kajian ini pembuktian hipotesis telah dilakukan dengan menggunakan kaedah analisis variasi (ANOVA) dengan membandingkan lebih dari dua faktor diantara berberapa bolehubah (Moris and Fraley, 1994; Levesque et al., 1997; Ramli et al., 2003). Hasil kajian menunjukkan bahawa ada hubungan yang signifikan di antara jenis tanah dan latar belakang geologi berbanding dengan bacaan dos sinar gama daratan. Ujian T bagi membandingkan nilai min untuk setiap jenis tanah telah dilakukan untuk membandingkan dapatan statistik bagi kawasan-kawasan di negeri Johor, Melaka dan Perak. Dalam menggunakan kaedah ANOVA, proses normalisasi data telah dilakukan (Montgomery 1991; Ramli et al, 2001). Ujian bagi menentukan kenormalan bagi masing-masing data dari jenis-jenis tanah, latar belakang geologi dan kedua-duanya sekali, telah dilakukan dengan menggunakan persamaan kepencongan α_3 (persamaan 2.1) dan persamaan kurtosis α_4 (persamaan 2.2)

$$\alpha_3 = \frac{\frac{1}{N}\sum_{i,j=1}^{N}(X_{i,j} - \mu)^3}{\sigma^3} \qquad (2.1)$$

$$\alpha_4 = \frac{\frac{1}{N}\sum_{i,j=1}(X_{i,j} - \mu)^4}{\sigma^4} \qquad (2.2)$$

dengan X_i = data cerapan jenis tanah *i* dan geologi *j*,

σ = sisihan piawai,

μ = min data bagi seluruh cerapan dos sinar gama daratan.

A.2.2. Analisis variasi bagi jenis tanah, latar belakang geologi dan dos sinar gama daratan

Pengaruh jenis tanah dan latar belakang geologi terhadap dos sinar gama daratan ditentukan dengan membandingkan aras dos sinaran gama daratan dengan berbagai jenis tanah dan latar belakang geologi. Dalam memperbandingkan, sangat penting diketahui variasi yang dihasilkan dari berbagai jenis tanah (*S*) dan latar belakang geologis (*G*), serta variasi yang disebabkan oleh kesalahan rawak dari pengukuran. Oleh kerana kesemua jenis tanah dan latar belakang geologi di negeri Perak dipilih dari berbagai keadaan secara rawak maka setiap jenis tanah dan latar belakang geologi dianggap sebagai bolehubah rawak. Oleh kerana pengukuran bacaan dos sinar gama daratan dilakukan secara rawak maka adalah lebih tepat sekiranya digunakan kaedah pengklasifikasian satu arah (*one way classification method*) yang memisahkan pengukuran yang berbeza sehingga diperolehi komponen variasi yang dapat dinilai (Montgomery 1991; Bechofer 1995 ; Walpole, 1982).

Hipotesis nul (H_o) digunakan untuk menentukan sama ada wujud perbezaan yang signifikan atau tidak di antara nilai min dos sinar gama daratan dari berbagai jenis tanah dan latar belakang geologi yang berbeza. Ujian hipotesis null secara tepat dilakukan untuk mengelompokan jenis tanah berdasarkan kewujudan nilai min bacaan sinar gama daratan dengan menggunakan analisis variasi (Morris dan Fraley, 1994). Dalam prosedur ini, pengamatan dilakukan dengan menggunakan suatu nilai khusus sebagai sebuah faktor. Jenis tanah (*S*) dan latar belakang geologi (*G*) adalah faktor yang saling terpisah, yang akan dibandingkan dengan bacaan sinar gama daratan. Model ANOVA satu arah ditunjukkan oleh persamaan 2.3

$$\left\{\begin{matrix} dij = \mu + (S)_i + \varepsilon_{ij} \text{ untuk berbagai jenis tanah } (i = 1,2,3,.......) \\ dij = \mu + (G)_i + \varepsilon_{ij} \text{ untuk berbagai jenis geologi } (i = 1,2,3,.......) \end{matrix}\right\} \quad (2.3)$$

dengan d_{ij} = sejumlah pengamatan ke-*i* dari dos sinar gama dalam berbagai jenis tanah atau latar belakang geologi *j*,

μ = nilai min keseluruhan,

$(S)_i$ dan $(G)_i$ = kesan jenis tanah dan latar belakang geologi terhadap bacaan sinar gama daratan,

ε_{ij} = bolehubah rawak yang menunjukkan perbezaan di antara pengukuran dos sinaran gama daratan pada jenis tanah dan latar belakang geologi yang sama, andaian yang digunakan dalam model ini ialah ε_{ij} dianggap bertaburan secara normal (Montgomery, 1991).

Dengan menggunakan model matematik berdasarkan persamaan di atas, variasi dari pengukuran secara rawak terhadap dos sinar gama daratan dapat dianalisis. Parameter *(S)i* atau *(G)i* dan ε_{ij} menyumbang secara separa terhadap hasil tambah kuasa dua (*total sum of squares*) dari setiap pengukuran dos (Montgomery, 1991). Hasil tambah kuasa dua (*SS*) secara berasingan dapat dinyatakan oleh persamaan 2.4. dengan SS total (SS_T) = SS antara kelompok (SS_G) + *SS* dalam kelompok (SS_T),

$$\begin{Bmatrix} SS_T = SS_S + SS_\varepsilon \ untuk\ berbagai\ jenis\ tanah \\ SS_T = SS_G + SS_\varepsilon \ untuk\ berbagai\ jenis\ geologi \end{Bmatrix} \quad (2.4)$$

A.2.3. Perbezaan antara jenis tanah dan latar belakang geologi

Oleh kerana pengukuran dos sinaran gama daratan dilakukan secara rawak dan tidak sama bagi setiap jenis tanah dan latar belakang geologi, maka kaedah yang digunakan adalah ANOVA satu arah tak seimbang (Montgomery, 1991). Ujian telah dilakukan untuk menentukan sama ada dos sinar gama daratan nilai min berbeza atau tidak bagi suatu jenis tanah yang sama berbanding dengan latar belakang geologinya. Hipotesis terhadap nilai min pengukuran dos sinaran gama daratan untuk setiap jenis tanah dan latar belakang geologi diuji dengan menggunakan analisis variasi. Ujian yang digunakan ialah:

$$H_o : \mu_1 = \mu_2 = \mu_3 = ...\mu_a \quad (2.5)$$

Ha : $\mu_i \neq \mu_j$ untuk sekurang-kurangnya satu pasangan.

persamaan (2.5) dapat ditulis dalam bentuk persamaan 2.6 dan 2.7 dengan H_o dan H_1 masing-masing mewakili hipotesis nul dan hipotesis alternatif.

$$\left\{\begin{array}{l} H_o = (S)_1 = (S)_2 = (S)_3 = ...(S)_a = 0 \\ H_1 = (S)_i \neq 0 \; untuk \; sekurangnya \; satu \; pasangan \; i, j \end{array}\right\} bagi \; berbagai \; jenis \; tanah \quad (2.6)$$

$$\left\{\begin{array}{l} H_o = (G)_1 = (G)_2 = (G)_3 = ...(G)_a = 0 \\ H_1 = (G)_i \neq 0 \; untuk \; sekurangnya \; satu \; pasangan \; i, j \end{array}\right\} bagi \; berbagai \; latar \; belakang \; geologi \quad (2.7)$$

Analisis menentukan apakah variasi pengukuran dipengaruhi oleh jenis tanah atau latar belakang geologi. Sekiranya hipotesis nul bernilai positif, ertinya setiap nilai min bacaan adalah sama dan pengaruh jenis tanah dan latar belakang geologis tidak wujud.

Besar perbezaan bacaan dos sinaran gama daratan akibat kesan jenis tanah atau latar belakang geologi, dapat ditentukan dengan menggunakan statistik F (Montgomery, 1991; Lui et al. 1996), iaitu nisbah di antara nilai min dos sinar gama kuasa dua antara kelompok jenis tanah dan atau latar belakang geologis dengan nilai min dos sinar gama daratan kuasa dua dalam kelompok. Persamaan F ditulis seperti berikut :

$$F_{df\ antara\,(v_1),\, df\ dalam\,(v_2)} = \left[\frac{(SS_{antara})/(df_{antara})}{(SS_{dalam})/(df_{dalam})}\right] x \, \frac{\chi^2_{v1}}{\chi^2_{v2}} \quad (2.8)$$

$$F_{v_1,v_2} = \left[\frac{MS_{antara}}{MS_{dalam}}\right] \qquad (2.9)$$

dengan, df = darjah kebebasan,

MS = nilai min kuasa dua,

v_1 dan v_2 menyatakan darjah kebebasan

χ^2_{v1} dan χ^2_{v2} menyatkan taburan kuasa dua chi dengan darjah kebebasan v_1 dan v_2.

Apabila nilai F berada pada had kepercayaan yang khusus yang lebih besar dari suatu nilai genting (F_α), maka hipotesis nul akan ditolak. Jadual berikut membina nilai ANOVA untuk suatu faktor tunggal,

Jadual A.2.1. Binaan nilai ANOVA untuk suatu faktor tunggal

Punca Variasi	Darjah kebebasan (df)	Hasil tambah kuasa dua (SS)	Min kuasa dua (MS)	F
Antara kelompok	a - 1	SS_{antara}	MS_{antara}	MS_{antara}/MS_{dalam}
Dalam kelompok	n - a	SS_{dalam}	MS_{dalam}	
Jumlah	n - 1	SS_{total}		

dengan a = Jumlah jenis tanah dan/atau latar belakang geologi,

n = Jumlah seluruh pengukuran dos sinar gama daratan.

A.2.4. Perbandingan antara kesan jenis tanah dan latar belakang geologi

Sekiranya hipotesis nul ditolak, maka ujian seterusnya perlu dilakukan. Ujian ini penting dilakukan untuk mengetahui jenis tanah atau latar belakang geologi manakah yang berbeza antara satu dengan yang lain. Terdapat berbagai ujian yang boleh digunakan untuk menentukan hubungan ini, antaranya ialah kaedah Tukey, kaedah Newman-Keuls, kaedah Baru Ujian Pelbagai Julat Duncan (*Duncan's New Multiple Range Test*), dan kaedah Scheffe. Setiap ujian ini berguna bagi beberapa keadaan. Ujian yang paling popular ialah Ujian Perbezaan Paling Tak Signifikan (*Least Significant Difference*, LSD) karena kemudahannya, iaitu hanya menggunakan sifir "t" . Ujian LSD juga berguna bagi menganalisis data yang berbeza saiz sampelnya.

Dalam ujian LSD, perbandingan dibuat di antara setiap pasang dos min d_i dan d_j. Persamaan untuk ujian ini ditulis seperti berikut (Montgomery, 1991) :

$$LSD = t_{\frac{\alpha}{2}, n\text{-}a} \sqrt{MS_{\varepsilon} \left[\frac{1}{n_i} + \frac{1}{n_j} \right]} \qquad (2.10)$$

dengan t = statistik t

α = aras kepercayaan (α = 0.05),

n = jumlah keseluruhan populasi,

a = jumlah antara kelompok,

MS_{ε} = min kuasa dua dalam kelompok,

n_i dan n_j adalah nilai cerapan dos sinar gama daratan ke-i dan ke-j pada suatu jenis tanah dan latar belakang geologi.

Apabila selisih nilai min dos sinaran gama pada jenis tanah ke-i dan/atau latar belakang geologi ke-i dan nilai min dos sinaran gama daratan pada jenis tanah ke-j dan/atau latar belakang geologi ke-j lebih besar dari LSD, maka dapat disimpulkan bahwa nilai min populasi μ_i dan μ_j pada keadaan ke-i dan keadaan ke-j untuk jenis tanah dan/atau jenis geologi adalah berbeza, yakni

$$\left| d_i - d_j \right| > LSD \qquad (2.11)$$

A.2.5. Hipotesis berdasarkan jenis tanah di berbagai negeri di semenanjung Malaysia

Ramli, 1997; Quindos, et al, 1994; Malanca, et al, 1993, telah melakukan kajian mengenai hubungan antara dos sinar gama daratan semula jadi dengan jenis tanah dan latar belakang geologi. Berdasarkan andaian adanya kesamaan jenis tanah dan latar belakang geologi di Semenanjung Malaysia (H_o: $\mu_o=\mu_x$) maka dos sinaran gama daratan semula jadi bagi jenis tanah dan latar belakang geologi tertentu dapat dijangkakan. Penggunaan dos jangkaan ini dapat menjimatkan masa kerja lapangan terutama bagi kawasan yang sangat sukar untuk dicapai.

Nilai jangkaan dapat dianggarkan dengan menggunakan persamaan berikut,

$$X_i \cap Y_i \ , \quad (i = 1,2,3, \ldots\ldots) \quad , \tag{2.12}$$

$$X_i = \bar{x}_i \pm \sqrt{\frac{n\sum x^2 - \left(\sum x\right)^2}{n\left(n-1\right)}} \quad , \tag{2.13}$$

$$Y_i = \overline{y_i} \pm \sqrt{\frac{n\sum y^2 - \left(\sum y\right)^2}{n(n-1)}} \quad , \tag{2.14}$$

dengan :

X = Bacaan dos sinaran gama daratan di negeri Johor

Y = Bacaan dos sinaran gama daratan di negeri Melaka

x, y = Bacaan dos sinaran gama daratan pada satu titik tertentu

i = Jenis tanah atau latar belakang geologi di suatu kawasan

n = Jumlah cerapan

Selanjutnya bagi jenis tanah yang sama digunakan persamaan :

$$Xi \cap Yi \cap Zi \ , \quad (i = 1,2,3, \ldots\ldots) \tag{2.15}$$

dengan :

Z = Bacaan dos sinaran gama daratan di negeri Perak

Ujian hipotesis nul untuk masing-masing jenis tanah, latar belakang geologi dan kedua-duanya sekali dilakukan dengan menggunakan ujian t dua hala.

A.2.6. Ujian statistik bagi berbagai jenis tanah dan latar belakang geologi

Ujian hipotesis nul untuk berbagai jenis tanah dan latar belakang geologi dilakukan dengan menggunakan persamaan berikut ,

Ho : Adanya kesamaan nilai min bagi jenis tanah dan atau latar belakang geologi di negeri Perak (μ_{si}) dan negeri-negeri lain di semenanjung Malaysia (μ_{sj}).

$$Ho : \mu_{si} = \mu_{sj} \tag{2.16}$$

$$Ha : \mu_{si} \neq \mu_{si}$$

dengan μ_i : min dos sinar gama daratan bagi jenis tanah atau latar belakang geologi s yang dicerap di kawasan i

μ_j : min dos sinar gama daratan bagi jenis tanah atau latar belakang geologi s di negeri-negeri di kawasan j

Pembuktian menggunakan prosedur ujian t (*pooled t procedure*) bagi data cerapan digunakan kerana data yang diambil bersifat rawak (Kitchens, 2003). Sekiranya diandaikan bahawa variasi dari masing-masing populasi adalah sama, persamaan bagi ujian t boleh ditulis seperti berikut :

$$t_{ij} = \frac{\mu_i - \mu_j}{s_{ij}\sqrt{\frac{n_i n_j}{n_i + n_j}}} \tag{2.17}$$

dengan ,

$$s_{ij} = \sqrt{\frac{(n_i - 1).s_i^2 + (n_j - 1).s_j^2}{n_i + n_j - 2}} \tag{2.18}$$

dan,

$$s_i^{\ 2} = \frac{\sum (x-\mu_i)^2}{N-1} \qquad (2.19)$$

dengan,

` t_{sij} = ujian t bagi jenis tanah s di kawasan i dan kawasan j.

μ_{si} = nilai min cerapan pada tanah s di kawasan i

μ_{sj} = nilai min cerapan pada tanah s di kawasan i

n_{si} = jumlah data cerapan pada tanah s di kawasan j

$_{si}$ = jenis tanah s di kawasan i iaitu di Perak

$_{sj}$ = jenis tanah s di negeri Johor dan Melaka

ss_i = sisihan piawai data cerapan tanah s di kawasan i

ss_j = sisihan piawai data cerapan tanah s di kawasan j

x = data cerapan di titik x

N = jumlah data cerapan bagi tanah s

Hipotesis nul diterima jika taburan bagi nilai t berada dalam julat $-t_{\alpha/2} < t < t_{\alpha/2}$, sebaliknya hipotesis nul ditolak.

A.2.7. Penentuan julat keyakinan bagi setiap jenis tanah, latar belakang geologi dan kedua-duanya di negeri Perak

Julat keyakinan pada masing-masing jenis tanah, latar belakang geologi dan kedua-duanya ditentukan berdasarkan kepada persamaan :

$$(\mu_1 - \mu_2) \pm t_{\frac{\alpha}{2},\gamma} . s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \qquad (2.20)$$

Perisian SPSS (*Statistical Package for social science*) digunakan untuk menafsir, menilai dan menganalisis data statisitk yang terlibat. (Ogiu et al, 1997).

BAB A III

METODOLOGI

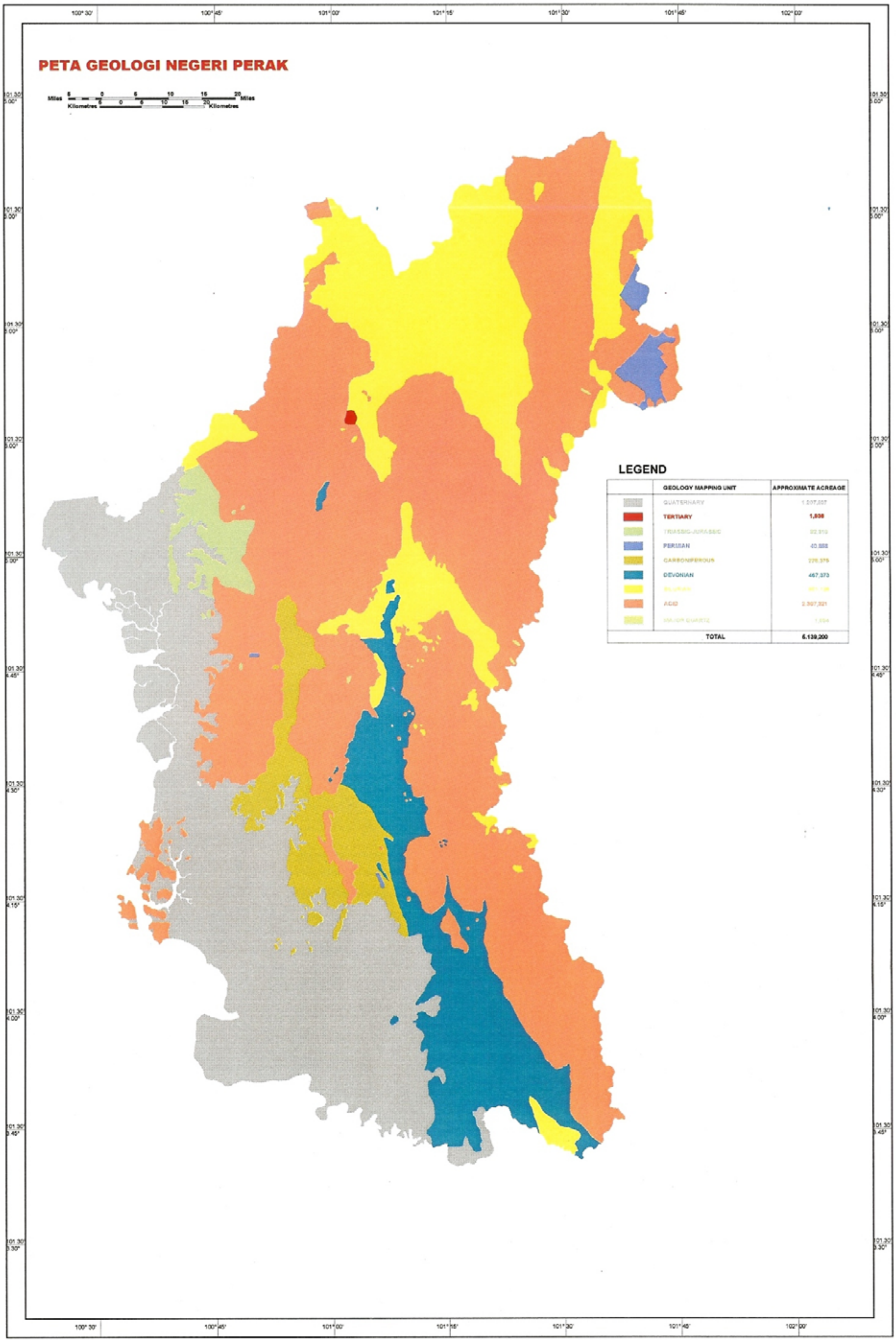
Metodologi yang digunakan boleh dibahagikan kepada dua, iaitu kajian yang berdasarkan kepada data dos sinar gama daratan, dan kajian terhadap kesan kesihatan kepada penduduk yang tinggal dikawasan dos sinaran gama daratan tinggi. Metodologi kajian dapat diringkaskan seperti berikut :

A 3.1. Kajian Dos Sinaran Gama Daratan

Kajian dos sinar gama daratan dilakukan dengan menggunakan tiga kaedah iaitu kaedah jangkaan, kaedah cerapan dilapangan serta analisis sampel di makmal dan kaedah analisis statistik.

A 3.2. Kaedah Jangkaan

Jangkaan dos sinar gama daratan semula jadi di semua lokasi dianggar berdasarkan kepada maklumat peta jenis tanah Semenanjung Malaysia (Jabatan Pertanian Malaysia,1968), *Schematic Reconnaissance Soil Map* Perak (Pengarah Pemetaan Malaysia, 1970), Peta Kajibumi Semenanjung Malaysia (Pengarah Penyiasatan Kajibumi, 1988), Peta Sumber-Sumber Mineral Negeri Perak Semenanjung Malaysia (Jabatan Penyiasatan Kaji Bumi, Ipoh, 1979), Peta topografi bagi negeri Perak (Pengarah Pemetaan Negara, 1989), kajian-kajian dos sinar gama daratan di negeri Johor dan Melaka. Maklumat geologi diberi dalam Jadual A3.1. dan Rajah A3.1. yang merupakan peta geologi negeri Perak

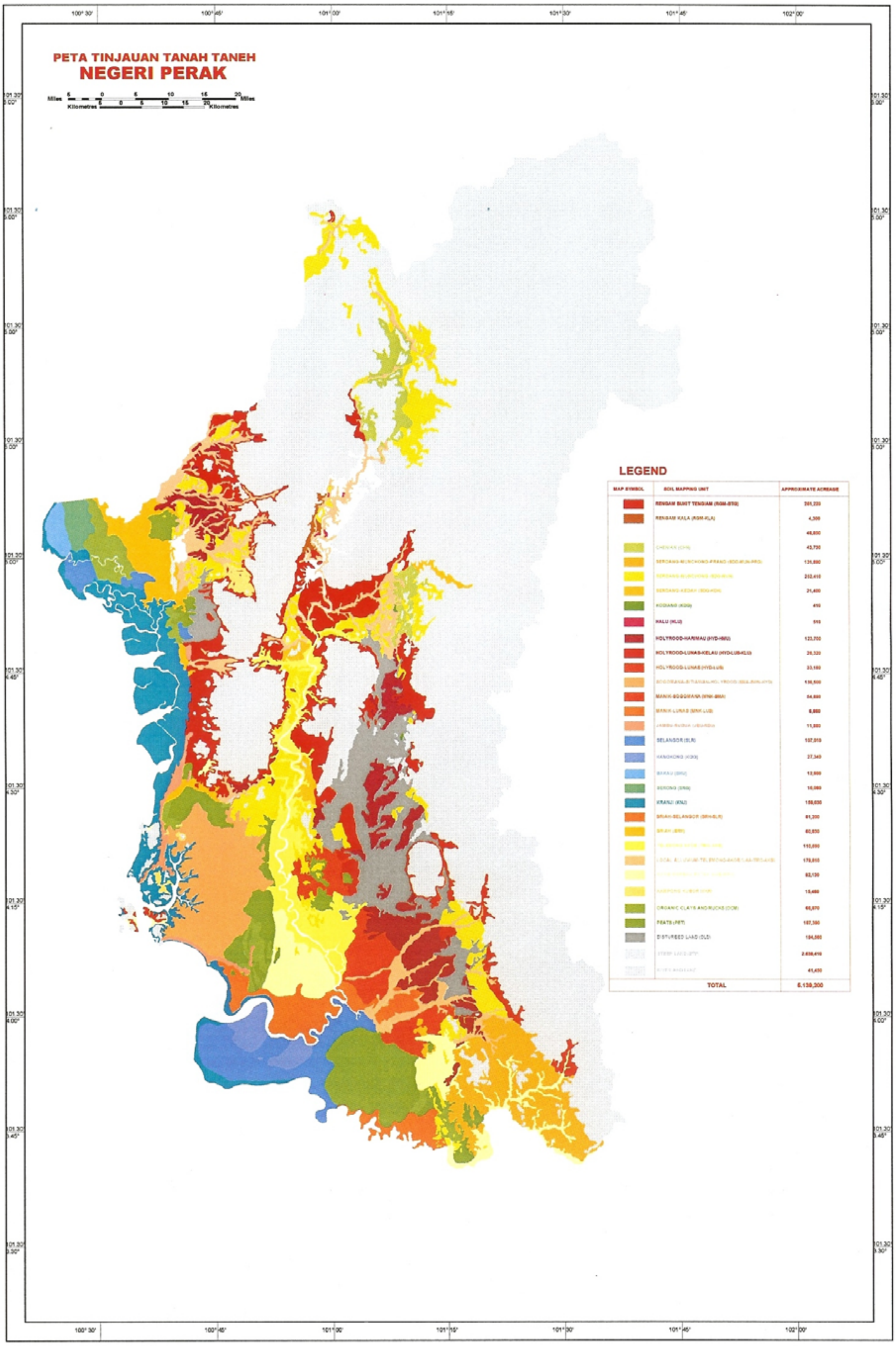


Rajah A 3.1. Peta geologi negeri Perak

Jadual A 3.1. Latar belakang geologi negeri Perak

Jenis Geologi	Luas km^2	Masa (tahun)	Komposisi
Kuatenari	4,940	~3 juta	batuan Lumpur, tanah liat, kelodak, tanah gambut, batuan kawasan sungai, kerikil dan pasir
Trias - Jura	737	~225 juta	batuan granit biotit, riolit, batu pasir, batu kapur, lekahan dan syal
Permian	167	~270 juta	tuf, tuf lapili, konglomerat berasid, volcano riolit, batu pasir, syis (Permian awal)
Karbon ferrous	934	~350 juta	Phylite, shale, batu pasir, slate,
Devon	1,887	~400 juta	Batuan lemstone, berpasir, konglomerat, dan beberapa batuan volcano
Silures	3,277	~435 juta	batuan schist, shale, phyllite, slate , dan limestone. Beberapa kawasan batuan pasir dan volkanik.
Batuan rejahan	9,437	~500 juta	batuan igneus ber asid dan granit, batuan ini berasal daripada pembekuan magma yang sangat lama

Berdasarkan Jadual A3.1 dan Rajah A3.1, 52 % keluasan negeri Perak terdiri dari batuan rajahan yang merupakan batuan igneus berasid dan bergranit yang lazimnya menghasilkan bacaan dos sinaran semula jadi yang lebih tinggi, kerana batuan jenis ini lebih kaya uranium dan torium. Oleh itu hampir sebahagian besar kawasan di negeri Perak berpotensi menghasilkan bacaan dos sinar gama daratan semulajadi yang secara relatif lebih tinggi. Maklumat jenis tanah tanih juga boleh memberikan jangkaan dos sinaran latar belakang semula jadi. Jenis tanah taneh di negeri Perak diberi dalam Jadual A3.2. dan Rajah A3.2.



Rajah A 3.2 Peta tanah taneh negeri Perak

Jadual A 3.2. Jenis tanah tanih di negeri Perak

Nama Tanah	Luas km^2	Jenis Tanah	Kawasan
Jambu-Rudua	49	Tanah lanar (aluvium)	Dataran pinggir laut
Bakau	53	Tanah lanar	Dataran pinggir laut
Kranji	650	Tanah lanar	Dataran pinggir laut
Serong	558	Tanah lanar	Dataran pinggir laut
Selangor	438	Tanah lanar	Dataran pinggir laut
Briah-Selangor	332	Tanah Lanar	Dataran pinggir laut dan atau dataran mendap sungai
Briah	249	Tanah Lanar	Dataran pinggir laut dan atau dataran mendap sungai
Tanah liat organik dan kapur	273	Tanah Lanar	Dataran pinggir laut dan atau dataran mendap sungai
Tanah gambut	766	Tanah Lanar	Dataran pinggir laut dan atau dataran mendap sungai
Akob-Merbau Patah	336	Tanah Lanar	Dataran mendap sungai dan atau teres-teres sungai rendah
Kampong Kubor	63	Tanah Lanar	Dataran mendap sungai dan atau teres-teres sungai rendah
Aluvia Tempatan -Telemong-Akob	736	Tanah Lanar	Dataran mendap sungai dan atau teres-teres sungai rendah
Telemong-Akob	453	Tanah Lanar	Dataran mendap sungai dan atau teres-teres sungai rendah
Manik-Lunas	28	Tanah Lanar	Teres-teres perantaraan sungai dan tinggi
Manik-Sogomana	225	Tanah Lanar	Teres-teres perantaraan sungai dan tinggi
Sogomana-Sitiawan-Holyrood	66	Tanah Lanar	Teres-teres perantaraan sungai dan tinggi
Holyrood-Harimau	506	Tanah Lanar	Teres-teres perantaraan sungai dan tinggi
Holyrood-Lunas	136	Tanah Lanar	Teres-teres perantaraan sungai dan tinggi
Holyrood-Lunas-Kelau	108	Tanah Lanar	Teres-teres perantaraan sungai dan tinggi
Serdang-Munchong	1,032	Tanah asal	Dataran alun tanah tinggi-rendah
Serdang-Munchong-Prang	539	Tanah asal	Dataran alun tanah tinggi-rendah
Serdang-Kedah	88	Tanah asal	Dataran alun tanah tinggi-rendah

Nama Tanah	Luas km^2	Jenis Tanah	Kawasan
Chenian	179	Tanah asal	Dataran tanah tinggi-rendah dan berbukit rendah
Kala	200	Tanah asal	Dataran tanah tinggi-rendah dan berbukit rendah
Rengam-Kala	18	Tanah asal	Dataran tanah tinggi-rendah dan berbukit rendah
Rengam-Bukit Temiang	1,068	Tanah asal	Dataran tanah tinggi-rendah dan berbukit rendah
Tanah curam (*Steep Land*)	10,791	Tanah asal	Diatas bukit dan gunong
Tanah terganggu	796	Tanah Bandar dan Lombong	Tanah Bandar dan Lombong

Dari Jadual A3.2 dan Rajah A3.2. dapat dilihat bahawa 51 % keluasan negeri Perak terdiri dari tanah curam yang berada pada kawasan bukit dan gunung. Di negeri Perak terdapat juga tanah jenis Rengam (*Haplic Acrisol [FAO/UNESCO]*) dan Bukit Temiang (*Ferric Acrisol*) yang bahan induknya adalah granit. Biasanya bacaan dos sinaran semula jadi pada tanah jenis ini adalah lebih tinggi, sebagai contoh, sebagaimana yang dijumpai di Palong, Johor di mana bacaannya lebih dari 18 kali ganda nilai purata dunia.

Berdasarkan maklumat jenis mineral, latar belakang geologi, jenis tanah, topografi dan maklumat dari survey udara (Agoes dan Paton, 1959), dijangkakan ada kawasan bacaan dos sinar gama daratan tinggi di negeri Perak.

A 3.3. Cerapan

Pengukuran dilapangan dilakukan secara rawak dan dengan memberikan fokus kepada kawasan yang dijangkakan mempunyai bacaan dos sinaran yang tinggi. Perhatian khusus juga diberikan kepada kawasan yang mempunyai jenis tanah dan latar belakang geologi yang belum dikaji. Bacaan dos sinaran gama daratan dilakukan 1 meter di atas permukaan tanah dengan menggunakan alat pengesan sintilasi sinar gama NaI (Tl) bersaiz 2.54 cm x 2.54 cm model 19 *Micro R meter Ludlum*. Alat ini dapat mengesan sinar gama yang bertenaga di antara 50 keV sampai 1200 keV (Ludlum, 1993). Alat ini menggunakan skala pengukuran dos dalam mikrorontgen se jam ($\mu R\ j^{-1}$).

Data cerapan merupakan nilai min dari beberapa bacaan pada setiap titik. Penentuan kedudukan geografi dilakukan menggunakan alat GPS (*Geographical Positioning by Satelite*) model GARMEN 45. Pencerapan telah dilakukan dari Januari 2004 sehingga Disember 2006. Sebanyak 2390 Bacaan telah diperolehi. Disamping itu sebanyak 156 sampel tanah telah di ambil untuk analisis kepekatan keradioaktifan unsur uranium, torium dan kalium menggunakan spektrometri gama. Beberapa sampel tumbuh-tumbuhan dan air turut diambil, sampel ini dianalisis menggunakan kaedah Analisis Pengaktifan Neutron (APN). Beberapa pengukuran aras radon dan toron juga turut dilakukan, terutamanya di kawasan bacaan dos sinaran gama daratan tinggi.

A 3.4. Ujian kenormalan data

Ujian kenormalan taburan bagi semua data dilakukan dengan menggunakan persamaan kurtosis dan skwenes, yang telah diberikan sebelum ini (persamaan 2.1 dan 2.2.). Hasil ujian kenormalan juga dipersembahkan dalam bentuk histogram Rajah 3.3.

A 3.5. Ujian Statitik

Ujian hipotesis bagi membuktikan hubungan jenis tanah, latar belakang geologi dan dos sinaran gama daratan dilakaukan dengan kaedah ANOVA, t test sebagaimana yang telah dijelaskan dalam Bab II (Latar Belakang Statistik).

A 3.6. Analisis kepekatan radionuklid uranium, torium dan kalium

Analisis sampel tanah dilakukan untuk mengenal pasti kepekatan radionuklid uranium, dan torium pada tumbuh-tumbuhan dan air dilakukan dengan menggunakan kaedah Analisis Pengaktifan Neutron. Pengukuran kepekatan radionuklid dalam tanah digunakan dengan kaedah spektrometri gama, penyedian sampel piawai dan analisis sampel dengan menggunakan kaedah spektrometri gama, dihuraikan dalam laporan kinta.

A3.6.1. Sampel Piawai

Sampel piawai bagi uranium dan torium menggunakan larutan U-Th yang mempunyai jisim ~0.20 g dan kepekatan 100 ppm uranium dan 98 ppm torium. Terdapat empat sampel rujukan piawai iaitu IAEA-312 (~0.20 g), SL-1 (~0.10 g), soils-7 (~0.20 g) dan soils-5 (~0.10 g). Kesemua sampel piawai yang digunakan mempunyai sijil sah oleh International Atomic Energy Agency (IAEA). Nilai hasil ujikaji diperolehi dengan melakukan perbandingan dengan nilai sebenar yang diberikan oleh sijil IAEA di atas.

A 3.6.2. Penyinaran Sampel

Sampel yang telah diproses dimasukkan ke dalam reaktor nuklear TRIGA Mark II yang mempunyai kuasa 750 kW. Untuk analisis kandungan uranium dan torium sampel tanah dan bahan piawai disinari secara serentak di dalam reaktor nuklear selama 6 jam pada fluks neutron 3 x10^{12} n cm^{-1} s^{-1}. Selanjutnya sampel disejukkan selama 4 hari.

A 3.6.3. Pengukuran kepekatan radionuklid uranium, dan torium dalam sampel tumbuh-tumbuhan dan air.

Penentuan kepekatan uranium, torium dan kalium dalam sampel tanah dilakukan melalui perbandingan keaktifan piawai dan keaktifan sampel. Pengiraan kandungan radionuklid di dalam sampel ditentukan menggunakan persamaan.

$$C_{smp} = M_{std} \cdot \left(\frac{PA_{smp}}{PA_{std}}\right) \cdot \left(\frac{CT_{std}}{CT_{smp}}\right) \cdot \left(\frac{DC_{smp}}{DC_{std}}\right) \cdot \left(\frac{1}{m_{smp}}\right) \mu g\ g^{-1} \qquad (3.1)$$

$$DC = eks\,(\lambda\,\Delta t) \qquad (3.2)$$

dengan ,

C_{smp} = Kepekatan unsur ujikaji
M_{std} = Kandungan unsur dalam sampel piawai (µg)
PA_{smp} = Luas di bawah puncak foto sampel ujikaji
PA_{std} = Luas di bawah puncak foto sampel piawai
CT_{smp} = Masa pembilangan bagi sampel uji kaji (s)
CT_{std} = Masa pembilangan bagi sampel piawai (s)
DC_{smp} = Pembetulan masa reputan sampel ujikaji
Dc_{std} = Pembetulan masa reputan sampel piawai
Ms_{mp} = jisim sampel ujikaji.
Δ = pemalar reputan
Δt = Tempoh diantara masa akhir penyinaran dan masa pembilangan.

A 3.6.4. Ujian kebolehpercayaan

Ujian t dilakukan untuk membolehkan kesimpulan dibuat samaada taburan kepekatan sampel tanah dengan taburan kepekatan sampel piawai berada dalam bentuk taburan yang sama.

$$t = \frac{|A - B|}{\sqrt{(a^2 + b^2)}} \qquad (3.3)$$

Secara statistik A dan B berada dalam bentuk taburan yang sama jika nilai t $\leq$ 2

A 3.7. Membina Peta Isodos.

Peta isodos dibina dengan menggunakan perisian GIS (*Geological Information System*) Arc View. Kaedah Kriging digunakan untuk melakar unjuran kontur isodos sinar gama daratan tabii di negeri Perak. Lakaran isodos yang terhasil kemudiannnya dilaraskan kembali secara manual dengan mengambil kira maklumat yang diketahui mengenai hubungan aras dos sinar gama daratan dengan jenis tanah, latar belakang geologi, topologi dan bacaan aras dos sebenar. Langkah-langkah yang diambil untuk membina peta isodos diringkaskan sepeti berikut :

a. Pengumpulan dan pengenal pastian data cerapan, yang kemudiannya dimasukan ke dalam peta negeri Perak.
b. Peta jenis tanah, latar belakang geologi, peta isodos melalui kaedah kriging serta data dugaan secara statistik ditindahkan bagi menganggar sempadan setiap julat dos sinar gama daratan yang telah ditentukan.
c. Berdasarkan kepada kajian Ramli, 2001, . garis kontur isodos yang digunakan adalah seperti berikut:20 nGy j^{-1},50 nGy j^{-1}, 100 nGy j^{-1}, 150 nGy j^{-1}, 200 nGy j^{-1}, 300 nGy j^{-1}, 400 nGy j^{-1}, 600 nGy j^{-1}, 800 nGy j^{-1}, dan 1000 nGy j^{-1}.

A 3.8. Tinjauan kesan kesihatan dos sinaran semulajadi di negeri Perak.

Selain daripada sumbangan dos sinar gama daratan kesan sinaran turut di sumbang oleh gas radon dan toron yang masuk ke dalam tubuh melalui penyedutan, dan bahan radionuklid yang ditelan melalui permakanan dan peminuman.Dos sinaran keseluruhan merupakan sumbangan dari sinaran luaran dan sinaran dalaman. Oleh itu untuk menganggar dos terhadap manusia disamping maklumat mengenai sinar gama daratan perlu juga dikatahui sumbangan dos dari proses penyedutan udara, pengambilan air dan aras keradioaktifan yang terdapat pada tumbuh-tumbuhan yang menjadi bahan makanan.

A 3.8.1. Dos berkesan sinaran gama daratan

Untuk menganggar dos berkesan sinar gama daratan telah digunakan faktor penukaran bernilai 0.7 Sv Gy^{-1} (UNSCEAR 2000). Dos berkesan tahunan dinyatakan oleh persamaaan,

$$E\ (\text{mSv y}^{-1}) = \textit{Dose rate}\ (\text{nGy h}^{-1}) \times 24\ \textit{jam} \times 365\ \textit{hari} \times Fk \times 0.7 \times 10^{-6} \quad (3.4)$$

Berdasarkan bahwa pekerja ladang umumnya bekerja sekita 6 jam sehari, 6 hari seminggu dan 50 minggu setahun maka diperkiraan faktor waktu bekerja (*Fk*) adalah 21 % setahun atau faktor 0.21 bagi perkiraan dos sinar gama daratan di luar rumah dan 0.79 bagi dos sinar gama daratan di dalam rumah. Anggaran kesan kesihatan kepada manusia yang diakibatkan oleh dos sinaran gama daratan merupakan jumlah dos berkesan di dalam dan diluar rumah.

A 3.8.2. Dos berkesan sumbangan tumbuh-tumbuhan dan air

Dos berkesan sumbangan tumbuh-tumbuhan dan air dianggar dari persamaan, berikut (Peterson, 1998, Badran, 2003, Pulhani, 2005):

$$E\ (\text{mSv y}^{-1}) = U \times C \times D_{fac} \quad (3.5)$$

Dengan ;

U = Kadar pengambilan air atau tumbuh-tumbuhan (kg thn^{-1} bagi tumbuh-tumbuan atau kg L^{-1} bagi air).

C = Kepekatan radionuklid di dalam tumbuh-tumbuhan atau air (Bq kg^{-1} atau Bq l^{-1})

D_{fac} = Faktor pertukaran dos bagi orang dewasa (μSv Bq^{-1}) : 4.50×10^{-8} Sv Bq^{-1}, 2.30×10^{-7} Sv Bq^{-1} masing-masing bagi ^{238}U dan ^{232}Th (ICRP, 1996, UNSCEAR, 2000)

A 3.8.3. Dos berkesan sumbangan radon dan toron

Dos berkesan akibat kemasukan radon dan toron gas ke dalam tubuh manusia, dianggar menggunakan faktor penukaran yang diberi oleh UNSCEAR 2000, nilainya ialah 9 nSv j^{-1} per Bq m^{-3} dan 40 nSv j^{-1} per Bq m^{-3} masing-masing bagi ^{222}Rn dan ^{220}Rn. Untuk menganggar dos berkesan tahunan, E (mSv setahun) telah digunakan persamaan berikut, (UNSCEAR, 2000)

$$E_{Rn222} = C_{Rn222} \text{ x } 8760 \text{ h y}^{-1} \text{ x } 0.6(\text{EEC}) \text{ x } 9 \text{ nSv per Bq h m}^{-3} (\text{EEC}) \text{ x } Fk \quad (3.6)$$

$$E_{Rn220} = C_{Rn220} \text{ x } 8760 \text{ h y}^{-1} \text{ x } 0.6(\text{EEC}) \text{ x } 40 \text{ nSv per Bq h m}^{-3} (\text{EEC}) \text{ x } Fk \quad (3.7)$$

dengan C_{Rn222} = kepekatan gas radon dalam unit Bq m^{-3}

C_{Rn220} = kepekatan gas toron dalam unit Bq m^{-3},

Fk = faktor waktu bekerja dengan menggunakan nilai 0.21 bagi penyedutan yang berlaku di luar rumah dan 0.79 bagi penyedutan yang berlaku di dalam rumah

A 3.8.4. Anggaran Kesan Kesihatan Radiologi

Kesan kesihatan radiologi dianggarkan menggunakan persamaan berikut (Alvarez, 1997, Jibiri, 2001) :

$$\hat{R}_i = aH_E \quad (3.9)$$

dengan $\hat{R}_i$ = kesan kesihatan

a = faktor kesan kesihatan yang bernilai 0.04 per sievert bagi pekerja sinaran dan 0.05 per sievert bagi orang awam untuk dos sinar gama daratan di udara (ICRP 60, 1990),

H_E = dos berkesan. yang diterima (mSv).

BAB A IV

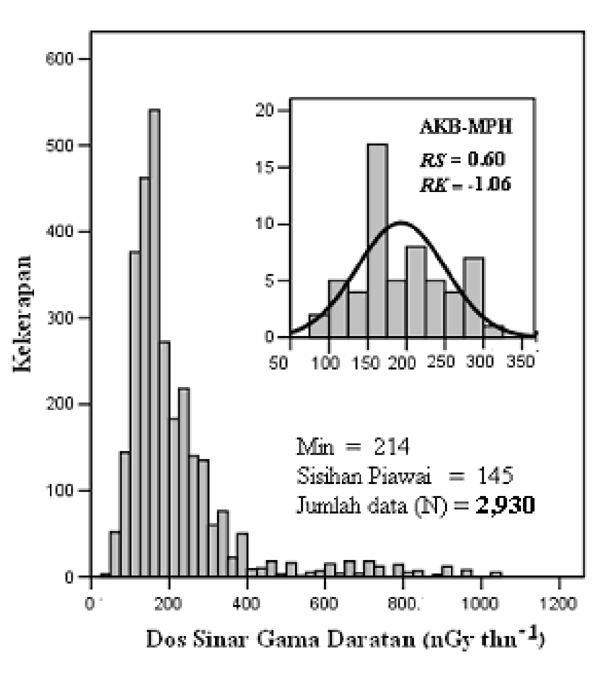
KEPUTUSAN DAN RUMUSAN

A 4.1. Keputusan

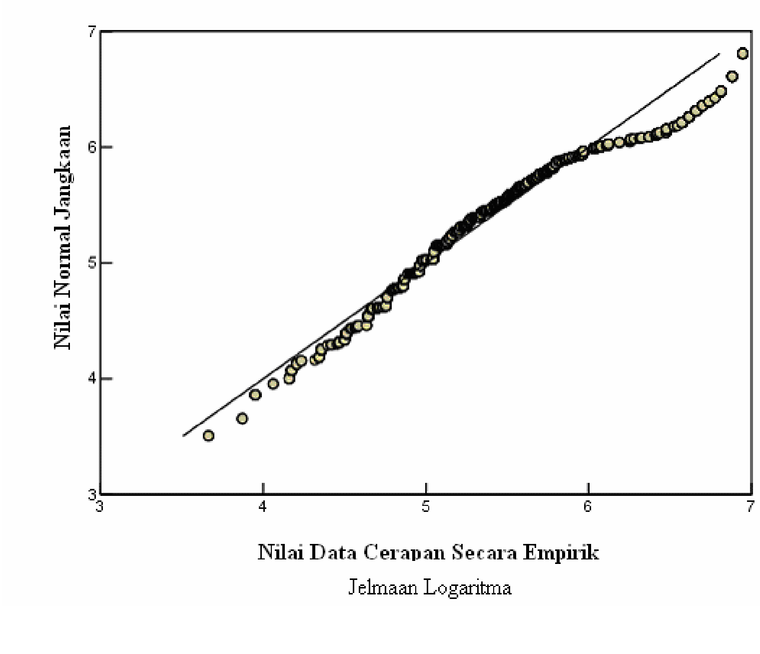
A 4.1.1. Dos Sinar Gama Daratan Semula Jadi di Negeri Perak

Terdapat 31 jenis tanah di negeri Perak (*Schematic Reconnaissance Soil Map* Perak, Pengarah Pemetaan Malaysia, 1970) dan 8 jenis latar belakang geologi (Peta Kajibumi Semenanjung Malaysia, Pengarah Penyiasatan Kajibumi, 1988), tumpuan pencerapan telah diberikan kepada kawasan yang mempunyai aras dos sinar gama daratan yang tinggi berdasarkan maklumat jenis tanah dan latar belakang geologi. Ada Beberapa data daripada jenis tanah dan latarbelakang geologi telah tidak di analisis kerana data yang ada tidak mencukupi secara statistik disebabkan keluasan kawasan yang terlalu kecil, contohnya tanah yang berjenis Halu, Kodiang dan Manik-Lunas, dan berlatar belakang geologi Tertiari, dan Permian, yang masing-masingnya mempunyai keluasan kurang dari 1 % dari keluasan negeri Perak. Sebanyak 2,930 bacaan dos sinar gama daratan telah diambil dalam kajian ini. Rajah A4.1 menunjukan data dos sinar gama daratan yang dipaparkan dalam bentuk histogram, dan contoh data histogram yang diambil bagi tanah berjenis Akob Merbau Patah.

Kaedah lain yang digunakan untuk memudahkan ujian taburan data ialah lakaran kebarangkalian sebagaimana yang ditunjukan oleh kaedah lakaran Q-Q (*Q-Q plot*). Lakaran kebarangkalian normal bagi data kajian ini diberikan dalam Rajah A.4.2.



Rajah A4.1 Taburan data dos sinar gama daratan secara histogram dan sebuah sampel jenis tanah Akob Merbau Patah dengan garis normalisasinya di negeri Perak



Rajah A4.2. Lakaran Q-Q bagi taburan data dos sinar gama daratan di negeri Perak

Rajah A4.1. menunjukkan kekerapan bacaan data sinar gama daratan di negeri Perak melawan julat dos sinaran. Analisis terhadap data yang dicerap menunjukan semua data cerapan berada dalam julat normal iaitu pada nisbah kepencongan (*skewness ratio*) dan nisbah kurtosis (*kurtosis ratio*) yang berada dalam julat -2 hingga 2. Sebagai contoh bagi tanah jenis Akob - Merbau Patah (AKB-MPH) nilai nisbah kepencongan dan nisbah kurtosis masing-masingnya ialah 0.60 dan -1.60, oleh itu boleh dianggap bahawa data cerapan pada jenis tanah Akob Merbau Patah berada pada taburan normal.

Rajah A.4.2. menunjukkan bentuk hubungan nilai data normal yang dijangkakan melawan nilai data yang dicerap secara empirik berdasarkaan kepada transformasi logaritma tabii (*natural logarithm transformation*), jika data merupakan taburan normal. Kebanyakan titik berada hampir dengan garis lurus rujukan, oleh itu dapat disimpulkan bahawa data dos sinaran gama daratan yang dicerap berada dalam taburan normal. Data yang menyimpang daripada garis lurus plot kebarangkalian merupakan data yang berada di luar kelompok (*outlayer*). Dari hasil pengamatan didapati ada terdapat sejumlah data bacaan yang berada diluar daripada nilai normal secara purata bagi dos sinar gama daratan di negeri Perak. Data di luar kelompok terdapat pada kawasan bacaan dos yang tinggi dan kawasan yang bacaan dosnya sangat rendah. Data di luar kelompok ini tidak tersebar secara meluas iaitu kewujudannya terhad kepada kepada kawasan yang khusus.

Daripada data cerapan dos sinaran gama daratan, nilai min dos sinar gama daratan bagi negeri Perak ialah 214 ± 145 nGy j^{-1}. Dos sinar gama daratan terendah bernilai 39 nGy j^{-1} terdapat di kawasan tanah gambut yang berlatar belakang kuaternari di dapat di daerah Hilir Perak, Kinta, Perak Tengah dan Kerian. Kadar dos sinaran gama daratan tertinggi bernilai 1039 nGy j^{-1}. Ianya berada dikawasan tanah berbukit, dan berjenis tanah Renggam dan Bukit Temiang dengan latar belakang granit berasid, bacaan tinggi ini terdapat di darah Kinta. Nilai dos sinar gama daratan di negeri Perak secara keseluruhan diberikan dalam Jadual A.4.1

Jadual A 4.1. Nilai min dos sinaran gama daratan di daerah-daerah di negeri Perak

Daerah	N	Min nGy j^{-1}	Ralat Piawai	95% aras kepercayaan Had bawah	95% aras kepercayaan Had atas	Minimum	Maksimum
Batang Padang	212	179	53	172	186	78	348
Hilir Perak	92	191	82	174	208	38	382
Kuala Kangsar	149	252	99	236	268	104	609
Kerian	140	149	35	143	155	77	295
Kinta	1419	223	185	214	233	38	1039
Larut Matang	187	207	86	195	220	58	522
Manjung	175	216	77	205	228	52	609
Perak Tengah	192	187	80	175	198	48	649
Selama	141	273	133	251	295	64	715
Hulu Perak	223	205	93	192	217	64	715
Negeri Perak	2930	214	145	209	219	38	1039
Bacaan Dunia (UNSCEAR, 2000)		57		18	93	8	1200

Nilai min terendah (92 ± 82) nGy j^{-1} bagi dos sinar gama daratan antara daerah-daerah terdapat di daerah Hilir Perak, tanah dikawasan ini terdiri dari tanah gambut dan Selangor, tanah ini selalunya berada di kawasan dataran pinggiran laut dan atau dataran mendap sungai di atas dataran pinggir laut. Termasuk dalam kelompok ini ialah jenis tanah Kranji, Bakau, Serong dan Briah. Jenis tanah tanih di atas sekiranya berlatar belakangkan batuan sedimen merupakan kawasan yang dos sinaran gamanya relatif rendah. Dos sinaran latar belakang bagi daerah-daerah dengan nilai min yang tertinggi (273±133) nGy j^{-1} terdapat di daerah Selama. Hampir 70 % daerah ini dilatarbelakangi oleh batuan bergranit dengan bahagian permukaannya dilitupi oleh tanah jenis Renggam Bukit Temiang dan tanah curam. Diperbandingkan dengan daerah Kinta, walaupun terdapat bacaan paling tinggi iaitu 1039 nGy j^{-1}, tapi secara keseluruhan kawasan ini hanya memberikan kontribusi kurang dari 2 % dibandingkan luasan keseluruhan daerah

Kinta, di daerah Kinta pula terdapat jenis tanah terganggu iaitu tanah lumbong dan tanah perkotaan yang telah banyak dibina bagi perumahan, jalan tar, sarana am, dan sebagainya. Sehingga dari keseluruhan bacaan pada kawasan Kinta lebih rendah dibandingkan bacaan dos sinaran gama daratan di daerah Selama maupun daerah Kuala Kangsar. Berikut adalah jadual bagi purata dos sinaran gama daratan berasaskan latar belakang geologi (Jadual A.4.2)

Jadual A 4.2. Purata dos sinar gama daratan berdasarkan latar belakang geologi di negeri Perak

Jenis Geologi	N	Min nGy j^{-1}	Sisihan Piawai	95% aras kepercayaan		Minimum	Maksimum
				Had bawah	Had atas		
Batuan rejahan	864	331	199	317	344	52	1039
Karbon ferrous	509	145	99	136	154	48	974
Devon	689	158	41	155	161	52	323
Kuatenari	577	189	66	184	195	38	522
Silures	215	172	62	163	180	64	435
Triasik-Jura	70	166	62	151	181	58	389
Negeri Perak	2930	214	145	209	219	38	1039

Nilai min tertinggi (331 ± 199) nGy j^{-1} bagi dos sinar gama daratan yang dilakukan pengukuran diperolehi pada kawasan yang berlatar belakang geologi batu rejahan ber asid, batu ini merupakan batuan igneus bergranit dan kaya uranium dan torium sebagaimana yang telah dijelaskan sebelum ini. Keputusan pengukuran dos sinar gama daratan bagi setiap jenis tanah di negeri Perak diberikan dalam Jadual A4.3.

Jadual A4.3. Purata dos sinar gama daratan berdasarkan jenis tanah di negeri Perak

Jenis Tanah	N	Min nGy j^{-1}	Sisihan Piawai	95% aras kepercayaan Had bawah	95% aras kepercayaan Had atas	Minimum	Maksimum
Jambu-Rudua	18	157	41	137	177	91	243
Bakau	9	147	15	136	158	117	156
Kranji	34	157	88	126	188	52	330
Serong	12	134	31	114	154	87	174
Selangor	43	143	37	132	155	75	226
Briah-Selangor	21	167	47	146	189	97	278
Briah	53	157	36	147	167	69	261
Tanah liat organik dan kapur	33	162	37	149	175	104	243
Gambut	82	164	104	141	187	38	747
Akob-Merbau Patah	58	193	57	178	208	78	313
Kampong Kubor	13	188	46	160	216	104	240
Lokal Alluvium-Telemong-Akob	143	212	68	200	223	103	389
Telemong-Akob	101	243	71	229	257	97	522
Manik-Sogomana	29	258	67	232	284	143	382
Sogomana-Sitiawan-Holyrood	67	242	42	231	252	139	313
Holyrood-Harimau	375	160	51	154	165	52	357
Holyrood-Lunas	75	249	253	191	308	64	909
Holyrood-Lunas-Kelau	36	204	68	181	227	91	348
Serdang-Munchong	193	150	75	139	160	48	624
Serdang-Munchong-Prang	51	172	44	159	184	97	278
Serdang-Kedah	20	160	81	123	198	78	330
Chenian	45	185	58	168	203	116	382
Kala	13	272	66	232	312	194	417
Rengam-Kala	8	236	91	160	312	116	365
Rengam-Bukit Temiang	517	329	243	308	351	52	1039
Tanah curam	311	260	118	247	273	64	715
Tanah terganggu	570	167	80	161	174	52	780
Total	2930	214	145	209	219	38	1039

Berdasarkan maklumat dari jenis tanah dan latar belakang geologi, di dapati bahawa nilai min dos sinar gama daratan tinggi iaitu diantara 260 nGy j^{-1} hingga 329 nGy j^{-1} berada pada tanah berjenis Rengam, Bukit Temiang, Kala, dan tanah curam. Tanah jenis tersebut kebanyakannya berlatar belakangkan batuan granit. Tanah jenis ini di negeri Perak meliputi 60 % dari keluasan negeri Perak. Kawasan berlatar belakang geologi batu rejahan dan batuan igneus mempunyai aras dos sinar gama daratan semulajadi yang paling tinggi. Bagi jenis tanah pula yang mempunyai aras dos sinar gama daratan terendah dengan nilai min didapati diantara 134 nGy j^{-1} hingga 157 nGy j^{-1} berada pada tanah berjenis Serong, Selangor, dan Briah. Jenis tanah tersebut di dapati di daerah lembahan sungai endapan. Secara statistik ada terdapat beberapa jenis tanah yang mempunyai sifat bacaan aras latar belakang sinar gama daratan yang berbeza satu dengan yang lainnya sebagaimana yang ditunjukkan dalam Jadual A.4.4. dengan nilai p < 0.05. Dari hasil ujian F didapati bahawa nilai ujian $F > F_{sifir}$, maka perbezaan terdapat pada dua atau lebih jenis tanah di negeri Perak atau terdapat perbezaan yang signifikan. Dari analisis statistik juga dapat disimpulkan bahawa ada jenis-jenis tanah yang mungkin mempunyai bacaan dos yang secara relatifnya sama. Dari Jadual A.4.5. dapat dilihat bahawa ada 4 kelompok jenis tanah yang masing-masing mempunyai julat aras dos sinar gama daratan yang relatifnya sama dengan aras keyakinannya 95 %.

Jadual A.4.4. Ujian ANOVA satu hala untuk melihat perbezaan dos sinar gama daratan di antara jenis tanah taneh di negeri Perak

.

Punca variasi	Jumlah kuasa dua	Darjah kebebasan df	Min kuasa dua	F	Signifikan p
Di antara kelompok	12267621	26	471832	28	0
Di dalam kelompok	48978897	2903	16872		
Jumlah	61246518	2929			

Jadual A4.5. Hasil ujian statistik *Post-Hoc* bagi mengenal pasti kelompok jenis tanah bersandarkan kepada nilai aras dos sinar gama daratan

Jenis Tanah	N	Subset bagi α = 0.05			
		1	2	3	4
Sogomana-Sitiawan-Holyrood	12	134			
Serdang-Munchong-Prang	43	143	143		
Bakau	9	147	147		
Serdang-Kedah	193	150	150	150	
Briah	53	157	157	157	
Jambu-Rudua	18	157	157	157	
Kranji	34	157	157	157	
Holyrood-Harimau	375	160	160	160	
Selangor	20	160	160	160	
Tanah liat organik dan batu kapur	33	162	162	162	
Tanah gambut	82	164	164	164	
Briah-Selangor	21	167	167	167	
Tanah terganggu	570	167	167	167	
Serdang-Munchong	51	172	172	172	
Chenian	45	185	185	185	
Kampong Kubor	13	188	188	188	
Akob-Merbau Patah	58	193	193	193	
Holyrood-Lunas-Kelau	36	204	204	204	
Lokal Alluvium-Telemong-Akob	143	212	212	212	
Rengam-Kala	8	236	236	236	236
Serong	67	242	242	242	242
Telemong-Akob	101	243	243	243	243
Holyrood-Lunas	75	249	249	249	249
Kala	13			272	272
Manik-Sogomana	29		258	258	258
Tanah curam	311		260	260	260
Rengam-Bukit Temiang	517				329
Signifikan (p)		0.102	0.093	0.052	0.104

Dari Jadual A 4.5. di atas dapat dilihat bahwa tidak terdapat perbezaan yang signifikan bagi aras sinar gama daratan beberapa jenis tanah kawasan pantai seperti Bakau, Briah, Jambu, Rudua dan Kranji, begitu juga bagi kumpulan tanah yang berlatar berlakang kan batuan granit seperti tanah curam, Kala, Rengam dan Bukit Temiang. Singkatnya tanah taneh sebegini boleh dikelompokan. Dalam Jadual A4.6. diberikan kod jenis tanah yang digunakan oleh Peta Tinjauan Tanah Taneh Semenanjung Malaysia 1968 yang dikeluarkan oleh Jabatan Pertanian Malaysia, 1968.

Jadual A4.6. Kod tanah negeri Perak berdasarkan Peta Tinjauan Tanah Taneh Semenanjung Malaysia, 1968.

Kod	Nama Tanah	Kawasan
S1	Jambu Rudua	Di atas dataran pinggir laut
S2	Keranji, Bakau	Diatas dataran pinggir laut
S4	Serong	Diatas dataran pinggir laut
S5	Selangor, Kangkong	Diatas dataran pinggir laut
S8	Briah	Diatas dataran pinggir laut dan atau dataran mendap sungai Diatas dataran pinggir laut
S9	Tanah liat organan dan tanah kapur	Diatas dataran pinggir laut dan atau dataran mendap sungai Diatas dataran pinggir laut
S10	Gambut	Diatas dataran pinggir laut dan atau dataran mendap sungai Diatas dataran pinggir laut
S11	Telemong, Akob, Merbau Patah, Kampung Kubor, tanah lanar tempatan	Diatas dataran mendap sungai dan atau teres sungai rendah
S16	Sogomana, Sitiawan, Manik	Diatas teres perantaraan sungai dan tinggi
S18	Holyrood, Lunas, Kelau	Diatas teres perantaraan sungai dan tinggi
S31	Serdang, Bungor, Munchong, Prang	Diatas dataran alun ka tanah tinggi-rendah
S41	Chenian	Diatas dataran tanah tinggi
S46	Serdang, Kedah	Diatas dataran tanah tinggi
S47	Rengam, Kala	Diatas dataran tanah tinggi
S48	Rengam, Bukit Temiang	Diatas dataran tanah tinggi
S49	Tanah curam	Diatas bukit dan gunung
S50	Tanah bandar	Tanah Bandar dan Lombong
S51	Tanah lombong	Tanah Bandar dan Lombong

Untuk menganalisis aras dos sinaran gama daratan bagi jenis tanah di negeri Perak berbanding dengan aras dos sinaran gama daratan bagi jenis tanah yang sama di negeri

Melaka dan Johor maka digunakan persamaan 2.12 sehingga 2.15. Dalam Jadual A.4.7 diberikan nilai min dos sinar gama daratan bagi setiap jenis tanah yang terdapat di negeri Johor dan Melaka..

Jadual A4.7. Min dos sinar gama daratan bagi setiap jenis tanah (Ramli, et. al. 2000)

JENIS TANAH	Kod Tanah[1)]	Min (nGy thn^{-1})	Julat Min	Negeri
Rudua-Rusila	1	82	17 – 200	Johor
Kranji	2	101	26 – 383	Johor
Linau-Sedu	3	129	70 – 322	Johor
Selangor-Kangkong	5	110	9 – 339	Johor
Beriah	8	146	44 – 365	Johor
Tanah liat organik dan Tanah kapur	9	124	9 – 400	Johor
Tanah gambut	10	59	9 – 400	Johor
Telemong Akob-Lokal Alumina	11	183	26 – 696	Johor
Holyrood Lunas	18	143	78 – 365	Johor
Harimau Tampoi	20	142	35 – 783	Johor
Batu Anam -Durian	21	234	52 – 809	Johor
Batu Anam-Melaka-Tavy	22	120	26 – 383	Johor
Marang -Apek	23	125	70 – 200	Johor
Melaka-Tavy-Gajah mati	25	122	78 – 226	Johor
Melaka-Durian-Munchong	26	131	26 – 217	Johor
Serdang-Bungor-Munchong	31	117	70 – 348	Johor
Rengam-Jerangau	32	206	35 – 696	Johor
Segamat-Katong	34	327	26 – 1262	Johor
Batang Merbau-Munchong	37	160	70 – 522	Johor
Kulai-Yong peng	43	129	35 – 322	Johor
Pohoi-Durian-Tavy	45	121	70 – 157	Johor
Tanah Churam	49	259	70 – 670	Johor
Tanah Bandar	50	170	26 – 435	Johor
Kranji	2	148	126 – 216	Malaka
Linau-Sedu	3	170	90 – 252	Malaka
Beriah	8	159	90 – 234	Malaka
Telemong Akob-Lokal Alumina	11	171	108 – 243	Malaka
Melaka-Tavy-Gajah mati	25	168	54 – 288	Malaka
Melaka-Durian-Munchong	26	162	54 – 324	Malaka

JENIS TANAH	Kod Tanah[1)]	Min (nGy thn^{-1})	Julat Min	Negeri
Durian-Malaka-Tavy	27	139	99 – 180	Malaka
Munching-Seremban	28	181	90 – 306	Malaka
Serdang-Bungor-Munchong	31	144	90 – 288	Malaka
Rengam-Jerangau	32	226	108 – 378	Malaka
Rengam-Tampin	33	233	198 - 288	Malaka
Tanah Churam	49	192	153 – 234	Malaka
Tanah Bandar	50	155	108 - 207	Malaka

[1)] Berdasarkan Peta Tinjauan Tanah Taneh Semenanjung Malaysia 1968 yang dikeluarkan oleh Jabatan Pertanian Malaysia

Berdasarkan Jadual A.4.6 dan A4.7, telah dikenal beberapa jenis tanah yang terdapat di negeri Melaka, negeri Johor dan atau negeri Perak sebagaimana ditunjukan pada Jadual A4.8. . Ketiga jenis tanah sebagai nilai rujukan bagi mengenal pasti nilai bacaan dos sinar gama daratan di Semenanjung Malaysia.

Jadual A 4.8. Jenis tanah yang terdapat di negeri Johor, Melaka dan Perak

Jenis Tanah	Kod Tanah	Johor		Melaka		Perak	
		Min	Julat min	Min	Julat min	Min	Julat min
Jambu-Rudua-Rusila	1	82	17 – 200			157	137 - 177
Keranji	2	101	26 – 383	148	126 – 216	157	126 - 188
Selangor-Kangkong	5	110	9 – 339			143	132 - 155
Beriah	8	146	44 – 365	159	90 – 234	157	147 - 167
Tanah liat organan dan tanah kapur	9	124	9 – 400			162	149 - 175
Gambut	10	59	9 – 400			164	141 - 187
Telemong-Akob-tanah lanar tempatan	11	183	26 – 696	171	108 – 243	212	200 - 223
Holyrood -Lunas	18	143	78 – 365			154	48 - 624
Serdang-Bungor-Munchong	31	117	70 – 348	144	90 – 288	154	48 - 624
Tanah curam	49	259	70 – 670	192	153 – 234	260	247 - 273
Tanah bandar	50	170	26 – 435	155	108 - 207	167	161 - 174

Seterusnya dengan menggunakan ujian t dapat dilihat hubungan di antara jenis tanah yang terdapat di negeri Perak dan yang terdapat di negeri Melaka dan Johor. Keputusan ujian t dan ujian z yang dilakukan diberi dalam Jadual A 4.9.

Jadual A 4.9. Keputusan ujian hipotesis nul bagi dos sinar gama daratan untuk berbagai jenis tanah di negeri Perak, Melaka dan Johor.

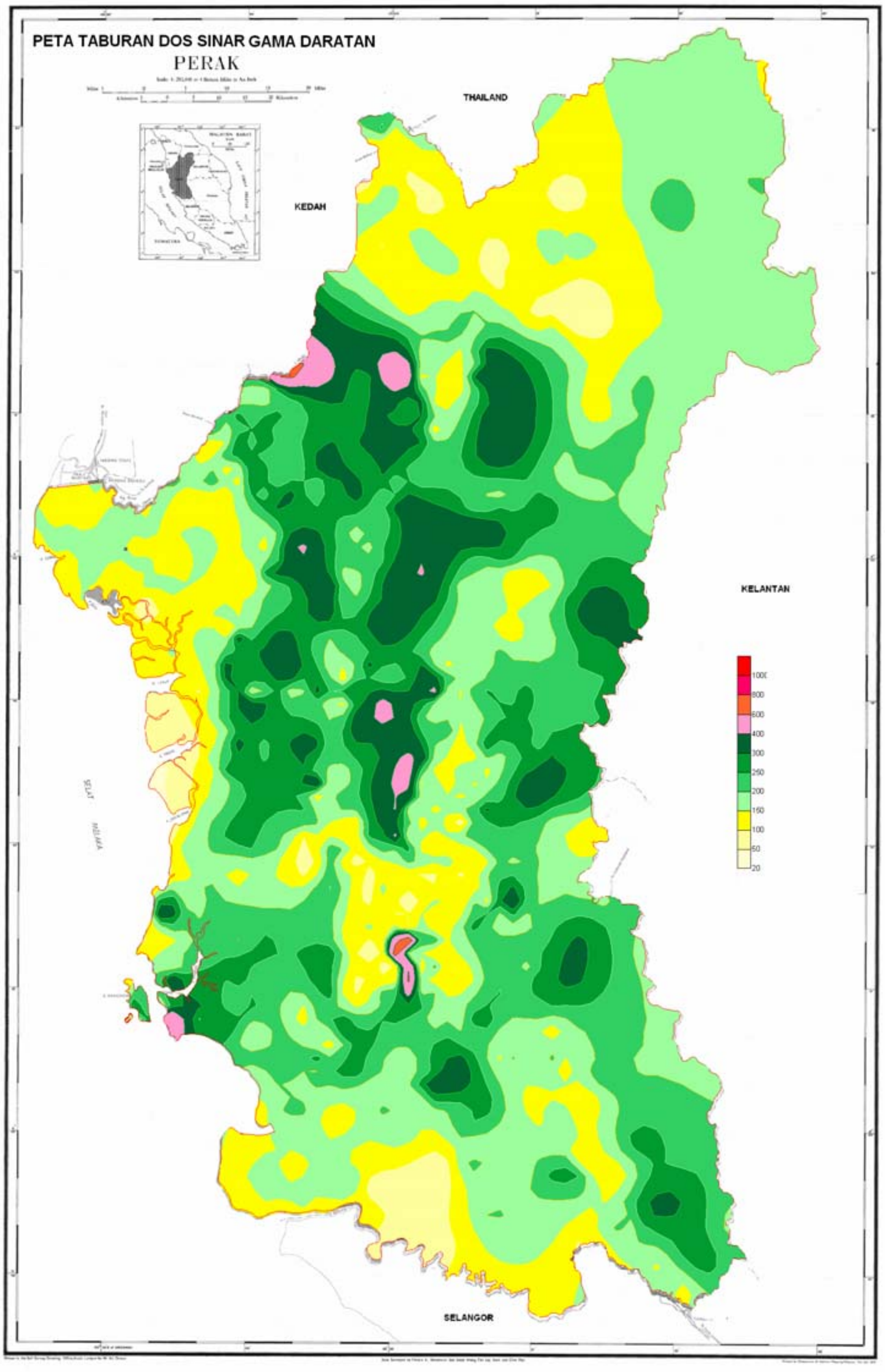
Jenis Tanah	Kod tanah	μ_o	μ_ξ	Ujian t atau z	Ho:μ_o=μ_x Aras keyakinan 95%
Jambu-Rudua-Rusila	1	157	154	0.21	diterima
Keranji	2	155	171	1.31	diterima
Selangor-Kangkong	5	144	143	0.25	diterima
Beriah	8	157	154	0.55	diterima
Tanah liat organan dan tanah kapur	9	162	152	1.78	diterima
Gambut	10	164	150	1.23	diterima
Telemong-Akob-tanah lanar tempatan	11	212	210	1.65	diterima
Holyrood -Lunas	18	176	170	1.31	diterima
Serdang-Bungor-Munchong	31	154	150	0.95	diterima
Tanah curam	49	260	192	16.15	ditolak
Tanah bandar	50	167	160	2.21	diterima

Nilai jangkaan (μ_x) berdasarkan adanya julat min yang sama di antara kawasan kajian.

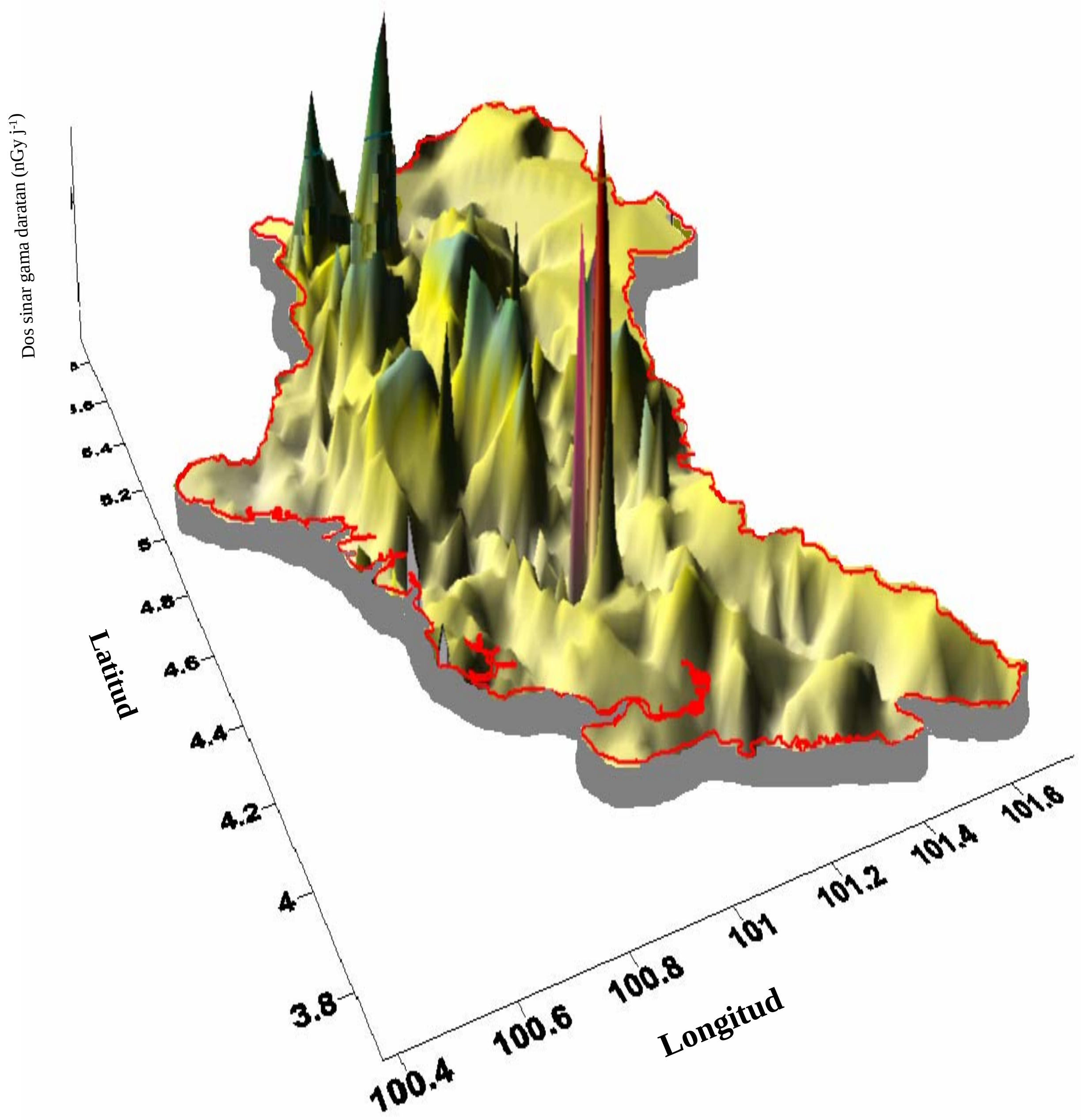
Keputusan hipotesis nul ujian t atau z bagi beberapa jenis tanah dapat diterima. Hasil ini menyatakan tidak ada perbezaan yang signifikan bagi jenis tanah yang sama di negeri Perak, Melaka dan Johor. Keputusan ini mungkin boleh diunjurkan sebagai sah bagi seluruh semenanjung Malaysia, dan oleh itu mungkin boleh digunakan untuk menganggarkan aras dos sinar gama daratan di seluruh Semenanjung Malaysia berdasarkan kepada maklumat jenis tanah dan latar belakang geologi. Untuk jenis tanah berkod 49, hipotesis nul di tolak dikarenakan terlalu jauhnya beza nilai min yang terdapat diantara negeri-negeri kajian (Jadual A.4.8). Ada beberapa jenis tanah di negeri Perak tidak terdapat di negeri Melaka dan Johor. Oleh itu dapatan kajian ini merupakan dapatan awal. Contohnya jenis tanah Chenian yang mempunyai nilai min 185 nGy j^{-1} (168 nGy j^{-1} – 203 nGy j^{-1}), Manik Sogomana (258 nGy j^{-1}, 232 nGy j^{-1} – 284 nGy j^{-1}), Kampong Kubor (188 nGy j^{-1}, 160 nGy j^{-1} – 216 nGy j^{-1}), Rengam-Bukit Temian (329 nGy j^{-1}, 308 nGy j^{-1} – 351 nGy j^{-1}) dan sebagainya.

A 4.1.2. Peta Isodos

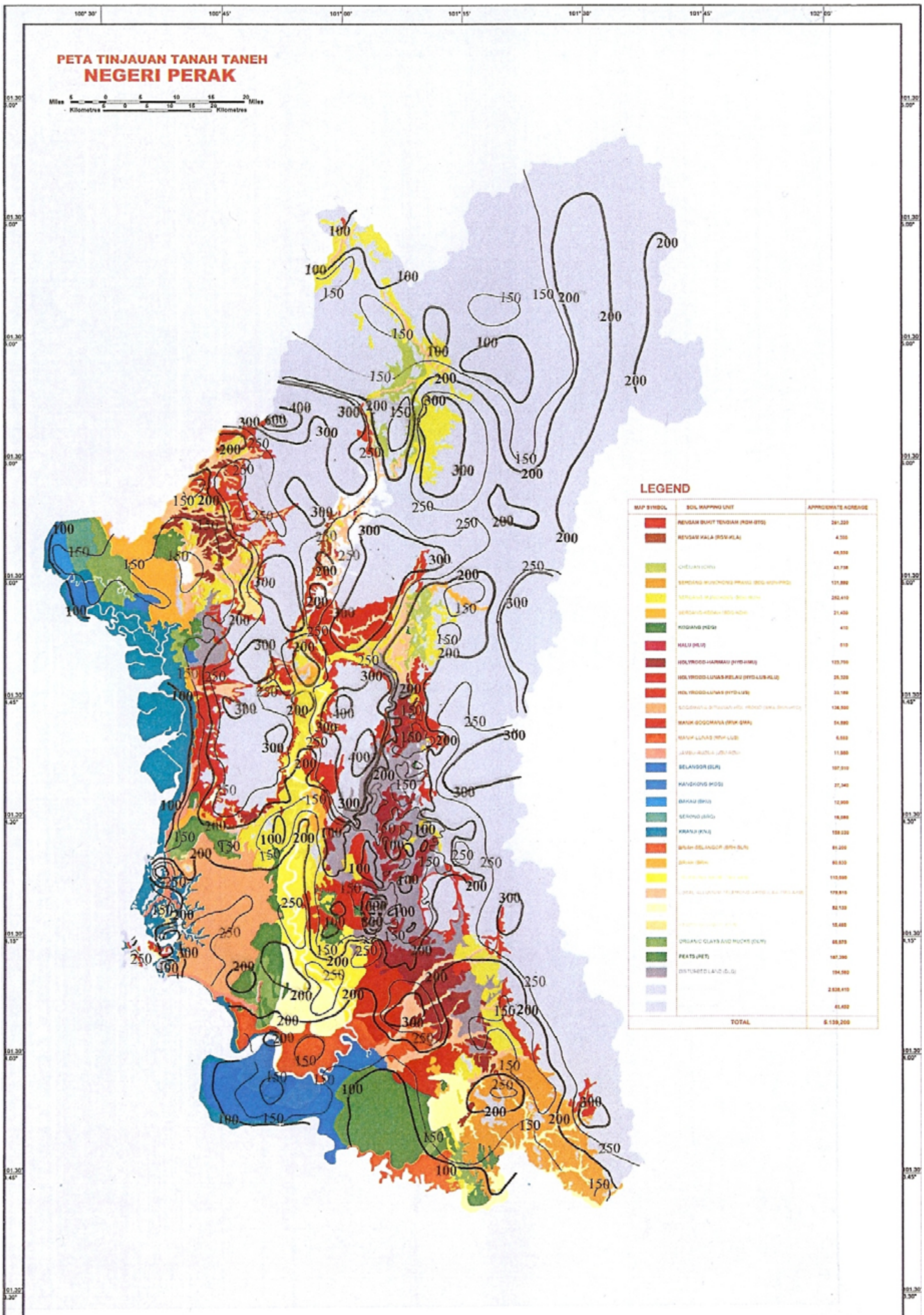
Dalam Rajah A.4.3. diberikan peta isodos sinar gama daratan semulajadi bagi negeri Perak, dan rajah 3 dimensinya diberikan dalam Rajah A.4.4. Garis kontur isodos bagi peta ini diunjurkan menggunakan kaedah Kriging dan mengikut prosedur yang diberikann dalam Bahagian A.3.2. Peta isodos yang berdasarkan kaedah Kriging masih bersifat anggaran kasar terutamanya bagi kawasan yang mempunyai data aras dos sinar gama yang jarang-jarang. Kaedah Kriging mengandaikan bentuk profil dos sinar gama daratan yang landai dan berselenjar, sedangkan mungkin terdapat batas sempadan kawasan aras dos sinar gama daratan yang jelas atau mendadak akibat dari perubahan jenis tanah, latar belakang geologi dan topografi. Berdasarkan kepada maklumat jenis tanah dan latar belakang geologi didapat penambah baikan terhadap peta isodos yang dihasilkan melalui kaedah Kriging. Dalam Rajah A.4.5. dan Rajah A.4.6. masing-masing ditunjukan tindihan peta isodos yang dihasilkan dengan jenis tanah dan latar belakang geologi.



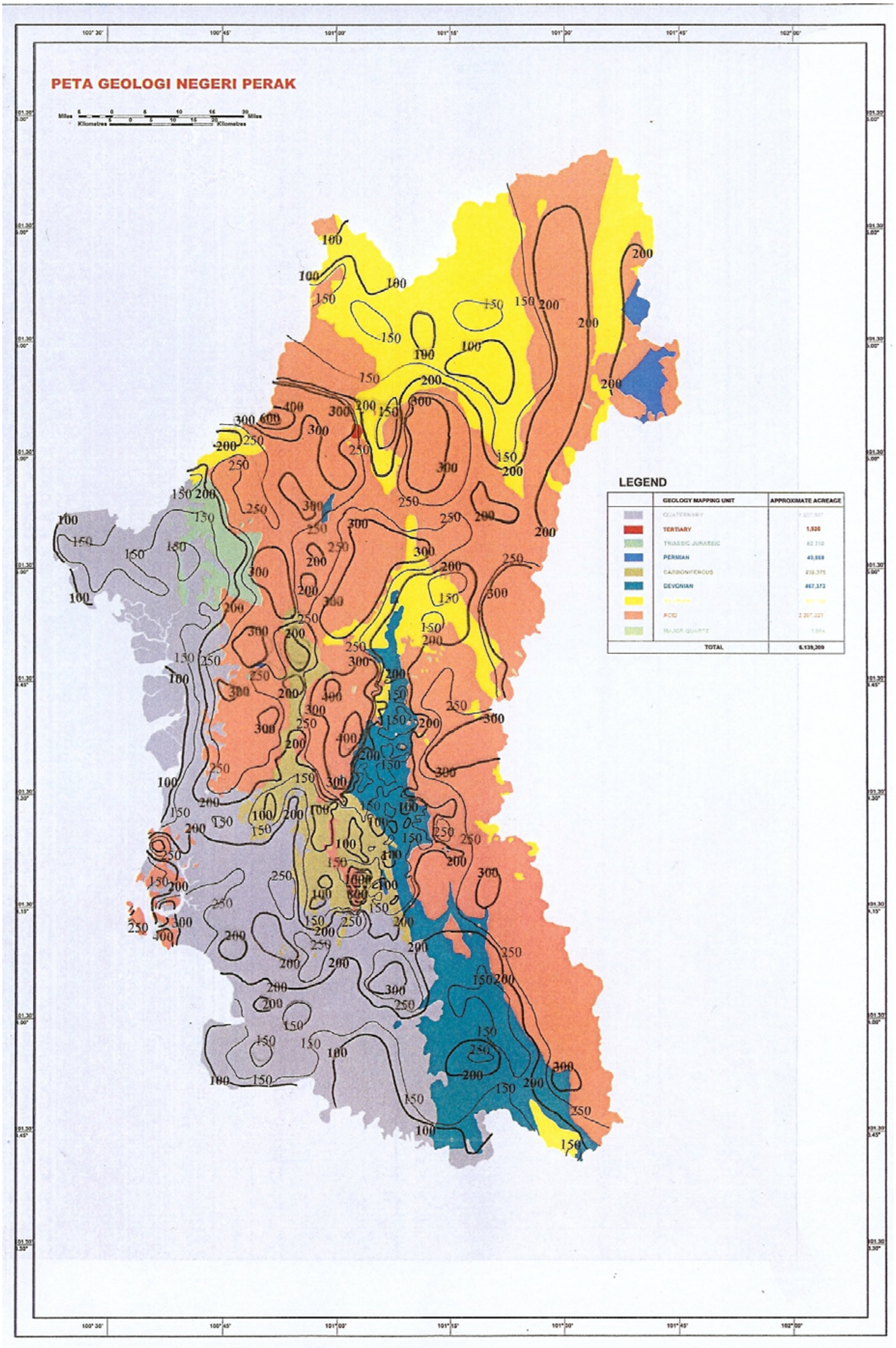
Rajah A 4.3. Peta isodos berdasarkan kaedah kriging



A 4.4. Peta isdos 3 dimensi berkaedahkan Kriging



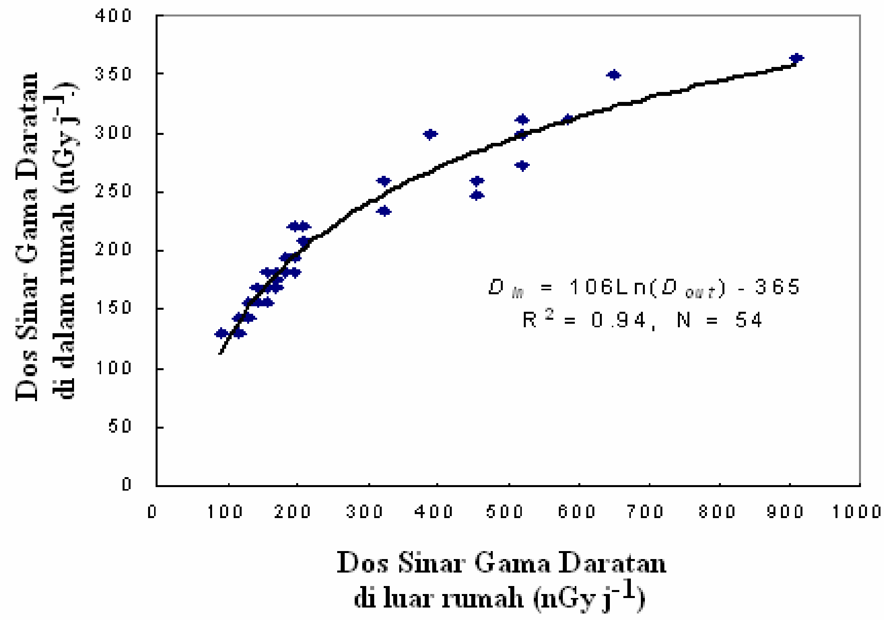
Rajah A.4.5 Peta isodos dan jenis tanah negeri Perak



Rajah A.4.6 Peta isodos dan geologi negeri Perak

A.4.1.3. Bacaan Dos sinar gama di dalam bangunan

Pengukuran dos sinaran di dalam bangunan telah dilakukan di 54 lokasi. Di dapati apabila nilai dos sinar gama daratan kurang dari 200 nGy j^{-1}, bacaan dos sinar gama di dalam bangunan meningkat di antara 5% sehingga 10 % lebih tinggi dari bacaan di luar bangunan. Sebaliknya apabila bacaan dos sinaran gama daratan di lapangan melebihi 200 nGy j^{-1}, dos sinar gama di dalam bangunan di dapati lebih rendah dari bacaan di luar bangunan. Ini berlaku kerana apabila dos sinar gama daratan rendah, dos dari bahan bangunan merupakan nilai dos tambahan kepada dos sinar gama di dalam bangunan. Sebaliknya apabila dos sinar gama daratan tinggi, sumbangan dos dari bahan bangunan menjadi secara relatifnya lebih kecil berbanding dengan peranan bahan bangunan yang bertindak sebagai perisaian terhadap dos sinar gama daratan dari luar bangunan menjadikan dos di dalam bangunan secara keseluruhannya lebih rendah dari dos di luar bangunan. Hubungan dos sinaran gama di dalam dan di luar bangunan diberikan dalam Rajah A.4.7



Rajah A4.7. Graf yang menggambarkan hubungan nilai dos sinaran gama di dalam bangunan melawan di luar bangunan.

Berdasarkan Rajah A4.7. hubungan di antara sinar gama di dalam bangunan dan di luar bangunan diberikan oleh persamaan 4.1.

$$D_{in} = 106\mathrm{Ln}(D_{out}) - 365 \qquad (4.1)$$

dengan D_{in} = dos sinar gama daratan di dalam bangunan (nGy j^{-1}),

D_{out} = dos sinar gama daratan di luar bangunan.

Keputusan persamaan 4.1 diberikan dalam Jadual A4.8. dengan dos berkesan tahunan bag setiap daerah di negeri Perak merupakan jumlah min dari sinar gama daratan di luar dan di dalam bangunan.

Jadual A.4.8. Dos berkesan tahunan yang diterima penduduk di daerah di Negeri Perak

Daerah	Dos sinaran gama daratan (nGy thn^{-1})		Dos Berkesan Tahunan (mSv)		Dos berkesan tahunan (mSv)
	di luar rumah	di dalam rumah	Di luar rumah	di dalam rumah	
Batang Padang	179	185	0.18	0.940	1.127
Hilir Perak	191	192	0.20	0.977	1.177
Kuala Kangsar	252	221	0.26	1.125	1.388
Kerian	149	166	0.15	0.843	0.999
Kinta	223	208	0.23	1.060	1.292
Larut Matang	207	201	0.21	1.021	1.237
Manjung	216	205	0.22	1.043	1.268
Perak Tengah	187	189	0.19	0.963	1.158
Selama	273	230	0.28	1.168	1.453
Hulu Perak	205	199	0.21	1.013	1.226
Negeri Perak	214	219	0.22	1.11	1.338
Malaysia (UNSCEAR, 2000)	92	96			
Bacaan Dunia (UNSCEAR, 2000)	57	75	0.07	0.41	0.48

Dari Jadual A4.8. dapat dilihat bahawa bagi semua di negeri Perak dos purata berkesan tahunan dari sinar gama daratan di dalam dan di luar bangunan adalah lebih tinggi daripada purata dunia yang bernilai 0.48 mSv setahun (UNSCEAR, 2000). Di anggarkan berdasar persamaan 3.9 dan perisian *Radiation Dose to Risk Converter* (www.wise-uranium.or/rdcri.html) kesan sinaran yang boleh menyebabkan maut bagi tempoh 70 tahun adalah 1:196 per penduduk akibat dos sinaran gama daratan. Menggunakan kaedah yang sama aras risiko purata akibat dari kesan dos sinaran gama daratan di negeri Perak bagi tempoh masa 70 tahun ialah 1:213 per penduduk. Jadual 4.9 menunjukan dos sinaran terkumpul setahun, dan aras risiko purata akibatkan dos sinar gama daratan semulajadi di daerah-daerah di negeri Perak.

Jadual A4.9. Aras risiko per penduduk dalam tempoh 70 tahun akibat dari dos sinar gama bagi daerah-daerah di negeri Perak

Daerah	Penduduk	Dos berkesan mSv thn^{-1}	Kesan kesihatan perorangan dalam tempoh 70 tahun (%)
Kinta	605,954	1.296	0.454 (1:220)
Kerian	98,572	0.995	0.348 (1:287)
Kuala Kangsar	95,784	1.396	0.489 (1:205)
Larut Matang	198,112	1.239	0.434 (1:231)
Selama	28,100	1.463	0.512 (1:195)
Hilir Perak	110,228	1.176	0.412 (1:243)
Hulu Perak	56,249	1.228	0.430 (1:233)
Perak Tengah	39,938	1.157	0.405 (1:247)
Batang Padang	99,094	1.126	0.394 (1:254)
Manjung	167,790	1.271	0.445 (1:225)
Negeri Perak	1,499,821	1.340	0.469 (1:213)

A.4.1.4. Kepekatan keradioaktifan di dalam sampel tanah

157 sampel tanah telah diambil dari setiap daerah di negeri Perak dengan tumpuan diberikan kepada kawasan dos sinaran gama daratan tinggi. Kaedah penyampelan dihuraikan dalam laporan *Suvey of Natural Background Radiation and Amang samples in Kinta District* (Bahagian B). Keputusan analisis yang dilakukan diberikan dalam Lampiran A.1. Dalam Jadual A.4.10 diberikan nilai min kepekatan keradioaktifan radionuklid ^{238}U, ^{232}Th dan ^{40}K bagi sampel tanah dari berbagai daerah di negeri Perak

Jadual A4.10. Kepekatan keradioaktifan di dalam sampel tanah dari berbagai daerah di negeri Perak.

DAERAH	N	Kepekatan keradioaktifan (Bq kg^{-1})		
		^{238}U	^{232}Th	^{40}K
		Min	Min	Min
Batang Padang	7	90 ± 28	144 ± 76	220 ± 25
Hilir Perak	10	87 ± 66	118 ± 67	333 ± 74
Kuala Kangsar	6	113 ± 44	238 ± 84	185 ± 16
Kerian	7	54 ± 13	105 ± 30	347 ± 60
Kinta	76	131 ± 69	418 ± 93	285 ± 77
Larut Matang	12	164 ± 13	279 ± 53	468 ± 33
Manjung	6	99 ± 12	173 ± 23	106 ± 85
Perak Tengah	11	69 ± 57	87 ± 57	379 ± 79
Selama	15	178 ± 96	353 ± 144	296 ± 85
Hulu Perak	7	114 ± 39	155 ± 83	197 ± 45
Negeri Perak	157	123 ± 64	305 ± 74	295 ± 82
Bacaan Dunia (UNSCEAR, 2000)		35	30	400

Penyumbang utama keradioaktifan dalam tanah bagi negeri Perak ialah radionuklid ^{232}Th. Julat masing-masing ^{238}U, ^{232}Th dan ^{40}K, masing-masing 7 Bq kg^{-1} – 426 Bq kg^{-1}, 23 Bq kg^{-1} – 1390 Bq kg^{-1}, dan 6 Bq kg^{-1} – 2204 Bq kg^{-1}

A.4.1.5. Kepekatan keradioaktifan di dalam tumbuh-tumbuhan.

Sampel tumbuh-tumbuhan telah diambil di beberapa kawasan di negeri Perak. Analisis kepekatan radionuklid telah dilakukan menggunakan kaedah analisis pengaktifan neutron (APN). Keputusan analisis diberi dalam Jadual A.4.11. Anggaran dos berkesan akibat dari kepekatan radionuklid ini diberikan dalam Jadual A.4.12. Lokasi pengambilan sampel diberikan dalam Lampiran A2. Dos berkesan akibat daripada aras keradiaoaktifan yang terdapat dalam tumbuh-tumbuhan dianggar menggunakan persamaan 3.5 dan dengan mengambil kira tabiat pemakanan penduduk tempatan. Nilai purata kepekatan keradioaktifan di dalam tumbuh-tumbuhan di negeri Perak lebih tinggi dibandingkan dengan bacaan purata dunia.

Jadual A.4.11 Nilai min kepekatan keradioaktifan dan dos berkesan akibat keradioaktifan di dalam tumbuh-tumbuhan.

DAERAH	N	Min Keradioaktifan tumbuh-tumbuhan ($Bq\ kg^{-1}$) Uranium	Torium	Dos berkesan $\mu Sv\ thn^{-1}$
Batang Padang	5	0.185 ± 0.037	0.388 ± 0.189	5.35
Hilir Perak	6	0.144 ± 0.046	0.328 ± 0.160	4.53
Kuala Kangsar	6	0.159 ± 0.039	0.467 ± 0.140	6.44
Kerian	6	0.262 ± 0.030	0.161 ± 0.035	2.22
Kinta	17	0.688 ± 0.187	0.387 ± 0.084	5.34
Larut Matang	5	0.866 ± 0.338	0.192 ± 0.039	2.65
Manjung	5	0.688 ± 0.279	0.275 ± 0.086	3.80
Perak Tengah	5	0.864 ± 0.147	0.215 ± 0.057	2.96
Selama	6	0.688 ± 0.252	0.166 ± 0.014	2.29
Hulu Perak	5	0.086 ± 0.044	0.202 ± 0.082	2.79
Negeri Perak (berat kering)	66	0.495 ± 0.071	0.298 ± 0.035	4.11
Rujukan Dunia				
UNSCEAR 2000, berat basah				
Daun tumbuh-tumbuhan		20×10^{-3}	15×10^{-3}	
Akar tumbuh-tumbuhan		3×10^{-3}	3×10^{-3}	

Nilai julat keradioaktifan yang diakibatkan daripada tumbuh-tumbuhan di negeri Perak iatu pada julat 0.02 Bq kg^{-1} hingga 2.35 Bq kg^{-1} bagi uranium, dan 0.01 Bq kg^{-1} hingga 1.13 Bq kg^{-1} bagi torium. Dos berkesan pada tumbuh-tumbuhan di dapat berdasarkan kesan uranium dan torium yang ada. Dos berkesan yang diakibatkan keradioaktifan pada tumbuh-tumbuhan di dapat 4.11 μSv setahun, kontribusi uranium dan torium secara purata akibat penelanan pada bacaan dunia iaitu 0.12 mSv setahun (UNSCEAR 2000). Pada tumbuh-tumbuhan hampir secara purata uranium memberikan sumbangan yang tinggi dibandingkan torium.

A.4.1.6. Kepekatan keradioaktifan di dalam air

Sampel air telah diambil dari beberapa sungai di negeri Perak, seperti Sungai Perak, Sungai Nur, Sungai Ulu Dedah, Sungai Papulut, dan Tasik Temenggor. Sungai-sungai ini merupakan sumber bekalan air minum bagi penduduk di sekitarannya. Hasil analisis diberikan dalam Jadual A 4.12.

Jadual A.4.12 Nilai Min dan dos berkesan akibat keradioaktifan di dalam air

		Min Keradioaktifan di dalam air (Bq kg^{-1})		Dos berkesan
DAERAH	N	Uranium	Torium	Sv thn^{-1}
Batang Padang	3	0.35 ± 0.14	0.10 ± 0.05	0.04
Hilir Perak	3	0.40 ± 0.03	0.01 ± 0.00	0.02
Kuala Kangsar	3	1.24 ± 0.17	0.10 ± 0.10	0.08
Kerian	2	0.43 ± 0.28	0.11 ± 0.06	0.04
Kinta	16	1.55 ± 0.23	0.30 ± 0.07	0.14
Larut Matang	4	1.45 ± 0.56	0.27 ± 0.10	0.13
Manjung	2	0.35 ± 0.09	0.08 ± 0.07	0.03
Perak Tengah	3	0.34 ± 0.09	0.07 ± 0.04	0.03
Selama	3	0.89 ± 0.58	0.19 ± 0.04	0.08
Hulu Perak	3	0.38 ± 0.18	0.14 ± 0.08	0.05
Negeri Perak	42	1.02 0.14	0.19 0.03	0.09

Jadual A4.12 menunjukan anggaran dos berkesan akibat dari kepekatan radionuklid yang terdapat dalam sampel air di daerah-daerah di negeri Perak. Lokasi pengambilan sampel diberikan dalam Lampiran A.3. Dos berkesan akibat daripada aras keradiaoaktifan yang terdapat dalam air dianggarkan menggunakan persamaan 3.5.

Nilai julat kepekatan keradioaktifan radionuklid bagi air di negeri Perak yang diukur adalah diantara 0.10 Bq l^{-1} hingga 3.76 Bq l^{-1} bagi uranium, dan 0.01 Bq l^{-1} hingga 0.99 Bq l^{-1} bagi torium. Nilai dos berkesan sekiranya menjadi sumber air minuman mentah ialah 0.09 mSv setahun. Sampel air dari Sungai Kinta dan Sungai Kampar memberikan nilai yang lebih tinggi iaitu 0.14 mSv setahun. Bacaan lebih tinggi ini terhasil kerana sampel air di ambil berhampiran dengan kilang amang. Aras dos ini masih terlalu rendah untuk menyumbang kepada kebarangkalian kesan kesihatan yang signifikan.

A.4.1.7. Aras kepekatan gas radon dan toron

Beberapa pengukuran gas radon dan toron dilakukan bagi mendapatkan maklumat terhadap dos berkesan yang diterima oleh penduduk di kawasan dos sinaran daratan tinggi di negeri Perak. Pengukuran ditumpukan di Kampung Sungai Durian. Nilai maksimum dos sinar gama daratan di sini ialah 1039 nGy j^{-1}. Keputusan yang diperolehi dikemukakan dalam Jadual A4.13 dan Jadual A4.14. Dos berkesan dikira menggunakan persamaan A3.6 dan A3.7 yang digunakan oleh perisian *Radon Individual Dose Calculator* (www.wise-uranium.org/rdcrn.html)

Jadual A.4.13. Aras kerja, aktiviti spesifik gas radon dan toron

Lokasi	Dos gama daratan (nGy j^{-1})	Radon		Dos berkesan	Toron		Dos berkesan
		Min aras kerja mWL	Aktifiti Spesifik Bq m^{-3}	mSv thn^{-1}	Min aras kerja mWL	Aktifiti Spesifik Bq m^{-3}	mSv thn^{-1}
L1	118	0.7	3.28	0.03	0.6	2.81	0.12
L2	183	1.7	7.96	0.08	0.3	1.41	0.06
L3	210	2	9.37	0.09	0.9	4.21	0.19
L4	210	7.7	36.05	0.36	1	4.68	0.21
L5	248	4.2	19.67	0.20	1.2	5.62	0.25
L6	261	3	14.05	0.14	1.5	7.02	0.31
L7	262	4.8	22.48	0.22	1.2	5.62	0.25
L8	327	4.3	20.14	0.20	1.2	5.62	0.25
L9	392	6.4	29.96	0.30	1.5	7.02	0.31
L10	588	2.7	12.64	0.13	1.6	7.49	0.33
L11	654	11.7	54.79	0.54	1.5	7.02	0.31
L12	850	3.4	15.92	0.16	1.9	8.89	0.39
L13	1039	47	220.08	2.19	16.1	75.39	3.33

Bacaan radon dan toron di kawasan kajian masing-masingnya berada dalam julat 0.70 mWL hingga 47 mWL dan 0.60 hingga 16.10, dengan purata tahunan dos berkesan pada daerah kajian 1.29 mSv bagi radon dan 0.39 mSv bagi toron. Bacaan ini lebih besar daripada bacaan purata dunia yang memberikan kesan dos pada manusia yang diakibatkan dos sinaran radon iaitu 1.15 mSv setahun.

4.2. Rumusan

Analisis variansi (ANOVA) dan ujian t boleh digunakan bagi menjangka dos sinaran gama daratan dan untuk melihat perbezaan dos yang terdapat bagi berbagai jenis tanah di suatu tempat kajian. Ujian di atas juga dapat memberikan maklumat mengenai dos akibat dari perbezaan jenis tanah dan latar belakang geologi. Singkatnya hasil kajian menunjukkan bahawa maklumat jenis tanah dan latar belakang geologi boleh digunakan untuk menganggarkan dos sinar gama daratan secara yang sah dari segi statistik.

Dos sinaran gama daratan yang diperolehi berada dalam julat 38 nGy j^{-1} sehingga 1039 nG j^{-1}. Bacaan tertinggi adalah berkaitan dengan kepekatan uranium dan torium yang tinggi terdapat pada kawasan berlatar belakang batuan rejahan berasid. Daerah Selama, Kuala Kangsar dan Kinta yang banyak dilatarbelakangi batuan jenis ini mempunyai nilai bacaan min dos sinaran gama daratannya adalah melebihi 3 kali ganda daripada bacaan purata dunia yang bernilai 57 nGy setahun. Secara umumnya kawasan di pinggiran pantai, lembah mendapan sungai, tanah bekas lombong (tanpa longgokan amang), dan tanah gambut memberikan bacaan yang lebih rendah, walau bagaimanapun masih lebih tinggi dari nilai purata dunia. Nilai julat kepekatan keradioaktifan ^{238}U, ^{232}Th dan ^{40}K masing-masingnya ialah 7 Bq kg^{-1} – 426 Bq kg^{-1}, 23 Bq kg^{-1} – 1390 Bq kg^{-1}, dan 6 Bq kg^{-1} – 2204 Bq kg^{-1}. Nilai min didapati (123 ± 94) Bq kg^{-1} bagi ^{238}U, (305±137) Bq kg^{-1} bagi ^{232}Th, dan. (295±108) Bq kg^{-1} bagi ^{40}K. Bacaan tersebut jauh lebih tinggi jika dibandingkan nilai rujukan iaitu 35 Bq kg^{-1} , 30 Bq kg^{-1} dan 400 Bq kg^{-1} masing-masing bagi ^{238}U, ^{232}Th dan ^{40}K (UNSCEAR, 2000).

Nilai julat kepekatan keradioaktifan pada sampel tumbuh-tumbuhan yang diukur iaitu diantara 0.02 Bq kg^{-1} hingga 2.38 Bq kg^{-1} bagi uranium, dan 0.01 Bq kg^{-1} hingga 1.13 Bq kg^{-1} bagi torium bacaan ini jauh lebih tinggi jika dibandingkan dengan nilai rujukan bagi ^{238}U iaitu 0.02 Bq kg^{-1} dan bagi ^{232}Th iaitu 0.015 Bq kg^{-1}. Nilai yang tinggi ini adalah kerana kebanyakan sampel tumbuh-tumbuhan diambil dari kawasan dos sinaran gama daratan tinggi. Nilai kepekatan keradioaktifan uranium dan torium di dalam tumbuh-tumbuhan seperti di atas akan menyebabkan dos berkesan tahunan bernilai diantara 0.0022 mSv hingga 0.0064 mSv kepada manusia.

Nilai julat kepekatan keradioaktifan pada sampel air yang diukur iaitu diantara 0.10 Bq l^{-1} hingga 3.76 Bq l^{-1} bagi uranium, dan 0.01 Bq l^{-1} hingga 0.99 Bq l^{-1} bagi torium. Bacaan ini jauh lebih tinggi jika dibandingkan dengan nilai rujukan bagi ^{238}U di dalam air minum iaitu 1 mBq l^{-1} dan bagi ^{232}Th di dalam air minum iaitu 0.05 mBq l^{-1}. Nilai yang tinggi ini adalah karena kebanyakan sampel diambil dari sungai-sungai di kawasan dos sinaran gama daratan tinggi. Nilai kepekatan keradioaktifan uranium dan torium seperti di atas di dalam air sungai akan menyebabkan dos berkesan tahunan bernilai diantara 0.02 mSv hingga 0.14 mSv kepada manusia sekiranya ia merupakan sumber air minuman.

Bacaan radon dan toron di negeri Perak yang dalam kajian ini ditumpukan kepada kawasan bacaan dos sinaran daratan tinggi khusunya di Kampung Sungai Durian berada dalam julat masing-masingnya 0.7 mWL hingga 47.0 mWL dan 0.3 mWL hingga 16.1 mWL. Aras radon seperti di atas menyebabkan penduduk menerima julat dos di antara 0.33 mSv sehingga 7.76 mSv setahun, dan aras toronnya pula menyebabkan penduduk menerima julat dos di antara 0.05 mSv sehingga 2.66 mSv. Nilai purata dunia bagi dos berkesan akibat pendedahan kepada radon ialah 1.15 mSv dan bagi toron pula ialah 0.10 mSv setahun (UNSCEAR, 2000). Dapat dilihat bahwa nilai di atas adalah lebih tinggi dari nilai rujukan bagi radon dan toron. Di kawasan dimana bacaan dos sinar gama daratan tertinggi iaitu bernilai 1039 nGy j^{-1} di Kampung Sungai Durian, dianggarkan penduduk dilokasi tersebut secara statistik menerima kebarangkalian kesan somatik stokastik yang bernilai 1:26 per orang per 70 tahun. Nilai ini agak tinggi, oleh itu dicadangkan supaya kajian lanjut kemungkinan kesan stokastik sinaran terhadap penduduk dilakukan.

Aras dos sinaran seperti yang terdapat di atas adalah terlalu kecil untuk menyebabkan kesan deterministik, tetapi mempunyai nilai kebarangkalian yang signifikan untuk menyebabkan kesan-kesan stokastik.

Kajian ini telah menghasilkan peta isodos sinar gama daratan yang boleh dimanfaatkan untuk amalan perlindungan dan kesihatan radiologi khususnya untuk tujuan perlindungan radiologi alam sekitar, terutamanya untuk penilaian impak terhadap alam sekitar akibat dari operasi industri amang. Setakat ini, kajian ini mendapati bahawa kesan dari industri amang merupakan kesan setempat dan tidak meningkatkan dos latar belakang secara signifikan kepada alam sekitar kecuali bagi kawasan kilang itu sendiri dan jiran terdekatnya. Aras dos sinaran yang terdapat di kawasan kilang amang adalah jauh melebihi aras yang lazimnya dapat diterima bagi kawasan kerja sinaran.

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Lampiran A.1 Lokasi cerapan dos sinar gama daratan berdasarkan kedudukan latitud, longitud, daerah, jenis tanah dan latar belakang geologi

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
1	3.6955	101.3237	BP	AKBMPH	Q	156
2	3.7428	101.3340	BP	AKBMPH	D	130
3	3.6734	101.2651	BP	AKBMPH	Q	130
4	3.7312	101.4432	BP	AKBMPH	D	104
5	3.7818	101.3350	BP	AKBMPH	Q	104
6	3.7010	101.4996	BP	AKBMPH	S	169
7	3.7981	101.3381	BP	AKBMPH	Q	78
8	3.9367	101.2584	BP	AKBMPH	D	169
9	3.8305	101.4048	BP	AKBMPH	D	171
10	3.8998	101.3617	BP	AKBMPH	D	174
11	3.7432	101.3421	BP	AKBMPH	D	174
12	3.9394	101.2649	BP	AKBMPH	D	243
13	3.9115	101.3562	BP	AKBMPH	D	174
14	3.7361	101.4463	BP	AKBMPH	D	174
15	3.8646	101.4497	BP	AKBMPH	D	313
16	3.7945	101.4402	BP	AKBMPH	D	208
17	3.8909	101.2723	BP	AKBMPH	D	208
18	3.7122	101.4834	BP	AKBMPH	S	229
19	3.7534	101.4933	BP	AKBMPH	S	156
20	4.0597	101.0512	BP	BRHSLR	Q	208
21	4.1095	101.2897	BP	DLD	D	208
22	4.1088	101.2893	BP	DLD	D	191
23	4.1390	101.2799	BP	DLD	D	208
24	4.2282	101.2240	BP	DLD	D	226
25	4.1184	101.2784	BP	DLD	D	191
26	4.0960	101.2758	BP	DLD	D	143
27	4.1335	101.3275	BP	DLD	D	168
28	4.2579	101.1913	BP	DLD	D	261
29	4.2835	101.2509	BP	DLD	D	236
30	4.1482	101.3016	BP	DLD	D	191
31	4.0705	101.2736	BP	DLD	D	128
32	4.3142	101.2426	BP	DLD	C	201
33	4.1400	101.2752	BP	DLD	D	177
34	4.0519	101.2579	BP	DLD	D	130
35	4.1321	101.2763	BP	DLD	D	156
36	4.1163	101.2815	BP	DLD	D	156
37	4.1195	101.2885	BP	DLD	D	236
38	4.0389	101.3011	BP	HYDHMU	D	278
39	4.1873	101.1437	BP	HYDHMU	Q	222

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J-1
50	4.0027	101.2893	BP	HYDHMU	D	174
51	4.0039	101.3091	BP	HYDHMU	D	174
52	4.1729	101.1929	BP	HYDHMU	Q	191
53	4.1688	101.1482	BP	HYDHMU	Q	174
54	4.0751	101.2909	BP	HYDHMU	D	125
55	4.0134	101.3041	BP	HYDHMU	D	208
56	4.1330	101.2246	BP	HYDHMU	Q	219
57	4.1920	101.1630	BP	HYDHMU	D	323
58	4.0799	101.2822	BP	HYDHMU	D	182
59	4.1842	101.2175	BP	HYDHMU	D	181
60	3.9926	101.3015	BP	HYDHMU	D	156
61	4.1929	101.1271	BP	HYDHMU	Q	160
62	4.0276	101.3030	BP	HYDHMU	D	156
63	4.1094	101.2925	BP	HYDHMU	D	149
64	3.9677	101.2903	BP	HYDHMU	D	191
65	3.9978	101.3060	BP	HYDHMU	D	191
66	4.0702	101.2898	BP	HYDHMU	D	226
67	4.0903	101.2841	BP	HYDHMU	D	226
68	4.0692	101.2909	BP	HYDHMU	D	121
69	4.1103	101.2928	BP	HYDHMU	D	156
70	4.1115	101.2878	BP	HYDHMU	D	156
71	4.1118	101.2934	BP	HYDHMU	D	182
72	3.9220	101.3462	BP	LAATMGAKB	D	243
73	3.9377	101.3447	BP	LAATMGAKB	D	243
74	4.1988	101.2631	BP	LAATMGAKB	D	208
75	3.9723	101.3158	BP	LAATMGAKB	D	163
76	4.1022	101.1027	BP	LAATMGAKB	Q	348
77	3.9411	101.3438	BP	LAATMGAKB	D	160
78	3.9897	101.3196	BP	LAATMGAKB	D	171
79	3.9786	101.3234	BP	LAATMGAKB	D	205
80	4.1026	101.3025	BP	LAATMGAKB	D	207
81	3.9555	101.2805	BP	LAATMGAKB	D	174
82	4.0755	101.3488	BP	LAATMGAKB	D	104
83	4.1262	101.2048	BP	LAATMGAKB	Q	125
84	4.0468	101.2999	BP	LAATMGAKB	D	104
85	4.1011	101.3177	BP	LAATMGAKB	D	208
86	4.1011	101.3267	BP	LAATMGAKB	D	103
87	4.0821	101.3392	BP	LAATMGAKB	D	139
88	3.9533	101.3314	BP	LAATMGAKB	D	139
89	4.1026	101.3071	BP	LAATMGAKB	D	139
90	4.0931	101.3370	BP	LAATMGAKB	D	156
91	3.9283	101.3506	BP	LAATMGAKB	D	247
92	3.9947	101.3122	BP	LAATMGAKB	D	174
93	3.9680	101.3257	BP	LAATMGAKB	D	174
94	3.9695	101.3293	BP	LAATMGAKB	D	156
95	4.1029	101.3030	BP	LAATMGAKB	D	182
96	4.1856	101.0778	BP	MNKSMA	Q	267
97	3.7369	101.2800	BP	OCM	D	104
98	3.7372	101.2660	BP	OCM	D	117
99	3.7075	101.2877	BP	PET	Q	78
100	3.7244	101.2783	BP	PET	D	117
101	3.7777	101.3182	BP	PET	D	117
102	3.7272	101.2854	BP	PET	D	156
103	3.7527	101.4737	BP	pSDGMUNPRG	S	174

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
104	4.1043	101.2913	BP	RGMBTG	D	156
105	4.3108	101.2321	BP	RGMBTG	A	261
106	4.0933	101.3310	BP	RGMBTG	D	123
107	4.0689	101.3438	BP	RGMBTG	D	91
108	4.0661	101.3582	BP	RGMBTG	D	117
109	4.0941	101.3334	BP	RGMBTG	D	139
110	4.3136	101.2470	BP	RGMBTG	A	240
111	4.1231	101.3252	BP	RGMBTG	D	129
112	4.1213	101.3213	BP	RGMBTG	D	129
113	4.0722	101.3563	BP	RGMBTG	D	156
114	4.2846	101.2503	BP	RGMBTG	D	155
115	4.1978	101.2317	BP	RGMBTG	D	191
116	4.3427	101.2357	BP	RGMBTG	A	226
117	4.3497	101.2345	BP	RGMBTG	A	226
118	4.1249	101.3313	BP	RGMBTG	D	130
119	4.0710	101.3578	BP	RGMBTG	D	156
120	3.8905	101.4892	BP	RGMBTG	D	316
121	4.1143	101.2891	BP	RGMBTG	D	130
122	4.1019	101.3339	BP	RGMBTG	D	130
123	4.0733	101.3457	BP	RGMBTG	D	121
124	4.1199	101.3305	BP	RGMBTG	D	246
125	4.0881	101.3463	BP	RGMBTG	D	182
126	4.1062	101.3043	BP	SDGMUN	D	182
127	4.2252	101.2933	BP	SDGMUN	D	261
128	4.1257	101.3238	BP	SDGMUN	D	116
129	4.1060	101.3204	BP	SDGMUN	D	143
130	3.7758	101.2756	BP	SDGMUN	D	117
131	4.0976	101.3265	BP	SDGMUN	D	139
132	4.0954	101.3059	BP	SDGMUN	D	208
133	4.1044	101.3002	BP	SDGMUN	D	139
134	4.1778	101.2892	BP	SDGMUN	D	106
135	4.0436	101.3269	BP	SDGMUN	D	107
136	4.0967	101.2919	BP	SDGMUN	D	174
137	3.9708	101.3250	BP	SDGMUN	D	174
138	4.1015	101.3160	BP	SDGMUN	D	155
139	4.0454	101.3234	BP	SDGMUN	D	149
140	4.0315	101.3153	BP	SDGMUN	D	156
141	4.2165	101.2457	BP	SDGMUN	A	226
142	4.1005	101.3222	BP	SDGMUN	D	121
143	4.1074	101.3150	BP	SDGMUN	D	130
144	3.9962	101.2724	BP	SDGMUN	D	174
145	4.1183	101.3185	BP	SDGMUN	D	116
146	4.0965	101.2847	BP	SDGMUN	D	156
147	3.8342	101.4032	BP	SDGMUNPRG	D	278
148	3.9130	101.2643	BP	SDGMUNPRG	D	226
149	3.8513	101.2830	BP	SDGMUNPRG	D	191
150	3.8349	101.2783	BP	SDGMUNPRG	D	191
151	3.9057	101.3627	BP	SDGMUNPRG	D	174
152	3.8224	101.2760	BP	SDGMUNPRG	D	174
153	3.8676	101.2794	BP	SDGMUNPRG	D	174
154	3.9227	101.3526	BP	SDGMUNPRG	D	174
155	3.7523	101.4558	BP	SDGMUNPRG	D	208
156	3.9304	101.3461	BP	SDGMUNPRG	D	278
157	3.7227	101.4810	BP	SDGMUNPRG	S	156

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
158	3.9360	101.3711	BP	SDGMUNPRG	D	156
159	3.9117	101.3550	BP	SDGMUNPRG	D	222
160	3.7334	101.5281	BP	SDGMUNPRG	S	139
161	3.7901	101.4788	BP	SDGMUNPRG	D	182
162	3.9417	101.2901	BP	SDGMUNPRG	D	261
163	3.9576	101.3318	BP	SDGMUNPRG	D	167
164	3.8650	101.3779	BP	SDGMUNPRG	D	160
165	3.8906	101.3719	BP	SDGMUNPRG	D	160
166	3.7803	101.4603	BP	SDGMUNPRG	S	125
167	3.8683	101.3867	BP	SDGMUNPRG	D	212
168	3.9619	101.3343	BP	SDGMUNPRG	D	117
169	3.9466	101.3000	BP	SDGMUNPRG	D	243
170	3.9475	101.3254	BP	SDGMUNPRG	D	243
171	3.7884	101.3943	BP	SDGMUNPRG	D	139
172	3.9256	101.3471	BP	SDGMUNPRG	D	205
173	3.7531	101.2717	BP	SDGMUNPRG	S	156
174	3.7662	101.4556	BP	SDGMUNPRG	D	156
175	3.8565	101.3710	BP	SDGMUNPRG	D	117
176	3.9293	101.3478	BP	SDGMUNPRG	D	208
177	3.7250	101.4733	BP	SDGMUNPRG	S	208
178	3.7684	101.4668	BP	SDGMUNPRG	D	117
179	3.9659	101.3380	BP	SDGMUNPRG	D	97
180	3.7143	101.5193	BP	SDGMUNPRG	S	121
181	3.9337	101.4235	BP	SDGMUNPRG	D	135
182	3.8813	101.3833	BP	SDGMUNPRG	D	135
183	3.8428	101.4048	BP	SDGMUNPRG	D	177
184	3.9298	101.3576	BP	SDGMUNPRG	D	156
185	3.9347	101.3437	BP	SDGMUNPRG	D	191
186	3.9355	101.3494	BP	SDGMUNPRG	D	174
187	3.8981	101.3656	BP	SDGMUNPRG	D	229
188	3.7901	101.2739	BP	SDGMUNPRG	D	156
189	3.8018	101.2723	BP	SDGMUNPRG	D	174
190	3.8515	101.3779	BP	SDGMUNPRG	D	156
191	3.9280	101.3935	BP	SDGMUNPRG	D	107
192	3.8437	101.4154	BP	SDGMUNPRG	D	130
193	3.7456	101.4486	BP	SDGMUNPRG	D	130
194	3.9744	101.3418	BP	SDGMUNPRG	D	130
195	3.9405	101.3508	BP	SDGMUNPRG	D	130
196	3.9083	101.3785	BP	SDGMUNPRG	D	130
197	4.0907	101.2861	BP	SMASWNHYD	D	156
198	4.3671	101.3569	BP	STP	A	274
199	3.9797	101.4328	BP	STP	A	278
200	3.7752	101.5585	BP	STP	A	278
201	3.7799	101.5256	BP	STP	A	261
202	4.4071	101.3861	BP	STP	A	250
203	4.3337	101.3342	BP	STP	A	316
204	3.9312	101.4659	BP	STP	A	261
205	3.7452	101.5540	BP	STP	A	243
206	4.0878	101.3693	BP	STP	A	207
207	3.9402	101.5043	BP	STP	A	243
208	4.0893	101.3649	BP	STP	A	207
209	3.8664	101.5320	BP	STP	A	295
210	4.4056	101.3832	BP	STP	A	229
211	4.0817	101.3708	BP	STP	A	208

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy\ J^{-1}$
212	4.2665	101.3203	BP	STP	A	323
213	3.9205	101.2286	HP	AKBMPH	Q	156
214	3.8566	101.1820	HP	AKBMPH	Q	208
215	3.9002	101.1868	HP	AKBMPH	Q	191
216	4.0115	101.1295	HP	BRHSLR	Q	261
217	4.0277	100.9160	HP	BRHSLR	Q	97
218	3.7638	101.1423	HP	BRHSLR	Q	121
219	3.9844	100.8718	HP	BRHSLR	Q	174
220	3.9998	101.0998	HP	BRHSLR	Q	156
221	4.0462	101.0390	HP	BRHSLR	Q	156
222	4.0211	100.9782	HP	BRHSLR	Q	156
223	3.9996	100.9407	HP	BRHSLR	Q	174
224	4.0078	100.9041	HP	BRHSLR	Q	130
225	4.0248	101.1297	HP	BRHSLR	Q	174
226	3.9662	100.9160	HP	BRHSLR	Q	156
227	3.7357	101.2061	HP	BRHSLR	Q	130
228	4.0306	101.1996	HP	HYDHMU	Q	278
229	4.1376	101.1473	HP	HYDHMU	Q	234
230	4.0647	101.1817	HP	HYDHMU	Q	261
231	4.0375	101.2037	HP	HYDHMU	D	195
232	3.9211	100.9509	HP	KGG	Q	191
233	4.0647	101.1634	HP	LAATMGAKB	Q	278
234	3.9724	101.0958	HP	LAATMGAKB	Q	104
235	4.0787	101.1187	HP	LAATMGAKB	Q	320
236	4.0669	101.1226	HP	LAATMGAKB	Q	313
237	4.1352	101.1451	HP	LAATMGAKB	Q	313
238	4.1299	101.1460	HP	LAATMGAKB	Q	313
239	4.0242	101.1920	HP	LAATMGAKB	Q	182
240	4.0755	101.1239	HP	LAATMGAKB	Q	330
241	4.0172	101.1635	HP	MNKLUS	Q	261
242	4.0507	101.1697	HP	MNKLUS	Q	313
243	4.0489	101.1371	HP	MNKLUS	Q	226
244	4.1340	101.0832	HP	MNKSMA	Q	278
245	4.1511	101.0656	HP	MNKSMA	Q	226
246	4.0585	101.0583	HP	MNKSMA	Q	156
247	4.1155	101.0823	HP	MNKSMA	Q	261
248	4.1242	101.0875	HP	MNKSMA	Q	264
249	3.9745	101.1517	HP	MNKSMA	Q	143
250	4.1112	101.0853	HP	MNKSMA	Q	261
251	4.1097	101.1167	HP	MNKSMA	Q	348
252	4.1205	101.1227	HP	MNKSMA	Q	334
253	4.1518	101.1009	HP	MNKSMA	Q	261
254	4.0852	101.1013	HP	MNKSMA	Q	382
255	4.1112	101.0672	HP	MNKSMA	Q	243
256	3.9487	101.1436	HP	MNKSMA	Q	243
257	4.1193	101.0797	HP	MNKSMA	Q	243
258	4.0827	101.0775	HP	MNKSMA	Q	365
259	4.1048	101.0897	HP	MNKSMA	Q	261
260	4.0712	101.0858	HP	MNKSMA	Q	365
261	4.1402	101.0763	HP	MNKSMA	Q	313
262	4.0680	101.0869	HP	MNKSMA	Q	330
263	4.0905	101.0315	HP	MNKSMA	Q	156
264	4.0895	101.0365	HP	MNKSMA	Q	191
265	4.0597	101.0962	HP	MNKSMA	Q	247

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
266	4.1163	101.0550	HP	MNKSMA	Q	149
267	4.1636	101.0918	HP	MNKSMA	Q	226
268	3.9091	101.0881	HP	PET	Q	38
269	4.3186	100.9722	HP	PET	C	67
270	3.9272	101.0926	HP	PET	Q	69
271	3.8570	100.9965	HP	PET	Q	104
272	3.9383	101.1302	HP	PET	Q	156
273	3.8018	101.1167	HP	PET	Q	87
274	3.9430	101.1099	HP	PET	Q	87
275	3.9163	100.9981	HP	PET	Q	87
276	4.3309	100.9602	HP	SDGMUN	C	67
277	3.9272	100.9773	HP	SLR	Q	104
278	3.9324	100.8377	HP	SLR	Q	104
279	3.9108	100.9649	HP	SLR	Q	75
280	3.9939	101.0246	HP	SLR	Q	191
281	3.9118	100.9453	HP	SLR	Q	191
282	3.8624	100.9646	HP	SLR	Q	117
283	3.8034	100.9964	HP	SLR	Q	87
284	3.9560	100.9813	HP	SLR	Q	117
285	3.8740	100.8172	HP	SLR	Q	117
286	3.9344	100.9686	HP	SLR	Q	104
287	3.9375	100.9650	HP	SLR	Q	104
288	3.9634	100.7541	HP	SLR	Q	117
289	3.9103	100.8126	HP	SLR	Q	191
290	3.8909	100.8667	HP	SLR	Q	208
291	3.9090	100.7738	HP	SLR	Q	174
292	3.8941	100.8100	HP	SLR	Q	174
293	3.8948	100.8071	HP	SLR	Q	191
294	3.9294	100.7776	HP	SLR	Q	191
295	3.9387	100.9637	HP	SLR	Q	87
296	4.0357	100.9989	HP	SLR	Q	226
297	3.9504	100.7069	HP	SLR	Q	156
298	3.9183	100.8673	HP	SLR	Q	174
299	3.8897	100.8763	HP	SLR	Q	174
300	3.9090	100.7595	HP	SLR	Q	130
301	3.8791	100.8791	HP	SLR	Q	130
302	3.8901	100.8396	HP	SLR	Q	174
303	4.3548	100.8746	HP	TMGAKB	C	97
304	4.3499	100.8932	HP	TMGAKB	C	145
305	4.8242	101.1358	KK	CHN	S	174
306	4.9605	101.1450	KK	CHN	S	174
307	4.9474	101.1439	KK	CHN	S	174
308	4.9365	101.1772	KK	CHN	S	174
309	4.9211	101.1719	KK	CHN	S	130
310	4.8324	100.9840	KK	DLD	A	278
311	4.8142	101.0915	KK	DLD	D	174
312	4.8224	101.0733	KK	DLD	Q	191
313	4.8255	101.2062	KK	DLD	S	208
314	4.8150	101.0682	KK	DLD	A	330
315	4.5832	100.8761	KK	HYDHMU	D	104
316	4.8552	101.1339	KK	LAATMGAKB	S	174
317	4.9402	100.9234	KK	LAATMGAKB	A	261
318	4.8680	100.9532	KK	LAATMGAKB	C	261
319	4.9982	101.1463	KK	LAATMGAKB	S	191

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
320	5.0045	100.8058	KK	LAATMGAKB	A	126
321	5.0348	101.1604	KK	LAATMGAKB	S	365
322	4.8099	101.1031	KK	LAATMGAKB	D	121
323	4.9534	101.1307	KK	LAATMGAKB	S	174
324	4.9568	100.9283	KK	LAATMGAKB	A	155
325	4.9551	101.1357	KK	LAATMGAKB	S	174
326	4.8946	101.1314	KK	LAATMGAKB	S	174
327	4.9972	101.1463	KK	RGMBTG	S	278
328	4.9235	101.0607	KK	RGMBTG	A	330
329	4.9485	101.0938	KK	RGMBTG	A	330
330	4.9285	101.0658	KK	RGMBTG	A	330
331	4.9102	100.9061	KK	RGMBTG	A	330
332	4.9118	100.9928	KK	RGMBTG	A	330
333	4.8256	100.9503	KK	RGMBTG	C	174
334	4.6189	100.9164	KK	RGMBTG	C	104
335	4.9313	101.0683	KK	RGMBTG	A	348
336	4.9658	100.9252	KK	RGMBTG	A	194
337	4.7488	100.9838	KK	RGMBTG	A	522
338	4.9166	100.9032	KK	RGMBTG	A	194
339	4.8555	100.8950	KK	RGMBTG	C	174
340	4.5616	100.8632	KK	RGMBTG	A	261
341	4.5997	100.8794	KK	RGMBTG	C	207
342	4.6826	100.9021	KK	RGMBTG	C	207
343	4.9036	100.8953	KK	RGMBTG	C	365
344	4.7155	100.9467	KK	RGMBTG	A	365
345	4.7968	100.8349	KK	RGMBTG	A	365
346	4.8251	100.9617	KK	RGMBTG	C	243
347	4.9302	101.0513	KK	RGMBTG	A	365
348	4.8557	100.8969	KK	RGMBTG	C	174
349	4.6085	100.8706	KK	RGMBTG	A	454
350	4.8811	101.0471	KK	RGMBTG	S	313
351	4.9157	100.9994	KK	RGMBTG	A	295
352	4.9358	101.0438	KK	RGMBTG	A	295
353	4.9231	101.0267	KK	RGMBTG	A	295
354	4.9267	100.9187	KK	RGMBTG	A	182
355	4.6855	100.9896	KK	RGMBTG	A	324
356	5.0533	101.1635	KK	RGMBTG	S	435
357	4.8378	101.1560	KK	RGMBTG	S	174
358	4.9914	101.2114	KK	SDGKDH	S	278
359	4.7955	100.8944	KK	SDGKDH	A	330
360	4.8012	101.0604	KK	SDGKDH	A	330
361	4.9405	101.2766	KK	SDGKDH	S	174
362	4.7888	100.8965	KK	SDGKDH	A	278
363	4.9745	101.2274	KK	SDGKDH	S	104
364	4.7998	100.9038	KK	SDGKDH	C	117
365	4.7851	100.9250	KK	SDGKDH	C	104
366	4.9865	101.2084	KK	SDGKDH	S	191
367	4.7821	100.8979	KK	SDGKDH	A	139
368	4.9689	101.2338	KK	SDGKDH	S	104
369	4.9521	101.2582	KK	SDGKDH	S	104
370	4.9378	101.2996	KK	SDGKDH	S	130
371	4.9816	101.1774	KK	SDGKDH	S	174
372	4.9070	101.1758	KK	SDGMUN	S	174
373	4.8448	101.1777	KK	SDGMUN	S	174

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
374	4.8279	101.1060	KK	SDGMUN	D	174
375	4.9042	101.1534	KK	SDGMUN	C	174
376	4.8251	101.0910	KK	SDGMUN	D	174
377	4.7154	100.9059	KK	SDGMUN	C	188
378	4.7481	100.9789	KK	SDGMUN	A	348
379	4.7277	100.9068	KK	SDGMUN	C	194
380	4.6289	100.8813	KK	SDGMUN	C	207
381	4.9192	101.1756	KK	SDGMUN	S	174
382	4.8670	101.2127	KK	SDGMUN	S	121
383	4.8474	101.1954	KK	SDGMUN	S	226
384	4.8536	101.1928	KK	SDGMUN	S	174
385	4.9221	101.1776	KK	SDGMUN	S	174
386	4.8953	101.3714	KK	STP	A	330
387	4.6052	100.8549	KK	STP	A	272
388	4.9293	101.3242	KK	STP	A	261
389	4.9370	100.9100	KK	STP	A	609
390	4.6788	100.8611	KK	STP	A	348
391	4.8187	100.9673	KK	STP	A	348
392	4.9329	101.3083	KK	STP	A	243
393	4.9770	101.0778	KK	STP	A	435
394	4.9112	101.3504	KK	STP	A	365
395	4.9501	101.1900	KK	STP	S	174
396	4.9068	101.2495	KK	STP	S	174
397	4.8031	101.2246	KK	STP	S	243
398	4.9181	101.3508	KK	STP	A	365
399	4.8661	101.2105	KK	STP	S	121
400	4.8755	101.2241	KK	STP	S	121
401	4.6978	101.0240	KK	STP	A	389
402	4.9665	101.0848	KK	STP	A	313
403	4.9182	101.3463	KK	STP	A	313
404	4.8151	101.2205	KK	STP	A	208
405	4.8350	101.2023	KK	STP	A	208
406	4.6857	100.8818	KK	STP	A	324
407	4.7842	100.8440	KK	STP	A	174
408	4.8542	101.2869	KK	STP	S	174
409	4.9342	101.3002	KK	STP	A	174
410	4.9409	101.0261	KK	STP	A	435
411	4.9389	101.0253	KK	STP	A	435
412	5.0585	101.1571	KK	STP	S	435
413	4.7944	101.2267	KK	STP	A	226
414	4.7861	100.9843	KK	STP	C	191
415	4.9368	100.9075	KK	STP	A	435
416	4.7865	101.0283	KK	STP	A	208
417	4.5803	100.9243	KK	TMGAKB	C	278
418	4.7683	100.9325	KK	TMGAKB	C	278
419	4.7872	100.9536	KK	TMGAKB	C	278
420	4.6096	100.8752	KK	TMGAKB	A	330
421	4.6105	100.8818	KK	TMGAKB	A	261
422	4.7704	100.8789	KK	TMGAKB	A	330
423	4.8984	100.9023	KK	TMGAKB	C	330
424	4.6075	100.8753	KK	TMGAKB	A	522
425	4.7727	100.9165	KK	TMGAKB	A	165
426	4.7708	100.8831	KK	TMGAKB	A	174
427	4.7712	100.9308	KK	TMGAKB	C	337

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
428	4.6904	100.9797	KK	TMGAKB	A	330
429	4.7789	100.8416	KK	TMGAKB	A	174
430	4.6913	100.8981	KK	TMGAKB	C	220
431	4.8962	100.9977	KK	TMGAKB	A	417
432	4.6075	100.8743	KK	TMGAKB	A	417
433	4.6632	100.9327	KK	TMGAKB	A	261
434	4.6513	100.8979	KK	TMGAKB	C	207
435	4.8548	100.9487	KK	TMGAKB	C	243
436	4.8357	100.9375	KK	TMGAKB	C	243
437	4.7747	100.9182	KK	TMGAKB	C	243
438	4.8470	100.9520	KK	TMGAKB	C	243
439	4.6208	100.8895	KK	TMGAKB	C	207
440	4.8043	100.8953	KK	TMGAKB	A	208
441	4.8586	100.9537	KK	TMGAKB	A	243
442	4.7769	100.8266	KK	TMGAKB	A	243
443	4.6108	100.8796	KK	TMGAKB	A	382
444	4.6944	100.9622	KK	TMGAKB	A	365
445	4.7797	100.9015	KK	TMGAKB	C	207
446	4.7748	100.9020	KK	TMGAKB	C	295
447	4.7758	100.8306	KK	TMGAKB	A	174
448	4.6294	100.9067	KK	TMGAKB	C	188
449	4.8355	100.9675	KK	TMGAKB	A	243
450	4.7690	100.8493	KK	TMGAKB	A	155
451	4.7776	100.9002	KK	TMGAKB	C	191
452	4.8256	100.9704	KK	TMGAKB	A	226
453	4.6068	100.8745	KK	TMGAKB	A	417
454	5.0662	100.4134	KR	BKU	Q	139
455	5.1084	100.4138	KR	BKU	Q	117
456	5.0675	100.3782	KR	BKU	Q	156
457	5.0421	100.4173	KR	BKU	Q	156
458	5.0767	100.3927	KR	BKU	Q	156
459	5.0161	100.4160	KR	BKU	Q	156
460	5.0973	100.4041	KR	BKU	Q	156
461	5.0509	100.3908	KR	BKU	Q	156
462	5.0974	100.3902	KR	BKU	Q	130
463	5.0818	100.6009	KR	BRH	Q	191
464	5.0428	100.5518	KR	BRH	Q	156
465	5.0108	100.6425	KR	BRH	Q	143
466	5.1185	100.5996	KR	BRH	Q	143
467	4.9261	100.6281	KR	BRH	Q	143
468	4.9484	100.5922	KR	BRH	Q	174
469	5.0827	100.5909	KR	BRH	Q	174
470	5.0775	100.5998	KR	BRH	Q	174
471	5.0145	100.5396	KR	BRH	Q	174
472	5.0754	100.5216	KR	BRH	Q	208
473	5.0349	100.6513	KR	BRH	T	191
474	4.9798	100.5981	KR	BRH	Q	174
475	4.9386	100.6191	KR	BRH	Q	117
476	5.0265	100.5551	KR	BRH	Q	97
477	5.0411	100.5735	KR	BRH	Q	97
478	4.9228	100.6043	KR	BRH	Q	104
479	5.0279	100.5888	KR	BRH	Q	117
480	4.9244	100.6549	KR	BRH	Q	117
481	5.0458	100.5805	KR	BRH	Q	174

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
482	5.1012	100.5976	KR	BRH	Q	174
483	5.0817	100.5941	KR	BRH	Q	174
484	5.0419	100.6485	KR	BRH	Q	174
485	5.0680	100.5918	KR	BRH	Q	156
486	5.0340	100.6132	KR	BRH	Q	117
487	4.9505	100.6297	KR	BRH	A	156
488	4.9815	100.6413	KR	BRH	Q	117
489	5.1086	100.6026	KR	BRH	Q	174
490	5.0451	100.5911	KR	BRH	Q	156
491	4.9905	100.5836	KR	BRH	Q	156
492	5.0551	100.5925	KR	BRH	Q	156
493	4.9505	100.6244	KR	BRH	Q	191
494	4.9531	100.6264	KR	BRH	Q	191
495	5.1324	100.4873	KR	BRH	Q	191
496	5.0446	100.6016	KR	BRH	Q	156
497	4.9534	100.6380	KR	BRH	Q	156
498	5.1206	100.6175	KR	BRH	Q	226
499	4.9933	100.5661	KR	BRH	Q	191
500	5.0365	100.5682	KR	BRH	Q	191
501	4.9725	100.6085	KR	BRH	Q	130
502	5.0335	100.6408	KR	BRH	Q	130
503	5.0841	100.5849	KR	BRH	Q	130
504	5.0234	100.7326	KR	HYDHMU	T	142
505	5.1117	100.6965	KR	HYDHMU	T	129
506	5.0983	100.7188	KR	HYDHMU	T	129
507	5.1172	100.6598	KR	HYDHMU	Q	110
508	5.1326	100.7001	KR	HYDHMU	T	246
509	4.9268	100.5801	KR	KNJ	Q	78
510	4.9385	100.4687	KR	KNJ	Q	174
511	5.0185	100.4330	KR	KNJ	Q	156
512	5.0451	100.3747	KR	KNJ	Q	121
513	4.9239	100.4526	KR	KNJ	Q	117
514	4.9319	100.4652	KR	KNJ	Q	156
515	4.9367	100.5749	KR	KNJ	Q	104
516	5.0872	100.6643	KR	LAATMGAKB	Q	142
517	5.0755	100.3814	KR	LAATMGAKB	Q	191
518	5.0855	100.6663	KR	LAATMGAKB	Q	116
519	5.1268	100.6287	KR	LAATMGAKB	Q	169
520	5.1280	100.6353	KR	LAATMGAKB	Q	116
521	5.1159	100.7162	KR	LAATMGAKB	T	129
522	4.9931	100.6629	KR	LAATMGAKB	T	174
523	5.1342	100.6280	KR	LAATMGAKB	Q	221
524	4.9356	100.7070	KR	LAATMGAKB	T	129
525	5.1121	100.7004	KR	LAATMGAKB	T	129
526	5.0814	100.7217	KR	LAATMGAKB	T	129
527	5.1290	100.6206	KR	LAATMGAKB	Q	295
528	5.1296	100.6286	KR	LAATMGAKB	Q	226
529	5.1314	100.6282	KR	LAATMGAKB	Q	295
530	5.0085	100.5204	KR	OCM	Q	143
531	5.0077	100.4869	KR	OCM	Q	174
532	5.0196	100.4998	KR	OCM	Q	174
533	5.0261	100.4657	KR	OCM	Q	174
534	4.9648	100.5051	KR	OCM	Q	117
535	5.1293	100.4703	KR	OCM	Q	156

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
536	5.0836	100.4940	KR	OCM	Q	106
537	5.0203	100.4975	KR	OCM	Q	174
538	4.9710	100.5015	KR	OCM	Q	156
539	5.0168	100.5167	KR	OCM	Q	191
540	5.0267	100.6663	KR	OCM	Q	191
541	5.1310	100.4775	KR	OCM	Q	191
542	5.0099	100.5468	KR	OCM	Q	130
543	5.0871	100.6214	KR	PET	Q	130
544	5.0554	100.6306	KR	PET	Q	116
545	5.0456	100.6203	KR	PET	Q	97
546	5.0425	100.6312	KR	PET	Q	156
547	5.0093	100.7322	KR	SDGMUN	T	142
548	4.9834	100.7290	KR	SDGMUN	T	142
549	4.9812	100.7134	KR	SDGMUN	T	142
550	4.9947	100.7352	KR	SDGMUN	T	142
551	5.0861	100.6724	KR	SDGMUN	Q	142
552	4.9563	100.7270	KR	SDGMUN	T	142
553	5.0661	100.7196	KR	SDGMUN	T	136
554	5.0025	100.7360	KR	SDGMUN	T	129
555	5.0718	100.6687	KR	SDGMUN	Q	129
556	5.0376	100.7301	KR	SDGMUN	T	129
557	5.0623	100.6531	KR	SDGMUN	Q	123
558	4.9377	100.6976	KR	SDGMUN	Q	77
559	5.1023	100.6684	KR	SDGMUN	Q	116
560	4.9620	100.6587	KR	SDGMUN	T	174
561	5.0876	100.6850	KR	SDGMUN	T	143
562	4.9865	100.7117	KR	SDGMUN	T	129
563	4.9687	100.5700	KR	SLR	Q	117
564	4.9735	100.4699	KR	SLR	Q	156
565	5.0122	100.4173	KR	SLR	Q	156
566	4.9843	100.4489	KR	SLR	Q	156
567	5.0070	100.4453	KR	SLR	Q	117
568	4.9470	100.4544	KR	SLR	Q	117
569	4.9775	100.4333	KR	SLR	Q	117
570	4.9467	100.5850	KR	SLR	Q	174
571	4.9747	100.4594	KR	SLR	Q	156
572	5.1058	100.4090	KR	SLR	Q	156
573	4.9513	100.6093	KR	SLR	Q	156
574	4.9463	100.5661	KR	SLR	Q	121
575	4.9840	100.4517	KR	SLR	Q	156
576	4.9623	100.4684	KR	SLR	Q	156
577	4.9548	100.5447	KR	SLR	Q	156
578	4.9361	100.5750	KR	SLR	Q	104
579	5.0255	100.4354	KR	SRG	Q	174
580	5.1121	100.4169	KR	SRG	Q	156
581	5.1009	100.4590	KR	SRG	Q	156
582	5.0586	100.4443	KR	SRG	Q	156
583	5.1085	100.4381	KR	SRG	Q	174
584	5.1028	100.4624	KR	SRG	Q	156
585	5.1199	100.4146	KR	SRG	Q	97
586	5.0986	100.4644	KR	SRG	Q	117
587	5.1054	100.4221	KR	SRG	Q	104
588	5.1289	100.4618	KR	SRG	Q	87
589	5.0765	100.4660	KR	SRG	Q	104

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
590	5.1154	100.4381	KR	SRG	Q	130
591	5.0189	100.6508	KR	STP	Q	136
592	4.9615	100.6519	KR	STP	T	156
593	5.0018	100.6545	KR	STP	T	121
594	4.3333	101.0669	KT	DLD	C	208
595	4.2895	101.1305	KT	DLD	C	104
596	4.6616	101.1787	KT	DLD	A	190
597	4.6261	101.0523	KT	DLD	A	208
598	4.5595	101.0512	KT	DLD	C	104
599	4.2622	101.0415	KT	DLD	C	104
600	4.3663	101.0127	KT	DLD	C	130
601	4.2667	101.0665	KT	DLD	C	208
602	4.2834	101.1283	KT	DLD	C	104
603	4.4687	100.9992	KT	DLD	C	130
604	4.3926	100.9774	KT	DLD	C	130
605	4.3878	101.0123	KT	DLD	C	130
606	4.4414	100.9951	KT	DLD	A	130
607	4.3924	100.9996	KT	DLD	A	234
608	4.4620	100.9830	KT	DLD	C	130
609	4.4957	101.1376	KT	DLD	D	52
610	4.4435	100.9938	KT	DLD	A	130
611	4.3388	101.0530	KT	DLD	C	455
612	4.2782	101.0858	KT	DLD	C	156
613	4.4697	100.9992	KT	DLD	C	130
614	4.6255	101.1175	KT	DLD	D	156
615	4.5402	101.0439	KT	DLD	C	208
616	4.5989	101.1096	KT	DLD	D	190
617	4.5822	101.0914	KT	DLD	D	156
618	4.5824	101.1269	KT	DLD	D	104
619	4.5911	101.0940	KT	DLD	D	156
620	4.2944	101.1253	KT	DLD	C	104
621	4.5685	101.0797	KT	DLD	D	156
622	4.2845	101.0570	KT	DLD	C	156
623	4.3807	100.9936	KT	DLD	A	130
624	4.5968	101.0770	KT	DLD	D	156
625	4.2800	101.0760	KT	DLD	C	156
626	4.5508	101.0757	KT	DLD	D	156
627	4.5727	101.0998	KT	DLD	D	188
628	4.5420	101.0678	KT	DLD	D	156
629	4.3445	101.0825	KT	DLD	C	188
630	4.4667	101.1389	KT	DLD	D	65
631	4.3954	101.1333	KT	DLD	D	156
632	4.4856	101.0372	KT	DLD	C	156
633	4.2622	101.0415	KT	DLD	C	104
634	4.2825	101.0579	KT	DLD	C	156
635	4.4835	101.0078	KT	DLD	A	273
636	4.5396	101.1216	KT	DLD	D	156
637	4.4523	101.0111	KT	DLD	C	104
638	4.7706	101.1457	KT	DLD	D	156
639	4.2572	101.0347	KT	DLD	A	156
640	4.7816	101.1114	KT	DLD	S	187
641	4.7566	101.1214	KT	DLD	D	221
642	4.4947	101.0222	KT	DLD	C	273
643	4.5879	101.1064	KT	DLD	D	156

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
644	4.6360	101.0680	KT	DLD	D	156
645	4.4305	101.1865	KT	DLD	C	156
646	4.5886	101.1299	KT	DLD	D	156
647	4.3622	101.1269	KT	DLD	D	156
648	4.6448	101.0679	KT	DLD	D	156
649	4.2883	101.1456	KT	DLD	D	117
650	4.5520	101.0697	KT	DLD	D	156
651	4.2817	101.0640	KT	DLD	C	156
652	4.5961	101.1521	KT	DLD	D	117
653	4.2951	101.1407	KT	DLD	D	117
654	4.5697	101.0572	KT	DLD	D	117
655	4.6298	101.1517	KT	DLD	D	221
656	4.2840	101.1644	KT	DLD	D	156
657	4.6302	101.0627	KT	DLD	D	221
658	4.5935	101.1217	KT	DLD	D	156
659	4.5020	101.1576	KT	DLD	D	273
660	4.5133	101.0160	KT	DLD	C	208
661	4.5039	101.0239	KT	DLD	C	182
662	4.5406	101.0374	KT	DLD	A	208
663	4.5089	101.0465	KT	DLD	C	156
664	4.4551	100.9952	KT	DLD	A	104
665	4.4651	100.9968	KT	DLD	A	182
666	4.6258	101.0636	KT	DLD	D	221
667	4.2923	101.0825	KT	DLD	A	273
668	4.4657	101.1788	KT	DLD	C	156
669	4.5056	101.1537	KT	DLD	D	156
670	4.4755	101.0522	KT	DLD	C	156
671	4.4525	100.9963	KT	DLD	C	104
672	4.4978	101.0041	KT	DLD	A	286
673	4.5071	101.0618	KT	DLD	C	156
674	4.3014	101.1466	KT	DLD	D	130
675	4.3324	101.0662	KT	DLD	D	286
676	4.5758	101.0393	KT	DLD	D	156
677	4.5296	101.0643	KT	DLD	D	156
678	4.4925	101.0504	KT	DLD	D	156
679	4.4216	100.9754	KT	DLD	C	65
680	4.5117	101.0083	KT	DLD	A	182
681	4.5433	101.0507	KT	DLD	D	117
682	4.6105	101.1284	KT	DLD	D	177
683	4.5332	101.0577	KT	DLD	D	130
684	4.5499	101.0474	KT	DLD	C	182
685	4.5162	101.0317	KT	DLD	D	182
686	4.3900	101.0475	KT	DLD	C	104
687	4.2836	101.1492	KT	DLD	D	247
688	4.3821	101.0775	KT	DLD	C	143
689	4.5166	101.0564	KT	DLD	D	156
690	4.2554	101.0634	KT	DLD	C	143
691	4.6056	101.0858	KT	DLD	D	143
692	4.5578	101.0562	KT	DLD	C	143
693	4.5089	101.0229	KT	DLD	A	182
694	4.6139	101.1061	KT	DLD	D	143
695	4.2558	101.0608	KT	DLD	C	143
696	4.4551	100.9938	KT	DLD	C	117
697	4.6223	101.0830	KT	DLD	D	195

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
698	4.7340	101.1005	KT	DLD	S	143
699	4.5083	101.0542	KT	DLD	D	195
700	4.2809	101.0517	KT	DLD	A	195
701	4.2777	101.0821	KT	DLD	C	195
702	4.5851	101.1124	KT	DLD	D	143
703	4.5968	101.0735	KT	DLD	D	156
704	4.6025	101.0600	KT	DLD	D	143
705	4.3339	101.0933	KT	DLD	C	143
706	4.5813	101.1107	KT	DLD	D	143
707	4.3876	101.2082	KT	DLD	D	195
708	4.4743	101.0628	KT	DLD	C	143
709	4.5928	101.0922	KT	DLD	D	143
710	4.6118	101.0634	KT	DLD	D	143
711	4.4138	101.1047	KT	DLD	C	156
712	4.5772	101.0817	KT	DLD	D	143
713	4.3340	101.0910	KT	DLD	C	143
714	4.6111	101.1148	KT	DLD	D	143
715	4.5706	101.0986	KT	DLD	D	143
716	4.5985	101.0632	KT	DLD	D	143
717	4.6503	101.1704	KT	DLD	D	156
718	4.5324	101.0466	KT	DLD	D	130
719	4.2667	101.0665	KT	DLD	C	208
720	4.3293	101.1445	KT	DLD	D	156
721	4.4090	101.1036	KT	DLD	C	195
722	4.3590	101.1578	KT	DLD	C	208
723	4.2882	101.1184	KT	DLD	C	78
724	4.4693	101.1833	KT	DLD	C	78
725	4.3737	101.1653	KT	DLD	D	195
726	4.5617	101.1052	KT	DLD	D	123
727	4.2824	101.1171	KT	DLD	D	78
728	4.4830	101.1477	KT	DLD	D	78
729	4.5075	101.1557	KT	DLD	D	208
730	4.5837	101.0817	KT	DLD	D	169
731	4.4584	100.9826	KT	DLD	C	78
732	4.4233	100.9911	KT	DLD	A	143
733	4.3356	101.0391	KT	DLD	C	747
734	4.5754	101.0386	KT	DLD	D	156
735	4.4925	101.0558	KT	DLD	D	156
736	4.5510	101.0360	KT	DLD	D	163
737	4.5822	101.0986	KT	DLD	D	156
738	4.4226	101.0029	KT	DLD	C	169
739	4.5314	101.0577	KT	DLD	D	156
740	4.5058	101.0118	KT	DLD	A	169
741	4.2841	101.1658	KT	DLD	A	156
742	4.5885	101.1268	KT	DLD	D	156
743	4.3137	101.1575	KT	DLD	D	208
744	4.5000	101.0573	KT	DLD	D	156
745	4.6123	101.1147	KT	DLD	D	117
746	4.5774	101.1172	KT	DLD	D	195
747	4.3998	101.0665	KT	DLD	C	110
748	4.4162	101.0600	KT	DLD	C	117
749	4.4652	100.9914	KT	DLD	A	208
750	4.5424	101.0508	KT	DLD	D	117
751	4.5569	101.1142	KT	DLD	D	195

no	LOKASI (DEG) latitud	longitud	Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
752	4.7508	101.1141	KT	DLD	S	195
753	4.3072	101.0686	KT	DLD	C	117
754	4.5845	101.0735	KT	DLD	D	195
755	4.5416	101.0476	KT	DLD	C	143
756	4.4804	101.0044	KT	DLD	A	143
757	4.4648	101.0447	KT	DLD	C	143
758	4.5000	101.0564	KT	DLD	D	156
759	4.7315	101.0977	KT	DLD	A	169
760	4.2852	101.1417	KT	DLD	C	130
761	4.4749	101.0677	KT	DLD	D	130
762	4.3954	101.1252	KT	DLD	D	156
763	4.3160	101.0579	KT	DLD	C	130
764	4.4171	100.9800	KT	DLD	C	117
765	4.3330	101.0686	KT	DLD	C	130
766	4.3755	101.1682	KT	DLD	D	130
767	4.4862	101.1018	KT	DLD	C	169
768	4.3492	101.1581	KT	DLD	D	195
769	4.4245	101.1859	KT	DLD	D	130
770	4.3090	101.0869	KT	DLD	C	91
771	4.6013	101.1445	KT	DLD	D	156
772	4.7345	101.1042	KT	DLD	S	208
773	4.4208	101.1890	KT	DLD	D	130
774	4.3028	101.0686	KT	DLD	C	91
775	4.3171	101.0928	KT	DLD	C	91
776	4.3337	101.1440	KT	DLD	D	156
777	4.3793	101.0129	KT	DLD	C	91
778	4.5566	101.1170	KT	DLD	D	208
779	4.7663	101.1053	KT	DLD	S	169
780	4.5223	101.1298	KT	DLD	D	169
781	4.3840	101.0168	KT	DLD	C	91
782	4.3607	101.1247	KT	DLD	D	117
783	4.3834	101.1784	KT	DLD	D	195
784	4.2721	101.0936	KT	DLD	C	91
785	4.3299	101.0620	KT	DLD	A	325
786	4.8096	101.0954	KT	DLD	S	203
787	4.3257	101.1354	KT	DLD	D	169
788	4.4845	101.0558	KT	DLD	D	156
789	4.3943	101.1924	KT	DLD	D	195
790	4.2670	101.0502	KT	DLD	C	169
791	4.2811	101.1258	KT	DLD	D	117
792	4.5002	101.1340	KT	DLD	D	130
793	4.2916	101.1330	KT	DLD	C	117
794	4.3293	101.1433	KT	DLD	D	169
795	4.2996	101.1513	KT	DLD	D	169
796	4.3968	101.1445	KT	DLD	D	130
797	4.2833	101.0510	KT	DLD	A	169
798	4.3368	101.0755	KT	DLD	A	747
799	4.2882	101.1354	KT	DLD	D	104
800	4.4027	101.1167	KT	DLD	D	91
801	4.4467	101.1664	KT	DLD	D	91
802	4.4520	101.1423	KT	DLD	D	91
803	4.3668	101.1029	KT	DLD	C	91
804	4.2668	101.0518	KT	DLD	C	169
805	4.5853	101.0585	KT	DLD	D	169

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
806	4.6032	101.1204	KT	DLD	D	156
807	4.4202	101.1893	KT	DLD	D	195
808	4.5024	101.1520	KT	DLD	D	169
809	4.5614	101.0556	KT	DLD	C	169
810	4.5972	101.0852	KT	DLD	D	164
811	4.5806	101.1297	KT	DLD	D	130
812	4.3115	101.0573	KT	DLD	C	169
813	4.5618	101.0585	KT	DLD	D	169
814	4.5384	101.1529	KT	DLD	D	169
815	4.5774	101.1264	KT	DLD	D	195
816	4.6062	101.1417	KT	DLD	D	130
817	4.4404	101.1504	KT	DLD	D	169
818	4.4779	101.1520	KT	DLD	D	169
819	4.2996	101.1616	KT	DLD	A	195
820	4.4448	101.1951	KT	DLD	D	169
821	4.8096	101.0901	KT	DLD	D	203
822	4.5824	101.1297	KT	DLD	D	117
823	4.4925	101.0564	KT	DLD	D	169
824	4.2811	101.0671	KT	DLD	C	169
825	4.5238	101.0657	KT	DLD	D	169
826	4.2805	101.0680	KT	DLD	C	169
827	4.8253	101.0377	KT	DLD	S	195
828	4.2729	101.1500	KT	DLD	D	130
829	4.6033	101.1020	KT	DLD	D	91
830	4.5543	101.0795	KT	DLD	D	169
831	4.5275	101.0701	KT	DLD	D	169
832	4.3269	101.0417	KT	DLD	A	780
833	4.5837	101.0671	KT	DLD	D	169
834	4.4693	101.1667	KT	DLD	D	91
835	4.2734	101.0894	KT	DLD	C	91
836	4.3249	101.0577	KT	DLD	C	195
837	4.4178	101.1421	KT	DLD	D	130
838	4.4941	101.0168	KT	DLD	C	195
839	4.2712	101.1424	KT	DLD	D	130
840	4.6589	101.1667	KT	DLD	D	143
841	4.3311	101.0824	KT	DLD	C	169
842	4.5772	101.0794	KT	DLD	D	156
843	4.2931	101.1640	KT	DLD	D	247
844	4.4370	101.1557	KT	DLD	D	104
845	4.4840	101.1561	KT	DLD	D	104
846	4.2783	101.0832	KT	DLD	C	169
847	4.3427	101.0500	KT	DLD	C	435
848	4.6232	101.0940	KT	DLD	D	169
849	4.3366	101.1447	KT	DLD	D	130
850	4.4744	101.0485	KT	DLD	C	195
851	4.5958	101.1446	KT	DLD	D	130
852	4.3283	101.0548	KT	DLD	A	387
853	4.3509	101.0498	KT	DLD	A	195
854	4.3886	101.1807	KT	DLD	D	143
855	4.4713	101.1554	KT	DLD	C	52
856	4.3900	101.1827	KT	DLD	D	143
857	4.2746	101.0850	KT	DLD	C	130
858	4.2675	101.0838	KT	DLD	C	130
859	4.4198	100.9702	KT	DLD	C	91

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy\ J^{-1}$
860	4.3937	101.1969	KT	DLD	D	143
861	4.7649	101.1316	KT	DLD	D	208
862	4.4855	101.0161	KT	DLD	C	117
863	4.2559	101.0830	KT	DLD	C	130
864	4.6188	101.0620	KT	DLD	D	208
865	4.2737	101.0894	KT	DLD	C	130
866	4.2683	101.0782	KT	DLD	C	117
867	4.3131	101.0713	KT	DLD	C	143
868	4.4842	101.0942	KT	DLD	D	130
869	4.2503	101.0970	KT	DLD	C	130
870	4.5985	101.1107	KT	DLD	D	130
871	4.4682	101.0258	KT	DLD	C	117
872	4.5074	101.1480	KT	DLD	D	221
873	4.3883	101.2110	KT	DLD	A	195
874	4.6295	101.1558	KT	DLD	D	221
875	4.7567	101.1158	KT	DLD	D	208
876	4.4180	100.9888	KT	DLD	C	104
877	4.4005	100.9920	KT	DLD	A	117
878	4.5035	100.9984	KT	DLD	A	257
879	4.3528	101.0668	KT	DLD	C	650
880	4.5166	101.0465	KT	DLD	D	130
881	4.3587	101.1565	KT	DLD	D	221
882	4.7563	101.1302	KT	DLD	D	221
883	4.2829	101.1513	KT	DLD	D	169
884	4.3549	101.0244	KT	DLD	C	98
885	4.4476	101.0502	KT	DLD	C	169
886	4.3886	101.2151	KT	DLD	A	299
887	4.2640	101.0920	KT	DLD	C	117
888	4.6116	101.0584	KT	DLD	D	169
889	4.4827	101.0551	KT	DLD	C	143
890	4.4367	100.9742	KT	DLD	C	91
891	4.2990	101.1480	KT	DLD	D	117
892	4.4608	100.9936	KT	DLD	C	91
893	4.5166	101.0600	KT	DLD	D	143
894	4.5148	101.1456	KT	DLD	C	221
895	4.3366	101.1301	KT	DLD	D	143
896	4.4246	101.0026	KT	DLD	C	117
897	4.4312	100.9809	KT	DLD	C	104
898	4.4641	100.9868	KT	DLD	D	117
899	4.2845	101.1087	KT	DLD	C	130
900	4.3076	101.0730	KT	DLD	C	143
901	4.5455	101.0432	KT	DLD	D	286
902	4.5433	101.0600	KT	DLD	D	117
903	4.5082	101.1093	KT	DLD	D	143
904	4.7644	101.1285	KT	DLD	D	208
905	4.5844	101.0671	KT	DLD	D	208
906	4.3015	101.0670	KT	DLD	C	143
907	4.7549	101.1200	KT	DLD	D	143
908	4.2836	101.1510	KT	DLD	D	208
909	4.3192	101.1471	KT	DLD	C	143
910	4.4027	101.1332	KT	DLD	D	91
911	4.5051	101.1322	KT	DLD	D	143
912	4.7703	101.1317	KT	DLD	D	143
913	4.6034	101.1173	KT	DLD	D	143

no	LOKASI (DEG) latitud	longitud	Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan $nGy\ J^{-1}$
914	4.6435	101.1294	KT	DLD	D	143
915	4.7661	101.1021	KT	DLD	S	143
916	4.5166	101.0125	KT	DLD	A	390
917	4.3137	101.1546	KT	DLD	D	208
918	4.2921	101.1415	KT	DLD	D	117
919	4.4007	100.9850	KT	DLD	C	104
920	4.4347	100.9999	KT	DLD	A	117
921	4.5994	101.0454	KT	DLD	A	390
922	4.4482	101.1708	KT	DLD	D	143
923	4.4809	101.1424	KT	DLD	A	117
924	4.6062	101.1357	KT	DLD	D	143
925	4.6013	101.1417	KT	DLD	D	143
926	4.5039	101.0222	KT	DLD	D	182
927	4.3316	101.0653	KT	DLD	A	390
928	4.3016	101.1480	KT	DLD	D	117
929	4.2770	101.1504	KT	DLD	D	117
930	4.6095	101.1206	KT	DLD	D	182
931	4.5961	101.1506	KT	DLD	D	117
932	4.2960	101.1553	KT	DLD	D	117
933	4.3864	101.2130	KT	DLD	A	182
934	4.4630	101.1653	KT	DLD	D	117
935	4.4586	101.0470	KT	DLD	C	117
936	4.4773	101.0675	KT	DLD	D	117
937	4.3072	101.0668	KT	DLD	C	117
938	4.2919	101.1273	KT	DLD	C	117
939	4.2885	101.1503	KT	DLD	D	143
940	4.5850	101.0529	KT	DLD	D	169
941	4.5363	101.1173	KT	DLD	D	117
942	4.6514	101.1025	KT	DLD	D	135
943	4.6123	101.1102	KT	DLD	D	117
944	4.5905	101.1376	KT	DLD	D	143
945	4.4933	101.1200	KT	DLD	C	117
946	4.5266	101.0435	KT	DLD	D	130
947	4.3065	101.1571	KT	DLD	D	143
948	4.2789	101.0855	KT	DLD	C	117
949	4.6430	101.1573	KT	DLD	D	195
950	4.5223	101.0013	KT	DLD	A	299
951	4.5238	101.0564	KT	DLD	D	169
952	4.2863	101.1098	KT	DLD	C	117
953	4.5701	101.1022	KT	DLD	D	117
954	4.4965	101.0082	KT	DLD	A	299
955	4.3503	101.1160	KT	DLD	C	117
956	4.5152	101.0080	KT	DLD	A	195
957	4.3260	101.1385	KT	DLD	D	169
958	4.2749	101.0682	KT	DLD	C	117
959	4.4165	101.1874	KT	DLD	C	195
960	4.3346	101.0565	KT	DLD	A	299
961	4.3740	101.1667	KT	DLD	D	195
962	4.3904	100.9716	KT	DLD	C	130
963	4.3369	101.1461	KT	DLD	D	130
964	4.5700	101.0542	KT	DLD	D	117
965	4.5935	101.1299	KT	DLD	D	169
966	4.2842	101.1467	KT	DLD	D	143
967	4.2951	101.1382	KT	DLD	D	117

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
968	4.7568	101.1173	KT	DLD	D	200
969	4.2748	101.1423	KT	DLD	D	117
970	4.4464	101.1501	KT	DLD	D	91
971	4.3028	101.0670	KT	DLD	C	91
972	4.6145	101.0809	KT	DLD	D	221
973	4.4088	101.1082	KT	DLD	C	195
974	4.4331	101.0587	KT	DLD	C	137
975	4.3071	101.0579	KT	DLD	C	169
976	4.4351	101.0884	KT	DLD	C	91
977	4.6281	101.1357	KT	DLD	D	182
978	4.3248	101.1508	KT	DLD	D	143
979	4.5083	101.0573	KT	DLD	D	195
980	4.5504	101.0435	KT	DLD	D	130
981	4.2520	101.0276	KT	DLD	C	221
982	4.6192	101.0565	KT	DLD	A	221
983	4.4562	101.0771	KT	DLD	C	130
984	4.6219	101.0794	KT	DLD	D	195
985	4.6029	101.1107	KT	DLD	D	91
986	4.5541	101.0683	KT	DLD	D	169
987	4.6549	101.1653	KT	DLD	A	138
988	4.7243	101.0928	KT	DLD	A	221
989	4.6255	101.1173	KT	DLD	D	169
990	4.2581	101.0644	KT	DLD	C	117
991	4.5879	101.1124	KT	DLD	D	169
992	4.4387	101.1422	KT	DLD	C	91
993	4.5593	101.0640	KT	DLD	D	117
994	4.6589	101.1712	KT	DLD	D	143
995	4.4821	101.0706	KT	DLD	D	104
996	4.7155	101.1101	KT	DLD	S	221
997	4.4272	100.9963	KT	DLD	A	117
998	4.5089	101.0229	KT	DLD	D	182
999	4.6495	101.0761	KT	DLD	D	221
1000	4.6109	101.1005	KT	DLD	D	143
1001	4.2934	101.1635	KT	DLD	A	143
1002	4.3335	101.1426	KT	DLD	D	143
1003	4.2931	101.1620	KT	DLD	D	143
1004	4.3574	101.1411	KT	DLD	D	143
1005	4.3527	101.1575	KT	DLD	C	182
1006	4.2803	101.0740	KT	DLD	C	182
1007	4.6333	101.1523	KT	DLD	D	182
1008	4.5958	101.1042	KT	DLD	D	143
1009	4.2882	101.1515	KT	DLD	D	143
1010	4.4544	101.1422	KT	DLD	D	143
1011	4.2741	101.1501	KT	DLD	D	104
1012	4.3497	101.1392	KT	DLD	D	104
1013	4.4591	101.1509	KT	DLD	D	104
1014	4.8070	101.0840	KT	DLD	D	174
1015	4.3394	101.0506	KT	DLD	C	649
1016	4.3381	101.0520	KT	DLD	C	649
1017	4.5003	101.0137	KT	DLD	A	182
1018	4.4489	101.0477	KT	DLD	C	110
1019	4.3194	101.1485	KT	DLD	D	143
1020	4.5251	101.0657	KT	DLD	D	156
1021	4.3853	100.9996	KT	DLD	A	169

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1022	4.5166	101.0542	KT	DLD	D	143
1023	4.2918	101.1340	KT	DLD	D	104
1024	4.3250	101.1522	KT	DLD	D	143
1025	4.2721	101.0918	KT	DLD	C	104
1026	4.3294	101.0618	KT	DLD	A	247
1027	4.5806	101.1171	KT	DLD	D	143
1028	4.6000	101.0784	KT	DLD	D	247
1029	4.4665	100.9972	KT	DLD	C	156
1030	4.7259	101.0975	KT	DLD	A	247
1031	4.3014	101.1627	KT	DLD	D	286
1032	4.5621	101.0400	KT	DLD	D	130
1033	4.4967	101.0099	KT	DLD	A	156
1034	4.2507	101.0843	KT	DLD	C	208
1035	4.3882	101.2019	KT	DLD	A	169
1036	4.3076	101.0668	KT	DLD	C	143
1037	4.3883	101.0605	KT	DLD	C	234
1038	4.5266	101.0466	KT	DLD	C	130
1039	4.2590	101.0262	KT	DLD	C	130
1040	4.5361	101.0701	KT	DLD	D	143
1041	4.4682	101.0148	KT	DLD	C	130
1042	4.2715	101.0667	KT	DLD	C	130
1043	4.3706	101.0601	KT	DLD	C	143
1044	4.5787	101.0356	KT	DLD	D	130
1045	4.3015	101.0704	KT	DLD	C	143
1046	4.2631	101.0245	KT	DLD	C	130
1047	4.3938	101.0536	KT	DLD	C	110
1048	4.3468	101.1332	KT	DLD	D	104
1049	4.6419	101.0968	KT	DLD	D	114
1050	4.5819	101.0398	KT	DLD	D	234
1051	4.5782	101.0392	KT	DLD	D	130
1052	4.3434	101.0539	KT	DLD	C	182
1053	4.2805	101.0687	KT	DLD	C	182
1054	4.3449	101.0635	KT	DLD	C	130
1055	4.3167	101.0327	KT	DLD	C	143
1056	4.7706	101.1299	KT	DLD	D	143
1057	4.3491	101.0421	KT	DLD	C	130
1058	4.6593	101.1681	KT	DLD	D	143
1059	4.5507	101.0457	KT	DLD	D	130
1060	4.5324	101.0448	KT	DLD	C	130
1061	4.5506	101.0449	KT	DLD	A	130
1062	4.6429	101.1564	KT	DLD	D	182
1063	4.5981	101.0570	KT	DLD	D	143
1064	4.2585	101.0488	KT	DLD	C	130
1065	4.2608	101.0479	KT	DLD	C	130
1066	4.3310	101.0695	KT	DLD	C	130
1067	4.3285	101.0752	KT	DLD	C	130
1068	4.5166	101.0435	KT	DLD	C	130
1069	4.7652	101.1173	KT	DLD	D	143
1070	4.3423	101.0645	KT	DLD	C	130
1071	4.5590	101.0511	KT	DLD	D	130
1072	4.3002	101.0853	KT	DLD	C	130
1073	4.6275	101.0867	KT	DLD	D	130
1074	4.5811	101.1070	KT	DLD	D	143
1075	4.4116	101.1230	KT	DLD	D	104

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
1076	4.2913	101.1108	KT	DLD	P	104
1077	4.5905	101.1422	KT	DLD	D	143
1078	4.2835	101.1135	KT	DLD	C	104
1079	4.6546	101.1639	KT	DLD	D	143
1080	4.4086	101.1094	KT	DLD	C	104
1081	4.4983	101.1559	KT	DLD	D	120
1082	4.4079	101.1235	KT	DLD	D	104
1083	4.4046	101.1235	KT	DLD	D	104
1084	4.3176	101.0984	KT	DLD	C	104
1085	4.2840	101.0645	KT	DLD	A	130
1086	4.5372	101.1282	KT	DLD	D	182
1087	4.7600	101.1154	KT	DLD	S	182
1088	4.6082	101.0954	KT	DLD	D	182
1089	4.3016	101.1641	KT	DLD	A	286
1090	4.4983	101.1297	KT	DLD	D	182
1091	4.6281	101.1397	KT	DLD	D	182
1092	4.4083	101.0549	KT	DLD	C	104
1093	4.7149	101.0937	KT	DLD	S	104
1094	4.3795	101.0178	KT	DLD	C	107
1095	4.4080	101.1184	KT	DLD	D	104
1096	4.2714	101.0038	KT	DLD	C	156
1097	4.3757	100.9818	KT	DLD	A	156
1098	4.4960	101.0490	KT	DLD	C	390
1099	4.3485	101.1567	KT	DLD	D	182
1100	4.3525	101.1561	KT	DLD	C	182
1101	4.3349	101.1576	KT	DLD	D	182
1102	4.3669	101.1597	KT	DLD	D	182
1103	4.3861	101.2117	KT	DLD	D	182
1104	4.4307	100.9960	KT	DLD	A	257
1105	4.2934	101.1654	KT	DLD	A	247
1106	4.5052	101.0065	KT	DLD	A	257
1107	4.4079	100.9581	KT	DLD	C	78
1108	4.2824	101.1171	KT	DLD	C	78
1109	4.4621	101.1332	KT	DLD	D	104
1110	4.3992	101.1589	KT	HYDHMU	D	234
1111	4.4758	101.0777	KT	HYDHMU	D	104
1112	4.6837	101.0865	KT	HYDHMU	S	234
1113	4.3623	101.0542	KT	HYDHMU	C	78
1114	4.3668	101.0569	KT	HYDHMU	C	78
1115	4.6982	101.1230	KT	HYDHMU	D	188
1116	4.7746	101.1383	KT	HYDHMU	A	234
1117	4.3960	101.1559	KT	HYDHMU	D	221
1118	4.6495	101.0678	KT	HYDHMU	D	221
1119	4.6991	101.0828	KT	HYDHMU	A	273
1120	4.5150	101.0899	KT	HYDHMU	D	143
1121	4.6719	101.1579	KT	HYDHMU	D	190
1122	4.4562	101.1939	KT	HYDHMU	D	221
1123	4.4051	101.0935	KT	HYDHMU	C	143
1124	4.7042	101.1237	KT	HYDHMU	D	140
1125	4.4878	101.0802	KT	HYDHMU	D	104
1126	4.6765	101.1646	KT	HYDHMU	D	190
1127	4.3831	101.1252	KT	HYDHMU	D	104
1128	4.3875	101.1497	KT	HYDHMU	D	140
1129	4.3913	100.9674	KT	HYDHMU	C	104

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1130	4.6930	101.1375	KT	HYDHMU	D	137
1131	4.6910	101.1259	KT	HYDHMU	D	137
1132	4.6824	101.1223	KT	HYDHMU	D	174
1133	4.2693	101.1169	KT	HYDHMU	D	104
1134	4.4208	101.1581	KT	HYDHMU	D	130
1135	4.6875	101.1228	KT	HYDHMU	D	182
1136	4.7224	101.1383	KT	HYDHMU	D	117
1137	4.3622	101.0631	KT	HYDHMU	C	130
1138	4.6902	101.1397	KT	HYDHMU	D	182
1139	4.6655	101.1144	KT	HYDHMU	D	182
1140	4.6824	101.1207	KT	HYDHMU	D	182
1141	4.4463	101.1843	KT	HYDHMU	D	143
1142	4.3439	101.0710	KT	HYDHMU	C	104
1143	4.2822	101.1121	KT	HYDHMU	C	104
1144	4.4248	101.1541	KT	HYDHMU	D	143
1145	4.4633	101.1866	KT	HYDHMU	D	143
1146	4.5179	101.1329	KT	HYDHMU	D	130
1147	4.4431	100.9706	KT	HYDHMU	C	65
1148	4.4580	100.9782	KT	HYDHMU	C	65
1149	4.4111	101.1725	KT	HYDHMU	D	65
1150	4.6642	101.1177	KT	HYDHMU	D	104
1151	4.6801	101.1421	KT	HYDHMU	D	65
1152	4.4758	101.0814	KT	HYDHMU	D	107
1153	4.4113	101.1171	KT	HYDHMU	C	104
1154	4.2632	101.0952	KT	HYDHMU	C	117
1155	4.4339	101.1300	KT	HYDHMU	D	104
1156	4.4135	101.1037	KT	HYDHMU	C	143
1157	4.4310	100.9926	KT	HYDHMU	C	260
1158	4.5316	101.1351	KT	HYDHMU	D	169
1159	4.6729	101.1350	KT	HYDHMU	D	123
1160	4.6991	101.1425	KT	HYDHMU	D	104
1161	4.6742	101.1360	KT	HYDHMU	D	104
1162	4.7146	101.1201	KT	HYDHMU	D	266
1163	4.5355	101.1367	KT	HYDHMU	D	172
1164	4.5275	101.0743	KT	HYDHMU	D	169
1165	4.5042	101.0975	KT	HYDHMU	D	169
1166	4.6769	101.1220	KT	HYDHMU	D	156
1167	4.6627	101.1545	KT	HYDHMU	D	143
1168	4.6908	101.1306	KT	HYDHMU	D	156
1169	4.5339	101.1334	KT	HYDHMU	D	169
1170	4.7532	101.1516	KT	HYDHMU	A	325
1171	4.7224	101.1222	KT	HYDHMU	D	169
1172	4.2614	101.0987	KT	HYDHMU	C	143
1173	4.6658	101.1158	KT	HYDHMU	D	172
1174	4.6978	101.1334	KT	HYDHMU	D	169
1175	4.7441	101.1305	KT	HYDHMU	D	156
1176	4.4401	101.1693	KT	HYDHMU	D	156
1177	4.7010	101.1270	KT	HYDHMU	D	156
1178	4.7263	101.1356	KT	HYDHMU	D	156
1179	4.4343	101.1699	KT	HYDHMU	D	156
1180	4.4554	101.1897	KT	HYDHMU	D	156
1181	4.4525	101.1866	KT	HYDHMU	D	169
1182	4.6819	101.1158	KT	HYDHMU	D	156
1183	4.6679	101.1102	KT	HYDHMU	D	156

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1184	4.2882	101.1230	KT	HYDHMU	C	83
1185	4.7345	101.1212	KT	HYDHMU	D	156
1186	4.7034	101.1358	KT	HYDHMU	D	169
1187	4.3836	101.1579	KT	HYDHMU	D	169
1188	4.4307	101.1772	KT	HYDHMU	C	169
1189	4.4525	101.1957	KT	HYDHMU	D	169
1190	4.5042	101.0920	KT	HYDHMU	D	169
1191	4.5249	101.1010	KT	HYDHMU	D	169
1192	4.4116	101.1184	KT	HYDHMU	D	104
1193	4.7056	101.1313	KT	HYDHMU	D	117
1194	4.3516	101.0634	KT	HYDHMU	C	130
1195	4.2711	101.0999	KT	HYDHMU	C	143
1196	4.5014	101.0975	KT	HYDHMU	D	143
1197	4.2837	101.1223	KT	HYDHMU	C	104
1198	4.4421	101.1276	KT	HYDHMU	C	117
1199	4.7337	101.1286	KT	HYDHMU	D	208
1200	4.3623	101.0635	KT	HYDHMU	C	117
1201	4.2667	101.1016	KT	HYDHMU	C	104
1202	4.6624	101.1431	KT	HYDHMU	D	143
1203	4.3672	101.1337	KT	HYDHMU	D	143
1204	4.7357	101.1209	KT	HYDHMU	D	192
1205	4.2788	101.1198	KT	HYDHMU	C	81
1206	4.4512	100.9618	KT	HYDHMU	C	91
1207	4.5307	101.1230	KT	HYDHMU	D	130
1208	4.2882	101.1229	KT	HYDHMU	C	78
1209	4.5253	101.1112	KT	HYDHMU	D	130
1210	4.2750	101.1167	KT	HYDHMU	D	91
1211	4.7173	101.1228	KT	HYDHMU	D	247
1212	4.4367	100.9809	KT	HYDHMU	C	91
1213	4.4199	101.1128	KT	HYDHMU	C	91
1214	4.2727	101.1012	KT	HYDHMU	C	130
1215	4.4464	101.1829	KT	HYDHMU	D	156
1216	4.4299	101.1132	KT	HYDHMU	C	91
1217	4.4566	101.1952	KT	HYDHMU	D	195
1218	4.4339	101.1264	KT	HYDHMU	D	104
1219	4.3792	101.1616	KT	HYDHMU	D	195
1220	4.6777	101.1627	KT	HYDHMU	D	195
1221	4.6618	101.1258	KT	HYDHMU	D	130
1222	4.5056	101.1073	KT	HYDHMU	D	143
1223	4.5142	101.0854	KT	HYDHMU	D	169
1224	4.4418	100.9722	KT	HYDHMU	C	52
1225	4.4162	100.9574	KT	HYDHMU	C	91
1226	4.6829	101.1559	KT	HYDHMU	D	208
1227	4.4878	101.0828	KT	HYDHMU	D	130
1228	4.7371	101.1358	KT	HYDHMU	D	143
1229	4.3699	101.0602	KT	HYDHMU	C	130
1230	4.6826	101.1582	KT	HYDHMU	D	221
1231	4.4167	101.1168	KT	HYDHMU	D	130
1232	4.4154	101.1620	KT	HYDHMU	D	130
1233	4.2696	101.1115	KT	HYDHMU	C	130
1234	4.7155	101.1061	KT	HYDHMU	S	221
1235	4.7417	101.1422	KT	HYDHMU	D	156
1236	4.7166	101.1370	KT	HYDHMU	D	130
1237	4.7333	101.1272	KT	HYDHMU	D	210

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1238	4.4013	101.0995	KT	HYDHMU	C	156
1239	4.5247	101.0850	KT	HYDHMU	D	156
1240	4.6686	101.1046	KT	HYDHMU	D	143
1241	4.5288	101.1291	KT	HYDHMU	D	156
1242	4.4993	101.0777	KT	HYDHMU	D	130
1243	4.4410	101.1905	KT	HYDHMU	D	130
1244	4.5167	101.1046	KT	HYDHMU	D	143
1245	4.5307	101.1015	KT	HYDHMU	D	130
1246	4.7368	101.1288	KT	HYDHMU	D	195
1247	4.7221	101.1480	KT	HYDHMU	D	130
1248	4.4208	101.1589	KT	HYDHMU	D	130
1249	4.7780	101.1358	KT	HYDHMU	A	221
1250	4.3926	100.9729	KT	HYDHMU	C	130
1251	4.3923	100.9729	KT	HYDHMU	C	130
1252	4.5158	101.0852	KT	HYDHMU	D	130
1253	4.5253	101.1010	KT	HYDHMU	D	130
1254	4.4178	101.1479	KT	HYDHMU	C	130
1255	4.7191	101.1471	KT	HYDHMU	D	130
1256	4.6435	101.1175	KT	HYDHMU	D	130
1257	4.4309	101.1775	KT	HYDHMU	D	169
1258	4.6676	101.1172	KT	HYDHMU	D	169
1259	4.7008	101.1239	KT	HYDHMU	D	169
1260	4.7109	101.1266	KT	HYDHMU	D	98
1261	4.7669	101.1422	KT	HYDHMU	D	312
1262	4.6826	101.1545	KT	HYDHMU	D	221
1263	4.7665	101.1387	KT	HYDHMU	A	309
1264	4.5247	101.0988	KT	HYDHMU	D	156
1265	4.7333	101.1288	KT	HYDHMU	D	208
1266	4.3778	101.0438	KT	HYDHMU	C	98
1267	4.4606	101.1887	KT	HYDHMU	D	182
1268	4.6991	101.1355	KT	HYDHMU	D	96
1269	4.3957	101.1546	KT	HYDHMU	D	208
1270	4.3619	101.0618	KT	HYDHMU	D	117
1271	4.6906	101.1294	KT	HYDHMU	D	156
1272	4.5080	101.0829	KT	HYDHMU	D	117
1273	4.2701	101.0940	KT	HYDHMU	C	117
1274	4.2669	101.1112	KT	HYDHMU	C	117
1275	4.2589	101.1116	KT	HYDHMU	C	117
1276	4.2753	101.1123	KT	HYDHMU	C	117
1277	4.4419	101.1262	KT	HYDHMU	D	117
1278	4.7584	101.1387	KT	HYDHMU	A	117
1279	4.4528	101.1880	KT	HYDHMU	D	169
1280	4.6435	101.1175	KT	HYDHMU	D	133
1281	4.4248	101.1536	KT	HYDHMU	D	130
1282	4.6603	101.1128	KT	HYDHMU	D	169
1283	4.6584	101.1010	KT	HYDHMU	D	169
1284	4.7751	101.1395	KT	HYDHMU	D	169
1285	4.7748	101.1383	KT	HYDHMU	A	156
1286	4.4197	101.1245	KT	HYDHMU	C	169
1287	4.3764	101.1505	KT	HYDHMU	D	208
1288	4.5171	101.0988	KT	HYDHMU	D	156
1289	4.6755	101.1635	KT	HYDHMU	D	195
1290	4.3790	101.1601	KT	HYDHMU	D	195
1291	4.4408	101.1891	KT	HYDHMU	D	130

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J-1
1292	4.7368	101.1304	KT	HYDHMU	D	208
1293	4.3508	101.0503	KT	HYDHMU	C	195
1294	4.7748	101.1412	KT	HYDHMU	A	156
1295	4.5422	101.1229	KT	HYDHMU	D	156
1296	4.6310	101.1161	KT	HYDHMU	D	130
1297	4.4446	101.1711	KT	HYDHMU	D	156
1298	4.5309	101.1105	KT	HYDHMU	D	156
1299	4.7222	101.1208	KT	HYDHMU	D	182
1300	4.4198	100.9800	KT	HYDHMU	C	91
1301	4.4556	101.1912	KT	HYDHMU	D	156
1302	4.3917	101.0446	KT	HYDHMU	C	91
1303	4.4248	101.1581	KT	HYDHMU	D	133
1304	4.7784	101.1373	KT	HYDHMU	D	143
1305	4.6903	101.1338	KT	HYDHMU	D	143
1306	4.3778	101.1607	KT	HYDHMU	C	182
1307	4.4751	101.0814	KT	HYDHMU	D	143
1308	4.4017	101.0838	KT	HYDHMU	C	143
1309	4.6992	101.1539	KT	HYDHMU	D	182
1310	4.4993	101.0761	KT	HYDHMU	D	143
1311	4.7182	101.1199	KT	HYDHMU	D	182
1312	4.7441	101.1255	KT	HYDHMU	D	156
1313	4.4431	100.9722	KT	HYDHMU	C	65
1314	4.6978	101.1355	KT	HYDHMU	D	156
1315	4.5083	101.0998	KT	HYDHMU	D	156
1316	4.5405	101.1314	KT	HYDHMU	D	52
1317	4.6899	101.1383	KT	HYDHMU	D	179
1318	4.7435	101.1515	KT	HYDHMU	A	156
1319	4.4192	101.1230	KT	HYDHMU	D	156
1320	4.7441	101.1304	KT	HYDHMU	D	156
1321	4.4418	100.9742	KT	HYDHMU	C	52
1322	4.5357	101.1374	KT	HYDHMU	D	52
1323	4.7265	101.1344	KT	HYDHMU	D	143
1324	4.4927	101.0892	KT	HYDHMU	D	143
1325	4.5179	101.1014	KT	HYDHMU	D	156
1326	4.4105	101.1589	KT	HYDHMU	D	143
1327	4.5309	101.0850	KT	HYDHMU	D	156
1328	4.7340	101.1092	KT	HYDHMU	S	143
1329	4.4927	101.0885	KT	HYDHMU	D	143
1330	4.5178	101.0743	KT	HYDHMU	D	143
1331	4.5014	101.0892	KT	HYDHMU	D	143
1332	4.5178	101.0828	KT	HYDHMU	D	143
1333	4.4135	101.1036	KT	HYDHMU	C	143
1334	4.2707	101.1121	KT	HYDHMU	C	86
1335	4.4051	101.0880	KT	HYDHMU	C	143
1336	4.5361	101.0981	KT	HYDHMU	D	143
1337	4.3898	101.0995	KT	HYDHMU	C	117
1338	4.3821	101.0936	KT	HYDHMU	C	117
1339	4.6715	101.1431	KT	HYDHMU	D	146
1340	4.2795	101.1194	KT	HYDHMU	C	117
1341	4.7492	101.1488	KT	HYDHMU	D	143
1342	4.3883	101.1794	KT	HYDHMU	C	143
1343	4.4233	100.9936	KT	HYDHMU	C	143
1344	4.3898	101.0924	KT	HYDHMU	C	117
1345	4.2812	101.1006	KT	HYDHMU	C	117

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1346	4.6519	101.1190	KT	HYDHMU	D	143
1347	4.2640	101.0981	KT	HYDHMU	C	117
1348	4.5167	101.1093	KT	HYDHMU	D	143
1349	4.7033	101.1284	KT	HYDHMU	D	117
1350	4.5158	101.0854	KT	HYDHMU	D	117
1351	4.6715	101.1383	KT	HYDHMU	D	143
1352	4.7053	101.1272	KT	HYDHMU	D	117
1353	4.7053	101.1298	KT	HYDHMU	D	117
1354	4.4326	101.1358	KT	HYDHMU	D	117
1355	4.6625	101.1397	KT	HYDHMU	D	143
1356	4.7367	101.1344	KT	HYDHMU	D	143
1357	4.7033	101.1298	KT	HYDHMU	D	117
1358	4.3821	101.0924	KT	HYDHMU	C	117
1359	4.4810	101.0883	KT	HYDHMU	D	143
1360	4.6719	101.1444	KT	HYDHMU	D	143
1361	4.6817	101.1517	KT	HYDHMU	D	110
1362	4.3872	101.1483	KT	HYDHMU	D	143
1363	4.6627	101.1564	KT	HYDHMU	D	143
1364	4.4232	101.1289	KT	HYDHMU	D	143
1365	4.4343	101.0626	KT	HYDHMU	C	149
1366	4.5180	101.1101	KT	HYDHMU	D	156
1367	4.7265	101.1480	KT	HYDHMU	D	143
1368	4.4105	101.1569	KT	HYDHMU	D	143
1369	4.4112	101.0981	KT	HYDHMU	C	143
1370	4.5083	101.0920	KT	HYDHMU	D	156
1371	4.7367	101.1422	KT	HYDHMU	D	143
1372	4.5179	101.1046	KT	HYDHMU	D	156
1373	4.4992	101.0768	KT	HYDHMU	D	156
1374	4.5300	101.1015	KT	HYDHMU	D	182
1375	4.5158	101.1076	KT	HYDHMU	D	156
1376	4.3528	101.0668	KT	HYDHMU	C	156
1377	4.5162	101.0978	KT	HYDHMU	D	156
1378	4.4135	101.1073	KT	HYDHMU	C	156
1379	4.6630	101.1578	KT	HYDHMU	D	143
1380	4.4104	101.1569	KT	HYDHMU	D	143
1381	4.3379	101.0618	KT	HYDHMU	C	156
1382	4.5249	101.1160	KT	HYDHMU	D	156
1383	4.5300	101.1112	KT	HYDHMU	D	182
1384	4.6561	101.1096	KT	HYDHMU	D	143
1385	4.7536	101.1339	KT	HYDHMU	A	156
1386	4.7550	101.1305	KT	HYDHMU	D	143
1387	4.4391	101.0444	KT	HYDHMU	C	143
1388	4.7039	101.1222	KT	HYDHMU	D	143
1389	4.7221	101.1370	KT	HYDHMU	D	120
1390	4.4192	101.1300	KT	HYDHMU	D	156
1391	4.7417	101.1488	KT	HYDHMU	D	156
1392	4.3992	101.1589	KT	HYDHMU	D	234
1393	4.3778	101.1607	KT	HYDHMU	D	182
1394	4.4396	101.1825	KT	HYDHMU	D	244
1395	4.7264	101.1092	KT	HYDHMU	S	182
1396	4.7264	101.1101	KT	HYDHMU	S	182
1397	4.6899	101.1334	KT	HYDHMU	D	182
1398	4.5390	101.1326	KT	HYDHMU	D	182
1399	4.3491	101.0668	KT	HYDHMU	C	182

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1400	4.4584	100.9706	KT	HYDHMU	C	78
1401	4.2788	101.1198	KT	HYDHMU	C	78
1402	4.3678	100.9867	KT	HYDLUS	A	104
1403	4.2696	101.0182	KT	HYDLUS	C	130
1404	4.2754	101.0183	KT	HYDLUS	C	104
1405	4.2726	101.0300	KT	HYDLUS	A	520
1406	4.2894	101.0201	KT	HYDLUS	C	520
1407	4.2898	101.0098	KT	HYDLUS	C	104
1408	4.3018	101.0155	KT	HYDLUS	A	520
1409	4.2921	101.0160	KT	HYDLUS	C	104
1410	4.2749	101.0074	KT	HYDLUS	C	143
1411	4.2772	101.0252	KT	HYDLUS	C	130
1412	4.2692	101.0168	KT	HYDLUS	C	130
1413	4.3378	101.0092	KT	HYDLUS	C	130
1414	4.2882	101.0163	KT	HYDLUS	C	104
1415	4.2745	101.0019	KT	HYDLUS	C	143
1416	4.3169	101.0134	KT	HYDLUS	A	909
1417	4.2855	101.0248	KT	HYDLUS	A	909
1418	4.2863	101.0285	KT	HYDLUS	A	909
1419	4.3108	101.0118	KT	HYDLUS	A	909
1420	4.2840	101.0272	KT	HYDLUS	A	585
1421	4.2987	101.0192	KT	HYDLUS	C	169
1422	4.2919	101.0167	KT	HYDLUS	C	104
1423	4.3419	101.0218	KT	HYDLUS	A	585
1424	4.2847	101.0181	KT	HYDLUS	A	520
1425	4.3350	101.0152	KT	HYDLUS	A	715
1426	4.3502	101.0149	KT	HYDLUS	C	78
1427	4.2875	101.0163	KT	HYDLUS	C	130
1428	4.3095	101.0132	KT	HYDLUS	A	780
1429	4.2871	101.0174	KT	HYDLUS	C	91
1430	4.3368	101.0119	KT	HYDLUS	C	130
1431	4.3317	101.0120	KT	HYDLUS	C	130
1432	4.3580	101.0123	KT	HYDLUS	C	130
1433	4.3500	101.0146	KT	HYDLUS	C	130
1434	4.3334	101.0167	KT	HYDLUS	A	812
1435	4.2870	101.0250	KT	HYDLUS	C	257
1436	4.3234	101.0170	KT	HYDLUS	A	845
1437	4.2858	101.0251	KT	HYDLUS	A	845
1438	4.2692	101.0251	KT	HYDLUS	C	143
1439	4.3482	101.0157	KT	HYDLUS	C	117
1440	4.2887	101.0166	KT	HYDLUS	C	117
1441	4.2693	101.0300	KT	HYDLUS	A	286
1442	4.3008	101.0184	KT	HYDLUS	C	117
1443	4.3686	100.9810	KT	HYDLUS	A	117
1444	4.3462	101.0036	KT	HYDLUS	C	117
1445	4.2888	101.0082	KT	HYDLUS	C	117
1446	4.2687	101.0187	KT	HYDLUS	C	117
1447	4.3509	100.9984	KT	HYDLUS	C	117
1448	4.2804	101.0081	KT	HYDLUS	C	117
1449	4.3686	100.9815	KT	HYDLUS	A	117
1450	4.2834	101.0182	KT	HYDLUS	C	117
1451	4.2844	101.0020	KT	HYDLUS	C	117
1452	4.2667	101.0193	KT	HYDLUS	C	117
1453	4.2755	101.0055	KT	HYDLUS	C	117

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J-1
	latitud	longitud				
1454	4.2930	101.0118	KT	HYDLUS	C	117
1455	4.2900	101.0189	KT	HYDLUS	C	182
1456	4.2910	101.0204	KT	HYDLUS	C	182
1457	4.2749	101.0561	KT	HYDLUS	A	247
1458	4.3056	101.0228	KT	PET	A	273
1459	4.2953	101.0365	KT	PET	A	143
1460	4.3085	101.0346	KT	PET	A	143
1461	4.3440	100.9720	KT	PET	C	130
1462	4.3017	101.0361	KT	PET	A	143
1463	4.3134	101.0270	KT	PET	A	325
1464	4.3001	101.0245	KT	PET	A	325
1465	4.3113	101.0522	KT	PET	A	747
1466	4.2985	101.0332	KT	PET	A	455
1467	4.2970	101.0387	KT	PET	A	455
1468	4.3123	101.0301	KT	PET	A	130
1469	4.3067	101.0367	KT	PET	A	195
1470	4.3102	101.0247	KT	PET	A	169
1471	4.2975	101.0343	KT	PET	A	299
1472	4.3085	101.0334	KT	PET	A	156
1473	4.3024	101.0346	KT	PET	A	156
1474	4.3147	101.0298	KT	PET	A	117
1475	4.3035	101.0364	KT	PET	A	286
1476	4.3107	101.0367	KT	PET	A	156
1477	4.3124	101.0329	KT	PET	A	182
1478	4.3832	101.1252	KT	RGMBTG	C	104
1479	4.3798	101.0179	KT	RGMBTG	C	91
1480	4.4039	101.0357	KT	RGMBTG	C	91
1481	4.5052	101.1674	KT	RGMBTG	A	234
1482	4.5571	101.1763	KT	RGMBTG	A	234
1483	4.7746	101.1490	KT	RGMBTG	A	234
1484	4.3919	101.0417	KT	RGMBTG	C	91
1485	4.4039	101.0490	KT	RGMBTG	C	91
1486	4.7519	101.1625	KT	RGMBTG	A	234
1487	4.3368	101.0540	KT	RGMBTG	C	487
1488	4.3417	101.0301	KT	RGMBTG	A	455
1489	4.3283	101.0550	KT	RGMBTG	A	455
1490	4.3286	101.0537	KT	RGMBTG	A	455
1491	4.3826	101.0294	KT	RGMBTG	C	91
1492	4.3422	101.0468	KT	RGMBTG	A	455
1493	4.3914	101.0450	KT	RGMBTG	C	91
1494	4.6919	101.1845	KT	RGMBTG	A	455
1495	4.7651	101.0957	KT	RGMBTG	A	487
1496	4.3651	101.2309	KT	RGMBTG	A	143
1497	4.4066	101.0460	KT	RGMBTG	C	52
1498	4.6966	101.1681	KT	RGMBTG	A	221
1499	4.5575	101.1793	KT	RGMBTG	A	273
1500	4.4112	101.0294	KT	RGMBTG	C	52
1501	4.4066	101.0340	KT	RGMBTG	C	52
1502	4.6991	101.0809	KT	RGMBTG	A	273
1503	4.4023	101.0417	KT	RGMBTG	C	52
1504	4.4855	101.0044	KT	RGMBTG	C	114
1505	4.3702	101.0391	KT	RGMBTG	C	114
1506	4.3914	101.0410	KT	RGMBTG	C	91
1507	4.4992	100.9999	KT	RGMBTG	A	273

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy\ J^{-1}$
1508	4.6142	101.0732	KT	RGMBTG	A	221
1509	4.5572	101.1779	KT	RGMBTG	A	272
1510	4.7045	101.1612	KT	RGMBTG	A	221
1511	4.3202	101.0422	KT	RGMBTG	A	520
1512	4.4492	101.0411	KT	RGMBTG	C	104
1513	4.3359	101.0308	KT	RGMBTG	A	253
1514	4.7650	101.0957	KT	RGMBTG	A	520
1515	4.3726	101.0195	KT	RGMBTG	C	104
1516	4.3912	101.0684	KT	RGMBTG	C	169
1517	4.3338	101.0268	KT	RGMBTG	A	253
1518	4.4697	100.9914	KT	RGMBTG	C	143
1519	4.3236	101.0385	KT	RGMBTG	A	520
1520	4.4787	100.9996	KT	RGMBTG	C	143
1521	4.3177	101.0342	KT	RGMBTG	A	520
1522	4.3496	101.0316	KT	RGMBTG	C	143
1523	4.3359	101.0308	KT	RGMBTG	A	253
1524	4.4494	101.0187	KT	RGMBTG	C	104
1525	4.3309	101.0547	KT	RGMBTG	A	423
1526	4.3847	101.0475	KT	RGMBTG	C	65
1527	4.3315	101.0428	KT	RGMBTG	A	747
1528	4.3168	101.0133	KT	RGMBTG	A	130
1529	4.3703	101.0329	KT	RGMBTG	C	104
1530	4.4414	101.0377	KT	RGMBTG	C	104
1531	4.3820	101.0929	KT	RGMBTG	C	104
1532	4.2866	101.0339	KT	RGMBTG	A	585
1533	4.3757	100.9815	KT	RGMBTG	C	156
1534	4.6706	101.1970	KT	RGMBTG	A	260
1535	4.3328	101.0233	KT	RGMBTG	A	747
1536	4.3389	101.0460	KT	RGMBTG	A	715
1537	4.2677	101.0342	KT	RGMBTG	A	650
1538	4.3270	101.0443	KT	RGMBTG	A	715
1539	4.3487	101.0236	KT	RGMBTG	A	650
1540	4.3152	101.0408	KT	RGMBTG	A	325
1541	4.7532	101.1598	KT	RGMBTG	A	325
1542	4.3332	101.0482	KT	RGMBTG	A	747
1543	4.3366	101.0452	KT	RGMBTG	A	715
1544	4.7319	101.1576	KT	RGMBTG	A	156
1545	4.3667	101.0748	KT	RGMBTG	C	156
1546	4.3164	101.0200	KT	RGMBTG	A	715
1547	4.2895	101.0364	KT	RGMBTG	A	325
1548	4.3677	101.0250	KT	RGMBTG	C	104
1549	4.2698	101.0422	KT	RGMBTG	A	715
1550	4.7305	101.1640	KT	RGMBTG	A	159
1551	4.3308	101.0243	KT	RGMBTG	A	715
1552	4.3172	101.0360	KT	RGMBTG	A	213
1553	4.7046	101.1522	KT	RGMBTG	A	122
1554	4.6772	101.2010	KT	RGMBTG	A	247
1555	4.3224	101.0419	KT	RGMBTG	A	682
1556	4.3308	101.0323	KT	RGMBTG	A	715
1557	4.5542	101.1671	KT	RGMBTG	A	208
1558	4.3704	101.0179	KT	RGMBTG	C	104
1559	4.2676	101.0414	KT	RGMBTG	A	650
1560	4.2679	101.0337	KT	RGMBTG	A	650
1561	4.3058	101.0449	KT	RGMBTG	A	650

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
1562	4.3720	101.2425	KT	RGMBTG	A	156
1563	4.3231	101.0457	KT	RGMBTG	A	650
1564	4.5885	101.1268	KT	RGMBTG	A	156
1565	4.3167	101.0226	KT	RGMBTG	A	909
1566	4.3270	101.0461	KT	RGMBTG	A	715
1567	4.2743	101.0496	KT	RGMBTG	A	351
1568	4.2898	101.0254	KT	RGMBTG	A	909
1569	4.2663	101.0359	KT	RGMBTG	A	650
1570	4.2802	101.0383	KT	RGMBTG	A	909
1571	4.3365	101.0302	KT	RGMBTG	A	650
1572	4.2788	101.0438	KT	RGMBTG	A	909
1573	4.3221	101.0402	KT	RGMBTG	A	650
1574	4.2743	101.0495	KT	RGMBTG	A	650
1575	4.2864	101.0482	KT	RGMBTG	A	909
1576	4.3715	101.2489	KT	RGMBTG	A	182
1577	4.3232	101.0303	KT	RGMBTG	C	909
1578	4.3180	101.0448	KT	RGMBTG	A	909
1579	4.2751	101.0292	KT	RGMBTG	A	715
1580	4.3847	101.0434	KT	RGMBTG	C	65
1581	4.3198	101.0304	KT	RGMBTG	A	552
1582	4.7741	101.1526	KT	RGMBTG	A	247
1583	4.3759	101.2269	KT	RGMBTG	A	585
1584	4.3206	101.0447	KT	RGMBTG	A	715
1585	4.2848	101.0493	KT	RGMBTG	A	585
1586	4.3230	101.0239	KT	RGMBTG	A	909
1587	4.3326	101.0298	KT	RGMBTG	C	974
1588	4.3167	101.0167	KT	RGMBTG	A	974
1589	4.3754	101.2240	KT	RGMBTG	A	182
1590	4.2788	101.0336	KT	RGMBTG	A	974
1591	4.2748	101.0398	KT	RGMBTG	A	974
1592	4.3167	101.0452	KT	RGMBTG	A	974
1593	4.3398	101.0436	KT	RGMBTG	A	715
1594	4.4112	101.0303	KT	RGMBTG	C	52
1595	4.3228	101.0239	KT	RGMBTG	A	974
1596	4.3235	101.0304	KT	RGMBTG	A	974
1597	4.3228	101.0305	KT	RGMBTG	A	974
1598	4.3210	101.0419	KT	RGMBTG	A	585
1599	4.3218	101.0394	KT	RGMBTG	A	1039
1600	4.3397	101.0484	KT	RGMBTG	A	533
1601	4.3093	101.0552	KT	RGMBTG	C	169
1602	4.6440	101.0803	KT	RGMBTG	D	169
1603	4.2935	101.0502	KT	RGMBTG	A	715
1604	4.2832	101.0551	KT	RGMBTG	A	169
1605	4.2876	101.0418	KT	RGMBTG	A	1039
1606	4.2848	101.0432	KT	RGMBTG	A	1039
1607	4.3257	101.0313	KT	RGMBTG	A	1039
1608	4.3257	101.0288	KT	RGMBTG	A	1039
1609	4.7025	101.1392	KT	RGMBTG	D	169
1610	4.3816	101.2169	KT	RGMBTG	A	169
1611	4.3786	101.2195	KT	RGMBTG	A	169
1612	4.3168	101.0393	KT	RGMBTG	A	559
1613	4.3182	101.0310	KT	RGMBTG	A	169
1614	4.7025	101.1425	KT	RGMBTG	D	169
1615	4.3412	101.0451	KT	RGMBTG	C	715

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J-1
	latitud	longitud				
1616	4.6936	101.1946	KT	RGMBTG	A	278
1617	4.3284	101.0467	KT	RGMBTG	A	585
1618	4.5542	101.1693	KT	RGMBTG	A	208
1619	4.3147	101.0302	KT	RGMBTG	A	117
1620	4.3817	101.2167	KT	RGMBTG	A	169
1621	4.3768	101.0402	KT	RGMBTG	C	104
1622	4.3828	101.0494	KT	RGMBTG	C	110
1623	4.3495	101.0425	KT	RGMBTG	C	130
1624	4.7632	101.0962	KT	RGMBTG	A	377
1625	4.3136	101.0529	KT	RGMBTG	A	747
1626	4.3700	101.0492	KT	RGMBTG	C	91
1627	4.3290	101.0536	KT	RGMBTG	C	520
1628	4.3335	101.0410	KT	RGMBTG	A	747
1629	4.6913	101.1582	KT	RGMBTG	A	208
1630	4.3083	101.1687	KT	RGMBTG	A	208
1631	4.4029	101.0357	KT	RGMBTG	C	78
1632	4.7519	101.1598	KT	RGMBTG	A	247
1633	4.6837	101.0862	KT	RGMBTG	S	247
1634	4.4024	101.0342	KT	RGMBTG	C	78
1635	4.3136	101.0566	KT	RGMBTG	A	747
1636	4.7519	101.1638	KT	RGMBTG	A	247
1637	4.4022	101.0433	KT	RGMBTG	C	52
1638	4.5566	101.1748	KT	RGMBTG	A	247
1639	4.3352	101.0191	KT	RGMBTG	A	260
1640	4.4024	101.0365	KT	RGMBTG	C	78
1641	4.3115	101.0172	KT	RGMBTG	A	715
1642	4.5503	101.1738	KT	RGMBTG	A	247
1643	4.5545	101.1705	KT	RGMBTG	A	208
1644	4.3113	101.0538	KT	RGMBTG	A	747
1645	4.4023	101.0342	KT	RGMBTG	C	52
1646	4.4415	101.0377	KT	RGMBTG	C	130
1647	4.3492	101.2370	KT	RGMBTG	A	208
1648	4.3356	101.0391	KT	RGMBTG	A	747
1649	4.3317	101.0217	KT	RGMBTG	A	780
1650	4.3421	101.0338	KT	RGMBTG	A	520
1651	4.3278	101.0353	KT	RGMBTG	A	780
1652	4.7050	101.1625	KT	RGMBTG	A	216
1653	4.3186	101.0527	KT	RGMBTG	A	715
1654	4.2863	101.0309	KT	RGMBTG	A	780
1655	4.3334	101.0252	KT	RGMBTG	A	247
1656	4.7741	101.1687	KT	RGMBTG	A	247
1657	4.3184	101.0367	KT	RGMBTG	A	780
1658	4.6919	101.1849	KT	RGMBTG	A	450
1659	4.3373	101.0518	KT	RGMBTG	C	617
1660	4.3127	101.0529	KT	RGMBTG	A	780
1661	4.3223	101.0542	KT	RGMBTG	A	780
1662	4.3397	101.0386	KT	RGMBTG	A	780
1663	4.3193	101.0313	KT	RGMBTG	A	617
1664	4.3130	101.0394	KT	RGMBTG	A	195
1665	4.6812	101.0867	KT	RGMBTG	S	195
1666	4.2919	101.0503	KT	RGMBTG	C	195
1667	4.3222	101.1569	KT	RGMBTG	D	195
1668	4.2930	101.0531	KT	RGMBTG	A	195
1669	4.4146	101.0460	KT	RGMBTG	C	117

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1670	4.3406	101.0517	KT	RGMBTG	A	358
1671	4.6913	101.1521	KT	RGMBTG	A	195
1672	4.3933	101.0302	KT	RGMBTG	C	117
1673	4.4492	101.0341	KT	RGMBTG	C	104
1674	4.3678	101.0369	KT	RGMBTG	C	117
1675	4.3222	101.1546	KT	RGMBTG	D	195
1676	4.3580	101.0243	KT	RGMBTG	C	117
1677	4.2894	101.0329	KT	RGMBTG	A	195
1678	4.3486	101.0145	KT	RGMBTG	A	130
1679	4.4586	101.0411	KT	RGMBTG	C	117
1680	4.2855	101.0346	KT	RGMBTG	A	195
1681	4.3912	101.2230	KT	RGMBTG	D	195
1682	4.6700	101.0631	KT	RGMBTG	A	312
1683	4.4857	101.0040	KT	RGMBTG	A	286
1684	4.3362	101.0198	KT	RGMBTG	A	257
1685	4.2886	101.0334	KT	RGMBTG	A	195
1686	4.3723	101.2360	KT	RGMBTG	A	130
1687	4.3751	101.0491	KT	RGMBTG	C	130
1688	4.6703	101.1567	KT	RGMBTG	A	257
1689	4.6867	101.1741	KT	RGMBTG	A	257
1690	4.3043	101.0507	KT	RGMBTG	A	357
1691	4.4347	101.0405	KT	RGMBTG	C	110
1692	4.3097	101.0171	KT	RGMBTG	A	650
1693	4.2763	101.0520	KT	RGMBTG	A	221
1694	4.2672	101.0346	KT	RGMBTG	A	650
1695	4.3126	101.0538	KT	RGMBTG	A	650
1696	4.3168	101.0317	KT	RGMBTG	A	143
1697	4.3224	101.0448	KT	RGMBTG	A	682
1698	4.3365	101.0518	KT	RGMBTG	A	650
1699	4.3126	101.0516	KT	RGMBTG	A	650
1700	4.7478	101.1611	KT	RGMBTG	A	299
1701	4.3177	101.0531	KT	RGMBTG	A	650
1702	4.5571	101.1687	KT	RGMBTG	A	312
1703	4.5590	101.1903	KT	RGMBTG	A	208
1704	4.2756	101.0533	KT	RGMBTG	C	169
1705	4.6936	101.1946	KT	RGMBTG	A	286
1706	4.7781	101.1575	KT	RGMBTG	A	143
1707	4.2824	101.0492	KT	RGMBTG	A	221
1708	4.3268	101.0419	KT	RGMBTG	A	650
1709	4.6723	101.1958	KT	RGMBTG	A	143
1710	4.3152	101.0366	KT	RGMBTG	A	221
1711	4.4309	101.0459	KT	RGMBTG	C	143
1712	4.6924	101.1856	KT	RGMBTG	A	307
1713	4.5553	101.1693	KT	RGMBTG	A	286
1714	4.7036	101.1356	KT	RGMBTG	D	143
1715	4.3278	101.0461	KT	RGMBTG	A	780
1716	4.7034	101.1438	KT	RGMBTG	D	143
1717	4.3127	101.0516	KT	RGMBTG	A	780
1718	4.3325	101.0242	KT	RGMBTG	A	812
1719	4.5101	101.1705	KT	RGMBTG	A	195
1720	4.3900	101.0410	KT	RGMBTG	C	104
1721	4.6720	101.1944	KT	RGMBTG	A	169
1722	4.3202	101.0453	KT	RGMBTG	A	812
1723	4.6963	101.1840	KT	RGMBTG	A	221

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1724	4.6963	101.1667	KT	RGMBTG	A	221
1725	4.3176	101.0329	KT	RGMBTG	A	179
1726	4.3738	101.2326	KT	RGMBTG	A	130
1727	4.3328	101.0233	KT	RGMBTG	A	747
1728	4.3467	101.0168	KT	RGMBTG	A	299
1729	4.7475	101.1625	KT	RGMBTG	A	299
1730	4.3751	101.2277	KT	RGMBTG	A	299
1731	4.7475	101.1596	KT	RGMBTG	A	299
1732	4.3228	101.0443	KT	RGMBTG	A	812
1733	4.3216	101.0511	KT	RGMBTG	A	812
1734	4.3160	101.0429	KT	RGMBTG	A	780
1735	4.3217	101.0434	KT	RGMBTG	A	845
1736	4.3732	101.0733	KT	RGMBTG	C	130
1737	4.3118	101.0482	KT	RGMBTG	A	845
1738	4.3214	101.0520	KT	RGMBTG	A	845
1739	4.7750	101.1511	KT	RGMBTG	A	247
1740	4.3914	101.2246	KT	RGMBTG	A	195
1741	4.4370	100.9822	KT	RGMBTG	C	91
1742	4.7665	101.1490	KT	RGMBTG	A	312
1743	4.6627	101.0809	KT	RGMBTG	D	208
1744	4.3210	101.0433	KT	RGMBTG	A	845
1745	4.5574	101.1700	KT	RGMBTG	A	312
1746	4.2819	101.0507	KT	RGMBTG	C	156
1747	4.4750	100.9810	KT	RGMBTG	A	156
1748	4.3131	101.0551	KT	RGMBTG	A	208
1749	4.4494	101.0272	KT	RGMBTG	C	94
1750	4.3214	101.0507	KT	RGMBTG	A	845
1751	4.3205	101.0304	KT	RGMBTG	A	780
1752	4.3198	101.0300	KT	RGMBTG	A	780
1753	4.3271	101.0323	KT	RGMBTG	A	877
1754	4.4387	101.0341	KT	RGMBTG	C	117
1755	4.3167	101.0327	KT	RGMBTG	A	143
1756	4.4414	101.0433	KT	RGMBTG	C	94
1757	4.3271	101.0313	KT	RGMBTG	A	877
1758	4.4146	101.0405	KT	RGMBTG	C	117
1759	4.3678	101.0494	KT	RGMBTG	C	117
1760	4.3662	101.0629	KT	RGMBTG	C	117
1761	4.7632	101.0962	KT	RGMBTG	A	357
1762	4.4042	101.0340	KT	RGMBTG	C	104
1763	4.3677	101.0239	KT	RGMBTG	C	104
1764	4.3704	101.0250	KT	RGMBTG	C	104
1765	4.3437	101.0188	KT	RGMBTG	A	149
1766	4.3636	101.0353	KT	RGMBTG	C	117
1767	4.3906	101.2182	KT	RGMBTG	A	390
1768	4.3736	101.2313	KT	RGMBTG	A	117
1769	4.3365	101.0328	KT	RGMBTG	A	649
1770	4.4347	101.0436	KT	RGMBTG	C	110
1771	4.3828	101.0434	KT	RGMBTG	C	110
1772	4.3903	101.2168	KT	RGMBTG	A	390
1773	4.3828	101.0573	KT	RGMBTG	C	117
1774	4.6920	101.1843	KT	RGMBTG	A	325
1775	4.3508	101.0150	KT	RGMBTG	C	117
1776	4.7089	101.1564	KT	RGMBTG	A	156
1777	4.4496	101.0433	KT	RGMBTG	C	117

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1778	4.7535	101.1611	KT	RGMBTG	A	325
1779	4.3901	101.1827	KT	RGMBTG	C	143
1780	4.4170	101.0492	KT	RGMBTG	C	117
1781	4.3821	101.0775	KT	RGMBTG	C	143
1782	4.6686	101.1983	KT	RGMBTG	A	143
1783	4.3637	101.2323	KT	RGMBTG	A	143
1784	4.4415	101.0383	KT	RGMBTG	C	117
1785	4.3994	101.0505	KT	RGMBTG	C	117
1786	4.3316	101.0500	KT	RGMBTG	A	617
1787	4.4750	100.9809	KT	RGMBTG	A	153
1788	4.3280	101.0512	KT	RGMBTG	A	611
1789	4.3167	101.0566	KT	RGMBTG	A	228
1790	4.3278	101.2384	KT	RGMBTG	A	143
1791	4.3174	101.0574	KT	RGMBTG	A	156
1792	4.4042	101.0490	KT	RGMBTG	C	104
1793	4.6863	101.1725	KT	RGMBTG	A	234
1794	4.3440	101.0195	KT	RGMBTG	C	149
1795	4.3334	101.0572	KT	RGMBTG	A	228
1796	4.3167	101.0531	KT	RGMBTG	A	227
1797	4.3768	101.0477	KT	RGMBTG	C	104
1798	4.3900	101.0475	KT	RGMBTG	C	104
1799	4.7585	101.1526	KT	RGMBTG	A	156
1800	4.3502	101.0234	KT	RGMBTG	A	156
1801	4.2756	101.0331	KT	RGMBTG	C	156
1802	4.3660	101.1576	KT	RGMBTG	D	156
1803	4.3157	101.0345	KT	RGMBTG	A	156
1804	4.3335	101.2384	KT	RGMBTG	D	156
1805	4.7036	101.1358	KT	RGMBTG	D	148
1806	4.7435	101.1596	KT	RGMBTG	A	156
1807	4.3381	101.0536	KT	RGMBTG	A	257
1808	4.6920	101.1843	KT	RGMBTG	A	320
1809	4.3167	101.0327	KT	RGMBTG	A	143
1810	4.3304	101.0535	KT	RGMBTG	A	390
1811	4.7305	101.1515	KT	RGMBTG	A	156
1812	4.3718	101.2407	KT	RGMBTG	A	156
1813	4.3184	101.0576	KT	RGMBTG	A	156
1814	4.3048	101.0511	KT	RGMBTG	A	390
1815	4.6987	101.1521	KT	RGMBTG	A	182
1816	4.3425	101.0370	KT	RGMBTG	A	257
1817	4.3065	101.0529	KT	RGMBTG	A	390
1818	4.2985	101.0434	KT	RGMBTG	A	390
1819	4.3712	101.2473	KT	RGMBTG	A	182
1820	4.3180	101.0320	KT	RGMBTG	C	182
1821	4.3433	101.0425	KT	RGMBTG	A	182
1822	4.3251	101.0579	KT	RGMBTG	A	182
1823	4.3041	101.0483	KT	RGMBTG	A	390
1824	4.3791	101.1744	KT	RGMBTG	D	182
1825	4.2929	101.0527	KT	RGMBTG	A	182
1826	4.4783	101.0009	KT	RGMBTG	A	182
1827	4.4968	101.0012	KT	RGMBTG	A	182
1828	4.6987	101.1640	KT	RGMBTG	A	182
1829	4.3185	101.0284	KT	RGMBTG	A	182
1830	4.3176	101.0298	KT	RGMBTG	A	182
1831	4.3312	101.2381	KT	RGMBTG	D	182

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1832	4.3751	101.2228	KT	RGMBTG	A	182
1833	4.7745	101.1540	KT	RGMBTG	A	247
1834	4.3933	101.0143	KT	SDGMUN	C	78
1835	4.3996	101.0104	KT	SDGMUN	C	130
1836	4.4117	101.0023	KT	SDGMUN	C	117
1837	4.4011	101.0009	KT	SDGMUN	C	117
1838	4.3999	101.0082	KT	SDGMUN	C	117
1839	4.3956	101.0079	KT	SDGMUN	A	117
1840	4.3916	101.0072	KT	SDGMUN	C	117
1841	4.4944	101.1708	KT	SDGMUN	A	221
1842	4.4914	101.1722	KT	SDGMUN	A	117
1843	4.4953	101.1662	KT	SDGMUN	D	52
1844	4.4011	101.0155	KT	SDGMUN	C	117
1845	4.3933	101.0256	KT	SDGMUN	C	117
1846	4.3999	101.0020	KT	SDGMUN	C	117
1847	4.4580	100.9618	KT	SDGMUN	C	65
1848	4.3794	100.9674	KT	SDGMUN	C	104
1849	4.4512	100.9525	KT	SDGMUN	C	83
1850	4.6504	101.1705	KT	SDGMUN	D	161
1851	4.3745	101.0272	KT	SDGMUN	C	104
1852	4.4772	101.1888	KT	SDGMUN	A	169
1853	4.7585	101.1516	KT	SDGMUN	A	169
1854	4.3929	101.0091	KT	SDGMUN	C	78
1855	4.4468	101.1342	KT	SDGMUN	D	78
1856	4.4226	101.0155	KT	SDGMUN	C	120
1857	4.3929	101.0129	KT	SDGMUN	C	78
1858	4.4911	101.1596	KT	SDGMUN	D	78
1859	4.3237	101.0373	KT	SDGMUN	A	624
1860	4.3909	100.9568	KT	SDGMUN	C	104
1861	4.4026	101.0203	KT	SDGMUN	C	104
1862	4.4949	101.1722	KT	SDGMUN	A	208
1863	4.3913	100.9729	KT	SDGMUN	C	104
1864	4.3905	101.0053	KT	SDGMUN	C	130
1865	4.3993	101.0009	KT	SDGMUN	C	130
1866	4.3745	101.0276	KT	SDGMUN	C	104
1867	4.4026	101.0041	KT	SDGMUN	C	104
1868	4.4745	101.1894	KT	SDGMUN	A	104
1869	4.3905	101.0020	KT	SDGMUN	C	130
1870	4.3993	101.0091	KT	SDGMUN	C	130
1871	4.4770	101.1874	KT	SDGMUN	A	130
1872	4.8258	101.0603	KT	SDGMUN	S	177
1873	4.3826	101.0231	KT	SDGMUN	C	91
1874	4.4911	101.1708	KT	SDGMUN	A	117
1875	4.4520	101.1342	KT	SDGMUN	D	91
1876	4.4387	101.1365	KT	SDGMUN	D	91
1877	4.4078	100.9568	KT	SDGMUN	C	91
1878	4.4078	100.9574	KT	SDGMUN	C	91
1879	4.4002	101.0041	KT	SDGMUN	C	91
1880	4.3798	101.0231	KT	SDGMUN	C	91
1881	4.4162	100.9525	KT	SDGMUN	C	91
1882	4.4002	101.0082	KT	SDGMUN	C	91
1883	4.4544	101.1423	KT	SDGMUN	D	143
1884	4.4764	101.1756	KT	SDGMUN	A	143
1885	4.4836	101.1717	KT	SDGMUN	A	143

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
1886	4.4499	101.1394	KT	SDGMUN	D	143
1887	4.4409	101.1350	KT	SDGMUN	D	143
1888	4.4742	101.1880	KT	SDGMUN	A	117
1889	4.4013	101.0880	KT	SDGMUN	C	156
1890	4.3921	101.0067	KT	SDGMUN	A	182
1891	4.5267	101.0246	KT	STP	A	234
1892	4.7568	101.0962	KT	STP	A	273
1893	4.7650	101.0885	KT	STP	A	455
1894	4.6316	101.0429	KT	STP	A	455
1895	4.7568	101.0942	KT	STP	A	273
1896	4.6316	101.0433	KT	STP	A	455
1897	4.5210	101.0265	KT	STP	A	455
1898	4.6315	101.0417	KT	STP	A	455
1899	4.6253	101.0457	KT	STP	A	455
1900	4.7568	101.0943	KT	STP	A	273
1901	4.4933	101.2360	KT	STP	A	221
1902	4.4086	101.2043	KT	STP	A	221
1903	4.6352	101.1800	KT	STP	A	117
1904	4.6174	101.0444	KT	STP	A	429
1905	4.7466	101.0955	KT	STP	A	65
1906	4.6275	101.0940	KT	STP	D	130
1907	4.5673	101.2113	KT	STP	A	260
1908	4.5404	101.0297	KT	STP	A	325
1909	4.6330	101.0568	KT	STP	A	325
1910	4.5847	101.0414	KT	STP	A	325
1911	4.5404	101.0235	KT	STP	A	325
1912	4.5593	101.1916	KT	STP	A	234
1913	4.5270	101.0291	KT	STP	A	325
1914	4.4315	101.1960	KT	STP	D	265
1915	4.5507	101.0331	KT	STP	A	325
1916	4.4657	101.2218	KT	STP	A	169
1917	4.4559	101.2133	KT	STP	A	182
1918	4.7521	101.0954	KT	STP	A	156
1919	4.4042	101.2239	KT	STP	A	520
1920	4.5543	101.2995	KT	STP	A	182
1921	4.5669	101.3334	KT	STP	A	247
1922	4.6441	101.0680	KT	STP	A	169
1923	4.4692	101.2283	KT	STP	A	169
1924	4.5738	101.2549	KT	STP	A	234
1925	4.7077	101.0704	KT	STP	A	169
1926	4.7467	101.0975	KT	STP	A	78
1927	4.5164	101.1473	KT	STP	D	169
1928	4.4562	101.2147	KT	STP	A	169
1929	4.6393	101.1742	KT	STP	A	262
1930	4.5032	100.9790	KT	STP	A	208
1931	4.7466	101.0977	KT	STP	A	78
1932	4.3083	101.1833	KT	STP	A	208
1933	4.6786	101.2019	KT	STP	A	208
1934	4.5395	101.3565	KT	STP	S	117
1935	4.5090	101.1704	KT	STP	A	195
1936	4.5612	101.1923	KT	STP	A	195
1937	4.4624	101.2207	KT	STP	D	130
1938	4.3490	101.2356	KT	STP	A	195
1939	4.5338	101.0080	KT	STP	A	299

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
1940	4.5507	101.0297	KT	STP	A	299
1941	4.4175	101.1997	KT	STP	D	286
1942	4.6700	101.0579	KT	STP	A	312
1943	4.7149	101.0865	KT	STP	S	104
1944	4.7504	101.1412	KT	STP	A	312
1945	4.3883	101.2137	KT	STP	A	286
1946	4.4590	101.2087	KT	STP	A	312
1947	4.4587	101.2074	KT	STP	A	312
1948	4.5720	101.2480	KT	STP	A	299
1949	4.5362	101.0291	KT	STP	A	260
1950	4.5720	101.2485	KT	STP	A	299
1951	4.5223	100.9984	KT	STP	A	299
1952	4.5720	101.2485	KT	STP	A	304
1953	4.3532	101.2312	KT	STP	A	208
1954	4.5753	101.0322	KT	STP	A	390
1955	4.5764	101.2515	KT	STP	A	390
1956	4.5609	101.1909	KT	STP	A	195
1957	4.3071	101.0535	KT	STP	A	169
1958	4.3447	101.2348	KT	STP	A	169
1959	4.4551	101.2135	KT	STP	A	286
1960	4.5381	101.0053	KT	STP	A	299
1961	4.4261	101.1980	KT	STP	D	299
1962	4.4619	101.2193	KT	STP	A	130
1963	4.4670	101.2275	KT	STP	A	130
1964	4.4661	101.2232	KT	STP	A	169
1965	4.5724	101.2494	KT	STP	A	299
1966	4.5223	100.9984	KT	STP	A	299
1967	4.4692	101.2296	KT	STP	A	156
1968	4.5338	101.0026	KT	STP	A	286
1969	4.5669	101.3335	KT	STP	A	234
1970	4.7632	101.0957	KT	STP	A	390
1971	4.6174	101.0457	KT	STP	A	390
1972	4.6098	101.0454	KT	STP	A	390
1973	4.5994	101.0414	KT	STP	A	390
1974	4.6098	101.0444	KT	STP	A	390
1975	4.6428	101.0610	KT	STP	A	390
1976	4.5623	101.0322	KT	STP	A	390
1977	4.6098	101.0454	KT	STP	A	390
1978	4.5562	101.0331	KT	STP	A	390
1979	4.6428	101.0568	KT	STP	A	390
1980	4.6174	101.0444	KT	STP	A	390
1981	4.6330	101.0522	KT	STP	A	390
1982	4.6330	101.0523	KT	STP	A	351
1983	4.6537	101.0631	KT	STP	A	390
1984	4.5753	101.0322	KT	STP	A	390
1985	4.5350	101.0018	KT	STP	A	390
1986	4.6428	101.0568	KT	STP	A	390
1987	4.6253	101.0457	KT	STP	A	390
1988	4.6253	101.0433	KT	STP	A	390
1989	4.5753	101.0256	KT	STP	A	390
1990	4.5985	101.0434	KT	STP	A	325
1991	4.5267	101.0265	KT	STP	A	229
1992	4.5848	101.0355	KT	STP	A	325
1993	4.7521	101.0942	KT	STP	A	156

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy J^{-1}$
1994	4.5759	101.2499	KT	STP	A	325
1995	4.5270	101.0246	KT	STP	A	325
1996	4.7059	101.0448	KT	STP	A	325
1997	4.5546	101.3060	KT	STP	A	143
1998	4.7521	101.0955	KT	STP	A	156
1999	4.4041	101.2077	KT	STP	D	143
2000	4.5549	101.3075	KT	STP	A	143
2001	4.6348	101.1785	KT	STP	A	117
2002	4.5736	101.2528	KT	STP	A	234
2003	4.4252	101.2572	KT	STP	A	208
2004	4.5549	101.3022	KT	STP	A	182
2005	4.4590	101.2086	KT	STP	A	182
2006	4.5362	101.0235	KT	STP	A	257
2007	4.6703	100.9809	KT	STP	A	257
2008	4.5187	101.3867	KT	STP	A	112
2009	4.6775	101.2024	KT	STP	A	244
2010	4.5381	101.0026	KT	STP	A	286
2011	4.2693	101.0076	KT	TMGAKB	C	117
2012	4.2467	101.0603	KT	TMGAKB	C	169
2013	4.7842	100.6806	LM	BRH	Q	156
2014	4.7977	100.6785	LM	BRH	Q	156
2015	4.7754	100.6794	LM	BRH	Q	69
2016	4.8038	100.6723	LM	BRH	Q	117
2017	4.8870	100.6783	LM	BRH	Q	121
2018	4.9020	100.6749	LM	BRH	Q	117
2019	4.8572	100.7546	LM	DLD	Q	278
2020	4.8249	100.7158	LM	DLD	Q	278
2021	4.9063	100.7310	LM	DLD	Q	142
2022	4.8887	100.7360	LM	DLD	Q	142
2023	4.8622	100.7504	LM	DLD	Q	142
2024	4.8435	100.7470	LM	DLD	Q	295
2025	4.8668	100.7072	LM	DLD	Q	139
2026	4.8222	100.7083	LM	DLD	Q	330
2027	4.8798	100.7443	LM	DLD	Q	168
2028	4.8530	100.7245	LM	DLD	Q	174
2029	4.9066	100.7303	LM	DLD	Q	203
2030	4.8386	100.6982	LM	DLD	Q	139
2031	4.6946	100.7167	LM	DLD	Q	208
2032	4.9225	100.7037	LM	DLD	Q	130
2033	4.8507	100.7068	LM	DLD	Q	174
2034	4.8516	100.6951	LM	DLD	Q	117
2035	4.8599	100.7501	LM	DLD	Q	226
2036	4.8479	100.6991	LM	DLD	Q	243
2037	4.8654	100.7327	LM	DLD	Q	243
2038	4.9014	100.7359	LM	DLD	Q	143
2039	4.6854	100.7188	LM	DLD	Q	191
2040	4.8549	100.7385	LM	DLD	Q	243
2041	4.8403	100.7487	LM	DLD	Q	243
2042	4.6961	100.7169	LM	HYDLUS	Q	191
2043	4.7566	100.7454	LM	HYDLUSKLU	A	330
2044	4.6508	100.6971	LM	HYDLUSKLU	Q	191
2045	4.6517	100.6882	LM	HYDLUSKLU	Q	174
2046	4.6186	100.7119	LM	HYDLUSKLU	Q	130
2047	4.6283	100.6851	LM	HYDLUSKLU	Q	156

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2048	4.5778	100.6876	LM	HYDLUSKLU	Q	130
2049	4.6494	100.7267	LM	HYDLUSKLU	Q	208
2050	4.7862	100.6924	LM	HYDLUSKLU	Q	156
2051	4.6855	100.7165	LM	HYDLUSKLU	Q	191
2052	4.6701	100.7148	LM	HYDLUSKLU	Q	191
2053	4.8067	100.7159	LM	HYDLUSKLU	A	348
2054	4.6513	100.7096	LM	HYDLUSKLU	Q	182
2055	4.8035	100.7198	LM	HYDLUSKLU	A	348
2056	4.6627	100.6922	LM	HYDLUSKLU	Q	174
2057	4.8136	100.6838	LM	HYDLUSKLU	Q	174
2058	4.7997	100.7397	LM	HYDLUSKLU	Q	295
2059	4.7896	100.7207	LM	HYDLUSKLU	Q	295
2060	4.7907	100.7158	LM	HYDLUSKLU	Q	295
2061	4.6174	100.6858	LM	HYDLUSKLU	Q	174
2062	4.6074	100.6831	LM	HYDLUSKLU	Q	156
2063	4.6270	100.6874	LM	HYDLUSKLU	Q	174
2064	4.7645	100.6883	LM	HYDLUSKLU	Q	156
2065	4.6300	100.6831	LM	HYDLUSKLU	Q	91
2066	4.6531	100.7426	LM	HYDLUSKLU	A	295
2067	4.6261	100.6903	LM	HYDLUSKLU	Q	117
2068	4.6285	100.6847	LM	HYDLUSKLU	Q	121
2069	4.6655	100.7121	LM	HYDLUSKLU	Q	226
2070	4.7861	100.7210	LM	HYDLUSKLU	Q	226
2071	4.7852	100.7078	LM	HYDLUSKLU	Q	169
2072	4.7072	100.7102	LM	HYDLUSKLU	Q	143
2073	4.6772	100.7055	LM	HYDLUSKLU	Q	143
2074	4.8157	100.7074	LM	HYDLUSKLU	Q	243
2075	4.7583	100.7213	LM	HYDLUSKLU	Q	182
2076	4.7322	100.7104	LM	HYDLUSKLU	Q	243
2077	4.8194	100.7431	LM	HYDLUSKLU	Q	278
2078	4.7329	100.7148	LM	HYDLUSKLU	Q	243
2079	4.5388	100.6585	LM	JBURDU	Q	156
2080	4.5604	100.6721	LM	JBURDU	Q	156
2081	4.7983	100.6909	LM	JBURDU	Q	156
2082	4.5985	100.6822	LM	JBURDU	Q	156
2083	4.5835	100.6791	LM	JBURDU	Q	156
2084	4.5726	100.6766	LM	JBURDU	Q	156
2085	4.6074	100.6800	LM	JBURDU	Q	117
2086	4.8102	100.6901	LM	JBURDU	Q	104
2087	4.7862	100.6872	LM	JBURDU	Q	117
2088	4.9430	100.8123	LM	KKR	A	233
2089	4.9513	100.7913	LM	KKR	T	182
2090	4.9605	100.8142	LM	KKR	T	233
2091	4.9350	100.8169	LM	KKR	A	233
2092	4.9367	100.7983	LM	KKR	A	233
2093	4.9787	100.7981	LM	KKR	T	240
2094	4.9800	100.7676	LM	KKR	T	143
2095	4.6597	100.6689	LM	KNJ	Q	78
2096	4.8388	100.6330	LM	KNJ	Q	174
2097	4.6193	100.6670	LM	KNJ	Q	104
2098	4.6302	100.6756	LM	KNJ	Q	104
2099	4.6378	100.6659	LM	KNJ	Q	121
2100	4.5628	100.6586	LM	KNJ	Q	87
2101	4.7767	100.6599	LM	KNJ	Q	117

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy\ J^{-1}$
2102	4.6311	100.6641	LM	KNJ	Q	104
2103	5.0872	100.8608	LM	LAATMGAKB	Q	259
2104	5.0243	100.7967	LM	LAATMGAKB	T	184
2105	4.9727	100.7325	LM	LAATMGAKB	T	142
2106	5.0192	100.8012	LM	LAATMGAKB	T	142
2107	5.0239	100.7926	LM	LAATMGAKB	T	142
2108	4.9494	100.7254	LM	LAATMGAKB	T	129
2109	5.0850	100.8365	LM	LAATMGAKB	A	246
2110	5.0683	100.7838	LM	LAATMGAKB	T	194
2111	4.7716	100.6930	LM	LAATMGAKB	Q	156
2112	4.7823	100.7202	LM	LAATMGAKB	Q	261
2113	5.0349	100.8158	LM	LAATMGAKB	T	233
2114	5.0140	100.8245	LM	LAATMGAKB	A	389
2115	5.0343	100.7818	LM	LAATMGAKB	T	242
2116	4.7706	100.7409	LM	LAATMGAKB	A	295
2117	5.0236	100.7912	LM	LAATMGAKB	T	106
2118	4.8044	100.7164	LM	LAATMGAKB	Q	313
2119	5.0162	100.8040	LM	LAATMGAKB	A	291
2120	4.7777	100.7870	LM	LAATMGAKB	A	104
2121	4.7685	100.7453	LM	LAATMGAKB	A	330
2122	4.7811	100.7789	LM	LAATMGAKB	A	330
2123	4.9216	100.7234	LM	LAATMGAKB	T	155
2124	5.0317	100.8136	LM	LAATMGAKB	T	155
2125	5.0131	100.8218	LM	LAATMGAKB	A	324
2126	5.0862	100.8565	LM	LAATMGAKB	A	246
2127	4.8308	100.6651	LM	OCM	Q	156
2128	4.8502	100.6946	LM	OCM	Q	156
2129	4.8433	100.6605	LM	OCM	Q	156
2130	4.8502	100.6575	LM	OCM	Q	104
2131	4.8403	100.6438	LM	OCM	Q	104
2132	4.8359	100.6623	LM	OCM	Q	174
2133	4.8657	100.6446	LM	OCM	Q	117
2134	4.8940	100.6991	LM	PET	Q	129
2135	4.8980	100.6982	LM	PET	Q	174
2136	4.9047	100.6839	LM	PET	Q	130
2137	4.8804	100.6799	LM	PET	Q	156
2138	4.8698	100.6844	LM	PET	Q	156
2139	4.8580	100.6929	LM	PET	Q	226
2140	4.8889	100.6639	LM	PET	Q	117
2141	4.8719	100.6822	LM	PET	Q	330
2142	4.9321	100.7230	LM	RGMBTG	T	142
2143	4.9739	100.7694	LM	RGMBTG	T	142
2144	4.9306	100.7227	LM	RGMBTG	Q	142
2145	4.9731	100.8015	LM	RGMBTG	T	233
2146	5.0814	100.8643	LM	RGMBTG	A	233
2147	5.0763	100.7895	LM	RGMBTG	A	272
2148	4.9603	100.8239	LM	RGMBTG	T	233
2149	4.9971	100.8059	LM	RGMBTG	A	233
2150	4.9583	100.8213	LM	RGMBTG	T	233
2151	5.0788	100.8673	LM	RGMBTG	A	253
2152	4.9747	100.7923	LM	RGMBTG	T	165
2153	4.8570	100.7621	LM	RGMBTG	Q	261
2154	4.7785	100.8019	LM	RGMBTG	A	295
2155	4.7022	100.7223	LM	RGMBTG	Q	191

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy\ J^{-1}$
2156	4.7691	100.7690	LM	RGMBTG	Q	156
2157	4.8369	100.7531	LM	RGMBTG	Q	295
2158	4.8675	100.7395	LM	RGMBTG	Q	522
2159	4.7304	100.7162	LM	RGMBTG	Q	295
2160	4.6936	100.7329	LM	RGMBTG	Q	208
2161	4.9831	100.8078	LM	RGMBTG	T	389
2162	4.9848	100.8104	LM	RGMBTG	T	389
2163	4.7687	100.7673	LM	RGMBTG	Q	121
2164	4.7518	100.7617	LM	RGMBTG	A	330
2165	4.7237	100.7170	LM	RGMBTG	Q	226
2166	4.8751	100.7304	LM	RGMBTG	Q	121
2167	4.7475	100.7184	LM	RGMBTG	Q	226
2168	4.7621	100.7203	LM	RGMBTG	Q	226
2169	4.6736	100.7163	LM	RGMBTG	A	226
2170	4.6336	100.7234	LM	RGMBTG	A	313
2171	4.7611	100.7838	LM	RGMBTG	A	313
2172	4.9761	100.7896	LM	RGMBTG	T	291
2173	4.8835	100.7313	LM	RGMBTG	Q	155
2174	4.9261	100.8239	LM	RGMBTG	A	227
2175	4.8208	100.7517	LM	RGMBTG	Q	243
2176	4.7628	100.7775	LM	RGMBTG	A	278
2177	4.9938	100.8049	LM	RGMBTG	T	259
2178	4.9726	100.7680	LM	SDGMUN	T	58
2179	5.0263	100.8183	LM	SDGMUN	A	253
2180	5.0532	100.7827	LM	SDGMUN	T	142
2181	4.9862	100.7338	LM	SDGMUN	T	129
2182	4.9730	100.7560	LM	SDGMUN	T	142
2183	4.9666	100.7343	LM	SDGMUN	T	182
2184	4.9827	100.7338	LM	SDGMUN	T	142
2185	5.0379	100.7875	LM	SDGMUN	T	142
2186	4.9708	100.7364	LM	SDGMUN	T	97
2187	4.7476	100.9194	LM	SDGMUN	C	90
2188	5.0185	100.8470	LM	STP	A	455
2189	5.0133	100.8412	LM	STP	A	487
2190	4.8607	100.7934	LM	STP	A	295
2191	4.6882	100.7367	LM	STP	A	365
2192	5.0995	100.8260	LM	STP	A	389
2193	5.0121	100.8381	LM	STP	A	389
2194	4.8621	100.7955	LM	STP	A	330
2195	4.8621	100.7947	LM	STP	A	313
2196	4.6494	100.7405	LM	STP	A	295
2197	5.0159	100.8435	LM	STP	A	389
2198	5.0083	100.8408	LM	STP	A	390
2199	4.6718	100.7779	LM	STP	A	208
2200	4.5160	100.6821	MJ	BRH	Q	174
2201	4.4762	100.6343	MJ	BRH	Q	121
2202	4.5050	100.7445	MJ	BRH	A	261
2203	4.5131	100.6758	MJ	BRH	Q	174
2204	4.5172	100.6752	MJ	BRH	Q	156
2205	4.5209	100.6956	MJ	BRH	Q	226
2206	4.0933	100.7908	MJ	BRHSLR	Q	187
2207	4.1063	100.7728	MJ	BRHSLR	Q	130
2208	4.0419	100.7860	MJ	BRHSLR	Q	130
2209	4.0723	100.7963	MJ	BRHSLR	D	198

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2210	4.0538	100.8077	MJ	BRHSLR	Q	156
2211	4.5153	100.8349	MJ	HYDHMU	D	156
2212	4.5203	100.8409	MJ	HYDHMU	A	191
2213	4.4919	100.8019	MJ	HYDHMU	Q	191
2214	4.5232	100.8695	MJ	HYDHMU	A	191
2215	4.5198	100.8418	MJ	HYDHMU	C	156
2216	4.5050	100.8164	MJ	HYDHMU	A	243
2217	4.4993	100.7886	MJ	HYDHMU	A	226
2218	4.4936	100.7939	MJ	HYDHMU	A	226
2219	4.4930	100.7932	MJ	HYDHMU	A	243
2220	4.2652	100.9943	MJ	HYDLUS	C	104
2221	4.4937	100.6411	MJ	JBURDU	Q	156
2222	4.5128	100.6663	MJ	JBURDU	Q	191
2223	4.4441	100.6242	MJ	JBURDU	Q	91
2224	4.4782	100.6350	MJ	JBURDU	Q	174
2225	4.4705	100.6300	MJ	JBURDU	Q	104
2226	4.5005	100.6453	MJ	JBURDU	Q	174
2227	4.3560	100.6278	MJ	KKR	A	191
2228	4.3615	100.6273	MJ	KKR	A	191
2229	4.3122	100.6196	MJ	KKR	Q	191
2230	4.2752	100.6263	MJ	KKR	A	130
2231	4.2860	100.6291	MJ	KKR	A	143
2232	4.3448	100.6260	MJ	KKR	Q	104
2233	4.2157	100.6405	MJ	KNJ	Q	330
2234	4.1996	100.5561	MJ	KNJ	A	52
2235	4.2329	100.5420	MJ	KNJ	A	65
2236	4.4398	100.6142	MJ	KNJ	Q	65
2237	4.2088	100.6398	MJ	KNJ	A	295
2238	4.3606	100.6274	MJ	KNJ	A	261
2239	4.3757	100.6246	MJ	KNJ	A	330
2240	4.3987	100.6304	MJ	KNJ	A	330
2241	4.2259	100.5396	MJ	KNJ	A	78
2242	4.3459	100.6124	MJ	KNJ	Q	78
2243	4.3774	100.5866	MJ	KNJ	Q	174
2244	4.2546	100.6318	MJ	KNJ	A	330
2245	4.2339	100.6348	MJ	KNJ	A	288
2246	4.0448	100.8114	MJ	KNJ	Q	208
2247	4.2890	100.6310	MJ	KNJ	Q	174
2248	4.3816	100.5848	MJ	KNJ	Q	104
2249	4.5088	100.6289	MJ	KNJ	Q	104
2250	4.5313	100.6378	MJ	KNJ	Q	87
2251	4.2845	100.6356	MJ	KNJ	Q	191
2252	4.2005	100.5722	MJ	LAATMGAKB	A	221
2253	4.4833	100.7841	MJ	LAATMGAKB	Q	174
2254	4.5035	100.7708	MJ	LAATMGAKB	A	278
2255	4.2126	100.5702	MJ	LAATMGAKB	A	208
2256	4.1085	100.7816	MJ	OCM	Q	184
2257	4.4595	100.6303	MJ	OCM	Q	139
2258	4.4262	100.6336	MJ	OCM	Q	139
2259	4.4163	100.6320	MJ	OCM	A	191
2260	4.4343	100.6246	MJ	OCM	Q	208
2261	4.4330	100.6263	MJ	OCM	A	208
2262	4.4497	100.6383	MJ	OCM	Q	143
2263	4.4312	100.6323	MJ	OCM	A	226

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy\ J^{-1}$
2264	4.4602	100.6307	MJ	OCM	Q	191
2265	4.4316	100.6713	MJ	PET	Q	191
2266	4.4744	100.6874	MJ	PET	Q	191
2267	4.4315	100.6578	MJ	PET	Q	191
2268	4.4315	100.6642	MJ	PET	Q	174
2269	4.4275	100.7696	MJ	PET	Q	156
2270	4.4441	100.7310	MJ	PET	Q	121
2271	4.4291	100.7599	MJ	PET	Q	156
2272	4.4636	100.6682	MJ	PET	Q	156
2273	4.4537	100.7347	MJ	PET	Q	121
2274	4.1215	100.7731	MJ	PET	Q	243
2275	4.3600	100.8595	MJ	PET	Q	208
2276	4.4552	100.6457	MJ	PET	Q	104
2277	4.3208	100.6408	MJ	RGMBTG	A	191
2278	4.2306	100.5514	MJ	RGMBTG	A	330
2279	4.2679	100.6251	MJ	RGMBTG	A	417
2280	4.2120	100.5633	MJ	RGMBTG	A	243
2281	4.5025	100.7295	MJ	RGMBTG	A	243
2282	4.5013	100.7363	MJ	RGMBTG	A	243
2283	4.5079	100.7428	MJ	RGMBTG	A	313
2284	4.2158	100.6088	MJ	RGMBTG	A	93
2285	4.3283	100.6203	MJ	RGMBTG	A	174
2286	4.5032	100.7635	MJ	RGMBTG	A	278
2287	4.2015	100.6299	MJ	RGMBTG	A	609
2288	4.2033	100.5688	MJ	RGMBTG	A	234
2289	4.3885	100.5931	MJ	RGMBTG	Q	278
2290	4.5248	100.8646	MJ	SDGMUN	A	174
2291	4.4384	100.7802	MJ	SDGMUN	Q	156
2292	4.4558	100.7837	MJ	SDGMUN	D	174
2293	4.5233	100.8569	MJ	SDGMUN	C	104
2294	4.2323	100.5469	MJ	SLR	Q	83
2295	4.2264	100.7652	MJ	SMASWNHYD	Q	274
2296	4.1928	100.7523	MJ	SMASWNHYD	Q	278
2297	4.1990	100.6613	MJ	SMASWNHYD	Q	295
2298	4.1951	100.6924	MJ	SMASWNHYD	Q	261
2299	4.3983	100.6390	MJ	SMASWNHYD	A	191
2300	4.2036	100.7309	MJ	SMASWNHYD	Q	191
2301	4.3382	100.7462	MJ	SMASWNHYD	Q	191
2302	4.2094	100.7351	MJ	SMASWNHYD	Q	191
2303	4.3938	100.6546	MJ	SMASWNHYD	Q	191
2304	4.3856	100.6805	MJ	SMASWNHYD	Q	191
2305	4.2150	100.6905	MJ	SMASWNHYD	Q	295
2306	4.2809	100.7285	MJ	SMASWNHYD	Q	295
2307	4.1880	100.7649	MJ	SMASWNHYD	Q	139
2308	4.3666	100.7542	MJ	SMASWNHYD	Q	254
2309	4.3462	100.7106	MJ	SMASWNHYD	Q	226
2310	4.2702	100.7869	MJ	SMASWNHYD	Q	208
2311	4.1604	100.7238	MJ	SMASWNHYD	Q	226
2312	4.3145	100.7691	MJ	SMASWNHYD	Q	261
2313	4.3533	100.7764	MJ	SMASWNHYD	Q	208
2314	4.2951	100.7586	MJ	SMASWNHYD	Q	250
2315	4.3422	100.7828	MJ	SMASWNHYD	Q	261
2316	4.3528	100.7983	MJ	SMASWNHYD	Q	261
2317	4.3144	100.7683	MJ	SMASWNHYD	Q	261

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2318	4.2802	100.7294	MJ	SMASWNHYD	Q	278
2319	4.2675	100.7484	MJ	SMASWNHYD	Q	261
2320	4.2253	100.7468	MJ	SMASWNHYD	Q	208
2321	4.2813	100.7766	MJ	SMASWNHYD	Q	226
2322	4.2731	100.7870	MJ	SMASWNHYD	Q	226
2323	4.1952	100.7466	MJ	SMASWNHYD	Q	278
2324	4.3474	100.8095	MJ	SMASWNHYD	Q	226
2325	4.3434	100.7891	MJ	SMASWNHYD	Q	278
2326	4.4282	100.7274	MJ	SMASWNHYD	Q	156
2327	4.3634	100.7640	MJ	SMASWNHYD	Q	226
2328	4.3105	100.7650	MJ	SMASWNHYD	Q	261
2329	4.1842	100.6822	MJ	SMASWNHYD	Q	261
2330	4.1993	100.6662	MJ	SMASWNHYD	Q	201
2331	4.2798	100.7789	MJ	SMASWNHYD	Q	219
2332	4.3083	100.7645	MJ	SMASWNHYD	Q	295
2333	4.2729	100.7393	MJ	SMASWNHYD	Q	278
2334	4.4268	100.7803	MJ	SMASWNHYD	Q	156
2335	4.3300	100.7806	MJ	SMASWNHYD	Q	295
2336	4.3390	100.7860	MJ	SMASWNHYD	Q	261
2337	4.1533	100.7190	MJ	SMASWNHYD	Q	240
2338	4.3394	100.7243	MJ	SMASWNHYD	Q	208
2339	4.2707	100.7505	MJ	SMASWNHYD	Q	267
2340	4.3279	100.7781	MJ	SMASWNHYD	Q	267
2341	4.2745	100.7271	MJ	SMASWNHYD	Q	243
2342	4.1459	100.7225	MJ	SMASWNHYD	Q	243
2343	4.3351	100.7829	MJ	SMASWNHYD	Q	243
2344	4.3262	100.7769	MJ	SMASWNHYD	Q	243
2345	4.1992	100.6619	MJ	SMASWNHYD	Q	313
2346	4.2052	100.6718	MJ	SMASWNHYD	Q	313
2347	4.1752	100.7086	MJ	SMASWNHYD	Q	313
2348	4.1611	100.7302	MJ	SMASWNHYD	Q	198
2349	4.1750	100.7650	MJ	SMASWNHYD	Q	149
2350	4.3846	100.7057	MJ	SMASWNHYD	Q	226
2351	4.2127	100.7056	MJ	SMASWNHYD	Q	278
2352	4.3533	100.6989	MJ	SMASWNHYD	Q	226
2353	4.2032	100.6889	MJ	SMASWNHYD	Q	278
2354	4.4318	100.6839	MJ	SMASWNHYD	Q	226
2355	4.1780	100.6815	MJ	SMASWNHYD	Q	226
2356	4.2021	100.7202	MJ	SMASWNHYD	Q	278
2357	4.1971	100.7329	MJ	SMASWNHYD	Q	278
2358	4.2032	100.6759	MJ	SMASWNHYD	Q	278
2359	4.1927	100.5377	MJ	STP	Q	226
2360	4.1947	100.5703	MJ	STP	A	221
2361	4.1968	100.5617	MJ	STP	A	221
2362	4.2502	100.5559	MJ	STP	A	190
2363	4.2175	100.5441	MJ	STP	A	341
2364	4.1937	100.6086	MJ	STP	A	556
2365	4.2124	100.5676	MJ	STP	A	295
2366	4.5157	100.8003	MJ	STP	A	191
2367	4.2137	100.5448	MJ	STP	A	306
2368	4.1979	100.5406	MJ	STP	A	169
2369	4.3863	100.5948	MJ	STP	Q	417
2370	4.1973	100.5358	MJ	STP	A	234
2371	4.1906	100.5377	MJ	STP	A	208

no	LOKASI (DEG) latitud	longitud	Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
2372	4.5006	100.7842	MJ	TMGAKB	A	226
2373	4.5040	100.7695	MJ	TMGAKB	A	243
2374	4.5037	100.8213	MJ	TMGAKB	Q	191
2375	4.1065	100.9594	PT	AKBMPH	Q	278
2376	4.2197	100.8944	PT	AKBMPH	Q	278
2377	4.1178	100.9583	PT	AKBMPH	Q	278
2378	4.0572	100.8669	PT	AKBMPH	Q	226
2379	4.0756	100.8688	PT	AKBMPH	Q	226
2380	4.0971	100.8716	PT	AKBMPH	Q	261
2381	4.1521	100.9414	PT	AKBMPH	Q	261
2382	4.1969	100.8934	PT	AKBMPH	Q	191
2383	4.1353	100.8866	PT	AKBMPH	Q	278
2384	4.0743	100.9432	PT	AKBMPH	Q	169
2385	4.1965	100.8921	PT	AKBMPH	Q	116
2386	4.1462	100.8920	PT	AKBMPH	Q	97
2387	4.1602	100.8988	PT	AKBMPH	Q	116
2388	4.0804	100.8693	PT	AKBMPH	Q	226
2389	4.1016	100.8731	PT	AKBMPH	Q	126
2390	4.1534	100.9282	PT	AKBMPH	Q	195
2391	4.0894	100.8919	PT	AKBMPH	Q	195
2392	4.1108	100.9230	PT	AKBMPH	Q	271
2393	4.2163	100.8867	PT	AKBMPH	Q	288
2394	4.1358	100.9491	PT	AKBMPH	Q	288
2395	4.0945	100.9369	PT	AKBMPH	Q	271
2396	4.0895	100.8650	PT	AKBMPH	Q	169
2397	4.0490	100.8739	PT	AKBMPH	Q	169
2398	4.0531	100.9012	PT	AKBMPH	Q	169
2399	4.0603	100.9752	PT	AKBMPH	Q	169
2400	4.0657	100.8677	PT	AKBMPH	Q	106
2401	4.1729	100.8849	PT	AKBMPH	Q	156
2402	4.0487	100.9425	PT	AKBMPH	Q	156
2403	4.2258	100.8771	PT	AKBMPH	Q	208
2404	4.2242	100.8941	PT	AKBMPH	Q	145
2405	4.1929	100.8829	PT	AKBMPH	Q	208
2406	4.1316	100.8984	PT	AKBMPH	Q	208
2407	4.0779	100.9905	PT	AKBMPH	Q	182
2408	4.1187	100.8786	PT	AKBMPH	Q	292
2409	4.0953	100.9640	PT	AKBMPH	Q	208
2410	4.1191	100.9708	PT	AKBMPH	Q	208
2411	4.2054	100.8915	PT	BRHSLR	Q	278
2412	4.0352	100.9136	PT	BRHSLR	Q	116
2413	4.0508	100.8564	PT	BRHSLR	Q	226
2414	4.2520	101.0203	PT	DLD	C	221
2415	4.2510	101.0245	PT	DLD	C	142
2416	4.2482	101.0478	PT	DLD	Q	168
2417	4.2507	101.0417	PT	DLD	S	372
2418	4.2528	101.0428	PT	DLD	C	168
2419	4.2489	101.0494	PT	DLD	Q	215
2420	4.2663	101.0923	PT	DLD	C	130
2421	4.2502	101.0402	PT	DLD	C	649
2422	4.2353	101.0677	PT	HYDHMU	C	250
2423	4.5215	100.8692	PT	HYDHMU	C	123
2424	4.2358	101.0660	PT	HYDHMU	Q	254
2425	4.1819	101.0985	PT	HYDHMU	Q	271

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2426	4.4568	100.9740	PT	HYDHMU	D	104
2427	4.1820	101.0915	PT	HYDHMU	Q	254
2428	4.1901	101.0799	PT	HYDHMU	Q	111
2429	4.2999	100.9998	PT	HYDLUS	C	117
2430	4.3018	100.9917	PT	HYDLUS	C	64
2431	4.3263	100.9823	PT	HYDLUS	C	117
2432	4.2786	100.9901	PT	HYDLUS	C	67
2433	4.3362	100.9911	PT	HYDLUS	C	130
2434	4.3387	100.9477	PT	HYDLUS	C	130
2435	4.3060	100.9833	PT	HYDLUS	C	77
2436	4.3138	100.9312	PT	HYDLUS	C	156
2437	4.3537	100.9669	PT	HYDLUS	C	182
2438	4.3644	100.9824	PT	HYDLUS	C	158
2439	4.3182	100.9870	PT	HYDLUS	C	91
2440	4.2803	100.9314	PT	HYDLUS	C	130
2441	4.2668	100.9595	PT	HYDLUS	C	87
2442	4.3208	101.0025	PT	HYDLUS	C	130
2443	4.3240	100.9254	PT	HYDLUS	C	174
2444	4.2945	100.9932	PT	HYDLUS	C	90
2445	4.2912	100.9650	PT	HYDLUS	C	155
2446	4.1158	100.7867	PT	JBURDU	Q	226
2447	4.1282	100.7559	PT	JBURDU	Q	243
2448	4.1813	101.0791	PT	MNKSMA	Q	169
2449	4.1826	100.8111	PT	OCM	Q	208
2450	4.1682	100.8056	PT	OCM	Q	243
2451	4.3404	100.9626	PT	PET	C	48
2452	4.1548	100.7808	PT	PET	Q	117
2453	4.2864	100.9852	PT	PET	C	58
2454	4.3017	100.9609	PT	PET	C	67
2455	4.3103	100.9758	PT	PET	C	67
2456	4.3172	100.9620	PT	PET	C	67
2457	4.2354	100.9772	PT	PET	C	117
2458	4.2983	100.9839	PT	PET	C	67
2459	4.1460	100.7831	PT	PET	Q	208
2460	4.3052	100.9673	PT	PET	C	67
2461	4.1633	100.8002	PT	PET	Q	163
2462	4.3244	100.9667	PT	PET	C	67
2463	4.2886	100.9809	PT	PET	C	67
2464	4.1611	100.7975	PT	PET	Q	156
2465	4.1493	100.7841	PT	PET	Q	261
2466	4.3657	100.8416	PT	PET	Q	208
2467	4.1503	100.7836	PT	PET	Q	205
2468	4.2504	100.9720	PT	PET	Q	156
2469	4.2086	100.8568	PT	PET	Q	97
2470	4.3325	100.9752	PT	PET	C	116
2471	4.2375	100.9942	PT	PET	C	87
2472	4.2869	100.9882	PT	PET	C	97
2473	4.1319	100.7787	PT	PET	Q	226
2474	4.1689	100.7961	PT	PET	Q	156
2475	4.2397	100.9936	PT	PET	A	234
2476	4.2488	100.9965	PT	PET	C	208
2477	4.5235	100.9591	PT	RGMBTG	A	278
2478	4.5408	100.8641	PT	RGMBTG	A	243
2479	4.5511	100.9279	PT	SDGKDH	C	174

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J-1
	latitud	longitud				
2480	4.5320	100.9495	PT	SDGKDH	C	78
2481	4.5131	100.9459	PT	SDGKDH	C	104
2482	4.4872	100.9377	PT	SDGKDH	C	104
2483	4.5517	100.9316	PT	SDGKDH	C	104
2484	4.4867	100.9505	PT	SDGKDH	C	87
2485	4.4571	100.9340	PT	SDGMUN	Q	48
2486	4.4644	100.8665	PT	SDGMUN	Q	64
2487	4.3904	100.9716	PT	SDGMUN	C	130
2488	4.4549	100.8549	PT	SDGMUN	Q	77
2489	4.3277	100.9590	PT	SDGMUN	C	69
2490	4.4593	100.9253	PT	SDGMUN	D	156
2491	4.4867	100.9128	PT	SDGMUN	Q	156
2492	4.4492	100.9472	PT	SDGMUN	C	156
2493	4.4699	100.8630	PT	SDGMUN	C	77
2494	4.5011	100.8649	PT	SDGMUN	C	77
2495	4.3905	100.9754	PT	SDGMUN	C	260
2496	4.4703	100.9105	PT	SDGMUN	Q	156
2497	4.3909	100.9583	PT	SDGMUN	C	104
2498	4.4503	100.9433	PT	SDGMUN	C	156
2499	4.4683	100.9248	PT	SDGMUN	C	130
2500	4.3227	100.9307	PT	SDGMUN	C	191
2501	4.4634	100.9246	PT	SDGMUN	C	174
2502	4.4507	100.9404	PT	SDGMUN	D	174
2503	4.4577	100.9067	PT	SDGMUN	Q	145
2504	4.5249	100.9166	PT	SDGMUN	D	104
2505	4.3443	100.9337	PT	SDGMUN	C	87
2506	4.2580	100.9407	PT	SDGMUN	C	87
2507	4.5281	100.9088	PT	SDGMUN	D	104
2508	4.3575	100.8231	PT	SMASWNHYD	Q	261
2509	4.1894	100.7958	PT	SMASWNHYD	Q	243
2510	4.2542	100.9001	PT	TMGAKB	Q	278
2511	4.2599	100.8962	PT	TMGAKB	Q	278
2512	4.4242	100.8992	PT	TMGAKB	Q	261
2513	4.3172	100.8813	PT	TMGAKB	Q	261
2514	4.5035	100.9256	PT	TMGAKB	D	243
2515	4.2447	100.9157	PT	TMGAKB	Q	278
2516	4.4790	100.9006	PT	TMGAKB	Q	278
2517	4.2492	100.9012	PT	TMGAKB	Q	278
2518	4.2679	100.8969	PT	TMGAKB	Q	278
2519	4.3139	100.8837	PT	TMGAKB	Q	278
2520	4.5071	100.9222	PT	TMGAKB	D	156
2521	4.3601	100.8730	PT	TMGAKB	Q	208
2522	4.3963	100.8905	PT	TMGAKB	Q	264
2523	4.1729	100.9462	PT	TMGAKB	Q	264
2524	4.5139	100.9142	PT	TMGAKB	D	156
2525	4.4811	100.9122	PT	TMGAKB	Q	156
2526	4.4733	100.9063	PT	TMGAKB	Q	215
2527	4.2297	100.9480	PT	TMGAKB	C	116
2528	4.3556	100.8822	PT	TMGAKB	Q	174
2529	4.4748	100.9145	PT	TMGAKB	Q	195
2530	4.1656	100.9253	PT	TMGAKB	Q	295
2531	4.2015	100.9195	PT	TMGAKB	Q	295
2532	4.1184	101.0027	PT	TMGAKB	Q	174
2533	4.3326	100.8841	PT	TMGAKB	Q	295

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2534	4.3084	100.9117	PT	TMGAKB	Q	295
2535	4.1697	100.9266	PT	TMGAKB	Q	295
2536	4.4671	100.8846	PT	TMGAKB	C	103
2537	4.2492	100.9268	PT	TMGAKB	C	97
2538	4.2793	100.9017	PT	TMGAKB	Q	261
2539	4.3845	100.9031	PT	TMGAKB	Q	191
2540	4.2261	100.9291	PT	TMGAKB	C	126
2541	4.4863	100.9064	PT	TMGAKB	Q	261
2542	4.3729	100.8996	PT	TMGAKB	Q	261
2543	4.1626	100.9743	PT	TMGAKB	Q	261
2544	4.2359	100.8931	PT	TMGAKB	Q	261
2545	4.2874	100.8831	PT	TMGAKB	Q	261
2546	4.3365	100.8806	PT	TMGAKB	Q	243
2547	4.5069	100.9182	PT	TMGAKB	D	243
2548	4.4547	100.8979	PT	TMGAKB	D	243
2549	4.4235	100.8908	PT	TMGAKB	Q	243
2550	4.4019	100.8784	PT	TMGAKB	Q	243
2551	4.3340	100.8675	PT	TMGAKB	Q	243
2552	4.3912	100.8819	PT	TMGAKB	Q	243
2553	4.4321	100.9043	PT	TMGAKB	Q	243
2554	4.3661	100.8968	PT	TMGAKB	Q	313
2555	4.2960	100.8846	PT	TMGAKB	Q	271
2556	4.3548	100.8631	PT	TMGAKB	Q	254
2557	4.3693	100.8848	PT	TMGAKB	Q	226
2558	4.4474	100.9066	PT	TMGAKB	Q	226
2559	4.3414	100.8902	PT	TMGAKB	Q	226
2560	4.2220	100.9889	PT	TMGAKB	Q	226
2561	4.3620	100.8909	PT	TMGAKB	Q	155
2562	4.1334	100.9851	PT	TMGAKB	Q	226
2563	4.4556	100.9067	PT	TMGAKB	Q	226
2564	4.3548	100.8787	PT	TMGAKB	C	254
2565	4.2275	100.9775	PT	TMGAKB	C	145
2566	4.4155	100.8946	PT	TMGAKB	Q	254
2567	5.1496	100.8165	SL	DLD	A	227
2568	5.2418	100.7457	SL	HYDHMU	S	273
2569	5.2465	100.7756	SL	HYDHMU	A	221
2570	5.2389	100.7367	SL	HYDHMU	S	253
2571	5.1998	100.7020	SL	HYDHMU	T	129
2572	5.1454	100.6861	SL	HYDHMU	T	246
2573	5.3160	100.7689	SL	HYDHMU	S	246
2574	5.2479	100.7805	SL	HYDHMU	A	246
2575	5.2505	100.7654	SL	HYDHMU	S	194
2576	5.2448	100.7409	SL	HYDHMU	A	330
2577	5.2371	100.7245	SL	HYDHMU	S	266
2578	5.2506	100.7467	SL	HYDHMU	S	266
2579	5.2470	100.7790	SL	HYDHMU	A	165
2580	5.2641	100.8224	SL	HYDHMU	S	203
2581	5.2399	100.7398	SL	HYDHMU	A	203
2582	5.2501	100.7418	SL	HYDHMU	S	261
2583	5.2482	100.7392	SL	HYDHMU	A	313
2584	5.1187	100.7694	SL	HYDHMU	A	313
2585	5.2609	100.8056	SL	HYDHMU	A	324
2586	5.2615	100.8035	SL	HYDHMU	A	357
2587	5.2237	100.7503	SL	HYDHMU	A	165

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J-1
2588	5.2314	100.7135	SL	HYDHMU	Q	149
2589	5.1336	100.7554	SL	HYDHMU	T	155
2590	5.2402	100.7297	SL	HYDHMU	S	259
2591	5.2681	100.7330	SL	LAATMGAKB	S	188
2592	5.2331	100.7419	SL	LAATMGAKB	A	233
2593	5.1286	100.8188	SL	LAATMGAKB	A	233
2594	5.2408	100.7155	SL	LAATMGAKB	S	278
2595	5.2291	100.7472	SL	LAATMGAKB	S	233
2596	5.2344	100.6876	SL	LAATMGAKB	S	246
2597	5.2240	100.6971	SL	LAATMGAKB	S	272
2598	5.3045	100.7797	SL	LAATMGAKB	S	129
2599	5.2640	100.7933	SL	LAATMGAKB	A	246
2600	5.1853	100.6817	SL	LAATMGAKB	Q	123
2601	5.1383	100.6483	SL	LAATMGAKB	Q	194
2602	5.2641	100.8237	SL	LAATMGAKB	A	246
2603	5.2520	100.7646	SL	LAATMGAKB	S	246
2604	5.2158	100.7662	SL	LAATMGAKB	S	201
2605	5.2898	100.7418	SL	LAATMGAKB	S	182
2606	5.2718	100.7334	SL	LAATMGAKB	S	182
2607	5.3002	100.8027	SL	LAATMGAKB	A	214
2608	5.2593	100.7866	SL	LAATMGAKB	A	203
2609	5.1482	100.8803	SL	LAATMGAKB	A	246
2610	5.1276	100.7570	SL	LAATMGAKB	A	220
2611	5.2170	100.7620	SL	LAATMGAKB	S	220
2612	5.2668	100.8279	SL	LAATMGAKB	S	220
2613	5.1173	100.7736	SL	LAATMGAKB	A	220
2614	5.2253	100.6894	SL	LAATMGAKB	S	247
2615	5.1331	100.7575	SL	LAATMGAKB	T	311
2616	5.1922	100.7015	SL	LAATMGAKB	T	129
2617	5.2491	100.7433	SL	LAATMGAKB	A	285
2618	5.1351	100.7483	SL	LAATMGAKB	T	156
2619	5.2258	100.7540	SL	LAATMGAKB	S	227
2620	5.1493	100.8838	SL	LAATMGAKB	A	259
2621	5.1981	100.7788	SL	RGMBTG	A	233
2622	5.2076	100.6889	SL	RGMBTG	Q	123
2623	5.1919	100.7826	SL	RGMBTG	A	255
2624	5.1927	100.7381	SL	RGMBTG	A	311
2625	5.1399	100.8612	SL	RGMBTG	A	259
2626	5.3374	100.8373	SL	RGMBTG	A	609
2627	5.1197	100.8036	SL	RGMBTG	A	233
2628	5.1356	100.8455	SL	RGMBTG	A	233
2629	5.2067	100.7105	SL	RGMBTG	T	64
2630	5.3214	100.8183	SL	RGMBTG	A	609
2631	5.3278	100.8275	SL	RGMBTG	A	609
2632	5.2131	100.7087	SL	RGMBTG	T	129
2633	5.3203	100.8234	SL	RGMBTG	A	552
2634	5.2419	100.7804	SL	RGMBTG	A	422
2635	5.3135	100.7703	SL	RGMBTG	S	247
2636	5.1908	100.6835	SL	RGMBTG	Q	123
2637	5.3141	100.7615	SL	RGMBTG	S	266
2638	5.1579	100.8097	SL	RGMBTG	A	220
2639	5.3188	100.8147	SL	RGMBTG	A	715
2640	5.1826	100.7923	SL	RGMBTG	A	220
2641	5.3202	100.8181	SL	RGMBTG	A	617

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	$nGy\ J^{-1}$
2642	5.1312	100.8764	SL	RGMBTG	A	220
2643	5.2047	100.7776	SL	RGMBTG	A	232
2644	5.2098	100.6869	SL	RGMBTG	Q	174
2645	5.2390	100.7928	SL	RGMBTG	A	174
2646	5.3092	100.8038	SL	RGMBTG	A	382
2647	5.1823	100.7231	SL	RGMBTG	A	298
2648	5.2546	100.7995	SL	RGMBTG	A	305
2649	5.2520	100.7179	SL	RGMBTG	S	194
2650	5.2856	100.7923	SL	RGMBTG	S	129
2651	5.2110	100.7047	SL	RGMBTG	T	129
2652	5.2696	100.8353	SL	RGMBTG	A	207
2653	5.3097	100.8105	SL	RGMBTG	A	357
2654	5.3097	100.8011	SL	RGMBTG	A	357
2655	5.3200	100.8167	SL	RGMBTG	A	609
2656	5.3232	100.8251	SL	RGMBTG	A	617
2657	5.3129	100.7896	SL	RGMBTG	A	318
2658	5.1370	100.8452	SL	RGMBTG	A	246
2659	5.1585	100.7636	SL	RGMBTG	A	292
2660	5.3118	100.7955	SL	RGMBTG	S	246
2661	5.3151	100.7614	SL	RGMBTG	S	246
2662	5.2355	100.7145	SL	RGMBTG	S	246
2663	5.1896	100.7304	SL	RGMBTG	A	246
2664	5.3134	100.7407	SL	RGMBTG	S	246
2665	5.2067	100.7801	SL	RGMBTG	A	318
2666	5.1520	100.8913	SL	RGMBTG	A	259
2667	5.1553	100.6828	SL	SDGMUN	Q	233
2668	5.1709	100.6756	SL	SDGMUN	Q	129
2669	5.1496	100.7482	SL	SDGMUN	T	129
2670	5.2804	100.7791	SL	SDGMUN	S	168
2671	5.1644	100.7192	SL	SDGMUN	T	129
2672	5.1611	100.7248	SL	SDGMUN	T	129
2673	5.1631	100.6726	SL	SDGMUN	Q	121
2674	5.2980	100.7870	SL	SDGMUN	S	182
2675	5.1721	100.7149	SL	SDGMUN	T	142
2676	5.2788	100.7984	SL	SDGMUN	S	116
2677	5.2855	100.7700	SL	SDGMUN	S	168
2678	5.1863	100.6822	SL	SDGMUN	Q	174
2679	5.1625	100.6695	SL	SDGMUN	Q	191
2680	5.1582	100.6668	SL	SDGMUN	Q	123
2681	5.1675	100.7137	SL	SDGMUN	T	149
2682	5.2619	100.7815	SL	SDGMUN	S	246
2683	5.3586	100.8599	SL	STP	A	455
2684	5.3195	100.8290	SL	STP	A	519
2685	5.1699	100.8011	SL	STP	A	253
2686	5.3169	100.8302	SL	STP	A	696
2687	5.3285	100.8832	SL	STP	A	522
2688	5.3001	100.8334	SL	STP	A	552
2689	5.3020	100.8435	SL	STP	A	348
2690	5.3100	100.8335	SL	STP	A	417
2691	5.3001	100.8334	SL	STP	A	324
2692	5.1694	100.8020	SL	STP	A	266
2693	5.1706	100.8599	SL	STP	A	247
2694	5.3336	100.8490	SL	STP	A	696
2695	5.2159	100.7693	SL	STP	A	242

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2696	5.1426	100.8320	SL	STP	A	240
2697	5.1200	100.8383	SL	STP	A	324
2698	5.2071	100.7377	SL	STP	A	311
2699	5.1680	100.9199	SL	STP	A	324
2700	5.1604	100.8955	SL	STP	A	389
2701	5.1636	100.9079	SL	STP	A	389
2702	5.1551	100.8850	SL	STP	A	324
2703	5.2039	100.7346	SL	STP	A	285
2704	5.3352	100.8597	SL	STP	A	609
2705	5.1993	100.8262	SL	STP	A	234
2706	5.1731	100.9299	SL	STP	A	259
2707	5.1068	100.8452	SL	STP	A	259
2708	5.4106	101.1310	UP	CHN	S	243
2709	5.3921	101.0984	UP	CHN	S	243
2710	5.4618	101.1334	UP	CHN	S	117
2711	5.3005	101.1635	UP	CHN	A	221
2712	5.2933	101.0767	UP	CHN	S	174
2713	5.3301	101.1412	UP	CHN	A	174
2714	5.2692	101.0924	UP	CHN	S	130
2715	5.3480	101.0558	UP	CHN	S	130
2716	5.3120	101.0791	UP	CHN	S	156
2717	5.2888	101.0789	UP	CHN	S	174
2718	5.2975	101.0687	UP	CHN	S	156
2719	5.3360	101.0538	UP	CHN	A	348
2720	5.4568	101.1369	UP	CHN	S	116
2721	5.4828	101.1261	UP	CHN	S	116
2722	5.3091	101.1591	UP	CHN	A	295
2723	5.3125	101.0659	UP	CHN	K	174
2724	5.2986	101.0700	UP	CHN	S	191
2725	5.4258	101.1189	UP	CHN	S	191
2726	5.5039	101.1224	UP	CHN	S	174
2727	5.3137	101.1517	UP	CHN	A	382
2728	5.4391	101.1015	UP	CHN	S	174
2729	5.3594	101.1548	UP	CHN	S	261
2730	5.3400	101.1491	UP	CHN	A	174
2731	5.2984	101.0785	UP	CHN	S	174
2732	5.4323	101.1192	UP	CHN	S	174
2733	5.3517	101.1590	UP	CHN	A	195
2734	5.3322	101.0544	UP	CHN	S	261
2735	5.3154	101.1581	UP	CHN	A	286
2736	5.2717	101.0700	UP	CHN	S	174
2737	5.3114	101.1422	UP	CHN	A	130
2738	5.3840	101.1373	UP	CHN	S	130
2739	5.4528	101.1414	UP	CHN	S	194
2740	5.4539	101.1468	UP	CHN	S	195
2741	5.3621	101.1505	UP	CHN	S	174
2742	5.3142	101.1467	UP	CHN	A	174
2743	5.4909	101.1253	UP	CHN	S	129
2744	5.4500	101.1310	UP	CHN	S	156
2745	5.4153	101.1528	UP	CHN	S	143
2746	5.4483	101.1338	UP	CHN	S	155
2747	5.4184	101.1153	UP	CHN	S	143
2748	5.1870	101.0667	UP	KLA	A	234
2749	5.0211	101.0073	UP	KLA	A	260

no	LOKASI (DEG)		Daerah	Jenis	Geo	Sinaran gama daratan
	latitud	longitud		Tanah	logi	nGy J^{-1}
2750	5.1627	101.0018	UP	KLA	A	330
2751	5.1516	100.9920	UP	KLA	A	330
2752	5.1023	101.0280	UP	KLA	A	417
2753	5.1370	101.0479	UP	KLA	A	195
2754	5.1895	101.0567	UP	KLA	A	313
2755	5.1751	101.0384	UP	KLA	A	261
2756	5.1920	101.0601	UP	KLA	A	261
2757	5.0752	100.9973	UP	KLA	A	194
2758	5.0397	100.9800	UP	KLA	A	195
2759	5.1709	101.0216	UP	KLA	A	313
2760	5.1367	101.0100	UP	KLA	A	234
2761	5.4070	101.1274	UP	LAATMGAKB	S	243
2762	5.1208	100.9823	UP	LAATMGAKB	A	243
2763	5.0997	100.9912	UP	LAATMGAKB	A	243
2764	5.3406	101.0507	UP	LAATMGAKB	S	174
2765	5.1510	100.9907	UP	LAATMGAKB	A	182
2766	5.1232	100.9874	UP	LAATMGAKB	A	182
2767	5.3162	101.0621	UP	LAATMGAKB	S	130
2768	5.1402	100.9890	UP	LAATMGAKB	A	168
2769	5.0156	100.9824	UP	LAATMGAKB	A	168
2770	5.3023	101.0557	UP	LAATMGAKB	A	348
2771	5.2150	101.0695	UP	LAATMGAKB	A	330
2772	5.1370	100.9901	UP	LAATMGAKB	A	348
2773	5.2527	101.0681	UP	LAATMGAKB	A	330
2774	5.0775	100.9649	UP	LAATMGAKB	A	295
2775	5.1394	101.0318	UP	LAATMGAKB	A	156
2776	5.1200	101.0255	UP	LAATMGAKB	A	191
2777	5.3617	101.0412	UP	LAATMGAKB	S	295
2778	5.0025	100.9467	UP	LAATMGAKB	A	261
2779	5.2168	101.0922	UP	LAATMGAKB	S	174
2780	5.0469	100.9602	UP	LAATMGAKB	A	261
2781	5.1358	101.0385	UP	LAATMGAKB	A	261
2782	5.2400	101.0737	UP	LAATMGAKB	A	295
2783	5.1267	100.9998	UP	LAATMGAKB	A	174
2784	5.0654	100.9632	UP	LAATMGAKB	A	155
2785	5.0238	100.9939	UP	LAATMGAKB	A	259
2786	5.4175	101.1486	UP	LAATMGAKB	S	191
2787	5.4165	101.1537	UP	LAATMGAKB	S	191
2788	5.2256	101.0750	UP	LAATMGAKB	A	104
2789	5.3013	101.0564	UP	RGMBTG	K	278
2790	5.2700	101.0517	UP	RGMBTG	S	174
2791	5.2208	100.6989	UP	RGMBTG	S	174
2792	4.9868	100.9274	UP	RGMBTG	A	168
2793	5.2710	101.0632	UP	RGMBTG	A	348
2794	5.3119	100.8000	UP	RGMBTG	A	365
2795	5.2893	101.0594	UP	RGMBTG	A	208
2796	5.2983	101.0610	UP	RGMBTG	A	261
2797	5.2764	101.0578	UP	RGMBTG	A	261
2798	5.3100	101.0534	UP	RGMBTG	K	261
2799	5.2195	101.0841	UP	RGMBTG	S	104
2800	5.0996	100.9628	UP	RGMKLA	A	330
2801	5.1043	100.9672	UP	RGMKLA	A	116
2802	5.1187	100.9700	UP	RGMKLA	A	365
2803	5.0877	100.9606	UP	RGMKLA	A	295

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2804	5.0638	100.9670	UP	RGMKLA	A	208
2805	5.1013	100.9680	UP	RGMKLA	A	261
2806	5.0920	100.9619	UP	RGMKLA	A	155
2807	5.0418	100.9519	UP	RGMKLA	A	155
2808	5.4501	101.2002	UP	SDGMUN	S	129
2809	5.7210	101.0025	UP	SDGMUN	S	129
2810	5.4696	101.1883	UP	SDGMUN	S	64
2811	5.6542	100.9457	UP	SDGMUN	S	91
2812	5.5162	101.1894	UP	SDGMUN	S	64
2813	5.4998	101.1876	UP	SDGMUN	S	64
2814	5.6414	101.0276	UP	SDGMUN	S	129
2815	5.7458	101.0221	UP	SDGMUN	S	77
2816	5.7474	101.0291	UP	SDGMUN	A	182
2817	5.4738	101.1986	UP	SDGMUN	S	77
2818	5.2851	101.0590	UP	SDGMUN	A	313
2819	5.2582	101.1750	UP	SDGMUN	A	330
2820	5.4945	101.1883	UP	SDGMUN	S	129
2821	5.2725	101.1918	UP	SDGMUN	A	348
2822	5.2089	101.1874	UP	SDGMUN	A	330
2823	5.2294	101.1822	UP	SDGMUN	A	330
2824	5.3584	101.1704	UP	SDGMUN	A	330
2825	5.7313	100.9901	UP	SDGMUN	S	142
2826	5.3385	101.1950	UP	SDGMUN	A	348
2827	5.2952	101.1868	UP	SDGMUN	A	382
2828	5.2800	101.1868	UP	SDGMUN	A	261
2829	5.2255	101.1856	UP	SDGMUN	A	382
2830	5.6269	100.9567	UP	SDGMUN	S	90
2831	5.6168	100.9552	UP	SDGMUN	A	194
2832	5.7348	101.0203	UP	SDGMUN	S	90
2833	5.2223	101.1853	UP	SDGMUN	A	435
2834	5.6602	100.9735	UP	SDGMUN	S	90
2835	5.4425	101.2053	UP	SDGMUN	S	155
2836	5.6672	101.0206	UP	SDGMUN	S	155
2837	5.4613	101.1825	UP	SDGMUN	S	155
2838	5.5264	101.1247	UP	SDGMUN	S	155
2839	5.4064	101.2934	UP	STP	S	182
2840	5.6624	101.0237	UP	STP	S	77
2841	5.5302	101.2941	UP	STP	S	182
2842	5.6036	101.0723	UP	STP	S	77
2843	5.5741	101.0589	UP	STP	S	182
2844	5.3304	101.3539	UP	STP	S	182
2845	5.2360	101.3935	UP	STP	A	191
2846	5.3239	101.3597	UP	STP	S	129
2847	5.5048	101.2442	UP	STP	S	129
2848	5.5313	101.2508	UP	STP	S	129
2849	5.5602	101.0066	UP	STP	S	129
2850	5.3024	101.3675	UP	STP	S	129
2851	5.5708	101.0113	UP	STP	S	129
2852	5.5355	101.2670	UP	STP	S	129
2853	5.5757	101.4071	UP	STP	S	129
2854	5.2988	101.3576	UP	STP	S	129
2855	5.3152	100.9612	UP	STP	A	234
2856	5.5221	101.1919	UP	STP	S	64
2857	5.6267	101.3169	UP	STP	S	64

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2858	5.4046	101.3358	UP	STP	S	64
2859	5.1021	101.2089	UP	STP	A	191
2860	5.6947	101.0316	UP	STP	S	77
2861	5.5647	101.3653	UP	STP	S	142
2862	5.1899	100.9802	UP	STP	A	313
2863	5.1627	101.3320	UP	STP	A	208
2864	5.4229	101.3108	UP	STP	S	77
2865	5.4248	101.2586	UP	STP	S	77
2866	5.5374	101.3016	UP	STP	S	142
2867	5.2612	101.3837	UP	STP	S	77
2868	5.1891	100.9665	UP	STP	A	313
2869	5.1674	101.0124	UP	STP	A	313
2870	5.6054	101.0374	UP	STP	S	142
2871	5.3308	101.0323	UP	STP	A	715
2872	5.2045	101.1848	UP	STP	A	330
2873	5.5505	101.2812	UP	STP	S	191
2874	5.1584	101.3287	UP	STP	A	121
2875	5.1958	101.4002	UP	STP	A	208
2876	5.6005	101.5683	UP	STP	S	142
2877	5.1652	101.3517	UP	STP	A	208
2878	5.0813	101.2709	UP	STP	A	261
2879	5.7319	100.9735	UP	STP	S	142
2880	5.2484	101.0700	UP	STP	A	261
2881	5.2408	100.9850	UP	STP	A	313
2882	5.4102	101.2822	UP	STP	S	116
2883	5.3920	101.1338	UP	STP	S	261
2884	5.2836	101.3715	UP	STP	S	116
2885	5.5982	101.0326	UP	STP	S	116
2886	5.5573	100.9877	UP	STP	S	116
2887	5.1685	101.3602	UP	STP	A	208
2888	5.4065	101.2939	UP	STP	S	116
2889	5.4376	101.0388	UP	STP	S	116
2890	5.0933	101.2860	UP	STP	A	278
2891	5.1858	100.9874	UP	STP	A	295
2892	5.7451	100.9958	UP	STP	A	278
2893	5.1096	100.9643	UP	STP	A	295
2894	5.1982	101.3985	UP	STP	A	208
2895	5.0887	101.1952	UP	STP	A	278
2896	5.6054	101.5166	UP	STP	A	259
2897	5.0876	101.2776	UP	STP	A	295
2898	5.1817	101.3854	UP	STP	A	208
2899	5.0746	101.1610	UP	STP	S	208
2900	5.3862	101.1336	UP	STP	S	174
2901	5.5907	101.4922	UP	STP	A	207
2902	5.6134	101.6554	UP	STP	P	194
2903	5.6088	101.4545	UP	STP	A	195
2904	5.5852	101.4708	UP	STP	A	194
2905	5.2799	101.3961	UP	STP	S	194
2906	5.5444	101.3387	UP	STP	S	194
2907	5.1000	101.1930	UP	STP	S	174
2908	5.3268	101.0800	UP	STP	S	174
2909	5.4898	101.3400	UP	STP	S	90
2910	5.6052	101.0537	UP	STP	S	90
2911	5.3291	101.3706	UP	STP	S	90

no	LOKASI (DEG)		Daerah	Jenis Tanah	Geo logi	Sinaran gama daratan nGy J^{-1}
	latitud	longitud				
2912	5.5517	100.9934	UP	STP	S	90
2913	5.4412	101.1325	UP	STP	S	182
2914	5.1995	101.1869	UP	STP	A	435
2915	5.0930	100.9539	UP	STP	A	278
2916	5.3167	100.8350	UP	STP	A	609
2917	5.5845	101.2703	UP	STP	S	143
2918	5.5791	101.4486	UP	STP	A	155
2919	5.5445	101.3243	UP	STP	S	155
2920	5.4858	101.2339	UP	STP	S	155
2921	5.6987	101.0343	UP	STP	S	155
2922	5.3911	101.3102	UP	STP	S	155
2923	5.1721	101.0348	UP	STP	A	313
2924	5.6548	101.6363	UP	STP	A	208
2925	5.6517	101.5913	UP	STP	S	156
2926	5.1585	101.3419	UP	STP	A	243
2927	5.6445	101.0093	UP	STP	A	208
2928	5.0957	101.2002	UP	STP	A	208
2929	5.3171	101.4436	UP	STP	A	208
2930	5.1288	101.3449	UP	STP	A	182

Lampiran A 2, Lokasi sampel tanah dan kepekatan keradioaktifan

NO	Latitud	Longitud	Daerah	Sinaran gama daratan nGy J^{-1}	Kepekatan Keradioaktifan Bq kg-1		
					U-238	Th-232	K-40
1	3.865	101.450	BP	234	130	258	102
2	3.909	101.088	HP	39	20	24	31
3	3.927	101.093	HP	65	66	42	127
4	3.934	101.423	BP	182	103	151	101
5	3.939	100.964	HP	116	41	121	349
6	4.035	100.914	HP	155	102	146	512
7	4.038	101.204	HP	195	74	107	110
8	4.085	101.101	HP	286	242	208	595
9	4.102	101.103	HP	260	113	236	305
10	4.103	101.320	BP	143	71	152	75
11	4.107	101.315	BP	78	27	75	46
12	4.123	101.325	BP	130	90	101	61
13	4.126	101.205	BP	91	45	50	658
14	4.146	100.892	PT	130	67	89	527
15	4.161	100.797	PT	117	42	70	790
16	4.194	100.609	MJ	416	337	377	22
17	4.212	100.563	MJ	169	88	183	181
18	4.216	100.609	MJ	91	58	94	59
19	4.252	101.020	PT	221	191	188	1184
20	4.266	101.092	PT	130	57	102	115
21	4.266	101.320	BP	247	164	221	500
22	4.267	100.960	PT	117	93	82	136
23	4.269	101.008	KT	117	57	100	115
24	4.270	101.042	KT	780	162	1021	165
25	4.272	101.092	KT	104	32	77	85
26	4.2745	101.0019	KT	143	79	142	95
27	4.282	101.117	KT	78	35	78	21
28	4.286	101.025	KT	845	213	1131	133
29	4.288	101.042	KT	1039	148	908	166
30	4.2876	101.0418	KT	1039	194	1629	631
31	4.2894	101.0201	KT	520	181	732	226
32	4.302	101.015	KT	520	139	563	74
33	4.312	101.017	KT	715	205	778	78
34	4.312	101.048	KT	845	173	1239	144
35	4.3118	101.0482	KT	846	324	1806	1014
36	4.317	101.039	KT	488	426	399	1940
37	4.318	101.037	KT	780	167	1209	144
38	4.321	101.045	KT	715	227	989	136
39	4.3228	101.0443	KT	805	308	1752	326
40	4.3234	101.0170	KT	845	295	1286	177
41	*4.3257*	*101.0313*	KT	1039	225	1400	186
42	4.326	101.024	KT	1039	197	1298	210
43	4.3269	101.0417	KT	780	554	707	2522
44	4.328	100.959	PT	52	16	27	25
45	4.3332	101.0482	KT	747	267	1011	101
46	4.338	101.033	KT	780	72	1141	57
47	4.3440	100.9720	KT	130	38	95	61
48	4.344	100.934	HP	91	31	84	28
49	4.350	100.893	HP	195	138	132	401

NO	Latitud	Longitud	Daerah	Sinaran gama daratan nGy J^{-1}	Kepekatan Keradioaktifan Bq kg-1 U-238	Th-232	K-40
50	4.350	101.015	KT	78	30	83	26
51	4.353	101.231	KT	208	162	198	345
52	4.355	100.875	HP	117	45	79	872
53	4.362	101.062	KT	117	99	130	131
54	4.362	100.891	PT	208	155	116	746
55	4.364	100.982	KK	65	57	42	127
56	4.376	100.625	MJ	78	54	60	241
57	4.377	101.048	KT	104	61	109	73
58	4.379	101.001	KT	91	58	73	54
59	4.382	100.585	MJ	78	47	78	72
60	4.399	101.009	KT	130	58	108	177
61	4.401	101.001	KT	117	93	56	67
62	4.401	101.001	KT	117	61	123	274
63	4.402	101.040	KT	52	12	37	25
64	4.413	101.104	KT	143	85	124	142
65	4.4192	101.1230	KT	157	75	153	237
66	4.422	100.970	KT	65	21	33	6
67	4.431	100.991	KT	260	100	310	94
68	4.431	100.975	KT	104	42	52	782
69	4.434	101.130	KT	104	43	63	29
70	4.441	100.996	KT	117	123	132	82
71	4.441	101.043	KT	91	34	59	52
72	4.442	101.038	KT	130	88	129	28
73	4.442	100.974	KT	52	24	31	26
74	4.449	101.027	KT	91	52	91	147
75	4.452	101.134	KT	91	86	119	339
76	4.453	101.187	KT	169	128	194	205
77	4.457	100.934	PT	52	18	26	228
78	4.459	101.209	KT	312	206	258	290
79	4.459	100.925	PT	156	68	183	152
80	4.459	100.958	KT	117	12	23	83
81	4.464	100.867	PT	65	27	30	49
82	4.470	100.991	KT	156	95	118	29
83	4.475	101.070	KT	130	54	155	428
84	4.476	101.081	KT	104	74	135	211
85	4.487	100.950	PT	65	27	47	219
86	4.4947	101.0222	KT	273	248	244	1539
87	4.514	101.093	KT	156	104	210	153
88	4.516	100.800	MJ	156	7	247	59
89	4.516	101.085	KT	117	76	96	78
90	4.532	101.135	KT	118	76	96	78
91	4.536	101.117	KT	164	132	45	90
92	4.551	101.030	KT	299	109	174	744
93	4.554	101.170	KT	208	151	224	78
94	4.607	100.875	KK	390	101	447	431
95	4.630	101.151	KT	208	85	291	51
96	4.632	101.043	KT	455	307	519	262
97	4.643	101.156	KT	182	61	99	98
98	4.659	101.167	KT	143	54	95	90
99	4.659	101.171	KT	143	76	117	69
100	4.671	101.143	KT	143	74	157	28
101	4.681	101.087	KT	195	184	280	186
102	4.691	101.129	KT	156	91	190	60

NO	Latitud	Longitud	Daerah	Sinaran gama daratan nGy J^{-1}	Kepekatan Keradioaktifan Bq kg-1		
					U-238	Th-232	K-40
103	4.691	101.158	KT	208	86	214	170
104	4.692	101.185	KT	455	252	403	2204
105	4.703	101.144	KT	156	105	160	104
106	4.705	101.163	KT	221	111	228	93
107	4.708	101.083	KT	182	169	154	650
108	4.730	100.716	LM	208	54	160	241
109	4.748	100.979	KK	325	66	488	78
110	4.773	100.916	KK	221	148	155	330
111	4.775	100.679	LM	52	18	39	199
112	4.794	101.227	KK	169	147	164	121
113	4.962	100.468	KR	117	51	128	69
114	4.971	100.736	LM	130	49	137	245
115	4.973	100.801	LM	233	307	408	954
116	4.976	100.790	LM	390	256	363	670
117	4.983	100.808	LM	390	95	404	52
118	4.983	100.808	LM	208	180	237	389
119	4.985	100.810	LM	390	319	356	18
120	5.004	100.801	KK	169	156	131	20
121	5.014	100.824	LM	390	259	401	529
122	5.016	100.804	LM	390	245	334	813
123	5.024	100.792	LM	143	24	130	980
124	5.034	100.782	LM	325	166	378	531
125	5.046	100.620	KR	130	42	79	806
126	5.085	100.666	KR	117	65	104	485
127	5.111	100.508	KR	143	72	92	389
128	5.120	100.415	KR	130	63	134	402
129	5.129	100.462	KR	117	38	138	207
130	5.131	100.628	KR	193	47	60	72
131	5.138	100.648	SL	260	126	252	290
132	5.160	100.896	SL	390	158	459	378
133	5.170	100.801	SL	260	152	245	251
134	5.213	100.709	SL	130	57	207	198
135	5.213	100.709	SL	142	65	384	215
136	5.216	100.769	SL	325	357	297	601
137	5.224	100.697	SL	273	139	272	291
138	5.239	100.793	SL	234	140	211	464
139	5.242	100.780	SL	429	206	507	104
140	5.245	100.741	SL	330	117	625	60
141	5.255	100.799	SL	311	166	247	579
142	5.264	100.822	SL	273	96	224	455
143	5.289	101.059	UP	156	105	168	103
144	5.299	101.070	UP	143	94	102	421
145	5.300	100.833	SL	559	286	566	78
146	5.310	100.810	SL	364	247	276	439
147	5.312	101.079	UP	104	54	60	305
148	5.317	100.835	UP	390	266	297	301
149	5.320	100.818	SL	520	364	521	36
150	5.324	101.360	UP	130	86	106	139
151	5.330	101.354	UP	182	87	231	83
152	5.544	101.324	UP	156	107	120	27

Lampiran A.3 Lokasi pensampelan dan kepekatan radionuklid uranium dan torium di dalam sampel tumbuh-tumbuhan

Latitud	Longitud	Daerah	*uranium*	*torium*
			Bq kg-1	
3.6734	101.2651	BP	0.233	0.167
3.9091	101.0881	HP	0.025	0.037
3.9337	101.4235	BP	0.197	0.342
3.9387	100.9637	HP	0.259	0.212
3.9634	100.7541	HP	0.056	1.066
4.0276	101.3030	BP	0.151	1.129
4.0352	100.9136	PT	1.044	0.107
4.0689	101.3438	BP	0.279	0.157
4.1249	101.3313	BP	0.064	0.143
4.1462	100.8920	PT	0.690	0.305
4.1906	100.5377	MJ	1.397	0.217
4.2015	100.6299	MJ	1.295	0.322
4.2264	100.7652	MJ	0.142	0.580
4.2668	100.9595	PT	0.950	0.060
4.2752	100.6263	MJ	0.518	0.187
4.3041	101.0483	KT	0.363	1.072
4.3117	101.0135	KT	1.075	0.123
4.3117	101.0135	KT	1.198	0.458
4.3117	101.0135	KT	0.165	0.748
4.3117	101.0135	KT	2.016	0.951
4.3443	100.9337	HP	0.185	0.110
4.3499	100.8932	HP	0.284	0.464
4.3532	101.2312	KT	0.259	0.145
4.3620	100.8909	PT	0.395	0.354
4.3878	101.0123	KT	0.058	0.033
4.4571	100.9340	HP	0.057	0.079
4.4748	100.9145	PT	1.242	0.247
4.5037	100.8213	MJ	0.086	0.070
4.5997	100.8794	KK	0.148	0.012
4.7368	101.1304	KT	0.240	0.717
4.7727	100.9165	KK	0.034	0.500
4.8150	101.0682	KK	0.246	0.476
4.9211	101.1719	KK	0.093	1.040
4.9474	101.1439	KK	0.141	0.245
4.9708	100.7364	LM	0.500	0.100
5.0043	100.8058	KK	0.291	0.528
5.0162	100.8040	LM	1.665	0.245

Latitud	Longitud	Daerah	*uranium*	*torium*
			Bq kg-1	
5.0236	100.7912	LM	0.245	0.095
5.0343	100.7818	LM	1.703	0.277
5.0379	100.7875	LM	0.215	0.244
5.0456	100.6203	KR	0.175	0.142
5.1023	101.0280	UP	0.259	0.187
5.1084	100.4138	KR	0.369	0.227
5.1102	100.5184	KR	0.204	0.243
5.1187	100.9700	UP	0.030	0.042
5.1199	100.4146	KR	0.298	0.212
5.1289	100.4618	KR	0.306	0.129
5.1342	100.6280	KR	0.219	0.012
5.1383	100.6483	SL	1.286	0.185
5.1394	101.0318	UP	0.015	0.098
5.1993	100.8262	SL	0.207	0.163
5.2159	100.7693	SL	0.036	0.218
5.2390	100.7928	SL	1.433	0.155
5.2501	100.7418	SL	0.185	0.112
5.2641	100.8224	SL	0.982	0.164
5.3152	100.9612	UP	0.062	0.513
5.5374	101.3016	UP	0.065	0.172
4.4783	101.0009	KT	0.025	0.085
4.5307	101.1230	KT	0.259	0.204
4.6174	101.0444	KT	0.268	0.040
4.3237	101.0373	KT	0.296	0.159
4.2848	101.0432	KT	2.121	0.322
4.3218	101.0394	KT	0.518	0.114
4.3228	101.0239	KT	0.395	0.248
4.2985	101.0332	KT	0.099	0.305
4.3257	101.0288	KT	2.348	0.855

Lampiran A.4 Lokasi pensampelan air dan kepekatan radionuklid uranium dan torium di dalam sampel air

Latitud	Longitud	Daerah	uranium	torium
			Bq/L	
5.139	101.032	UP	0.102	0.273
3.939	100.964	HP	0.407	0.020
4.035	100.914	PT	0.518	0.063
4.125	101.331	BP	0.604	0.059
4.146	100.892	PT	0.261	0.010
4.202	100.630	MJ	0.799	0.472
4.226	100.765	MJ	0.261	0.012
4.275	100.626	MJ	0.437	0.053
4.278	101.082	KT	1.555	0.002
4.307	101.037	KT	2.197	0.505
4.328	100.959	PT	0.235	0.130
4.3388	101.0530	KT	1.603	0.084
4.355	100.875	HP	0.437	0.008
4.3754	101.2240	KT	0.438	0.002
4.4911	101.1596	KT	0.617	0.098
4.5720	101.2480	KT	1.340	0.092
4.600	100.879	KK	0.986	0.009
4.749	100.984	KK	1.171	0.293
4.815	101.068	KK	1.566	0.012
4.868	100.740	LM	0.555	0.387
5.016	100.804	LM	1.393	0.216
5.110	100.518	KR	0.703	0.171
5.120	100.415	KR	0.152	0.051
5.320	100.818	SL	0.268	0.260
Hulu Berenam		BP	0.105	0.047
Kg Sg Durian		KT	1.566	0.010
Kg Sg Durian		KT	1.739	0.012
Kg Sg Durian		KT	2.480	0.578
Kp Sg Durian		KT	1.063	0.562
Sg Ara		LM	3.055	0.094
Sg Durian		KT	3.758	0.488
Sg Kampar		KT	2.700	0.989
Sg Kinta		KT	0.530	0.085
Sg Mega Selama		SL	2.059	0.106

Latitud	Longitud	Daerah	uranium	torium
			Bq/L	
Sg Nur		SL	0.346	0.010
Sg Papulut		UP	0.321	0.142
Sg Perak		PT	0.690	0.011
Sg Ulu Dedah		HP	0.344	0.008
Tasik Temengor		UP	0.719	0.106
Tj Tualang		KT	0.623	0.052
Tj Tualang		KT	1.914	0.323

BAHAGIAN B

SURVEY OF NATURAL BACKGROUND RADIATION AND ANAYLSIS OF AMANG SAMPLES IN KINTA DISTRICT

SUMMARY

A survey of natural background radiation levels in the Kinta district was carried out between 2003 and 2005. Dose rates were measured from 1007 locations using a portable gamma-ray survey meter, Model 19 Micro R meter manufactured by Ludlum. The measured dose rates ranged from 39 to 1039 nGy h^{-1} and have a mean dose rate of 222 ± 191 nGy h^{-1} (1.36 mSv y^{-1}). Two small areas of hot spots around Kampung Sungai Durian with dose rates of 1039 nGy h^{-1} were found. This is the highest dose rate recorded in Perak to date. A total of 128 soil samples collected were analyzed for the activities of the naturally occurring radionuclides, gross alpha and gross beta activities. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K were analyzed by using a HPGe detector. The ranges are 12 – 426 Bq kg^{-1} for ^{238}U, 19 – 1377 Bq kg^{-1} for ^{232}Th and from less than 19 – 2204 Bq kg^{-1} for ^{40}K. Based on the radioactivity levels determined, the gamma absorbed dose rates in air at 1 meter above the ground were calculated using the procedure applied by UNSCEAR 2000. The total calculated dose rates and measured dose rates have shown good correlation coefficient of 0.94. The calculated Radium Equivalent Activity (Ra_{eg}) range from 0.14 to 6.01 mSv y^{-1}. The gross alpha activity of the soil samples range from 15 to 9634 Bq kg^{-1} with a mean value of 1558 ± 121 Bq kg^{-1}. The gross beta activity range from 142 to 6173 Bq kg^{-1} with a mean value of 1112 ± 32 Bq kg^{-1}. The mean population weighted dose rate for the Kinta district is 1.2 mSv y^{-1}. Gamma isodose map for the Kinta District was plotted.

CHAPTER BI

B1. INTRODUCTION

B1.1 Introduction

When the earth was formed four billion years ago, it contained many radioactive isotopes (Wang et al. 1975; Foster, 1985). Since then, all the shorter-lived isotopes have decayed. Only those isotopes very long half-lives (100 million years or more) remain, along with the isotopes formed from the decay of the long-lived isotopes. These naturally occurring isotopes include uranium, thorium and their decay products, such as radon. The presence of these radionuclides in the ground leads to both external gamma ray exposure and internal exposure from radon and its progeny.

Environmental gamma activities results from potassium, uranium, thorium, and their daughters in various rocks and soils; estimates of such activities at a height of about 1 m over granite areas are typically on the order of 1.5 mGy y^{-1} and over limestone on the order of 0.2 mGy y^{-1} (Henry, 1969). Obviously, the actual level of radiation caused by the radioisotopes content of rocks and soil varies widely from place to place, and the actual background at a given location can be determined only by measurement. Thus the dose rate depends on the geological location (Martin and Harbison, 1972). In order to predict the environmental quality, monitor continuously the air gamma radiation level for 24 hours and to detect the abnormal, we need to know the natural background of gamma radiation (Tu Yu and Jiang Dezhi, 1996).

Granite is the major igneous rock that is abundantly available in Peninsular Malaysia. It is distributed in Western Belts and Eastern Belt, running roughly north south along the length of the Peninsula. The Western Belt consists of the Main Range, the Kledang Range and other granite further west. The ages of the granites range from Permian to Cretaceous, with the majority of Triassic age (Bignell and Snelling, 1977).

The main sources of natural background radiation are as follows:

1. Radioactive substances in the earth crust.
2. Emanation of radioactive gas from the earth.
3. Cosmic rays from outer space which bombarded the earth.
4. Trace amounts of radioactivity in the body.

B1.2 Research Objectives

Research objectives are:

i. To establish a baseline data of natural background radiation levels in the Kinta District. The baseline data can be used as reference information to assess any changes in the natural background radiation level due to various geological processes or any artificial influences due to fallout.

ii. To identify areas where the dose rate levels are high, medium and low.

iii. To analyze the activity concentrations of the radionuclides of ^{238}U, ^{232}Th and ^{40}K from the soil samples and compare the calculated total dose rates with the measured dose rates.

iv. To analyze the gross alpha and gross beta activities of the soil samples.

v. To analyze the concentrations of uranium and thorium in amang samples.

vi. To plot the isodose contour map of gamma dose rate.

B1.3 Importance of this Research

1. A need to establish a baseline data which can be used as reference information to assess any changes in the natural background radiation level due to various geological processes or any artificial influences due to fallout (Goddard, 2000; Ibrahiem et al., 1993; Quindős et al., 1994).

2. A need to identify areas with high natural radiation (Erickson et al., 1993) or hot spot areas.

3. Identification of natural radioactive elements presented in soil, geology, and sediments in minor concentrations are of large interest because of their detrimental effects on natural environment (Vertacnik et al., 1977).

4. Radioactivity is present everywhere in nature and it is necessary to study the radiation levels and to access the dose to the population, in order to know the health risks.

B1.4 Statement of Hypotheses.

1. The natural background radiation level mapping for isodose gamma-rays can be produced by using a portable survey meter.

2. Kinta District has many tin mining sites, and is expected to have high background radiation from the minerals such as monazite and zircon.

3. Granite which forms the Main Range on the east and the Kledang Range on the west of the Kinta District are expected to have high radiation level than the limestone areas found in between them.

B1.5 Scope of Study

This project covers the Kinta District, Perak. It is bounded on the north and south by lines of latitude 4° 45' N. and 4° 15' N. respectively, on the east by line of longitude 101° 15' E. and on the west by 101° 00' E.

Kinta District has 12 major towns such as Batu Gajah, Chemor, Gopeng, Ipoh, Kampar, Kellie's Castle, Malim Nawar, Pusing, Simpang Pulai, Tambun, Tanjung Rambutan, and Tanjung Tualang. It has an area of approximately 1958 km^2 and has a population of about 703493 (Population Census in 2000). Rainfall is throughout the year with 193 days recorded with a total of 2990 mm of rain. The temperature ranged from 23.9 to 32.9 ºC (Shaari, 2003).

B1.6 Research Methodology

A survey meter was used for the dose rate measurements in the Kinta District. Areas are chosen with flat ground away from obstacles, outcrops and buildings. At each location, the latitude and longitude were determined by using global positioning system (GPS) with an accuracy of about 100 meters.

The activities of the naturally occurring radionuclides ^{238}U, ^{232}Th and ^{40}K in the soil samples were measured by using HPGe gamma-ray spectrometry. Amang by-products were analyzed for ^{238}U and ^{232}Th.

Gross alpha and gross beta activities from the soil samples and amang by-products were analyzed by using Low Background Counting System Canberra Model LB5500.

B1.7 Natural Radioactivity

All common rock types and the soil derived from them contain a significant amount of all the naturally radioactive elements (radioelements). The presence of these radioelements is apparent in any gamma-ray survey, irrespective of whether or not it is the purpose of the survey to map their distribution in the natural environment.

The three naturally occurring radioelements are potassium, uranium and thorium. Whereas potassium undergoes a simple form of radioactive decay, the decay of uranium and thorium is complex, and proceeds sequentially along a chain of disintegration.

B1.8 The Radioactivity of Soil

Gamma radiation from radionuclides which are characterized by half-lives comparable to the age of the earth, such as ^{40}K and the nuclides from the ^{238}U and ^{232}Th series, and their decay products, represents the main external source of irradiation to the human body. The absorbed dose rate in air from cosmic radiation outdoors at sea level is about 30 nGy h^{-1} for the southern hemisphere (UNSCEAR, 2000). External exposures outdoors arise from terrestrial radionuclides occurring at trace levels in all ground formations. Therefore, the natural environmental radiation mainly depends on geological and geographical conditions (Florou and Kritidis, 1992). Higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks. There are exceptions, however, as some shale and phosphate rocks have relatively high content of radionuclides (UNSCEAR, 2000).

Background radiation levels result from a combination of terrestrial from the ^{40}K, ^{232}Th and ^{226}Ra and cosmic radiation. The level is fairly constant over the world, being 80 – 150 μGy h^{-1}. The highest are found in Brazil, India and China. The high radiation levels are due to high concentrations of radioactive minerals in soil. One such mineral is monazite, is a high insoluble rare earth mineral that occur in beach sand together with the mineral illuminate which give the sand a characteristic black color. The principal radionuclides in monazite are from the ^{232}Th series, but there is also some uranium and its progeny, ^{226}Ra. In Brazil, the monazite sand deposits are found along certain beaches. The external radiation levels on these black sands range up to 50 μGy h^{-1}, which is almost 400 times normal background in the United States of America. Some of the major streets of the surrounding cities have radiation levels as high as 1.3 μGy h^{-1}, which is more than 10 times the normal background. On the Southwest coast of India, the monazite deposits are larger than those in Brazil. The dose from external radiation is, on average similar to Brazil 5 – 6 mGy y^{-1}.

Most of Oman's surface is limestone, which is low in concentrations of radionuclides from uranium and thorium series. The mean population weighted dose rate is 39.8 nGy h^{-1} (0.30 mSv y^{-1}). The average dose rate is well below the world average of 0.45 mSv y^{-1}. (Goddard, 2002).

Wong (1985), measured the natural background radiation level (NBRL) at 41 randomly pick locations in the Kinta district. He used a Portable Victoreen GM Survey Meter (Model 491) connected with standard detector probe (Model 491-30) which responds to gamma and beta rays. Thirteen of the locations were on residual granitic soil, 12 on residual soil of metasediments, 13 on alluvium and 3 on soil in the vicinity of granite/metasediment contact. The recorded NBRL reading ranging from 0.10 to 0.68 μGy h^{-1} (above ground) and 0.18 to 1.45 μGy h^{-1} (inside borehole, 1 m deep) as shown in Table B2.4 (Wong, 1985)

Table B1.1 Range of NBRL readings over various geological materials (Wong, 1985)

Geological material	Above ground NBRL μGy h^{-1}	Borehole NBRL μGy h^{-1}
1. Granitic soil	0.41 to 0.68	0.70 to 1.45
2. Alluvium	0.26 to 0.35	0.43 to 0.60
3. Soil of metasediment	0.10 to 0.25	0.18 to 0.40

In the Kinta district, the natural background radiation level varies from 0.10 to 0.68 μGy h^{-1}. The average NRBL over residual soils of granite and metasediments, and over alluvium are: 0.51, 0.16 and 0.29 μGy h^{-1} respectively. The corresponding borehole averages are: 0.95, 3.0 and 5.1 μGy h^{-1} respectively (Wong, 1985).

Table B1.2 shows the uranium and thorium concentrations and specific activity of ^{226}Ra and ^{228}Ra at various places in Malaysia. Cs-137 was also detected, usually due to the fallout from nuclear testing where it has spread to Malaysia through rainfall and wind (Omar et al., 1991).

Table B1.2 Natural Radioactivity (Omar et al., 1991).

Place	Uranium ppm	Thorium ppm	^{226}Ra Bq kg^{-1}	^{228}Ra Bq kg^{-1}
Genting Highlands	17.3	69.5	241	316
East - West Highway	19.2	50.4	202	222
Taiping	26.7	89.6	175	375
Sik, Kedah	9.3	59.1	127	290
Pasir Hitam, Langkawi	47.8	54.6	330	145

B1.9 Tin Tailings (Amang)

In the Kinta district of Perak, naturally occurring radioactive materials like thorium and uranium are found along side tin ore deposits. In mining, after the tin oxide has been removed, the tailings called amang, containing the radioactive components, are sold to the amang upgrading plants. The amang upgrading plants involves the processing of tin tailings from primary tin-mining industries into concentrated tin ores and other economic mineral products such as monazite ([Ce,La,Y,Th]PO_4), xenotime (YPO_4), zicron ($ZrSiO_4$), ilmenite ($FeTiO_3$), rutile (TiO_2), magnetite (Fe_3O_4) and pyrite (FeS_2). Monazite is a cerium, yttrium, lanthanum, thorium phosphate which contains thorium from about 2% to 14% and uranium from about 0.05 % to 0.3%. Xenotime is a yttrium phosphate containing thorium ranging from about 0.02% to 2.5% and uranium from 0.03% to about 4%. Zircon may have about 0.01 % to 0.8% thorium and about 0.01% to 0.6% uranium. The non-radioactive minerals are ilmenite, magnetite, rutile, garnet, and pyrite. Some of these minerals, mainly monazite, xenotime and zircon, which contain substantial amounts of thorium and uranium (Hu et al., 1981), are radioactive and may pose high external radiation levels in the work place and the storage room.

In addition, the physical separation processes involved can generate a considerable amount of air-borne radioactive particles, which may pose inhalation hazards (Hu et al., 1983). The measurement of radiation levels and radioactivity associated with the amang upgrading plants is thus an important health consideration to the workers in the plants.

Tables B1.3 and B1.4 show the radiation levels in the mineral processing industry in Malaysia (Gangaharam E.V and Lam E.S., (1981). The relative abundance of the various radioactive materials is greatly variable at different locations within the amang plants. The exposure level recorded at any particular location depends on the stage of the processing, the relative abundance of the three radioactive minerals at that stage, the presence a water layer over the concentrated on the case of the shaking tables using water and finally the size and shape of the storage container or the stockpile. Despite these variables, which will be assessed in the future surveys, our preliminary results throw some light on the subject of potential exposure to personnel.

Table B1.3. Preliminary values of ranges of exposure levels in some amang processing plants, Malaysia (Gangadharam and Lam, 1981).

Location	Range of exposure levels in μGy h^{-1}
1. Background level Away from the working sheds or storage areas but within the plant premises.	0.2 – 0.6
2. Background level Inside a working shed but away from large piles of minerals	1 – 30
3. Inside offices – plant administration	0.2 – 50
4. Inside laboratories – with numerous sample bags of various sizes	1– 80
5. Feedstock – of raw amang, 1000 kg or more	1– 20
6. Shaking tables and separators	1– 30
7. Temporary storage piles – (within the plant) concentrations between stages of processing up to 500 kg	
Zircon	2 – 20
Xenotime	2 – 20
Monazite	4 – 100
8. Stockpiles of minerals separators	
Zircon	5 – 40
Xenotime	5 – 50
Monazite	40 – 140

Table B1.4. Preliminary values of exposure values of exposure levels measured in a typical amang plant (Gangadharam and Lam, 1981).

Location	Exposure levels in $\mu Gy\ h^{-1}$
1. Background level At the entrance	0.3
2. Background level Within plant shed but not far from temporary piles of concentrates	1.5
3. Raw amang feedstock pile A large outdoor pile, over 100,000 kg	3
4. Raw amang feedstock pile, inside plant input to the rotary dryer, approx. 300 kg.	1
5. Output of magnetic separator, on conveyor belt	
Non-magnetic fraction	1
Magnetic fraction	1.5
6. Holman's shaking table, using water	
Input – magnetic output above	1.5
Output – head	3
- Middling	3
- Tailings	1
7. Chinese dryer – head output above approx. 100 kg	10
8. Temporary storage piles from the Wheelman's table	
Middling, approx. 400 kg	9
Tailing, approx. 250 kg	5
9. Temporary stockpiles of minerals separators	
Zircon, approx. 300 kg	10
Xenotime, approx. 300 kg	25
Monazite, approx. 300 kg	45

Table B1.5 below shows the measurements taken by (Hu and Kandaiya, 1985). The exposure rate in a monazite storage room at a distance of 0.3 m from the concentrated monazite is about 90 μGy h^{-1} while at a distance of 0.01 m is observed to be greater than 100 μGy h^{-1}. Based on the value of 90 μGy h^{-1} no worker should be allowed to work in the monazite storage room for more than 1.78 h per day, assuming that he works 6 days per week and 8 hours per day will receive a minimum occupational exposure of 75 mSv y^{-1}, which exceeds the ICRP recommended value of 50 mSv y^{-1}. According to a survey, in spite of the high radiation levels observed in monazites stores and filling area (90 -170 μGy h^{-1}), personnel exposure in the plant was within the annual dose limit of 50 mSv and about 80% of the persons received exposure of less than 3/10 of that value. Actually with proper individual monitoring and shielding measures are taken, no personnel will receive exposures exceeding the recommended maximum value in spite of high external radiation levels.

Table B1.5. Average dose rate of various sites of the amang plants visited. Measurements were taken at a distance of 0.01 and 0.3 m away from pilings.

Sites	Dose rate (μGy h^{-1}) 0.3 m away	Dose rate (μGy h^{-1}) 0.01 m away
Monazite storage room	91	>100
Xenotime storage room	25	40
Zicron storage room	20	26
Tin ore storage room	10	15
Ilmenite piling in work place	3	10
Tin tailing outside plant	4	5
Struvilite and rutile outside plant	3	3
Pyrites piling outside plant	2	1

Hu and Kandaiya, (1985)

Table B1.6 below shows the measurements taken by Hu et al. (1984) in their research paper "Radioactivity Associated with Amang Upgrading Plants". The uranium and thorium concentrations from the amang plants were summarized below. Among the samples, monazite shows the highest total activity, followed by xenotime and zircon. Thorium cake, a waste product from xenotime itself. The highest gamma activity of these samples could thus pose an external radiation hazard to workers handling them or constantly near them. Individual monitoring and appropriate shielding measures must be adopted.

Table B1.6. Gamma activities of amang samples (Hu et al.,1984)

Amang sample	Activity in kBq kg^{-1}		
	Uranium	Thorium	Total
Zircon	18.3 ± 3.1	33.0 ± 1.3	51.3 ± 3.4
Xenotime	110.4 ± 3.4	23.5 ± 0.5	133.9 ± 3.4
Thorium cake	130.3 ± 3.1	48.7 ± 17.2	179.0 ± 17.5
Monazite	43.2 ± 21.2	265.0 ± 3.9	308.2 ± 21.6
Ilmenite	8.2 ± 0.9	10.5 ± 0.2	18.7 ± 0.9

B1.10 Global Positioning System

Global positioning system is commonly used to conduct radiological surveys. The GPS is a constellation of 24 satellites called the NAVISTAR system, which continuously send radio signals containing precise position and time information for each satellite back to earth. By knowing the position of any 3 or 4 of these satellites and calculating various time differences between the transmitted signals, the GPS receiver can display an individual's position on the earth's surface as measured in latitude and longitudes. The positioning system is subject to poor satellite reception or signals that are reflected from nearby buildings. The system works erratically under dense tree canopies because of poor signal reception. Moreover, the accuracy of the system is also dependent on the number of satellite signals it receives since the number of satellites present overhead varies over time; thereby, resulting in measurement locations with differing accuracy while surveys are being conducted. Garmin GPS Model 12XL was used in this survey has an accuracy of about 100 meters (Garmin, 1988).

B1.11 Commercial Uses of Amang Minerals.

Commercial uses of amang minerals are shown in Table B1.7.

Table B1.7. Commercial uses of amang minerals (Sahabat Alam Malaysia, 1984)

Amang minerals	Extracted elements/ minerals	Commercial uses
Ilmenite Rutile	Titanium dioxide ($TiO2$)	Titanium pigments, rubber goods, cosmetics, lather manufacture ceramics, paper manufacture and welding rod coatings
Zircon	Zircon	Refractory products, porcelain, vitreous enamels and glass manufacture
Monazite Xenotime	Yttrium oxide	Incandescent gas light mantles refractory, colour television, and nuclear fuels

B1.12 Geology of the Kinta District

The Kinta District is situated in the state of Perak near the western coast of Peninsular Malaysia. The valley is about 48 km long and 24 km at its widest part, and trends approximately south-southwest. The valley floor is gently undulating. It is flanked to the east by the Main Range and to the west by the Kledang Range. The major river, the Kinta river drains practically the whole length of the valley from north to south, and it's joined by a number of small tributaries.

The mountains ranges consist essentially of granitoids whose original sedimentary covers have been removed by weathering and erosion. The greater solubility of the limestones is responsible for their generally much lower relief; marked exceptions to this are the conspicuous limestones hills. Schists, interbedded with limestone, usually form low hills rising from the valley floor, or foothills flanking the granitic ranges.

The geology map of the Kinta tin field based on the worked of Ingham and Bradford (1960) and on the Geological Map of West Malaysia, 7^{Th} Edition (1973) is produced in Figure B1.1.

The Kinta District is underlain by a sequence of sedimentary rocks ranging in age from Silurian to Permian, which have been intruded by granitoids and associated late phase minor intrusive of probably Jurassic to Triassic age.

Most of the sedimentary rocks in the valley are Devonian in age. Rocks of Silurian age are present in the northern part, whereas rocks of Carboniferous underline areas in the southwestern part of the valley. Locally, outcrops of Permian limestones are also known. Alluvium covers almost the entire valley.

The sedimentary rocks have been affected both by thermal and regional metamorphism brought about by the intrusion of the granitoids, and by earth movements that preceded and continued during and after the granitic valley emplacement (Rajah, 1979).

B1.12.1 Calcareous Rocks

Rocks of the Calcareous Series are believed to be of Carboniferous age i.e. between 280 and 345 million years (Inghan and Bradford, 1960). The sedimentary rocks underlying the Kinta District is chiefly calcareous. They comprise relatively pure limestone, dolomite and ferroandolomite and occupy about 673 sq km of the valley. Generally, the limestone has recrystalline to form a crystalline marble. The resulting calcite crystals show great variation in grain size. Locally, the calcareous rocks may be interbedded with argillaceous beds. The limestone, with irregular pinnacles and forming a karst topography, has commonly been in mines working on stanniferous alluvium. In Kinta, limestone hills arising from the alluvial plain and forming a striking topographical feature occur particularly in the eastern portion of the valley. Permian limestone is known to be present north of Tanjung Rambutan and west of Kampar.

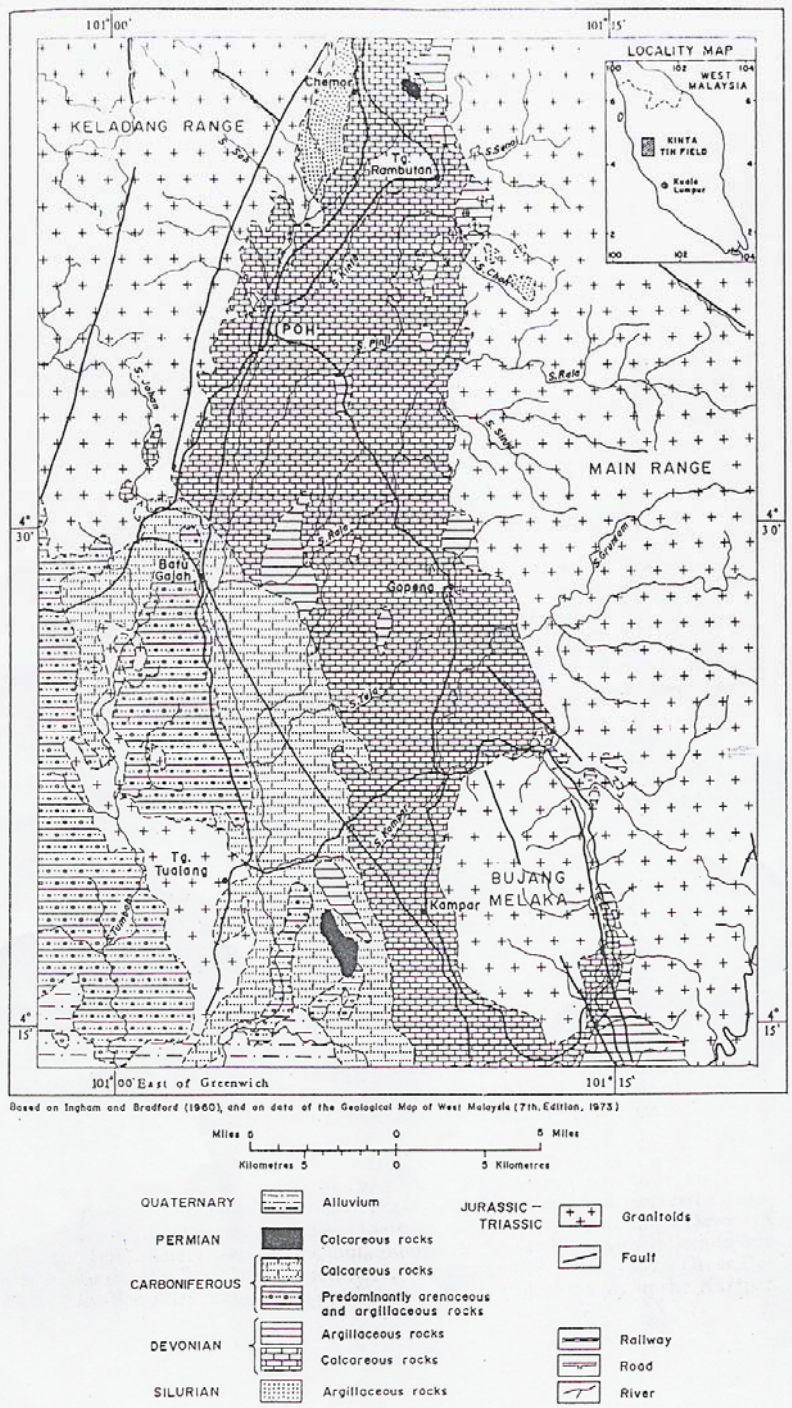

Figure B1.1 Geology of the Kinta District

B1.12.2 Argillaceous Rocks

The argillaceous rocks consist essentially of shale, phyllite and schist with subordinate siltstone and sandstone (quartize). The argillaceous strata are well exposed in numerous parts of the valley. The largest outcrops extend from Batu Gajah to Tanjung Tualang and form a stretch of undulating country.

B1.12.3 Arenaceous Rocks

The arenaceous rocks are composed mainly of sandstone (quartize) with minor interbeds of conglomerate, siltstone and shale. These rocks are found mainly in the west and southwest of the valley.

B1.12.4 Granitoids

Granitic rocks, in the shape of a giant horse-shoe, encircle the sedimentary strata that form the basement of the valley. They underlie an area of about 738 sq km i.e. about half the area of Kinta District.

B1.12.5 Alluvium

Alluvium covers most of the broad expanse of the Kinta valley plain. Its thickness varies considerably; the thickness increases southward from 6 m near Ipoh to more than 30 m in the southern part.

B1.13 Soil Types in the Kinta District

Table B1.8 below shows the types of soils found in the Kinta District. The soil map is shown in Appendix A.

Table B1.8 Soil Types in the Kinta District

Parent material	Soil mapping unit	Map symbol	Soil type No. - (FAO)
Granite	Rengam-Bukit-Temiang	RGM-BTG	48 – Haplic Acrisols
Shales, sandstones and schist	Serdang-Munchong	SDG-MUN	31 – Ferric Acrisols – Ferric Acrisols- Orthic Ferralsols
Subrecent and old alluvium	Holyrood-Harimau	HYD-HMU	18 – Xanthic Ferralsols- Dystric Gleysols
Recent deposits	Peats	PET	10 –Dystric Histosols
Miscellaneous, land unit	Disturbed land Steep land	DLD STD	50 – Urban land 49 – Steep land

B1.14 ICRP Annual Dose Limit

Table B1.9 shows the recommended values for workers and members of the public by ICRP. This gives us a guide for radiation safety.

Table B1.9 Annual Dose Limit, (ICRP, 1991)

Annual dose limit	For whole body exposure	For partial exposure
Workers	50 millisieverts (or mSv) Or 20 mSv averaged over period of 5 years	50 mSv (effective) 150 mSv for lens of the eye 500 mSv for each organ
Members of the public	1 mSv or 100 mrem	1 mSv (effective) 50 mSv for skin and lens of the eye

B1.15 Energy Response of Survey Meter Used

The energy response of instruments measuring gamma dose rate is important. In Figure B1.2 shows the typical response curves for the ion chamber, G-M tube and scintillation detector. If the instrument is used to measure radiation of different photon energy it may seriously underestimate or overestimate the dose rate. Recently, compensating devices have been incorporated into instrument using scintillation or G-M detector to give a relatively uniform response from 0.1 to 3 MeV (Martin and Haribson, 1972). The energy response curve for the survey meter used in this project is included in Appendix B.

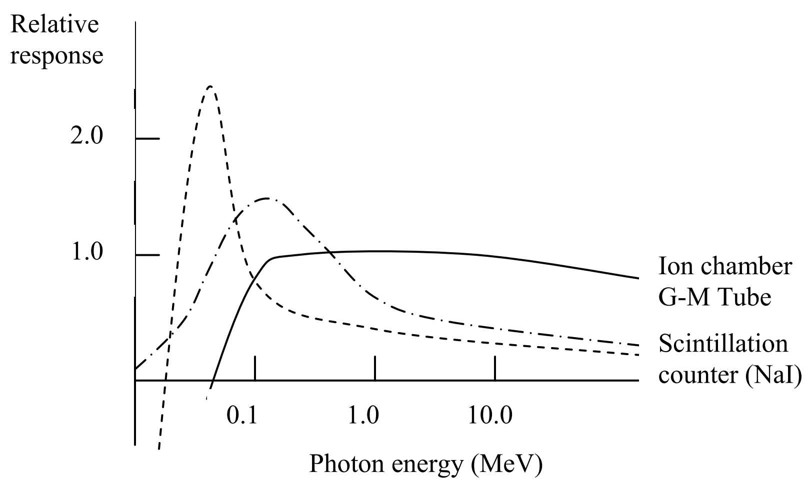

Figure B1.2 Energy response curves of various detectors.

CHAPTER BII

B2. METHODOLOGY

B2.1 Experimental Methods and Measurement Using Survey Meter

Dose rate measurements were performed by a portable survey meter (Figure B2.1) manufactured by Ludlum (Model 19 Micro R Meter, USA). The equipment uses a 2.54 cm x 2.54 cm NaI crystal doped with thallium [NaI(Tl)] to offer an optimum performance in counting low-level gamma radiation. The NaI scintillator is energy sensitive (Appendix B). The smallest scale division for the instrument is 1 μR h^{-1}. Conversion to dose rate in air (nGy h^{-1}) was made by multiplying the exposure rate in μR h^{-1} by 8.7. It has two scales meter face presenting 0 – 25 and 0 – 50 μR h^{-1}. The 0 – 25 scale corresponds to the 25 and 250 positions on the range selector switch. The 0 – 50 scale corresponds to the 50, 500 and 5000 positions in the range selector switch. It has a fast and slow response of 4 and 22 seconds for the meter to reach 90% of full scale meter deflection respectively. This instrument had a reported accuracy of ± 10%. (Ludlum Measurements, Inc. 1993). The detector was calibrated by Malaysian Institute for Nuclear Technology Research (MINT). The detection of gamma-rays from cosmic sources is negligible due to the low response of the instrument to high energy gamma radiation. This was observed when radiation level was measured on board of a ferry far away from land. It detected a reading of only about half of a division on the smallest scale 1 μR h^{-1} (~ 8.7 nGy h^{-1}). The NaI (Tl) detector is the most widely used device for all kinds of environmental gamma ray surveys due to its efficiency (IAEA, 1979).

The survey meter was placed on the floor in the back seat; the car was driven throughout Kinta District. In the initial stage, approximately every 2 km, three readings were taken outside the car covering major roads. During the second stage, every mukim were measured randomly at approximately every 1 km (or more frequently if the display indicated a significant change in the radiation level was detected) when ever access is possible by road. The following procedure was complied with at each measuring point:

(i) The car was driven off the road surface, usually into the nearby field.
(ii) The survey meter was held 1 m above the ground.
(iii) After 60 seconds warm-up an average of the radiation levels was recorded.
(iv) Take another two readings about 5 meters away from each other.
(v) The actual measurement data will be the mean of the three readings.
(vi) The latitude and longitude recorded from the GPS (Figure B2.1) at each location, the geological type and soil type were noted. This completed the measurement.
(vii) Soil samples were collected on the spot at selected sites at random (Mireles, 2003) for uranium, thorium and potassium analysis.

For each location, the latitude and the longitude were checked by using global positioning system (GPS) with an accuracy of about 100 meters. The dose measurements were taken randomly. The grounds at the measurement locations were unpaved and generally covered by grass. In some areas where access was restricted; therefore, no dose rates measured and no samples were taken e.g. on the eastern part of the Kinta District. These areas are mainly Bukit Kinta Forest Reserve and have very low population density. Locations chosen were flat ground away from obstacles, outcrops, and buildings (Goddard, 2002).

Figure B2.1 Survey meter and GPS

B2.2 Gamma Ray Spectrometer Analysis

B2.2.1 Sample Preparation for Counting

A total of 128 soil samples were collected about 10 cm from the surface of the soil. The samples were put to dry in an oven at 110 °C for 2 days. The samples were pulverized and then sieved through 325 micron. Each sample was weighted and sealed in standard 500 ml Marinelli beakers. It is stored for 4 weeks before counting in order to allow the in-growth of uranium and thorium decay products and achievement of equilibrium for ^{238}U and ^{232}Th with their respective progeny (Myrick et al., 1983; Quindós et al. 1994).

Each sample was put into the shielded HPGe detector and measured for a live-time for 3 hours (a typical spectrum is shown in Figure B2.4). Prior to the sample measurement, the environmental gamma background at the laboratory site has been determined with an empty Marinelli beaker under identical measurement conditions. It has been later subtracted from the measured gamma-ray spectra of each sample (Kohshi et al, 2001).

B2.2.2 Standard Samples Preparation for Soil Analysis

The IAEA standard samples (S-14) and (SL-2) were used as reference materials are mixed with SiO_2 in Marinelli beakers. The uranium and thorium content from S-14 are 29 ppm and 610 ppm respectively. A weight of 20.01 g from Sample IAEA S-14 was thoroughly mixed with 102.00 g of SiO_2 in a Marinelli beaker (labelled as SAMP012). After mixing with SiO_2, the uranium and thorium concentration are 4.72 ppm and 99.2 ppm respectively. Another Marinelli beaker contains 100.00 g of SiO_2 is labelled as SAMP011. This provides background for standard samples.

The IAEA standard sample SL-2 was used to calculate the specific activity of potassium. It has a specific activity of 240 Bq kg^{-1}. A weight of 100.00 g of SL-2 was mixed with 100.00 g of SiO_2 in a Marinelli beaker (labelled as SAMP025).

B2.2.3 Standard Samples Preparation for Amang Analysis

The IAEA standard sample S-15 of 15.00 g was sealed in a vial. The concentration of uranium and thorium are 85 and 3630 ppm respectively. This standard was used for the calculation of uranium and thorium in amang by-products.

B2.3 Gamma-Ray Detection System

A high resolution spectrometer was used for the measurement of the gamma energy spectrum of the emitted gamma-rays in the energy range between 50 keV and 2000 keV. The system consists of a high purity germanium (HPGe) detector with an efficiency of 20% and a resolution of 1.8 keV at 1332 keV. It has an operation voltage of 1900 V. See Figure B2.2a. During operation the detector is cooled down by liquid nitrogen at 77 K for the purpose of reducing leakage current and thermal noise, and its warm-up sensor is coupled to the high voltage detector bias supply, ORTEC 659 which is equipped with a remote shutdown feature. The signal-processing electronic includes a spectroscopy main amplifier, ORTEC 672 which incorporates an efficient pile-up rejector, and a MultiChannel buffer (MCB) which is a PC-based plug-in PCI card consisting of an 8k Analogue-to Digital Converter (ADC). An advanced Analyzer (MCA) emulation software (MAESTRO-32) enables data acquisition, storage and display of the acquired spectra (ORTEC, 2001). The block diagram is shown in Figure B2.2b. The detector is surrounded by lead shield to reduce the background radiation (Tsoulfanidis, 1995). Detection limits for counting time of 10,800 s were estimated to be 4 Bq kg^{-1} for ^{238}U, 9 Bq kg^{-1} for ^{232}Th and 19 Bq kg^{-1} for ^{40}K.

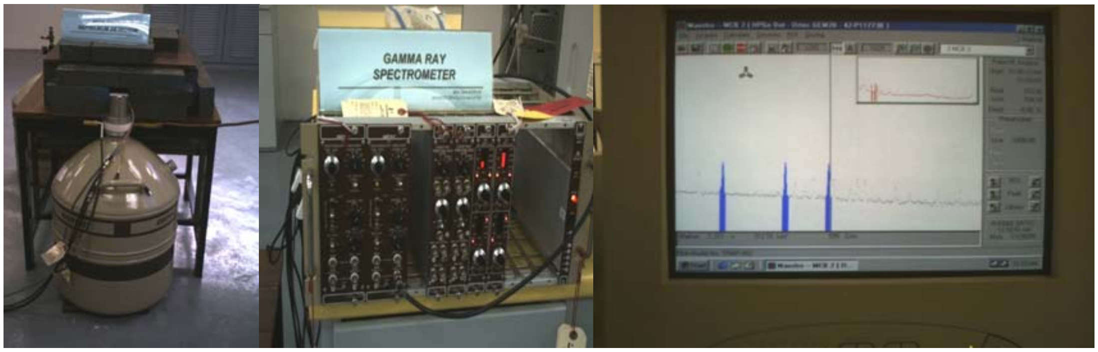

Figure B2.2a HPGe Detector with high voltage, amplifier and Multichannel Analyzer

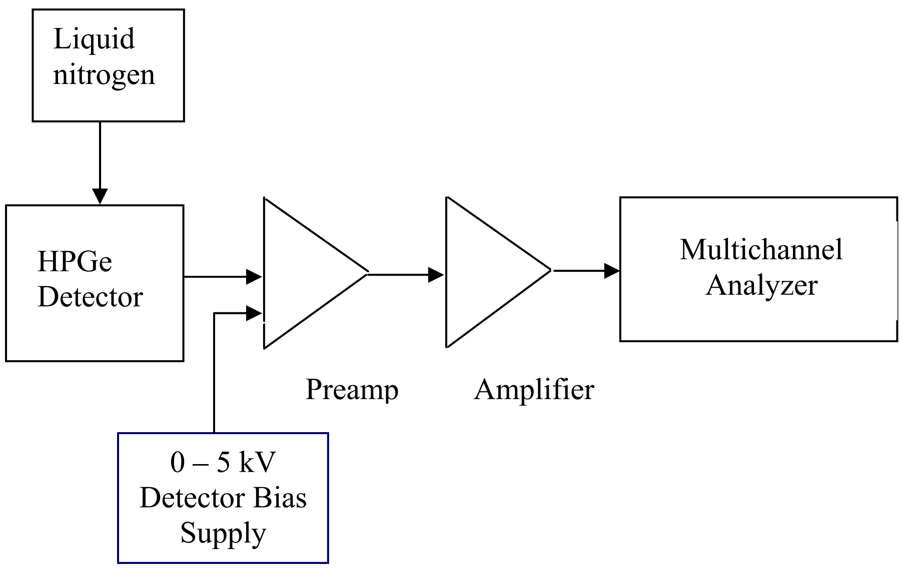

Figure B2.2b Block diagram of the HPGe detector spectrometer.

Figure B2.3 Gamma-ray spectrometer

B2.4 Measurement of Gamma-ray Radioactivity from Amang Samples

A total of 38 samples were collected from 4 amang upgrading plants and one factory processing ilmenite for rutile. The samples were prepared in the same way as the soil. The samples were packed into a polyethylene vial about 4 inches high and their weights were noted. The vial has an external diameter of 2.2 cm and a height of 5.5 cm. The vials were sealed and kept for 1 month before analysis. The vial was placed near the horizontal HPGe detector for analysis.

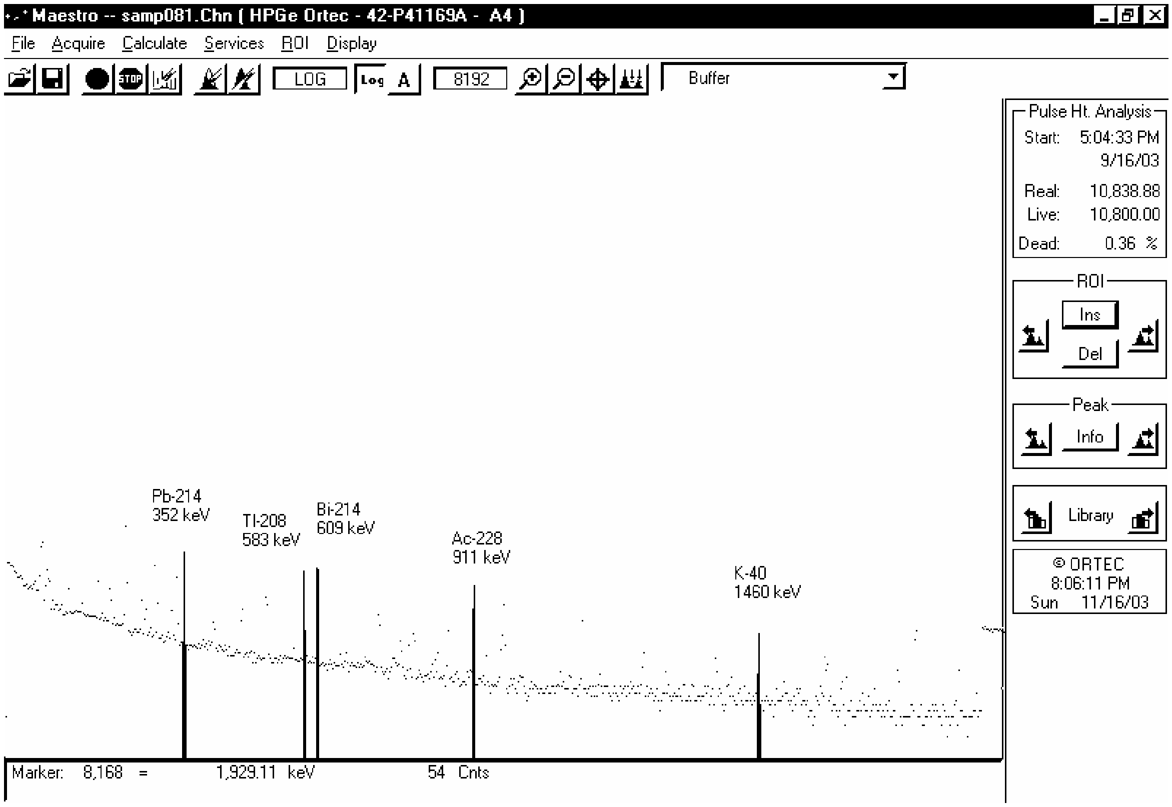

Figure B2.4 shows the typical spectrum for soil sample.
Energy peaks for the various radionuclides are indicated.

B2.5 Calculations of the Concentration of ^{232}Th, ^{238}U and ^{40}K

Calculations of count rates for each detected photopeak and radiological concentrations (activity per unit mass) of detected radionuclides depend on the establishment of secular equilibrium in the samples. Due to the smaller life-time of the daughter radionuclides in the decay series of ^{232}Th and ^{238}U, the ^{232}Th concentration was determined from the average concentration of ^{208}Tl at 583 keV and ^{228}Ac at 911 keV in the samples, and that of ^{238}U was determined from the average concentrations of the ^{214}Pb at 352 keV and ^{214}Bi at 609 keV decay products (Hamby and Tynybekov, 2000). Thus an accurate radiological concentration was made. The concentration of ^{40}K was based on 1460 keV peak.

The specific activity of uranium, thorium and potassium can be calculated by using the following formula:

$$C_{samp} = \frac{C_{std} \times W_{std} \times N_{samp}}{W_{samp} \times N_{std}} \quad \text{(B2.1)}$$

where

C_{samp} = the concentration of the sample collected (ppm)

C_{std} = the concentration of the standard sample (ppm)

W_{std} = the weight of the standard sample collected (g)

N_{samp} = the net counts of the photopeak area for the sample collected

W_{samp} = the weight of the sample collected (g)

N_{std} = the net counts of the photopeak area for the standard sample

The specific activity of potassium can be calculated by using the following formula:

$$A_{samp} = \frac{A_{std} \times W_{std} \times N_{samp}}{W_{samp} \times N_{std}} \quad \text{(B2.2)}$$

where

A_{samp} = the concentration of the sample collected (Bq kg^{-1})

A_{std} = the concentration of the standard sample (Bq kg^{-1})

W_{std} = the weight of the standard sample collected (kg)

N_{samp} = the net counts of the photopeak area for the sample collected

W_{samp} = the weight of the sample collected (kg)

N_{std} = the net counts of the photopeak area for the standard sample

B2.6 Neutron Activation Analysis Method

Neutron activation analysis (NAA) can be dated to the time of Hevesy and Levi 1936, who published their first report of the method. NAA is a sensitive multielement analytical method for accurate and precise determination of elemental concentrations in unknown materials. Sensitivities are sufficient to measure certain elements at the nanogram level and below, although the method is well suited for the determination of major and minor elemental components as well.

The method is based on the detection and measurement of characteristic gamma-rays emitted from radioactive isotopes produced in the sample upon irradiation with neutrons.

Typically, unknown samples together with standard materials of known elemental concentrations are irradiated with thermal neutrons in a reactor. After some appropriate decay period, high resolution gamma ray spectroscopy is performed to measure the intensity and energies of the gamma lines emitted. A comparison between specific activities induced in the standards and unknowns provided the basis for comparison of elemental abundances.

B2.6.1 Sample Preparation

A total of five samples were prepared and sent to MINT for irradiation using TRIGA MARK II reactor. Each sample about 0.2g was prepared in a polyethylene vial and labelled. Each sample has duplicates to assure quality of the analytical technique.

A uranium-thorium standard solution of 100 ppm U and 98 ppm Th was used. Approximately, 0.1000g (ml) U-Th solution was mixed with small amount of Silica (Si_2O-IAEA) in a vial (2.5 ml) and place in an oven for 4 hours at 60 °C until dry, then the vial was labelled and sealed.

B2.6.2 Sample Irradiation

Each batch of sample together with the reference standard sample and an empty vial (blank) were irradiated for 6 hours simultaneously at a neutron flux of 3 x 10^{12} n $cm^{-1}s^{-1}$ at MINT TRIGA MARK II reactor (Auu, 1998) operated at 750 kW power. After approximately 3 days radioactive decay (to allow interfering activities to decay away) of the samples, blank and reference standard sample are counted for 3600 s on the gamma detection system.

B2.6.3 Calculation of Element Concentration

The procedure generally used to calculate the concentration (i.e., ppm of element) in the unknown sample is to irradiate the unknown sample and a comparator standard containing a known amount of the element of interest together in the reactor. If the unknown sample and the comparator standard are both measured on the same detector, then one needs to correct the difference in decay between the two. One usually decay corrects the measured counts (or activity) for both samples back to the end of irradiation using the half-life of the measured isotope. The equation used to calculate the mass of an element in the unknown sample relative to the comparator standard is

$$\frac{A_{samp}}{A_{std}} = \frac{m_{samp}\,(e^{-\lambda T_{dsamp}})}{m_{std}\,(e^{-\lambda T_{dstd}})} \qquad \text{(B2.3)}$$

where A is the activity of the sample (*samp*) and standard (*std*), m is the mass of the element, λ is the decay constant for the isotope and T_d is the decay time. When performing short irradiation, the irradiation, decay and counting times are normally fixed the same for all samples and standards such that the time factors cancel. Thus the above equation simplifies into

$$C_{samp} = \frac{C_{std}\ W_{std}\ A_{samp}}{W_{samp}\ A_{std}} \qquad \text{(B2.4)}$$

where C is the concentration of the element and W is the weight of the sample and standard.

B2.6.4 Determination of the Concentration of ^{238}U and ^{232}Th.

The concentration of ^{238}U and ^{232}Th are based on the photopeaks of ^{239}Np at 277.9keV and ^{233}Pa at 311.9 keV obtained with NAA respectively. The concentrations were determined in parts-per million (ppm) units. The half-life and the energy lines are shown in Table B2.1. ^{233}Pa peak at 311.9 keV has an interference peak of ^{239}Np at 315.7 keV.

Table B2.1 Nuclides formed by neutron capture.

Element	Isotope	Production	Half-life (days)	Energy (keV)	Other energies (keV)
Uranium	^{239}Np	$^{238}U\ (n, \gamma, \beta^-)$	2.34	277.9	106.1, 181, 210, 228.2, 254, 285, 315.7, 334.3
Thorium	^{233}Pa	$^{232}Th\ (n, \gamma, \beta^-)$	27.4	311.9	75, 87, 104, 271, 299.9, 340.3, 375.2, 398.2, 415.6

Adams and Dam, (1969)

B2.7 Alpha and Beta Counting System

The counting system used was Tennelec Series 5 LB5500 Large Area Automatic Low Background Counting System with 2π geometry gas flow proportional counter, manufactured by Canberra Company, USA. (See Figure B2.5) This system is designed for counting alpha and beta particles from large samples, up to 12.7 cm (5 inch) in diameter. It incorporates anti-coincidence gating to further reduce the system background count rate due to external cosmic interactions with the sample detector. The guard detector and sample detector are similar in that they are both gas flow proportional detectors, but each has been optimized. The guard detector does not have a thin mylar window. It has a thick metal plate on both sides that maximizes the interaction of cosmic rays and gamma ray with the gas.

Figure B2.5 Low alpha beta counting system

When the pulse processing electronics sense a suitable event in the guard detector, the linear gate of the sample processing electronic is enabled. This disables the samples counter and timing electronics for a predefined time. This type of gating in the electronics is called anti-coincidence gating because the sample counters are turned off when an event is coincident in both the detectors. This suppression reduces spurious counts in the sample detector. The guard detector is most effective for rejection of gamma-ray, which could be counted as betas.

The passive lead shielding surrounding the detector effectively blocks all alpha and beta particles from reaching the detector unless it originates in the sample.

The counting gas used in the proportional counter is P-10 gas (10% CH_4, 90% Ar). The normal operational gas flow rate is set at 50 sccm (Standard Cubic Centimeters per Minute). The gas pressure should be set to 10 ± 1 PSI for normal operation. The maximum operating high voltage for Tennelec counting system is 1650 V (Canberra 2001a).

B2.7.1 Simultaneous Alpha and Beta Measurements

For simultaneous alpha and beta measurements, the Tennelec counting systems use pulse height discrimination, a measure of the pulse's voltage created from the interaction of radiation in the detector, to differentiate alpha from beta pulses. By examining the amount of charge produced in the detector and by recognizing the differences of how alpha and beta particles interact in the detector. Differences between the alpha versus beta particles are measured by examining the output pulse height of each. By setting not only a lower discriminator but a lower and upper discriminator for the beta and alpha windows, an energy range, ΔE, that corresponds to an output pulse voltage range, ΔV, for each type of radiation may be defined. When a pulse falls into the beta energy range, a counter range is incremented by one. Similarly, a counter for the alpha energy range is incremented when the particle's output pulse falls in this voltage range. By setting the discriminators precisely the interfering process are crosstalk and spillover were reduced to a minimum. In this way, the sample's alpha and beta activities may be determined simultaneously (Canberra Inc., 2001b). The efficiency of a gas proportional detector is inversely proportional to the mass of the samples.

B2.7.2 Sample Preparation

A total of 128 soil samples were prepared for the Alpha and Beta activity measurement.

Procedure:

1. Samples were dried in the oven (Figure B2.6) for 110 °C for two days.
2. Samples were grinded using swing grinding mill (Figure B2.7).
3. Samples were sieved to ensure that the sample is homogeneous (325 micron). Figure B2.8 shows the Retsh sieving machine.
4. About 2 g of the sample was put in the 2 inches diameter stainless planchet and the weight was recorded. Flatten the sample using a glass rod, diameter 1 cm.
5. A few drops of the diluted UHU (gum) with aceton with ratio 1:25 on the sample until wet.
6. Put the samples to dry under infrared lamp.
7. After dry, keep each planchet in a plastic disc.

Figure B2.6 Laboratory Oven

Figure B2.7 Swing Grinding Mill (Herzog)

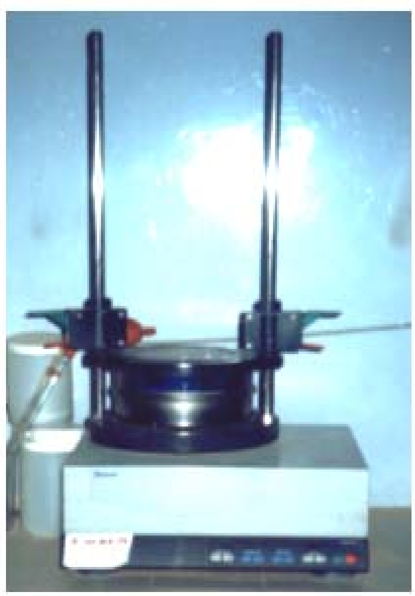

Figure B2.8 Sieve shaker (Retsh)

B2.7.3 Standard Samples Preparation for Alpha and Beta Analysis

Two standard samples were prepared. Uranium ore standard (pitchblende) 0.140 % U_3O_8 was prepared for alpha activity measurement and KCl standard was prepared for beta activity measurement.

Procedure:

1. Dry the standard samples U_3O_8 and KCl inside the oven, set temperature at 40 °C for 6 hours.
2. For each standard sample, a weight about 0.1, .05, 1, 2, 3, and 4 g were put in the planchets.
3. Flatten the samples with a glass rod of 1 cm diameter.
4. A few drops of diluted UHU (gum) with aceton with the ratio of 1:25 on the sample until wet.
5. Put the samples to dry under infrared lamp.
6. After dry, keep each planchet in a plastic disc

B2.7.4 Alpha Counting Efficiency

The efficiency of alpha counting system was obtained from the efficiency of the standard samples, Table B2.2.

Table B2.2 Weight, count rate and efficiency for Triuranium octaoxide (U_3O_8)

Weight (g) ± 0.0001	α net (cpm)	F_α =1737.82 dpm g^{-1} dpm = F_α x w(g)	Efficiency, ε = net cpm/dpm
0.1022	44.70	177.61	0.2517
0.5006	79.43	869.95	0.0913
1.0009	104.90	1739.38	0.0603
2.0004	112.76	3476.34	0.0324
3.0004	127.10	5214.16	0.0244
4.0002	127.86	6951.63	0.0184

B2.7.5 Beta Counting Efficiency

The efficiency of beta counting system was obtained from the efficiency of the standard samples, Table B2.3.

Table B2.3 Weight, count rate and efficiency for Potassium chloride (KCl)

Weight (g) ± 0.0001	β net (cpm)	F_β = 866.5 dpm g^{-1} dpm = F_β x w(g)	Efficiency, ε = net cpm/dpm
0.1016	46.87	88.04	0.5327
0.5003	217.72	433.50	0.5022
1.0041	374.27	870.05	0.4302
2.0002	554.80	1733.17	0.3201
3.0006	710.60	2600.02	0.2731
4.0005	745.23	3466.43	0.2150

B2.7.6 Calculation of Alpha and Beta Activity

The activity of the samples *A* in unit of Bq g^{-1} can be calculated from equation B2.5.

$$A = \frac{N}{60 \ x \ \varepsilon \ x \ w} \qquad \text{(B2.5)}$$

where

N = net counts per minute

ε = efficiency of the detector.

w = weight of the sample in gram

CHAPTER BIII

B3. RESULTS AND DISCUSSION

B3.1 Field Measurements in the Kinta District

A total of 1007 dose rate measurements were taken 1 m from the ground using a portable survey meter with unit in μR h^{-1} for natural background radiation. Conversion to dose rate in air (nGy h^{-1}) was made by multiplying the exposure rate in μR h^{-1} by 8.7. All the dose rate measurements were corrected by multiplying by a factor of 0.746 (1/1.3396). This factor was obtained from the correlation graph of total calculated dose rates versus measured dose rates (Figure B3.13).

The distribution of the gamma-ray dose data is presented by histogram in Figure B3.1a. The histogram of the gamma-ray dose data is skewed to the right. The most frequently recorded values were between 100 and 200 nGy h^{-1}. The frequency histogram becomes more symmetrical after the dose readings are transformed using a natural logarithmic transformation, as shown in Figure B3.1b.

The mean dose rate in the Kinta District is 222 ± 191 nGy h^{-1}. The mode is 143 nGy h^{-1} and median dose rate of 156 nGy h^{-1}. The highest dose rate measured was 1039 nGy h^{-1} in the rubber and oil palm estates in Kampung Sungai Durian, *mukim* Tg.Tualang where the soil type is granites and geological type is Jurassic- Triassic. The lowest dose rate of 39 nGy h^{-1} was located at *Ladang Lembah Kinta* near Chenderong town in *mukim* Tg. Tualang.

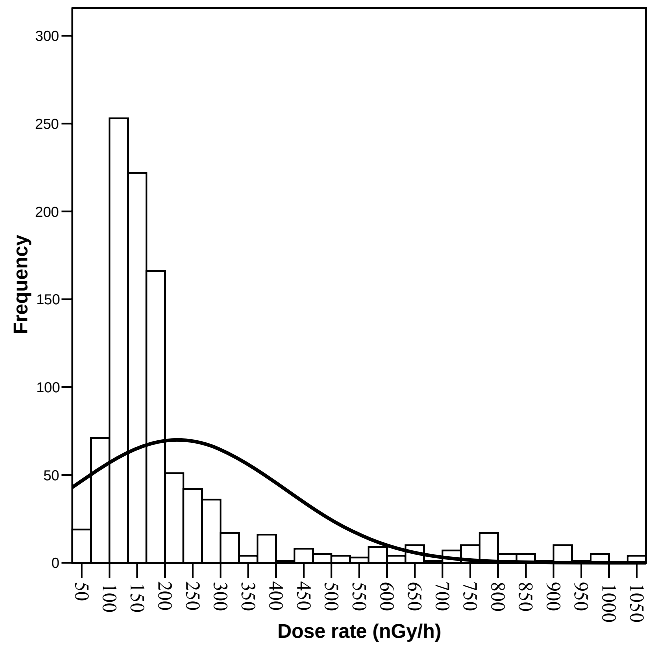

Figure B3.1a Frequency histogram of gamma-ray dose rate measurements.

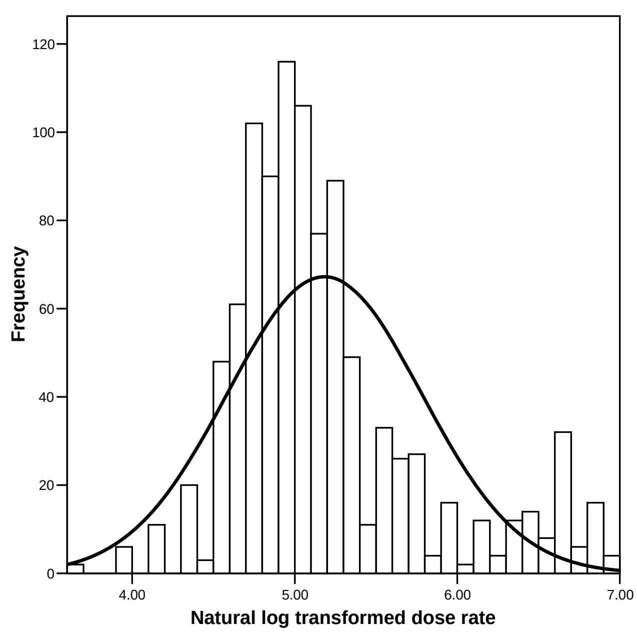

Figure B3.1b   Frequency histogram of the log-transformed data shown in Figure B3.1a

The normal probability plot (Figure B3.2) shows that the empirical data compare with the theoretical line, indicating the log-normality of dose measurements. The points were almost clustered around the straight reference line. The dose rates that deviate significantly from the straight line in the probability plot will be considered as outliers and extreme values as mentioned in the box plots in Figure B3.3.

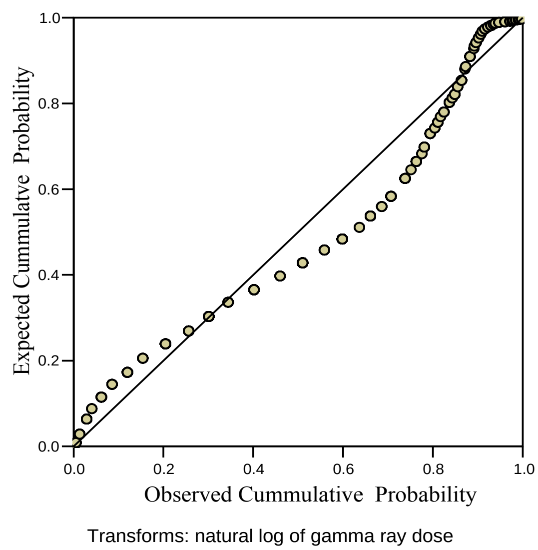

Figure B3.2 Proportion-Proportion plot of the natural log-transformed data

B3.2 Soil Types and Gamma-Ray Dose Rate Distribution

The soil types found in the Kinta District are shown in Table B3.1. They are five different soil types classified by FAO units (Paramanathan, 1978) namely *Dystric Histosols, Xanthic Ferrasols-Dystric Gleysols, Ferric Acrisols-Ferric Acrisols-Orthic Ferrasol, Haplic Acrisols*, Steep land and Urban land. For each soil type, the parent materials are different. Soil map is included in Appendix A.

Table B3.1 Soil types and parent material

Soil type No.	Soil type (FAO/ UNESCO)	Map symbol (Local name)	Parent material	Number of readings
10	Dystric Histosols	PET (Peat)	Organic deposit	5
18	Xanthic Ferrasols-Dystric Gleysols	HYD-HMU (Holyrood-Harimau)	Subrecent and older alluvium	233
31	Ferric Acrisols-Ferric Acrisols-Orthic Ferrasol	SDG-MUN (Serang-Munchung)	Shale, sandstones and schists	47
48	Haplic Acrisols	RGM-BTG (Rengam-Bukit-Temiang)	Granites	249
49	Steep land	STP (steep land)	Miscellaneous land units	55
50	Urban land	DLD (disturbed land)	Miscellaneous land units	418

From Table B3.2, the highest mean dose rate of 395 ± 297 nGy h^{-1} was found in soil type 48, *Haplic Acrisols* which is mainly granites. This soil type has higher content of uranium and thorium compared to other soil types. One of the interesting points from this table is the wide fluctuation from this type of rock. The dose rate range from 39 to 1039 nGy h^{-1}. This may be due to the underlying rock. Soil type 49, steep land exhibits a mean dose rate of 267 ± 95 nGy h^{-1} and follow by soil type 10, *Dystric Histosols* which is organic deposit exhibits a mean dose of 265 ± 136 nGy h^{-1} which is considered high. This could be due to the underlying geological features.

Table B3.2 Statistical summary and 95% Confidence limit for the mean gamma-ray dose rate for soil types (SPSS Output)

Soil type No.	Dose rate (nGy h^{-1})				95 % confidence intervals for mean
	Mean	Std. deviation	Range	Std. error	
10	265	136	117 – 455	61	97 – 433
18	164	99	52 – 779	7	151 – 177
31	134	50	65 – 286	7	119 – 149
48	395	297	39 – 1039	19	358 – 432
49	267	95	78 – 455	13	242 – 293
50	155	57	52 – 487	3	150 – 161
Total	222	191	39 – 1039	6	210 – 234

For a typical radiation field, the layer of soil that makes the predominant contribution to external gamma dose above the ground is about 30 cm thick (UNSCEAR, 1977). Soil type 18, *Xanthic Ferrasols-Dystric Gleysols* the parent materials are sub recent and older alluvium shows the mean dose rate of 164 ± 99 nGy h^{-1}. Soil type 50, which is urban land, shows 155 ± 57 nGy h^{-1}. Soil type 31, *Ferric Acrisols-Ferric Acrisols-Orthic Ferrasol* make up of shale, sandstones and schists shows the lowest mean dose rate of 134 ± 50 nGy h^{-1}.

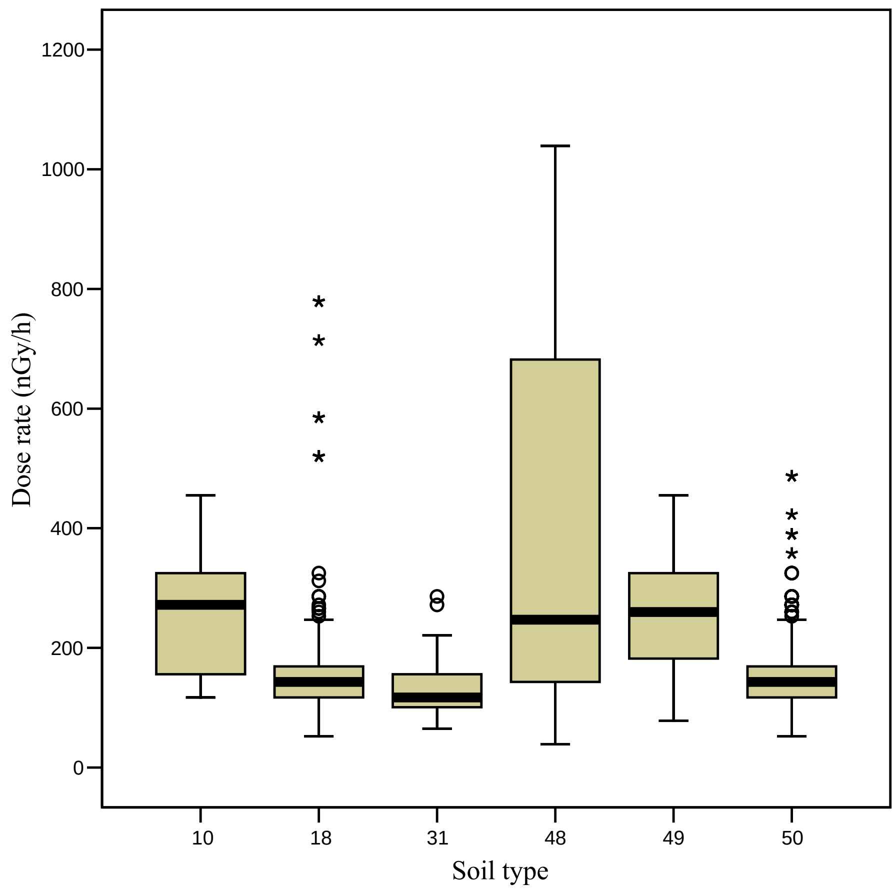

Figure B3.3 Box plot showing the distribution and the variability of gamma-ray dose rate for each soil type (* represents extreme values, and o represents outliers).

The box plot in Figure B3.3 shows the variability and the distribution of the data for each type of soil type. A box plot is a graph of a data set that consists of a line extending from the minimum value to the maximum value, and a box with lines drawn at the first quartile, a line in the box at the median value, and the third quartile. An outlier 'o' is a value that is located very far away from almost all of the other values. Relative to the other data, an outlier is an extreme '*' value (Triola, 2005).

The distributions of the dose rate are skewed for soil types 10, 31 and 48. Soil types 18, 49 and 50 which are almost symmetric. Soil types 18 and 50 have outliers and extreme values. Soil type 31 has outliers. These outliers affect the values of the mean and standard deviations. Soil types 10 and 49 have no outliers.

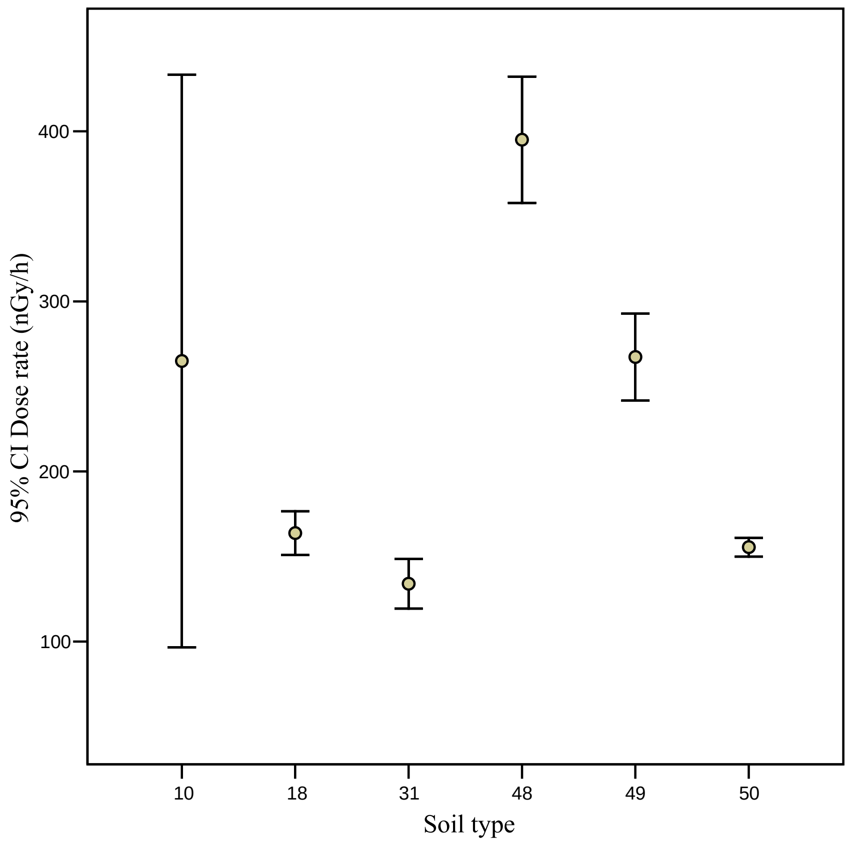

Figure B3.4 Mean dose rate and 95% confidence interval for the mean for types (SPSS output)

Figure B3.4 shows the mean dose rate and 95% confidence interval for the mean for various soil types. The mid-points of the vertical lines are the mean values and their lengths represent the 95% confidence limit for the mean. Soil type 48 shows the highest mean dose rate of 395 ± 297 nGy h^{-1} with 95% confidence limit dose rate range from 358 – 432 nGy h^{-1}. Soil type 49, steep land exhibits lower dose rate readings than granitic range from 242 – 293 nGy h^{-1}. Soil type 10 covers a small area, 5 readings were taken which shows a wide range from 97 to 433 nGy h^{-1}. The data is too small where number of readings is less than 30. It has a mean dose rate of 265 ± 136 nGy h^{-1}. Except for soil type 10, each soil type shows a different range of readings. The 95% confidence limit for the mean dose rate range for soil type 18 (151 – 177 nGy h^{-1}) and soil type 50 (150 – 161 nGy h^{-1}). These two soil types can be grouped together (Wahab 1988). The mean dose rate for soil types 18 and 50 are 164 ± 99 and 155 ± 57 nGy h^{-1} respectively. Soil type 31 shows the lowest dose rate range from 119 – 149 nGy h^{-1} mainly made up of shale, sandstones and schists. From Figure B3.4, the 95% confidence intervals for mean gamma-ray dose clearly shows that the dose rate for soil type 48 > soil type 49 > soil types18 and 50 > soil type 31. It shows that the mean dose rates are associated with the soil types.

B3.3 Geological Type and Gamma-Ray Dose Rate Distribution

In the Kinta District there are 7 different geological types are shown in Table B3.3. Geological types G1 and G2 are Carboniferous. Geological types G3 and G4 are Devonian. The geological types are differentiated by difference types of rocks. For geological type G1, the rocks are arenaceous and argillaceous, the dose rate readings range are wider than geological type G2, calcareous rock. From Table B3.4, the mean dose rate for geological types G1 and G2 are 133 ± 89 and 134 ± 41 nGy h^{-1} respectively. For geological types G3 and G4, they have the same mean dose rate of 153 ± 38 nGy h^{-1}. The rock types are argillaceous and calcareous respectively.

Table B3.3 Geological features with rock types and number of readings taken

Code	Geological and rock types		Number of readings
G1	CAAR	Carboniferous – Predominantly arenaceous and argillaceous	173
G2	CCR	Carboniferous – Calcareous rocks	131
G3	DAR	Devonian – Argillaceous rocks	22
G4	DCR	Devonian – Calcareous rocks	384
G5	JTG	Jurassic-Triassic – Granitods	271
G6	PCR	Permian – Calcareous rocks	7
G7	SAR	Silurian – Argillaceous rocks	19

Geological type G5 is Jurassic – Triassic, the rock type is granitiods. Geological type G5 exhibits the highest mean dose rate of 432 ± 259 nGy h^{-1}. The dose rate range from 91 to 1039 nGy h^{-1}. Geological type G6 is Permian. Permian limestone are present in the north of Tanjung Rambutan and west of Kampar with the lowest mean dose rate of 104 ± 17 nGy h^{-1}. Geological type G7 is Silurian, with the second highest mean dose of 176 ± 43 nGy h^{-1}. For geological types G3, G6 and G7, the areas covered are small and the number of readings taken were consider small (n < 30) are 22, 7 and 19 respectively. The results indicated that different geological types exhibit different values of the mean dose rates with Jurassic-Triassic > Silurian > Devonian > Carboniferous > Permian.

Table B3.4 Statistical summary and 95% confidence limit for the mean gamma-ray dose rate for geological types.

Geology	Dose rate (nGy h^{-1})				95 % confidence intervals for mean
	Mean	Std. deviation	Range	Std. error	
G1	133	89	39 – 779	7	120 – 146
G2	134	41	65 – 390	4	127 – 142
G3	153	37	65 – 266	8	137 – 169
G4	153	39	52 – 325	2	149 – 157
G5	432	259	91 – 1039	16	401 – 463
G6	104	17	78 – 130	6	88 – 120
G7	176	43	78 – 253	10	155 – 199
Total	222	191	39 – 1039	6	210 - 234

The mean gamma-ray dose measured under individual geological units for all locations varied from 104 nGy h^{-1} measured under calcareous rock to 432 nGy h^{-1} measured under granite, and this granite has relatively high content of radioactive materials. Granite has relatively higher content of radioactive materials (Omar and Hassan, 1990; Omar et al., 1991; Wong 1985).

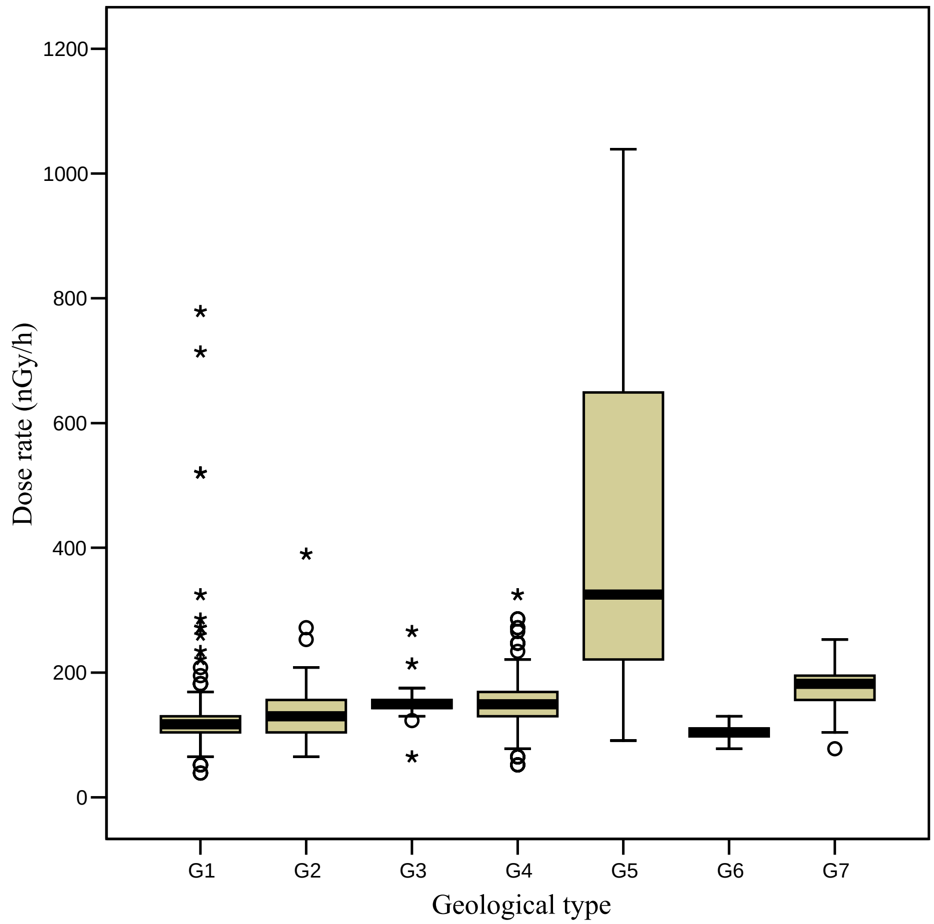

Figure B3.5 Box plot showing the distribution and the variability of gamma-ray dose rate for each geological type (* represents extreme values, and o represents outliers).

The box plot in Figure B3.5 shows the variability and distribution of the data for each geological type. Gamma-ray dose rate distribution are almost symmetrical for geological types G2 and G4, but are skewed for G5 and G7. For geological types G1, G2, G3 and G4 extreme values were recorded.

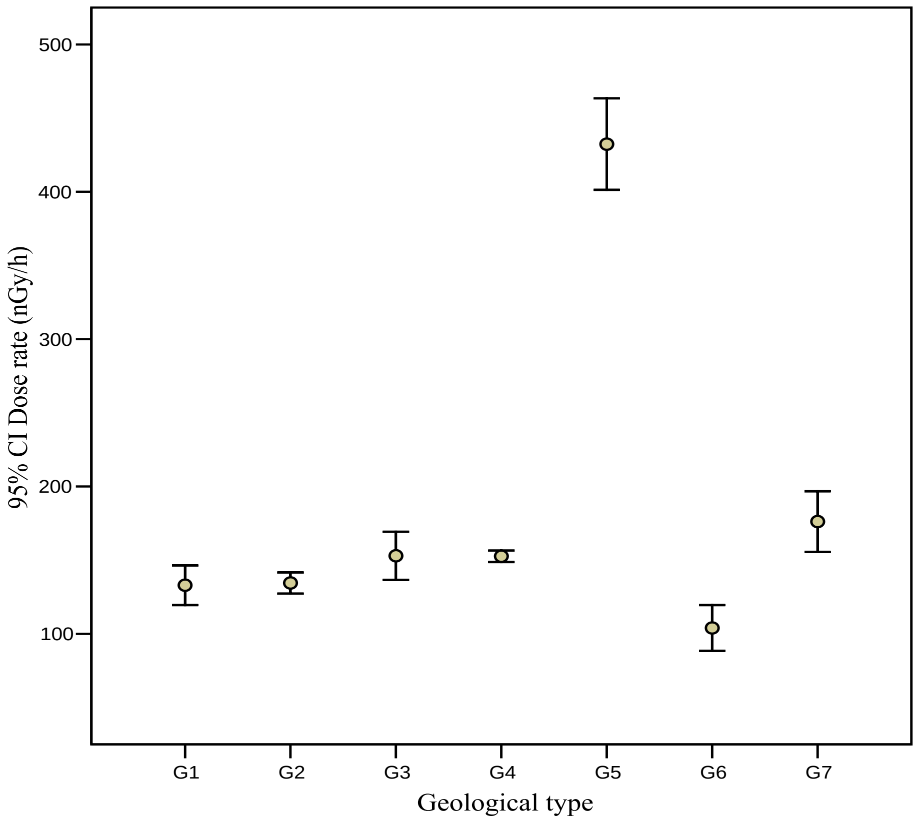

Figure 3.6 Mean dose rate and 95% confidence interval for mean.

Figure B3.6 shows the geological types G1, G2, G3, G4, G5, G6 and G7 display the range of readings within the 95% confidence limit.

B3.4 Gamma-Ray Dose Rate Distribution for Soil and Geological Types

Table B3.5 shows the summary for the mean gamma-ray dose rate for each soil type and geological type. Different soil types and geological types will yield different values of the mean dose rate. For Soil type 18, the highest mean dose rate of 416 ± 211 nGy h^{-1} was geological type G5 and the lowest was geological type G2 with 108 nGy h^{-1}. The highest mean dose rate of 543 ± 276 nGy h^{-1} was soil type 48 and geological type G5. Soil type 31 and geological type G1 show the lowest dose rate of 103 ± 24 nGy h^{-1}. For the soil types and the geological types, all the mean dose rates exhibit above 100 nGy h^{-1}.

Table B3.5 Statistical summary for the mean gamma-ray dose rate for soil types and geological types (SPSS Output)

Soil type No.	Geological type	Dose rate (nGy h^{-1})				95 % confidence intervals for mean
		Mean	Std deviation	Range	Std. error	
18	G1	155	135	52 – 779	21	112 – 197
18	G2	108	16	78 – 143	3	101 – 114
18	G3	160	35	123 – 266	8	142 – 178
18	G4	153	35	65 – 272	3	147 – 160
18	G5	416	211	143 – 779	61	282 – 550
31	G1	103	24	65 – 182	5	92 – 113
31	G4	151	44	104 – 286	10	130 – 172
48	G1	120	92	39 – 714	13	94 – 146
48	G2	159	25	130 – 195	8	140 – 178
48	G4	162	40	65 – 247	8	147 – 178
48	G5	543	276	130 – 1039	22	500 – 587
49	G5	267	95	78 – 455	18	242 – 293
50	G1	135	43	65 – 286	6	124 – 147
50	G2	137	42	65 – 390	4	129 – 146
50	G4	151	41	52 – 325	3	145 – 156
50	G5	237	84	91 – 487	12	213 – 261

B3.5 Mukim and Gamma-Ray Dose Rate Distribution

From Table B3.6 shows the mean gamma-ray dose for each *mukim* (parish) in the Kinta District. The highest mean dose rate of 378 ± 301 nGy h^{-1} which is 6 times higher than the world average of 59 nGy h^{-1} was in *mukim* Tg. Tualang, M5. The dose rate ranges from 39 nGy h^{-1} to 1039 nGy h^{-1}. The lowest mean dose rate of 133 ± 46 nGy h^{-1} was in *mukim* Teja, M3 which is 2 times over the world average. The dose rate ranges from 52 nGy h^{-1} to 312 nGy h^{-1}. The mean gamma-ray dose rate for the rest of the *mukims* range from 133 to 184 nGy h^{-1}, which are lower than mean value of 222 ± 191 nGy h^{-1}.

The mountainous regions are in *mukim* M1, Hulu Kinta. It is situated in the north-eastern part of the District, *mukim* M2, Sg. Raja, *mukim* M3, Teja and *mukim* M4, Kampar that are on the eastern part of the Kinta District. Only a few readings here were taken that is along the highway to Cameron Highland. Most of the area is Bukit Kinta Forest Reserve. There are some rubber and oil palm plantations. The population here is very small. The measurements taken here would not be representative of the dose received by the population as a whole.

Table B3.6 Statistical summary and 95% confidence limit for the mean gamma-ray dose rate for each *mukim* (SPSS Output)

	Dose rate (nGy h^{-1})				95 % confidence intervals for mean
Label – *Mukim*	Mean	Std. deviation	Range	Std. error	
M1 – Hulu Kinta	184	71	65 – 487	4	176 – 192
M2 – Sg. Raja	179	59	65 – 325	7	165 – 194
M3 – Teja	133	46	52 – 312	5	124 – 143
M4 – Kampar	152	51	65 – 390	4	1143 – 161
M5 – Tg. Tualang	378	301	39 – 1039	18	342 – 413
M6 – Belanja	165	85	52 – 455	11	143 – 186
M7 – Sg. Terap	144	48	65 – 390	5	134 – 153
Total	222	191	39 - 1039	6	210 – 234

Figure B3.7 shows the distribution of dose measurement for each *mukim* (Appendix C). The distributions of the dose rate are skewed upwards for *mukim* M1, M2, M4, M5, and M6. *Mukim* M3 and M7 which are almost symmetric. *Mukim* M1, M4 and M7 have outliers and extreme values. *Mukim* M3 and M6 have outliers. These outliers affect the values of the mean and standard deviations. Figure B3.8 shows the mean dose rate for each *mukim* and 95% confidence interval for mean.

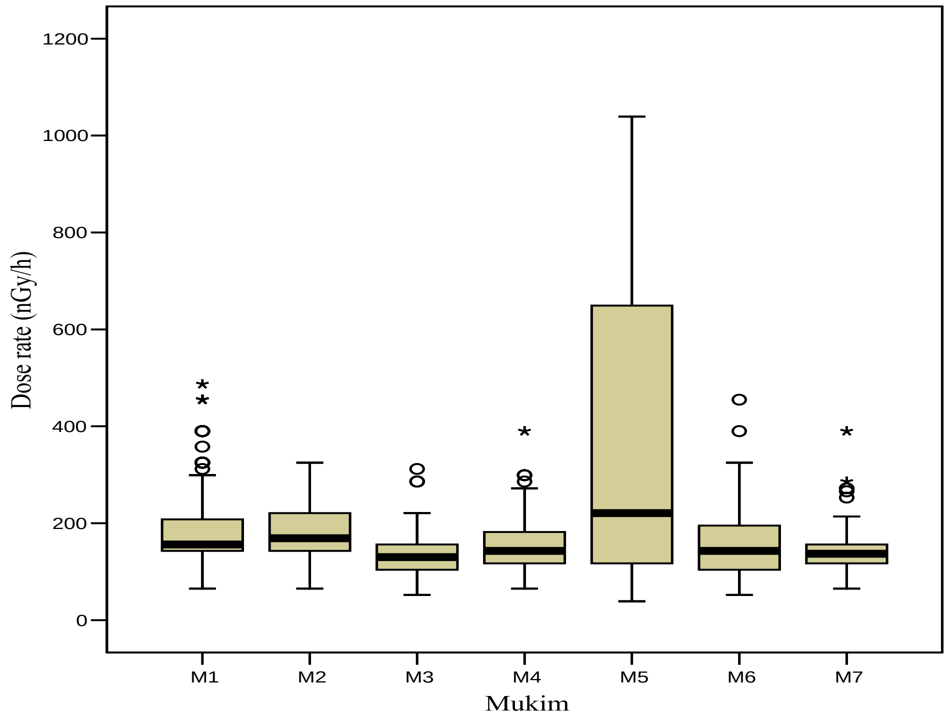

Figure B3.7 Box plot showing the distribution and the variability of gamma-ray dose rate for each *mukim* (* represents extreme values, and o represents outliers).

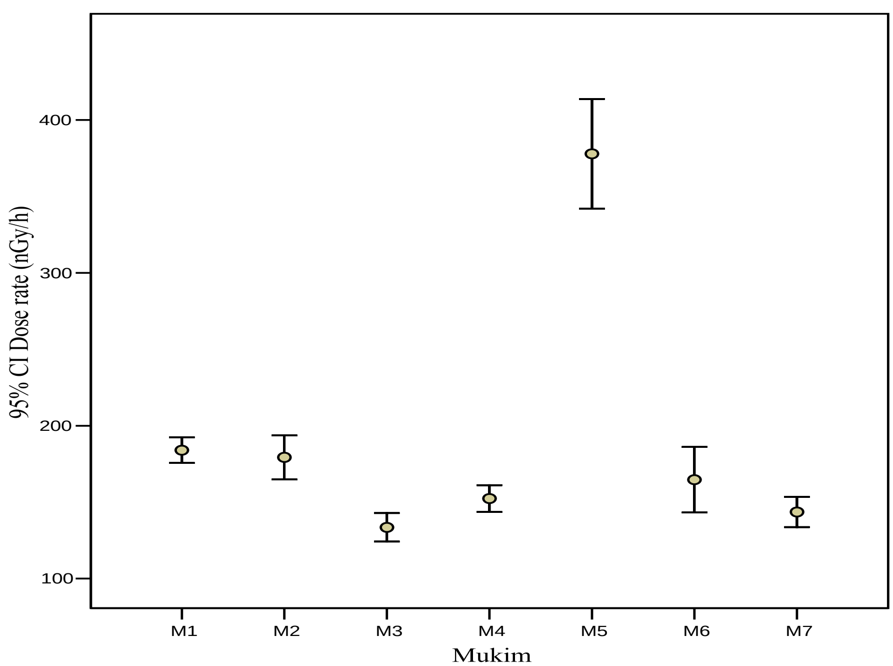

Figure B3.8 Mean dose rate for each *mukim* and 95% confidence interval for mean.

Table B3.7 Statistics for gamma dose rate (nGy h^{-1}) distribution for each *mukim* in the Kinta District

Mukim → Statistics	M1 Hulu Kinta	M2 Sungai Raja	M3 Teja	M4 Kampar	M5 Tg. Tualang	M6 Belanja	M7 Sungai Terap
No. of readings = 1007	281	68	97	134	273	63	91
Mean dose (nGy h^{-1})	184	179	**133**	152	**378**	165	144
Standard deviation (nGy h^{-1})	71	59	46	51	301	85	48
Mean dose (mSv y^{-1})	1.13	1.10	**0.82**	**0.93**	**2.32**	1.01	**0.88**
Range (nGy h^{-1})	65 – 487	65 - 325	52 – 312	65 - 390	36-1039	52 – 455	65 - 390
* Total population = 703493	533493	19094	23998	57389	17830	12210	39434

* Data from Department of Statistics, Malaysia, 2003. (Population census in 2000).

Table B3.7 shows the population and area for the *mukims*. In *mukim* Tg. Tualang, M5 shows the highest mean dose rate of 378 ± 301 nGy h^{-1}. The rest of the *mukims* have the mean dose rate less than half of *mukim* M5. In *mukim* M3 exhibits the lowest mean dose rate of 133 ± 46 nGy h^{-1} with a population of 23,998. *Mukims* M3, M4 and M7 have the mean annual gamma dose lower than 1 mSv. The mean population weighted gamma annual dose for Kinta District is 1.12 mSv.

B3.6 Measurement of Natural Background Radiation in the Kinta District

A total of 1007 measurements have been surveyed in the Kinta District (Figure B3.9).

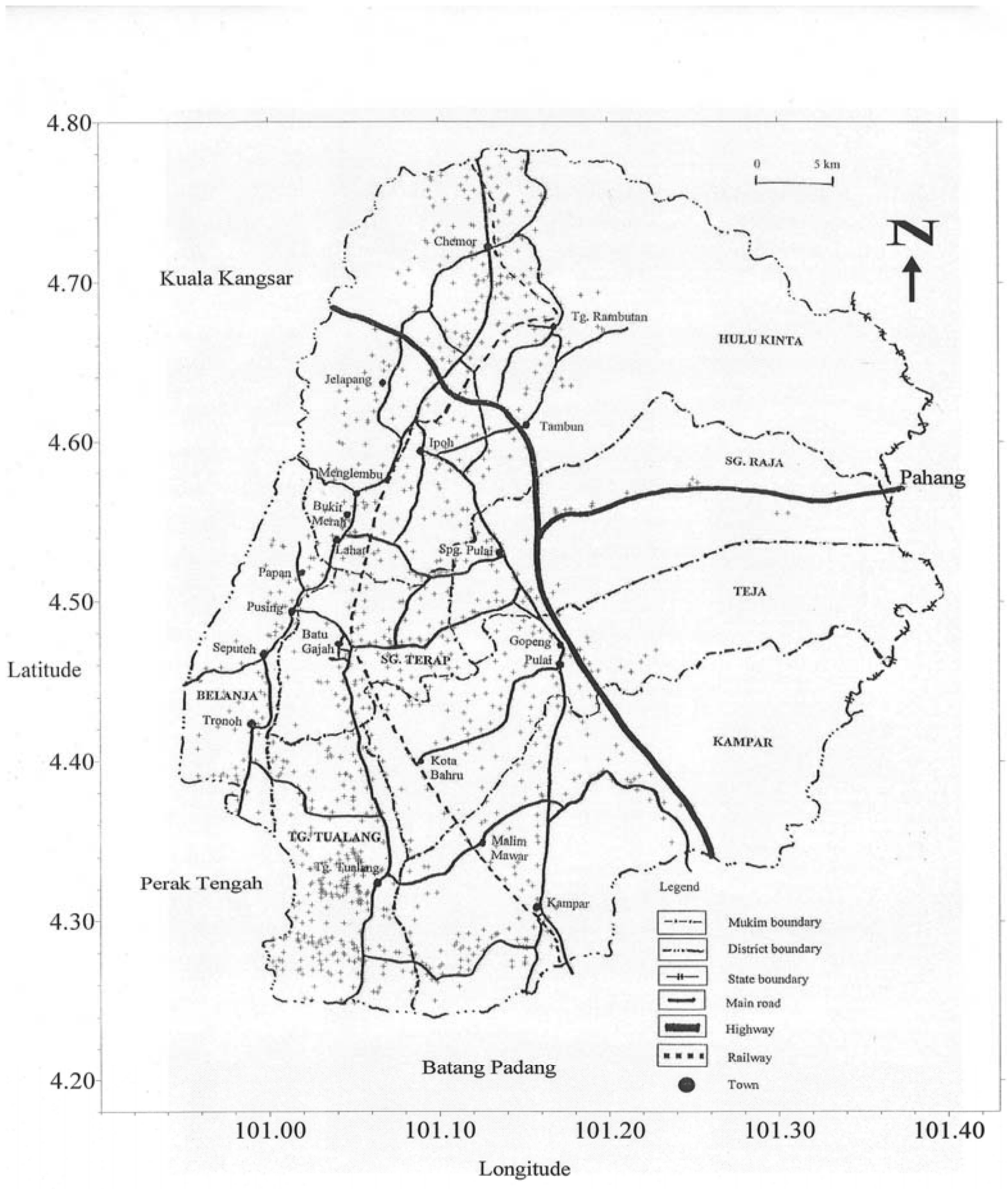

Figure B3.9 shows the locations of dose rate measurements

The dose rates range is shown in Figure B3.10 and the frequency of the dose rate in Table B3.8. It ranges from 39 nGy h^{-1} to 1039 nGy h^{-1} and has a mean dose rate of 222 ± 191 nGy h^{-1}. The highest reading of 1039 nGy h^{-1} was recorded in mukim Tanjung Tualang. Using the conversion factor of 0.7 Sv Gy^{-1} (UNSCEAR,1988) the mean natural background dose was 1.36 mSv y^{-1}. World average background is 0.45 mSv y^{-1}. It has been reported in Pontian and Kota Tinggi, Malaysia where the average dose rates were 67 nGy h^{-1} (0.42 mSv y^{-1}) and 180 nGy h^{-1} (1.12 mSv y^{-1}) respectively (Ramli, 1997; Ramli et al., 2003). The Johor State average dose rate is 165 nGy h^{-1} (Ramli et al, 2001). Note: These readings were not normalized. They used similar survey meters.

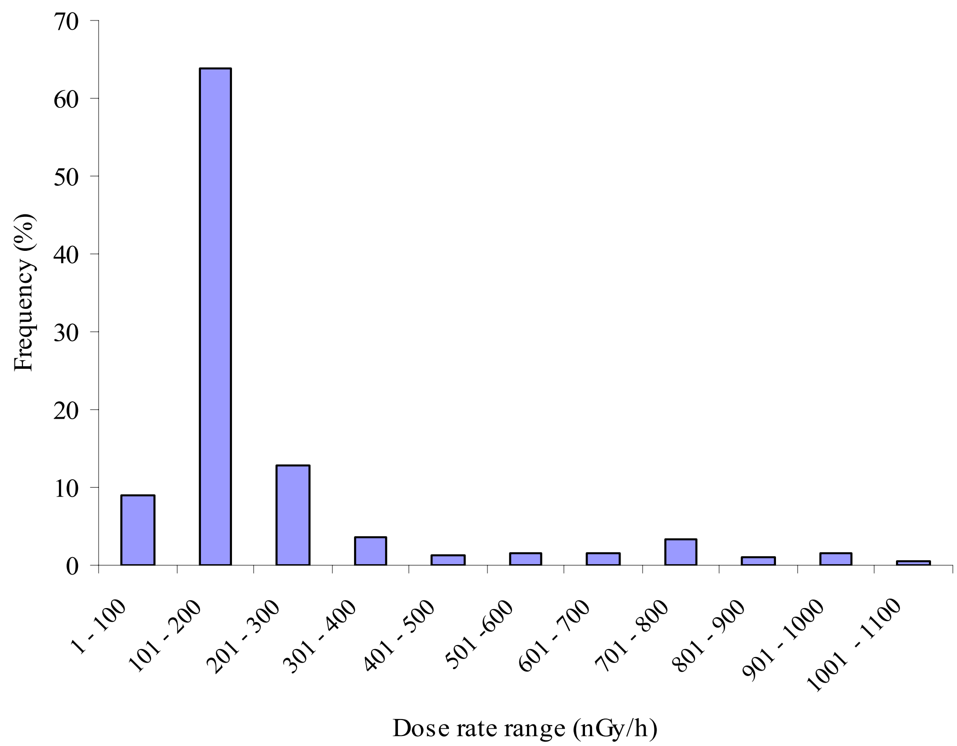

Figure B3.10 shows the bar chart where the highest frequency of 64 % is in the range of 101 – 200 nGy h^{-1}

Table B3.8 Frequency of the dose rate in the Kinta District

Range (nGy h^{-1})	Frequency	%
1 – 100	90	8.94
101 – 200	642	63.75
201 – 300	129	12.81
301 – 400	37	3.67
401 – 500	14	1.39
501 – 600	16	1.59
601 – 700	15	1.49
701 – 800	33	3.28
801 – 900	11	1.09
901 – 1000	16	1.59
1001 – 1100	4	0.40

B3.7 High Natural Background Radiation Areas in Tg. Tualang

High natural background radiation (HNBR) areas in the Kinta District were located in mukim Tg. Tualang, (M5). Two small areas of hot spots were located on higher ground with a dose rate of 1039 nGy h^{-1}. One is located at *Kemajuan Tanah Sg. Durian, Tg. Tualang* and the other location at *Hutan Rizab Tg. Tualang*. The hot spot areas are separated by a valley. These areas are cultivated with oil palms and rubber. About half a kilometer away from the hot spot, there were some residential houses in Kampung Sungai Durian. This area the dose rates range from 143 – 714 nGy h^{-1}. Fertilizers were used in these estates by the workers but the activity of potassium is low. The reason could be due to solubility of potassium and absorption by the plants. A total of 12 soil samples were taken from the hot spot areas to analyze the activity of natural radionuclides. The sample numbers are 88, 89, 101-108, 111 and 117.

The bar chart of Figure B3.11 shows the distribution of natural radinuclides. It shows that the dose rates are high with increasing activity of thorium except for sample number 117. The reasons could be due to outcrops or the ground was not level. The dose rates are high are due to high activity concentration of uranium and thorium from granite rocks. The level of ^{238}U, ^{232}Th and ^{40}K activities in the soil samples vary between 43 - 307 Bq kg $^{-1}$, 63 – 1377 Bq kg $^{-1}$ and 29 – 166 Bq kg $^{-1}$ respectively.

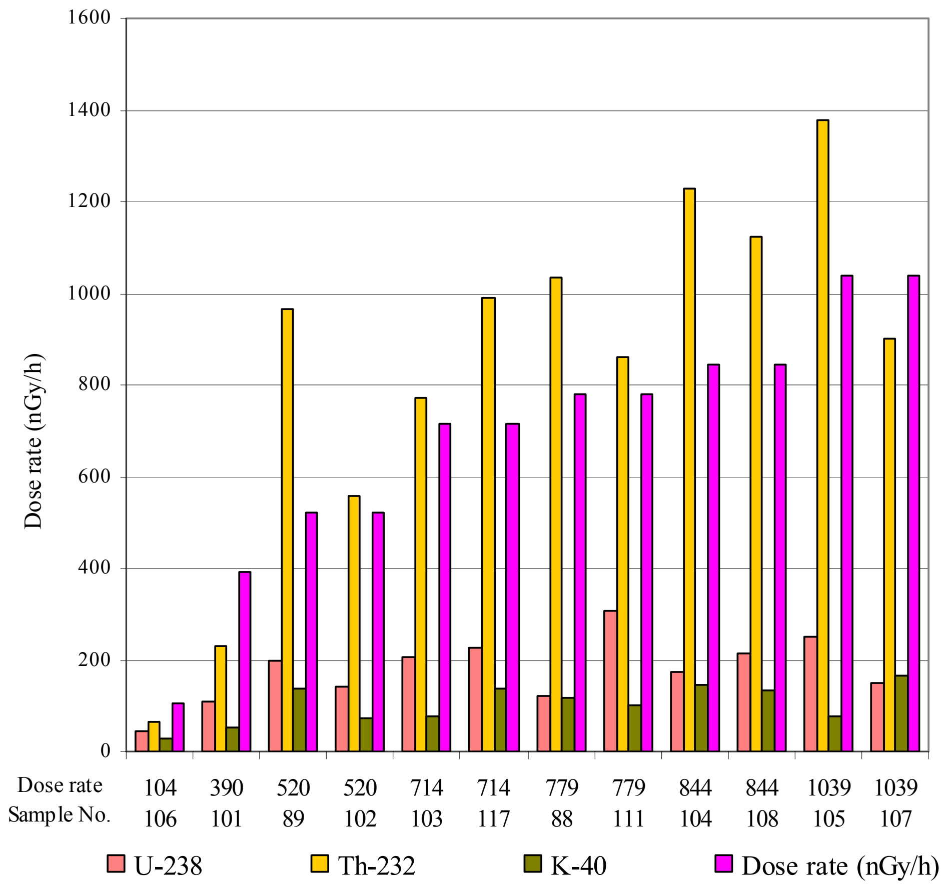

Figure B3.11 The activity of natural radionuclides and dose rate at various sampling points

The bar chart of Figure B3.12 shows the distribution of gross alpha and gross beta activities from the soil samples and dose rate measured from the sampling sites. These alpha and beta activities are the contributions from the uranium and thorium decay series. The activity of gross alpha is higher than gross beta in all samples except for sample number 117.

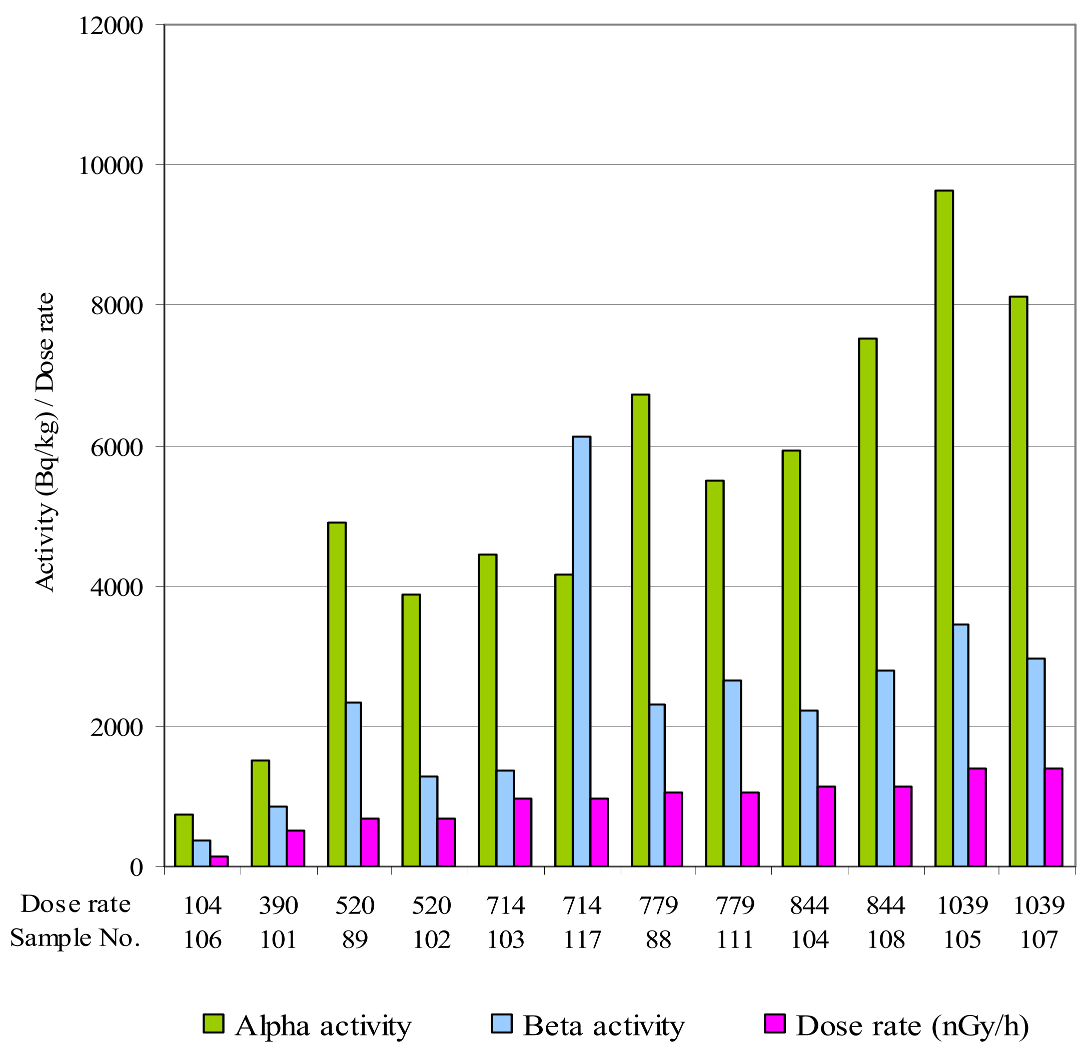

Figure B3.12 The activity of gross alpha, beta and dose rate at various sampling points

B3.8 Derivation of the Absorbed Dose Rates

If natural radioactive nuclides are uniformly distributed in the ground, dose rate at 1 m above the ground surface are calculated by the following formula (Kohshi et.al., 2001):

$$\text{Dose rate (nGy h}^{-1}\text{)} = \text{Radiological concentration (Bq kg}^{-1}\text{)} \times \text{Conversion factor (nGy h}^{-1}\text{ per Bq kg}^{-1}\text{)} \qquad \text{(B3.1)}$$

In order to calculate the exposure rates 1 m above the ground level for distributed sources of gamma emitters in soil, conversion factors (absorbed dose rate in air per unit activity per unit soil mass, nGy h^{-1} per Bq kg^{-1}) were extensively calculated during the last forty years by many researches. For this project, the considered dose rate calculation is determined by (UNSCEAR, 2000) and uses extensively for all similar calculation in the Saito et al. 1990 and UNSCEAR 1993 report. It should be pointed out here that, using this calculation, the dose rate for the ^{238}U and ^{232}Th series is the average of the respective radiological concentrations multiplied by the conversion factors corresponding to each series. The total dose rate for each of the measured samples is the sum of the dose rates contributed by both series of ^{238}U and ^{232}Th, and for ^{40}K. ^{235}U decay series is neglected as they contribute very little to the total dose from environmental background (Kocher and Sjoreen, 1985; Jacob et al. 1986; Leung et al. 1990).

The validity of the dose rate measurements was confirmed by calculating the dose rate above each soil sample collected (Saito and Jacob, 1995).

The activity concentrations of ^{238}U and ^{232}Th series and ^{40}K measured in Bq kg^{-1} were used to determine the calculated dose rate D_c in nGy h^{-1} at a height of 1 m above the ground (UNSCEAR, 2000).

$$D_c = 0.462\,A[^{238}U] + 0.604\,A[^{232}Th] + 0.0417\,A[^{40}K] \qquad \text{(B3.2)}$$

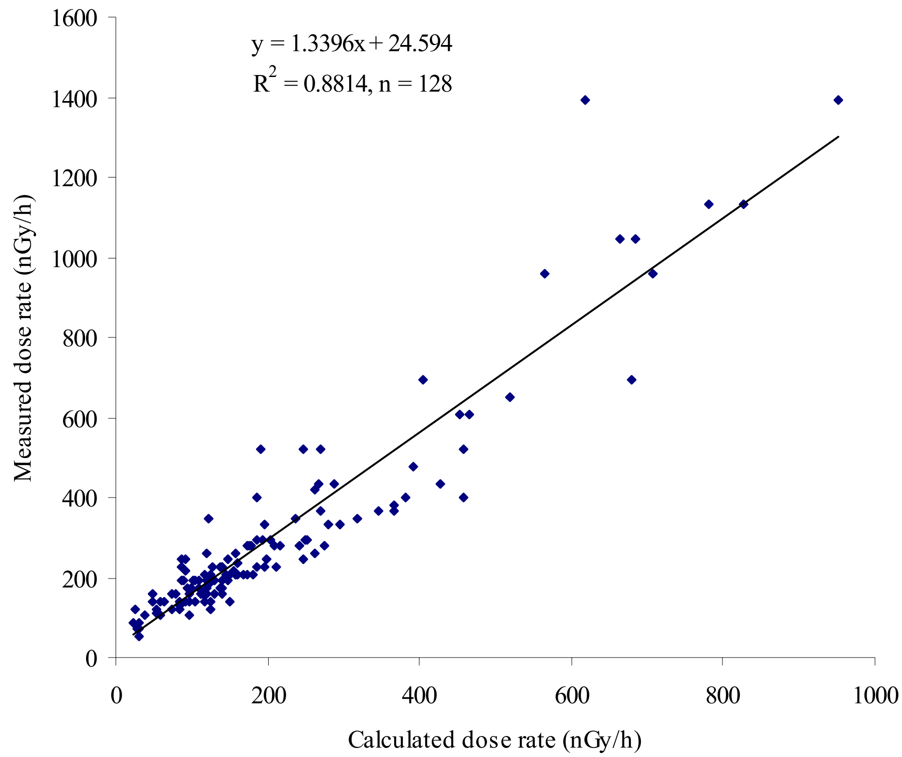

Figure B3.13 Total calculated dose rate versus measured dose rate (nGy h^{-1})

From Figure B3.13 above, the equation of the fitted straight line is

$$D_m = 1.3396D_c + 24.594 \qquad \text{(B3.3)}$$

indicating that the measured dose rate, D_m for this project could be overestimated by 34%. The intercept at 25 nGy h^{-1} could be interpreted as the contribution of high energy cosmic rays to the survey meter, variations in the energy response of the detector is not flat, so the response will vary if the radionuclide make up is very different from the calibration. It is therefore correction for the measured dose rates were done. The correlation coefficient R = 0.94 (R^2 = 0.8814) shows that there is good positive correlation between calculated dose rates and measured dose rates.

For complete correction of the high energy cosmic rays, measurement of gamma-ray dose rate in the absence of terrestrial gamma-rays is required. The surface of a deep lake is one possible place to measure the dose rate from self irradiation and cosmic rays (Takashi, 2002).

The total absorbed dose rates calculated from the concentrations of the nuclides of the ^{238}U and ^{232}Th series and ^{40}K, range from 23 to 950 nGy h^{-1} compared with the measured dose rates ranged from 39 to 1039 nGy h^{-1}. In situ measurement of dose rate is more sensitive and more representative of the area under consideration than are laboratory analyses of core samples taken from the soil in the area. A survey meter placed about 1 m above the earth detects gamma radiation from a larger area. This represents a large volume of soil compared to the size of a sample usually taken for laboratory analysis. In order to relate the counts recorded in the total energy peak of the gamma-ray spectrum to the concentration of radionuclides in the soil, a number of parameters must be taken into account. The primary factors are the efficiency of the detector as a function of energy, the absorption of gamma-rays by the soil and air, and the solid angle at the detector subtended by the source. The radioactivity distribution with soil depth, the soil density, moisture content, and chemical composition must either be assumed or else determined by time-consuming measurements (Dickson et al. 1976).

The correlation coefficients R and the R^2 values demonstrate significant relationships between gamma dose rates and total calculated dose rates. These linear relationships may be affected by some errors such as instrumental errors, human errors, and contribution from other nuclides, outcrops, small hot spots areas and uneven soil surfaces on the dose rates.

B3.9 Derivation of the Effective Dose Rates

In order to estimate the annual effective doses, one has to take into account the conversion coefficient from absorbed dose rate in air to effective dose and the outdoor occupancy factor. In the UNSCEAR recent reports (1988, 1993, 2000), the committee used 0.7 Sv Gy^{-1} for the conversion coefficient from absorbed dose in air to effective dose received by adults, and 0.8 for the indoor occupancy factor, implying that 20% of the time is spent outdoors, on average, around world. The effective dose rate, in units of mSv y^{-1}, is calculated from the following formula:

Effective dose rate (mSv y^{-1}) = Dose rate (nGy h^{-1}) x 24 (hour) x 365.25 (day) x 0.2 (spent outdoors) x 0.7 Sv Gy^{-1} (conversion coefficient) x 10^{-6} (B3.4)

B3.10 Measurement of Uranium, Thorium and Potassium in Soil Samples

A total of 128 soil samples from the Kinta District were taken for analysis. Figure B3.15 is a map of the area showing the sampling locations. The soil samples were analyzed for the uranium, thorium, potassium, gross alpha and gross beta activity. The uranium and thorium concentration ranges from 0.94 to 34.65 ppm and from 4.79 to 341.48 ppm respectively. Conversion factors were used to convert ppm to pCi g^{-1}. [^{238}U; 1 ppm = 0.3325 pCi g^{-1}; ^{232}Th: 1 ppm = 0.109 pCi g^{-1}]. 1 pCi g^{-1} = 37 Bq kg^{-1} (Tan, 2000).

The measured activity concentration of ^{238}U varies from 12 to 426 Bq kg^{-1} with a mean of 112 ± 18 Bq kg^{-1}, which is over three times higher than the world average. ^{232}Th activity ranges from 19 to 1377 Bq kg^{-1} with a mean of 246 ± 21 Bq kg^{-1} which is over five times higher the world average and that of ^{40}K activity ranges from less than 19 to 2204 Bq kg^{-1} with mean is 277 ± 127 Bq kg^{-1} which is less than the world average of 420 Bq kg^{-1}. The mean for total activity of natural radionuclides is 635 ± 130 Bq kg^{-1}. Bar charts from Figure B3.13a to B3.13d show the specific activities of uranium, thorium and potassium in soil sample at each the sampling point with dose rates in ascending order

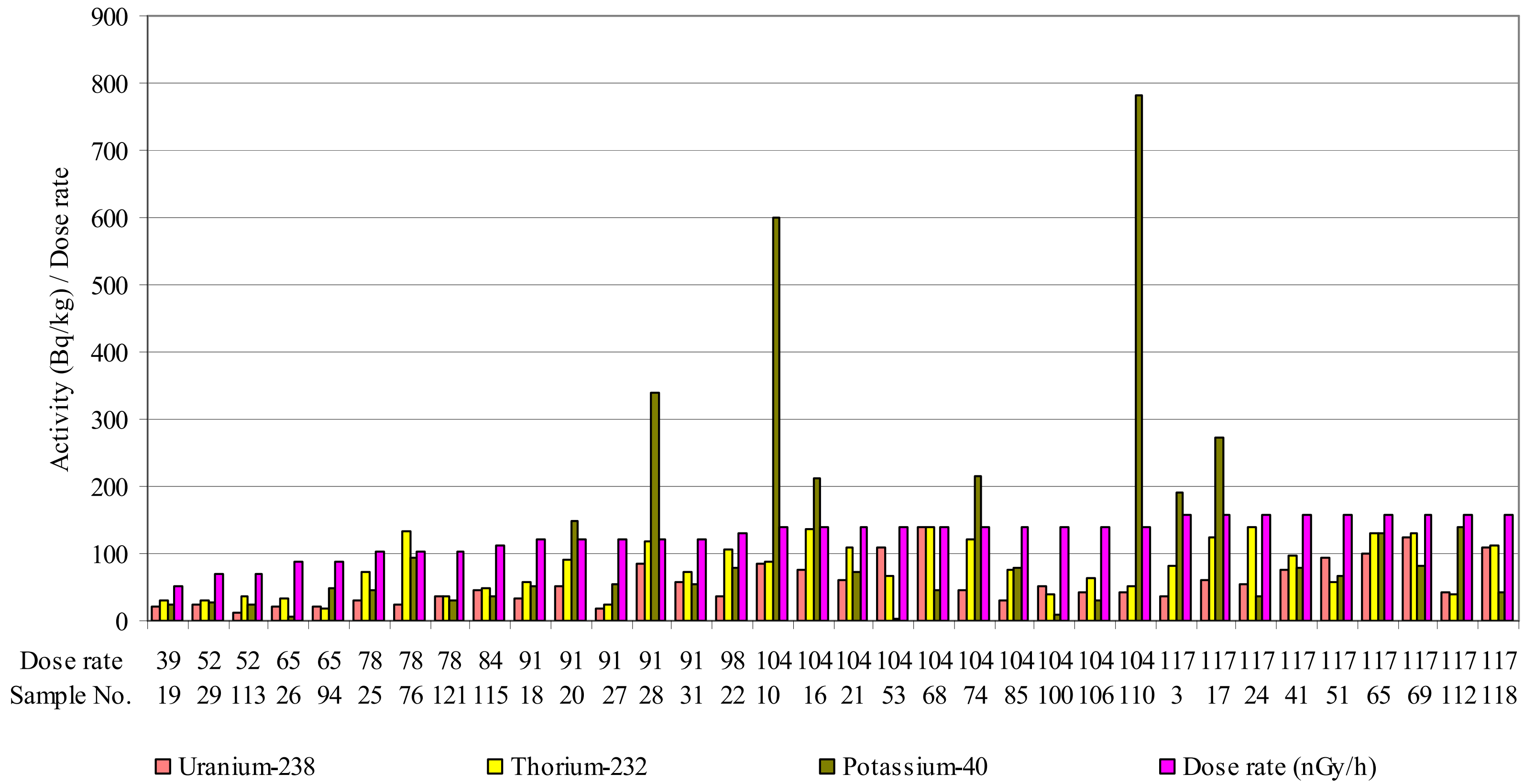

Figure B3.14a Bar chart of uranium, thorium, potassium activities and dose rate in soil samples

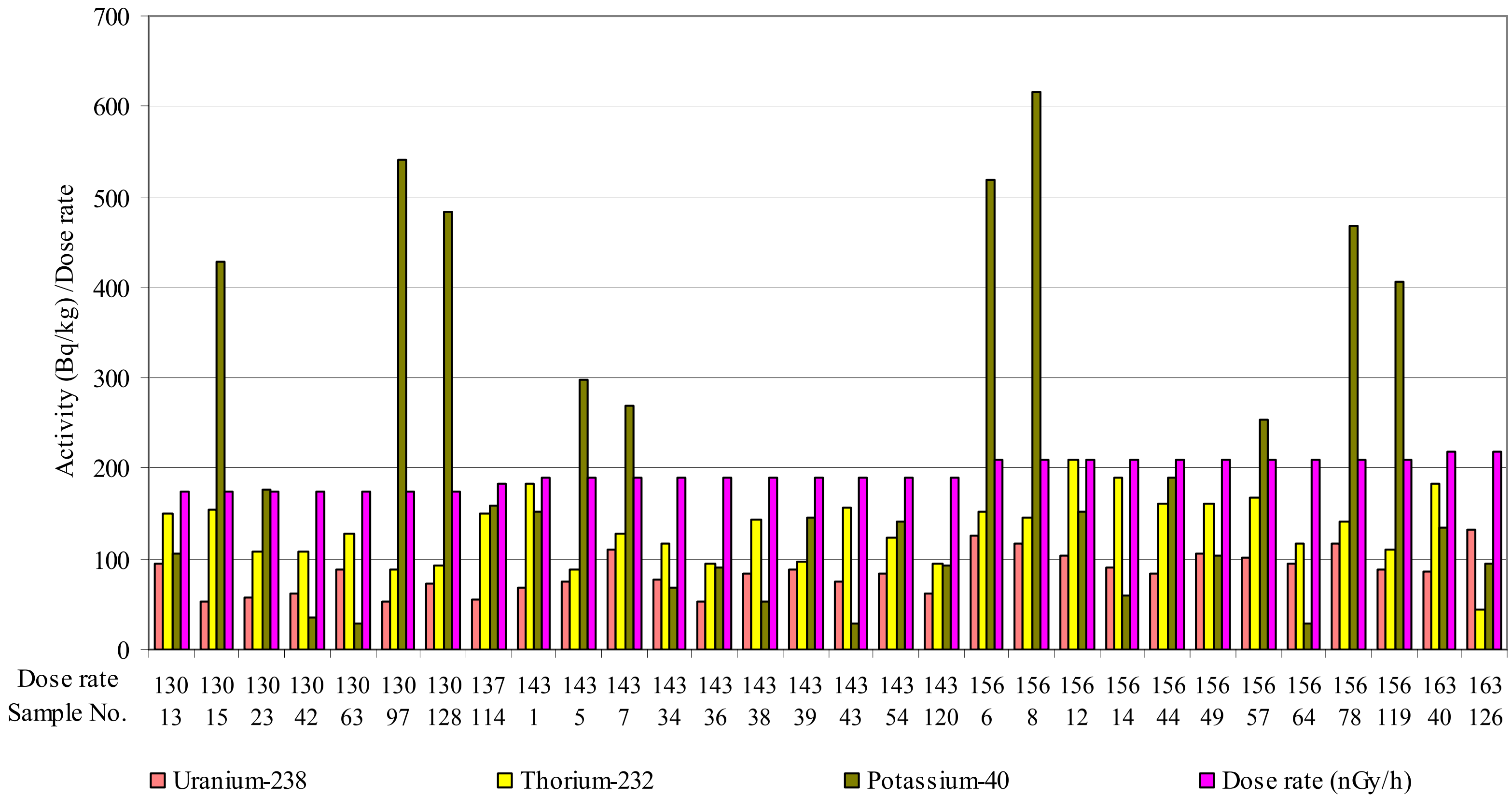

Figure B3.14b Bar chart of uranium, thorium, potassium activities and dose rate in soil samples

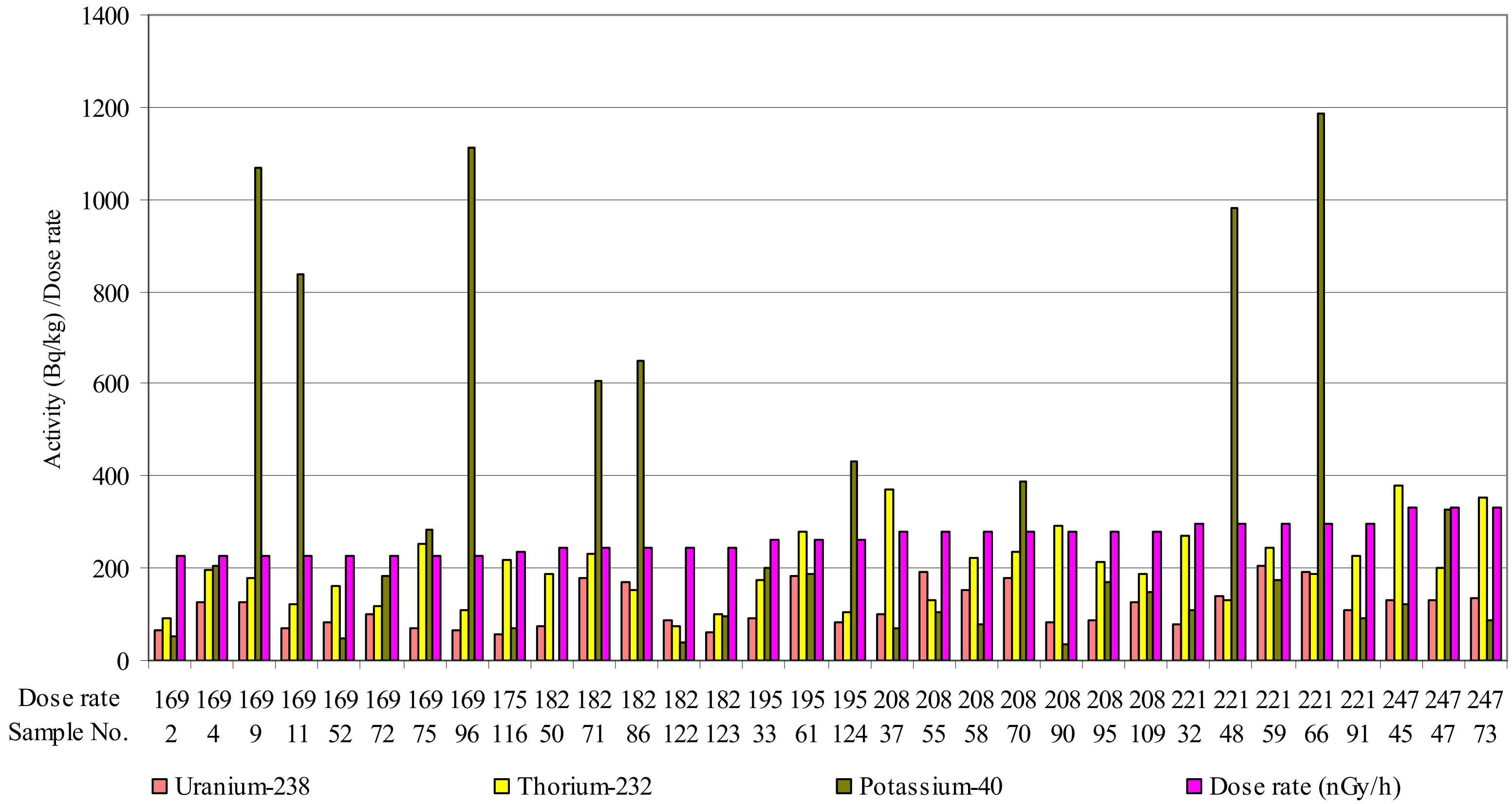

Figure B3.14c Bar chart of uranium, thorium, potassium activities and dose rate in soil samples

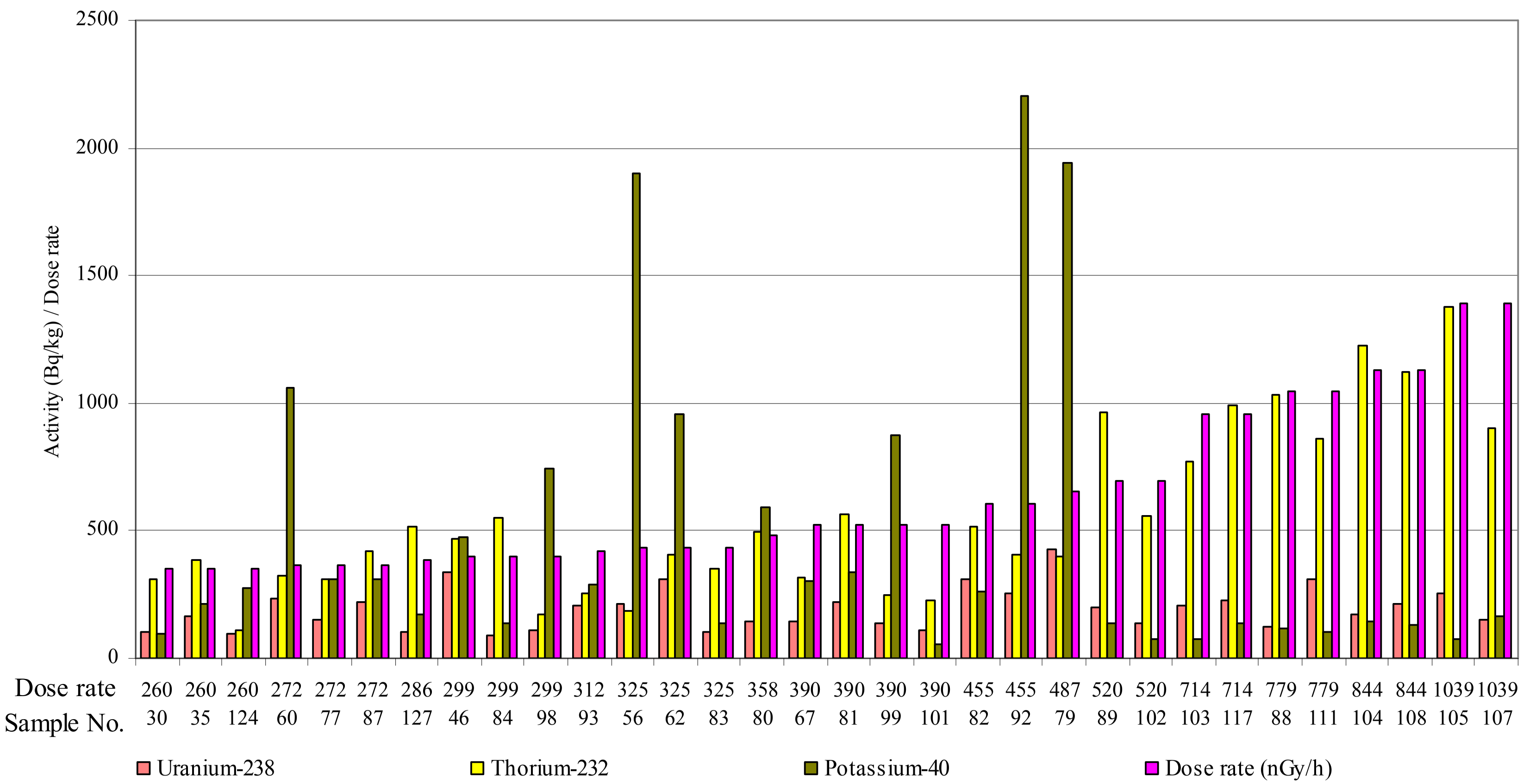

Figure B3.14d Bar chart of uranium, thorium, potssium activities and dose rate in soil samples

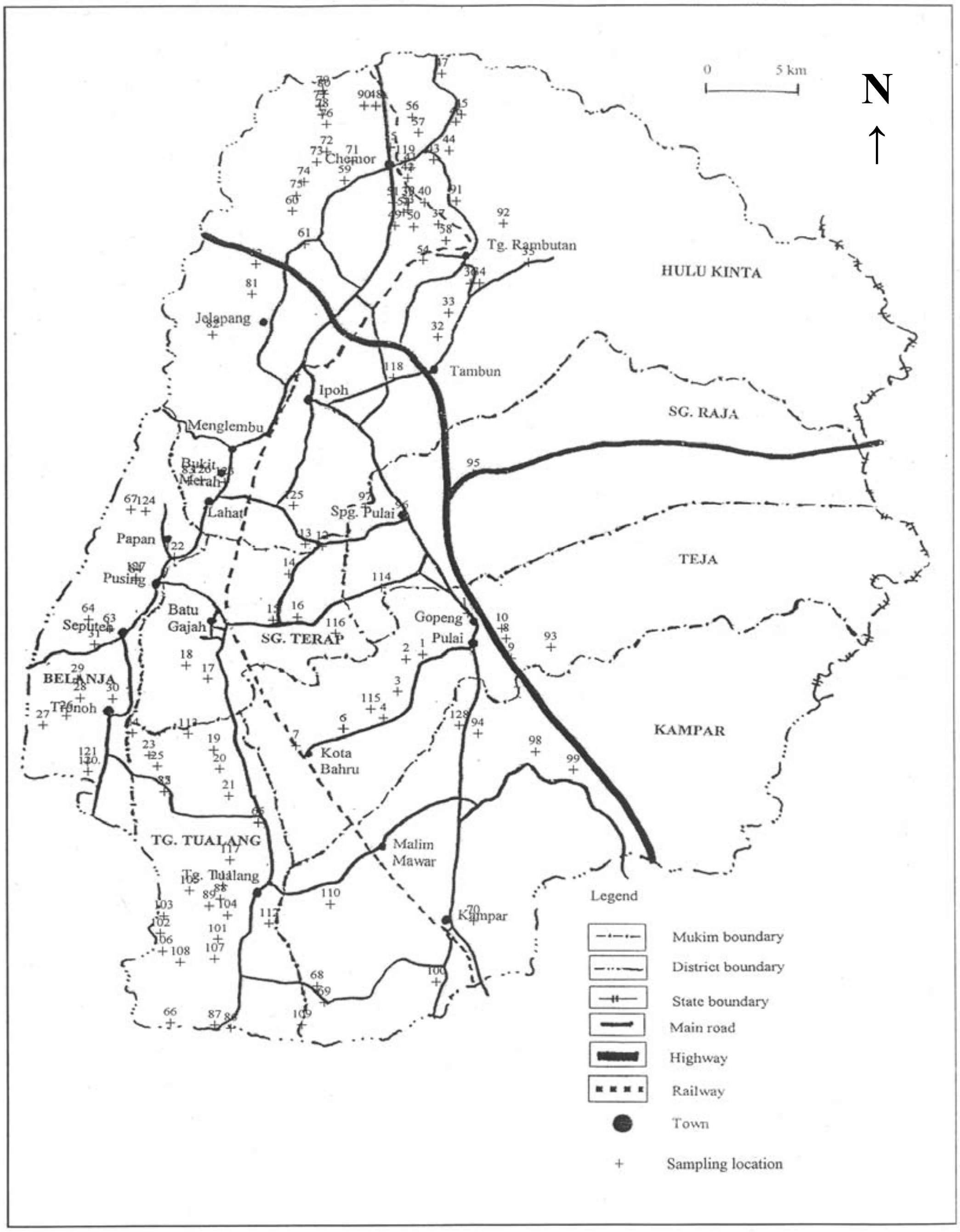

Figure B3.15 Sampling locations for soil samples

World average concentrations are 33 Bq kg^{-1} and 45 Bq kg^{-1} for ^{238}U and ^{232}Th , respectively; and typical ranges are 16 – 116 Bq kg^{-1} for ^{238}U and 7-50 Bq kg^{-1} for ^{232}Th. The world average concentration is 420 Bq kg^{-1} for ^{40}K, and the typical range is 100-700 Bq kg^{-1} for ^{40}K (UNSCEAR 2000).

Table B3.9 shows the radionuclide concentrations of this work, compared with Omar et al. (1991) and UNSCEAR (2000) world average.

Table B3.9 Radionuclide concentrations in surface soil

Radionuclide	Activity (Bq kg^{-1})		Dose rate		Activity (Bq kg^{-1})	
	Range	Mean	nGy h^{-1}	Percentage contribution	World average	Omar et. al. (1991)
^{238}U	12 – 426	112	52	24.8	33	73, 240*
^{232}Th	19 – 1377	241	146	69.5	45	91, 130*
^{40}K	<19 – 2204	277	12	5.7	420	n.a

n.a. – not available, * - granites

The percentage contributions of ^{238}U, ^{232}Th and ^{40}K to the external dose rates in air are also given in Table B3.9 (column 4). The mean values are 24.8, 69.5 and 5.7 % for ^{238}U, ^{232}Th and ^{40}K respectively. Sankaran et al. (1986) have reported the percentage contributions of 24.3, 60.8 and 14.9 % due to ^{238}U, ^{232}Th and ^{40}K, respectively for South Canara and North Canara of South India. Misha and Sadasivan (1971) have reported these percentage contributions on the order of 17.7, 33.6 and 48.7 due to ^{238}U, ^{232}Th and ^{40}K, respectively for Indian environments. Ibrahiem et al (1993) have reported for in the Nile Delta and Middle Egypt the relative contribution of ^{238}U, ^{232}Th and ^{40}K gamma dose rates in air are 55%, 5%, and 40% respectively. UNSCEAR (2000) has reported the world wide average values for the relative contributions from ^{238}U, ^{232}Th and ^{40}K gamma dose rates in air to be about 25%, 45%, and 30%, respectively.

The natural radioactivity of soil depends upon that of the parent rock as well as the soil formation and transport process that were involved. In the course of such formation, chemical and biochemical interactions influence the distribution patterns of uranium, thorium and potassium as well as all the radionuclides created by the radioactive decay of these elements. Potassium is located in several major minerals viz, mica, K-feldspar and plagioclase igneous rocks. The bulk of thorium and uranium, however, is not present in rock forming minerals. They are often concentrated in accessory minerals and along mineral boundaries. Accessory minerals containing thorium and uranium which are commonly found in granitoids include zircon, monazite, xenotime, apatite and allanite. These resistate minerals are also found in the alluvium and residual soils derived from granitoids (Wong, 1985). Mineral map of the Kinta District is included in Appendix D.

B3.11 Th/U ratio

With high rainfall, weathering is one of the processes will tend to oxidize and leach uranium, resulting in high Th/U ratios. However in terms of activity concentration, 12 samples were found to have higher ^{238}U concentration than ^{232}Th when the ratio of Th/U is 3.02 and below as seen in Table B3.10. These sample numbers are 48, 51, 53, 56, 66, 68, 79, 86, 94, 100, 112, and 126. From Table B3.11, the Th/U ratio varies from 1.03 to 25.65, it shows that concentration of uranium is lower than that of thorium in all samples.

Table B3.10 Soil samples with Th/U ratio of 3.02 and below

Sample number	Soil type No.	Geological type	Th/U (ppm)	^{238}U Bq kg^{-1}	^{232}Th Bq kg^{-1}
48	50	DCR	2.93	138	133
51	18	DCR	1.85	93	56
53	48	DCR	1.84	110	66
56	50	DCR	2.65	212	167
66	50	CAAR	3.00	191	188
68	50	CCR	3.02	140	139
79	48	JTG	2.86	426	399
86	50	JTG	2.78	169	154
94	50	DCR	2.82	21	19
100	50	DCR	2.33	51	39
112	50	CCR	2.72	43	38
126	50	DCR	1.03	132	45

Table B3.11 Activity of soil samples for gross alpha, gross beta, ^{238}U, ^{232}Th, ^{40}K in $Bqkg^{-1}$, calculated and measured dose rate in $nGy\ h^{-1}$, Th/U ratio, geological and soil type.

Sample No.	Gross alpha (Bq kg^{-1})	Gross beta (Bq kg^{-1})	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})	Calculated dose rate (nGy h^{-1})	Dose rate (nGy h^{-1}) ± 10%	Ratio Th/U (ppm)	Geology	Soil type No.
1	1178 ± 115	662 ± 28	68 ± 11	183 ± 16	152 ± 74	148	191	8.24	DCR	31
2	478 ± 84	414 ± 23	66 ± 11	91 ± 9	53 ± 34	88	226	4.20	DCR	31
3	854 ± 115	699 ± 28	37 ± 6	82 ± 8	190 ± 88	75	157	6.74	DCR	31
4	1162 ± 107	832 ± 30	128 ± 21	194 ± 17	205 ± 95	185	226	4.62	DCR	18
5	615 ± 91	680 ± 28	76 ± 12	88 ± 8	298 ± 133	101	191	3.52	DCR	18
6	1008 ± 107	946 ± 32	126 ± 20	153 ± 13	518 ± 230	172	209	3.71	DCR	18
7	478 ± 84	798 ± 30	111 ± 18	128 ± 11	270 ± 121	139	191	3.53	DCR	50
8	872 ± 103	1154 ± 35	117 ± 19	145 ± 13	617 ± 273	168	209	3.80	DCR	31
9	1403 ± 122	1536 ± 39	125 ± 20	181 ± 16	1069 ± 472	211	226	4.40	DCR	18
10	982 ± 107	1008 ± 33	84 ± 14	88 ± 8	599 ± 265	117	139	3.21	DCR	31
11	1025 ± 110	1011 ± 33	71 ± 11	120 ± 11	836 ± 369	140	226	5.19	DCR	31
12	1565 ± 129	954 ± 32	104 ± 17	210 ± 18	153 ± 73	181	209	6.16	DCR	18
13	992 ± 108	744 ± 29	96 ± 16	149 ± 13	105 ± 53	139	174	4.74	DCR	18
14	1308 ± 120	634 ± 27	91 ± 15	190 ± 16	60 ± 36	159	209	6.32	DAR	18
15	1051 ± 110	723 ± 29	54 ± 9	155 ± 13	428 ± 190	137	174	8.82	DAR	50
16	872 ± 103	685 ± 28	74 ± 12	135 ± 12	211 ± 98	125	139	5.55	DAR	18
17	1070 ± 110	661 ± 28	61 ± 10	123 ± 11	274 ± 124	114	157	6.16	CAAR	48
18	254 ± 73	285 ± 21	34 ± 6	59 ± 6	52 ± 31	53	122	5.27	CAAR	48
19	237 ± 71	483 ± 25	22 ± 4	30 ± 4	26 ± 21	30	52	4.24	CAAR	48
20	828 ± 100	505 ± 25	52 ± 9	91 ± 8	147 ± 69	85	122	5.31	CAAR	48
21	761 ± 98	579 ± 26	61 ± 10	109 ± 10	73 ± 42	97	139	5.49	CAAR	48
22	1136 ± 112	588 ± 26	37 ± 6	106 ± 10	78 ± 43	84	131	8.76	CAAR	50
23	897 ± 103	478 ± 24	58 ± 10	108 ± 10	177 ± 82	99	174	5.68	CAAR	31
24	974 ± 108	478 ± 24	56 ± 9	140 ± 12	38 ± 30	112	157	7.69	CAAR	48
25	280 ± 73	290 ± 21	29 ± 5	73 ± 7	47 ± 29	59	104	7.68	CAAR	31
26	365 ± 79	182 ± 18	21 ± 4	33 ± 4	<mdl	30	87	4.76	CAAR	50
27	255 ± 73	290 ± 21	18 ± 3	25 ± 3	54 ± 29	2	122	4.25	CAAR	31
28	768 ± 98	811 ± 30	86 ± 14	119 ± 11	339 ± 151	125	122	4.24	CAAR	31
29	434 ± 82	257 ± 20	24 ± 4	31 ± 4	26 ± 22	31	70	4.01	CAAR	18
30	1539 ± 129	1177 ± 35	100 ± 16	310 ± 26	94 ± 50	237	348	9.41	JTG	50
31	442 ± 82	459 ± 24	58 ± 10	73 ± 7	54 ± 33	73	122	3.83	CCR	50
32	1342 ± 120	766 ± 29	77 ± 13	270 ± 23	110 ± 61	203	296	10.76	DCR	50
33	1198 ± 115	720 ± 29	92 ± 15	175 ± 16	200 ± 95	157	261	5.81	DCR	50
34	494 ± 86	407 ± 23	76 ± 13	117 ± 11	69 ± 45	109	191	4.66	DCR	50
35	2202 ± 149	1421 ± 38	165 ± 27	384 ± 32	215 ± 100	317	348	7.08	JTG	48

36	596 ± 91	358 ± 22	54 ± 9	95 ± 9	90 ± 48	86	191	5.33	DCR	50
37	2380 ± 154	1043 ± 33	102 ± 17	370 ± 31	69 ± 42	274	278	11.09	DCR	48
38	1008 ± 107	652 ± 27	84 ± 14	144 ± 13	53 ± 35	128	191	5.21	DCR	48
39	957 ± 105	694 ± 28	88 ± 14	97 ± 9	146 ± 69	105	191	3.37	DCR	48
40	1687 ± 132	1149 ± 35	87 ± 14	183 ± 16	134 ± 64	156	218	6.47	DCR	48
41	725 ± 97	538 ± 26	76 ± 12	96 ± 9	78 ± 40	97	157	3.86	DCR	18
42	1077 ± 110	629 ± 27	62 ± 10	108 ± 10	35 ± 25	95	174	5.37	PCR	18
43	1121 ± 112	636 ± 27	74 ± 12	157 ± 14	28 ± 28	130	191	6.45	DAR	48
44	1386 ± 122	721 ± 29	57 ± 14	209 ± 18	189 ± 90	145	209	5.81	JTG	48
45	2396 ± 154	1285 ± 36	131 ± 21	380 ± 31	123 ± 62	295	331	8.82	JTG	48
46	3380 ± 179	2053 ± 45	338 ± 54	467 ± 39	472 ± 212	457	400	4.23	JTG	48
47	1584 ± 129	1429 ± 38	133 ± 21	199 ± 17	329 ± 147	195	331	4.56	JTG	48
48	1231 ± 117	1937 ± 44	138 ± 22	133 ± 12	980 ± 432	185	296	2.93	DCR	50
49	949 ± 105	1046 ± 33	105 ± 17	160 ± 14	104 ± 51	150	209	4.64	DCR	48
50	1188 ± 115	689 ± 28	72 ± 12	188 ± 16	< mdl	147	244	7.92	DCR	48
51	460 ± 84	678± 28	93 ± 15	56 ± 6	67 ± 36	80	157	1.85	DCR	18
52	1121 ± 112	670 ± 28	85 ± 14	159 ± 14	48 ± 31	137	226	5.75	DCR	48
53	735 ± 97	707± 28	110 ± 18	66 ± 7	< mdl	91	139	1.84	DCR	48
54	743 ± 96	644± 27	85 ± 14	124 ± 11	142 ± 67	120	191	4.48	DCR	18
55	1360 ± 122	1251 ± 36	194 ± 31	210 ± 18	103 ± 53	172	278	3.31	DCR	18
56	1591 ± 129	2518± 49	212 ± 34	184 ± 16	1900 ± 837	288	435	2.65	DCR	50
57	743 ± 98	727 ± 29	103 ± 17	167 ± 15	254 ± 116	159	209	4.96	DCR	18
58	1301 ± 120	1128 ± 34	151 ± 24	224 ± 19	78 ± 41	208	278	4.54	DCR	48
59	2550 ± 159	**6173 ± 77**	205 ± 33	246 ± 21	173 ± 82	250	296	3.67	SAR	18
60	2525 ± 157	2163 ± 46	235 ± 37	321 ± 27	1058 ± 467	346	365	4.17	JTG	48
61	1720 ± 134	1301± 36	184 ± 30	280 ± 23	186 ± 87	262	261	4.64	SAR	48
62	3822 ± 190	2317 ± 47	307 ± 49	408 ± 34	954 ± 422	428	435	4.06	JTG	48
63	1026 ± 110	709 ± 28	88 ± 14	129 ± 11	28 ± 23	119	174	4.47	CCR	48
64	957 ± 105	683 ± 28	95 ± 15	118 ± 10	29 ± 25	116	209	3.79	CCR	48
65	1018 ± 107	796 ± 30	99 ± 16	130 ± 11	131 ± 62	130	157	4.02	CAAR	18
66	1301 ± 120	1595± 40	191 ± 31	188 ± 17	1184 ± 523	251	296	3.00	CAAR	50
67	203 ± 69	400 ± 23	145 ± 23	316 ± 26	300 ± 134	270	522	6.67	JTG	49
68	1506 ± 127	1173 ± 35	140 ± 22	139 ± 12	47 ± 32	150	139	3.02	CCR	50
69	1291 ± 120	918 ± 31	123 ± 20	132 ± 12	82 ± 44	143	157	3.27	CAAR	50
70	1738 ± 134	1739 ± 42	180 ± 29	237 ± 20	389 ± 152	242	278	4.01	JTG	48
71	1018 ± 108	1988 ± 44	177 ± 28	230 ± 19	606 ± 268	246	244	3.96	SAR	18
72	956 ± 105	1129 ± 34	101 ± 16	120 ± 10	185 ± 84	127	226	3.61	SAR	50
73	1958 ± 142	1249 ± 36	136 ± 22	355 ± 29	86 ± 46	281	331	8.00	JTG	49
74	674 ± 93	629 ± 27	45 ± 7	122 ± 11	216 ± 98	103	139	8.30	SAR	48
75	1463 ± 125	966 ± 32	69 ± 11	251 ± 20	283 ± 125	195	226	11.05	SAR	49
76	710 ± 100	426 ± 23	26 ± 4	133 ± 12	93 ± 47	96	104	15.88	SAR	49

77	2150 ± 147	1753 ± 42	151 ± 24	310 ± 25	308 ± 135	270	365	6.26	JTG	49
78	956 ± 105	1052 ± 33	117 ± 10	141 ± 11	468 ± 206	159	209	3.67	JTG	49
79	2825 ± 164	3654 ± 59	**426 ± 68**	399 ± 32	1940 ± 854	519	653	2.86	JTG	48
80	2320 ± 152	1554 ± 40	144 ± 23	497 ± 40	590 ± 260	391	479	10.56	JTG	48
81	2783± 164	2161 ± 33	222 ± 35	564 ± 46	335 ± 148	457	522	7.77	JTG	48
82	2355 ± 152	2050 ± 45	307 ± 49	519 ± 43	262 ± 122	466	609	5.17	JTG	49
83	1411 ± 122	1034 ± 33	105 ± 17	350 ± 29	138 ± 71	266	435	10.17	JTG	49
84	2748 ± 164	1306 ± 36	90 ± 15	554 ± 45	136 ± 69	382	400	18.85	JTG	48
85	949 ± 105	368 ± 22	32 ± 5	77 ± 7	85 ± 41	64	139	7.42	CAAR	50
86	1378 ± 122	1479 ± 39	169 ± 27	154 ± 13	650 ± 287	199	244	2.78	JTG	50
87	2525 ± 157	2036 ± 44	219 ± 35	417 ± 34	342 ± 152	366	365	5.80	JTG	50
88	6734 ± 248	2322 ± 47	123 ± 20	1032 ± 84	128 ± 62	685	1044	25.65	JTG	48
89	4913 ± 212	2330 ± 48	201 ± 32	987 ± 80	118 ± 60	679	696	14.86	JTG	48
90	2027 ± 144	1282 ± 36	85 ± 14	291 ± 24	51 ± 33	217	278	10.46	DCR	50
91	1752 ± 134	790 ± 30	111 ± 18	228 ± 19	93 ± 47	193	296	6.28	JTG	48
92	864 ± 103	864 ± 50	252 ± 40	403 ± 33	**2204 ± 970**	452	609	4.87	JTG	48
93	1848 ± 137	2636 ± 19	206 ± 33	258 ± 21	290 ± 131	263	418	3.82	JTG	49
94	93 ± 62	**142 ± 29**	21 ± 4	**19 ± 4**	50 ± 30	23	87	2.82	DCR	50
95	1522 ± 127	774 ± 35	86 ± 14	214 ± 18	170 ± 79	176	278	7.61	JTG	48
96	846 ± 103	1174 ± 35	64 ± 10	107 ± 10	1110 ± 489	140	226	5.15	DCR	18
97	1051 ± 110	1193 ± 25	52 ± 9	88 ± 8	541 ± 239	100	174	5.16	DCR	18
98	1454 ± 124	1174 ± 36	109 ± 18	174 ± 15	744 ± 328	186	400	4.87	JTG	49
99	1772 ± 134	1307 ± 20	136 ± 14	245 ± 20	875 ± 386	247	522	5.49	JTG	48
100	229 ± 71	262 ± 31	51 ± 8	39 ± 5	< mdl	47	139	2.33	DCR	50
101	1505 ± 127	867 ± 31	110 ± 18	229 ± 19	53 ± 31	191	522	6.37	JTG	48
102	3884 ± 192	1288 ± 36	140 ± 23	558 ± 45	74 ± 42	405	696	12.13	CAAR	18
103	4453 ± 205	1381 ± 37	207 ± 33	771 ± 62	78 ± 39	565	957	11.39	CAAR	48
104	5923 ± 233	2233 ± 46	174 ± 28	1228 ± 99	144 ± 68	828	1131	21.48	JTG	48
105	**9634 ± 295**	3446 ± 57	214 ± 34	**1377 ± 111**	79 ± 40	951	1392	16.68	JTG	48
106	743 ± 98	361 ± 22	43 ± 7	63 ± 6	29 ± 20	59	139	4.51	CAAR	18
107	8117 ± 271	2960 ± 53	149 ± 24	1364 ± 110	166 ± 78	619	1392	18.43	JTG	48
108	7515 ± 261	2789 ± 52	215 ± 34	1122 ± 90	133 ± 64	782	1131	15.93	JTG	48
109	1635 ± 132	905 ± 31	125 ± 20	188 ± 16	149 ± 69	177	278	4.59	CAAR	50
110	581 ± 89	753 ± 29	42 ± 7	52 ± 5	782 ± 345	83	139	3.77	CAAR	50
111	5499 ± 225	2661 ± 51	305 ± 49	863 ± 70	79 ± 41	665	1044	8.53	JTG	48
112	324 ± 77	314 ± 21	43 ± 7	38 ± 4	138 ± 63	49	157	2.72	CCR	50
113	468 ± 84	144 ± 17	**12 ± 2**	37 ± 4	25 ± 17	29	70	9.67	CAAR	48
114	1213 ± 117	614 ± 27	55 ± 9	150 ± 13	158 ± 73	123	183	8.26	DCR	50
115	795 ± 100	337 ± 22	46 ± 8	49 ± 5	36 ± 22	52	113	3.21	DCR	18
116	1171 ± 115	761 ± 29	58 ± 9	216 ± 18	68 ± 34	160	235	11.39	DAR	18
117	4155 ± 197	6120 ± 77	227 ± 36	989 ± 80	136 ± 67	708	957	13.27	JTG	48

118	1085 ± 112	684 ± 28	110 ± 18	112 ± 10	34 ± 22	120	157	3.19	DCR	50
119	915 ± 105	698 ± 28	88 ± 14	111 ± 10	406 ± 180	125	209	3.88	DCR	18
120	453 ± 84	366 ± 22	62 ± 10	94 ± 8	92 ± 44	89	191	4.67	CAAR	50
121	**15 ± 56**	**142 ± 17**	35 ± 6	36 ± 4	39 ± 22	39	104	3.10	CAAR	50
122	349 ± 77	311 ± 21	84.1 ± 14	89 ± 8	40 ± 23	87	244	3.23	CCR	50
123	478 ± 84	303 ± 21	61 ± 10	99 ± 14	98 ± 46	92	244	4.96	DCR	50
124	648 ± 93	886 ± 31	98 ± 16	108 ± 10	272 ± 122	122	348	3.38	JTG	49
125	512 ± 86	814 ± 30	82 ± 13	106 ± 9	432 ± 192	120	261	3.95	JTG	49
126	401 ± 79	572 ± 26	132 ± 21	45 ± 4	90 ± 40	92	218	1.03	DCR	50
127	1523 ± 127	669 ± 28	104 ± 17	514 ± 42	174 ± 82	365	383	15.15	JTG	50
128	427 ± 82	373 ± 22	72 ± 11	93 ± 8	484 ± 213	109	174	3.92	DCR	18
Mean	1558 ± 121	1112 ± 32	112 ± 18	246 ± 21	277 ± 127	209	304			

< mdl = less than the minimum detection limit

B3.12 Radioactive Equilibrium

Radioactive equilibrium within the uranium decay series was found to exist in most soil samples analyzed, with a correlation coefficient of 0.98 (R^2 = 0.9697) almost 1:1 correlation between average ^{238}U and ^{226}Ra concentrations for the Kinta District.

B3.13 Measurement of Gross Alpha and Gross Beta in Soil Samples

Gross alpha and gross beta activities for 128 soil samples were measured using a Low alpha beta counter. About 2 g portion of the soil samples were placed in stainless steel planchets, wet with diluted UHU glue with acetone, dried under infrared lamp and counted for 30 min on the counter. The average instrument background was 0.79 cpm for alpha and 3.97 cpm for beta channels. The low background detection system counting efficiency was found to be 3.24 % for alphas based on U_3O_8 standard and 32.01 % for betas (based on KCl standard) using 2 g of the standard samples. The efficiency calibration curve for alpha and beta are shown in Figure B3.16 and Figure B3.17 respectively. From the graphs, the efficiency of the system decreases with mass.

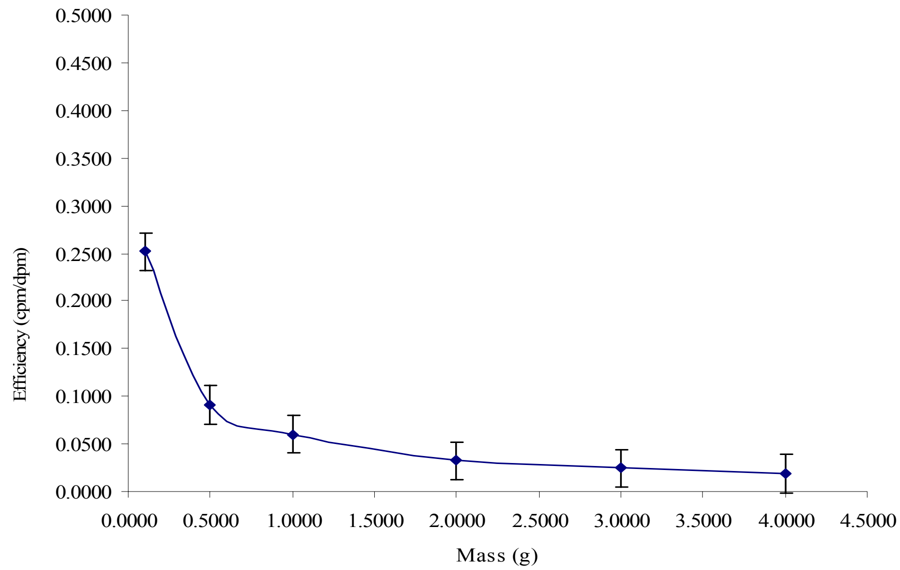

Figure B3.16 Efficiency calibration curve for alpha

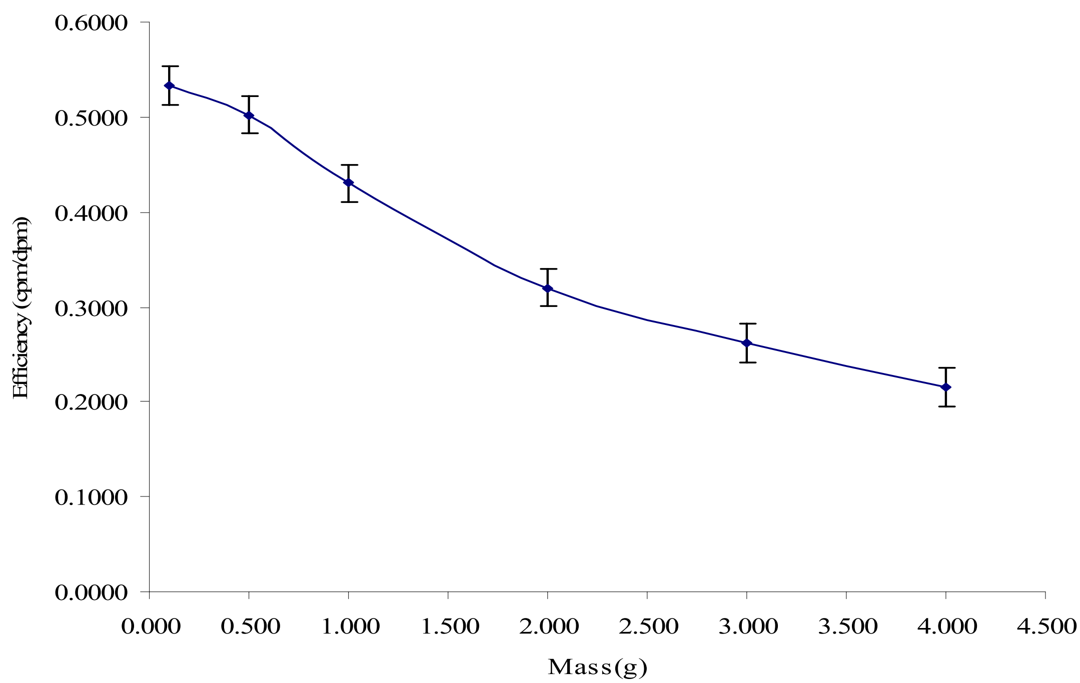

Figure B3.17 Efficiency calibration curve for beta

Gross alpha and gross beta specific activities were determined to study the trends in the concentration of radionuclides in the soil samples. Soil is an important subject of study for background radioactivity; its beta and gamma activities have been used to calculate the direct radiation dose (Lough and Solon,1958). The alpha activity range from 15 to 9634 Bq kg^{-1} with a mean of 1558 ± 121 Bq kg^{-1}. The beta activity range from 142 to 6173 Bq kg^{-1}. It has a mean of 1112 ± 32 Bq kg^{-1}. Bose et al. 1993 analyzed the gross alpha activities of the sediment samples found to range from 468 -1710 Bq kg^{-1} with an average of 1020 Bq kg^{-1}. The range of gross beta activities in the samples varied from 303 – 1125 Bq kg^{-1} with an average of 635 Bq kg^{-1}. The data confirmed that ^{40}K is not the major contributor to the gross beta activity where the correlation coefficient R was 0.29 (R^2 = 0.0839) (Figure B3.18). The other beta contributors are members of the uranium and thorium decay series. Radon and two of its disintegration decay products, ^{218}Po and ^{214}Po, are sources of alpha radiation. Radon also has two beta-decay products, ^{214}Pb and ^{214}Bi. Radionuclides from the thorium and uranium series are responsible for the majority of the alpha and beta activity.

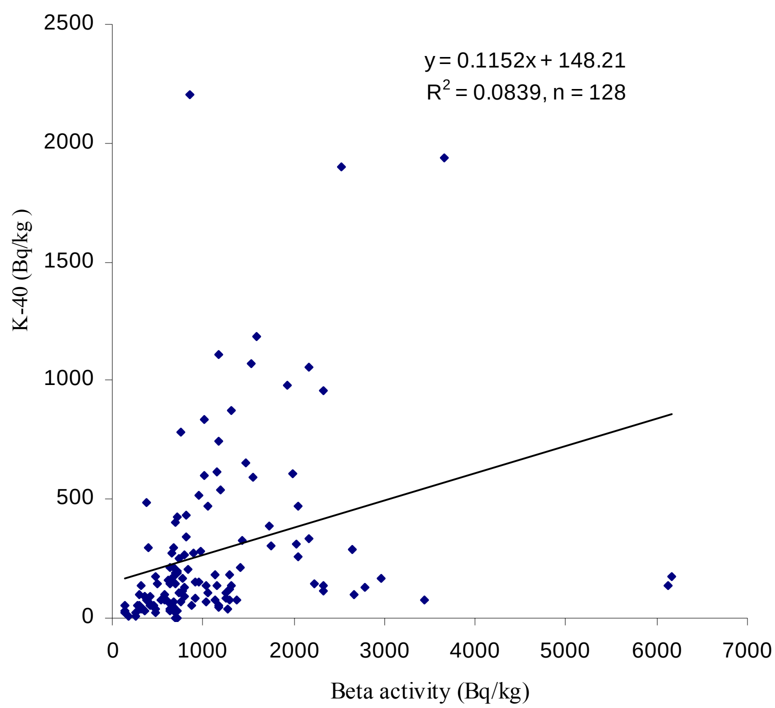

Figure B3.18 Correlation between beta activities versus ^{40}K

B3.14 Neutron Activation Analysis (NAA)

Table B3.12 Comparison between NAA and Direct Method

Sample number	*NAA* method		*Direct* method		Uranium	Thorium
	U (ppm)	Th (ppm)	U (ppm)	Th (ppm)	± %	± %
1	7	41#	6	45	16.7	8.9
104	12	219#	14	304	14.3	28.0
105	20	253	17	341	17.6	25.8
107	15	266#	12	339	25.0	21.5
108	21	202#	18	282	16.7	23.4

average of two readings

The results for the NAA method were obtained from MINT. The results of the NAA and direct method analysis for uranium and thorium for five samples were compared are shown in Table B3.12 above. For uranium the average difference is 18.1% and all the concentrations from NAA method are higher than the direct method except for sample no. 104. For thorium the average difference is about 21.5%. The thorium concentration from direct method analysis is higher than the NAA method for all samples. For the direct method, secular equilibrium assumption was made.

B3.15 Radium Equivalent Activity (Ra_{eq})

To represent the activities due to ^{226}Ra, ^{232}Th and ^{40}K by a single quantity which takes into account the radiation hazard with them, a common index called the radium equivalent activity (Ra_{eq}) in Bq kg^{-1} has been introduced, defined as; (Beretka and Mathew, 1985; Iqbal et al, 2000; Malanca et al. 1993)

$$Ra_{eq} = A_{Ra} + 1.43\, A_{Th} + 0.077\, A_K \qquad \text{(B3.5)}$$

where A_{Ra}, A_{Th} *and* A_K are the activity concentrations of $^{226}Ra \approx {}^{238}U$, ^{232}Th and ^{40}K in Bq kg^{-1} respectively. While defining Ra_{eq}, it has been assumed that 1 Bq kg^{-1} of ^{226}Ra, 0.7 Bq kg^{-1} of ^{232}Th and 13 Bq kg^{-1} of ^{40}K produce the same gamma-ray dose (Beretka and Mathew, 1985; Iqbal, 2000; Malanca et al. 1993). The radium equivalent activity for soil ranges from 52 to 2227 Bq kg^{-1}. The average value of Ra_{eq} for the soil is 478 Bq kg^{-1} (1.94 mSv y^{-1}). The world average in soils is 89 Bq kg^{-1}. As reference, the permissible dose limit for public which is recommended by ICRP is 1.5 mSv y^{-1} or equivalent to 370 Bq kg^{-1}. The calculated values of Ra_{eq} range from 0.14 to 6.01 mSv y^{-1}**.** The value of Ra_{eq} should be less than 370 Bq kg^{-1} or 1.5 mSv y^{-1}. The correlation coefficient between Ra_{eq} and dose rate was determined to be 0.94 (R^2 = 0.8851) (Figure B3.23), indicating good correlation, especially for field measurements.

B3.16 Linear Correlation Coefficient, R

The linear correlation coefficient, R measures the strength of the linear relationship between the paired x and y quantitative values in a sample. Its value is computed by using the equation 3.6 (Triola, 2005). R^2, which is usually referred to as the sample coefficient of determination. The value of R^2 is the proportion of the variation in y that is explained by the linear relationship between x and y.

$$R = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{[n(\Sigma x^2) - (\Sigma x)^2]^{½} \cdot [n(\Sigma y^2) - (\Sigma y)^2]^{½}} \qquad \text{(B3.6)}$$

where

n = represents the number of pairs of data present

Σ = denotes the addition of the items indicated

Σx = denotes the sum of all x values

Σy = denotes the sum of all y values

Σx^2 = indicates that each x value should be squared and then those squares added

$(\Sigma x)^2$ = indicates that the x values should be added and he total then squared

Σxy = indicates that each x value should first be multiplied by its corresponding y value. After obtaining all such products, find their sum.

R = represents the linear correlation coefficient for a sample.

B3.16.1 Correlation between Naturally Occurring Radionuclides and Dose Rate

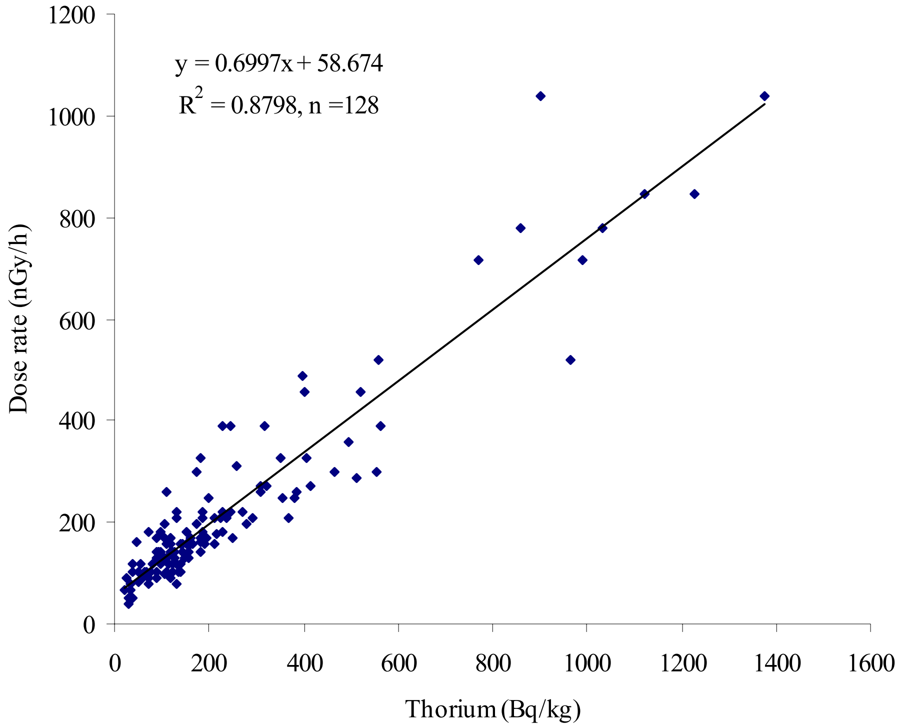

Figure B3.19 Correlation between thorium and dose rate

The correlation between ^{232}Th and dose rate, ^{238}U and dose rate, ^{40}K and dose rate and total activity (^{232}Th + ^{238}U + ^{40}K) and dose rate were plotted. The correlation coefficient between ^{232}Th and dose rate measurements is found to be 0.94 (R^2= 0.8798) or (88%) (Figure B3.19) indicating good correlation, which is significant at 95% confidence level. This implies that about 30 % of the variation in thorium activity cannot be explained by the dose rates. The correlation between ^{238}U and dose rate is linear with a correlation coefficient of 0.63 (R^2 = 0.4002) (Figure B3.20) and ^{40}K and dose rate is also poor with a correlation coefficient of 0.13 (R^2 = 0.0174) (Figure B3.21). The correlation coefficient between total activity and dose rate is linear at 0.65 (R^2 = 0.4226) (Figure B3.22). The correlation coefficient between radium equivalent activity and dose rate is 0.94 (R^2 = 0.8851) (Figure B3.23).

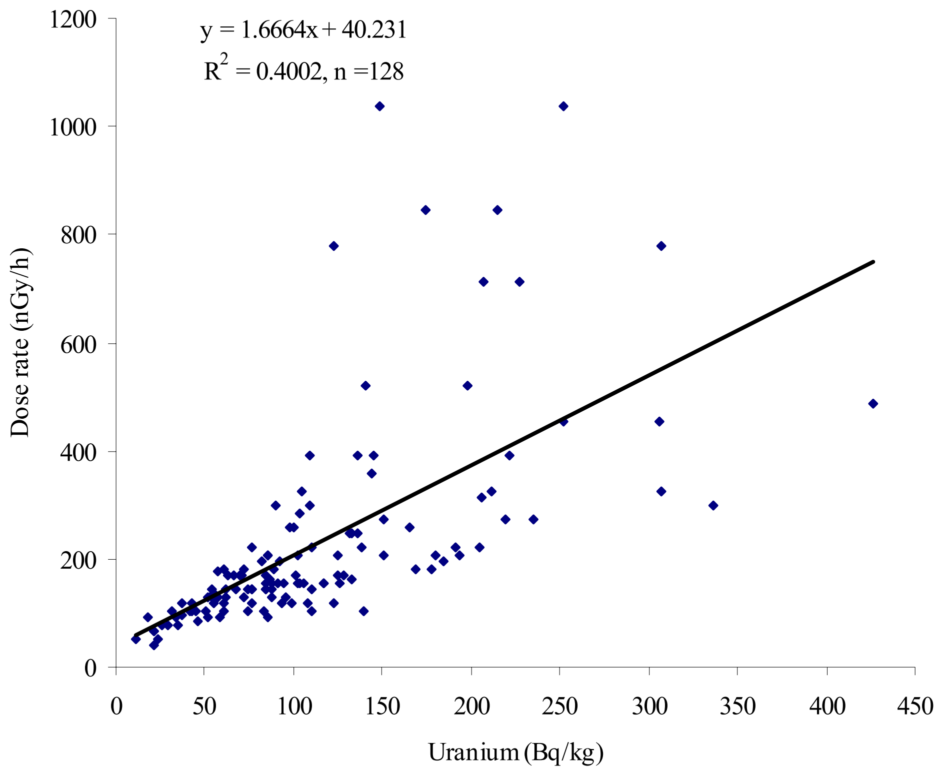

Figure B3.20 Correlation between uranium and dose rate

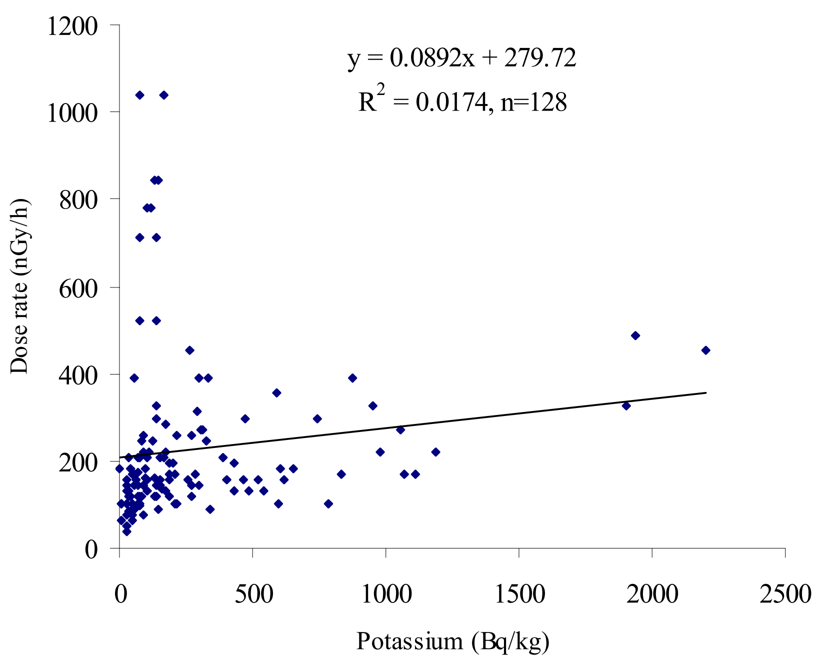

Figure B3.21 Correlation between potassium and dose rate

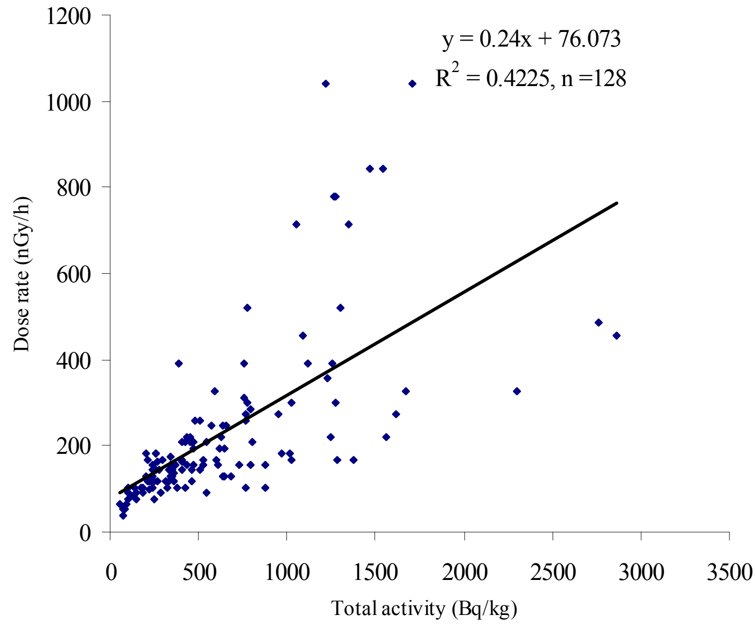

Figure B3.22 Correlation between total activity and dose rate

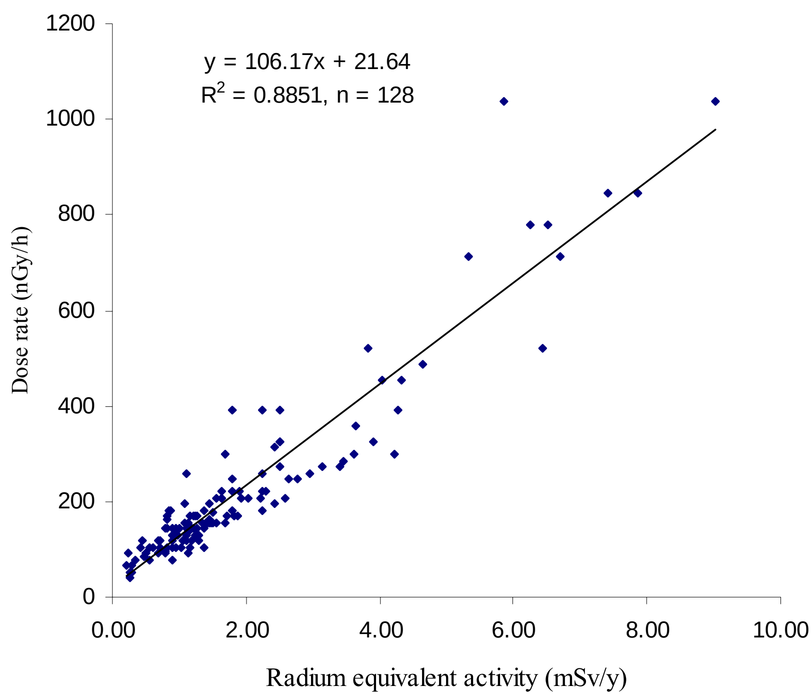

Figure B3.23 Correlation between radium equivalent activity and dose rate

B3.16.2 Correlation between Naturally Occurring Radionuclides

The correlation coefficient between uranium and thorium was determined to be 0.69 (R^2 = 0.3646) (Figure B3.24), between uranium and potassium 0.47 (R^2 = 0.2215) (Figure B3.25), and there is poor correlation between potassium and thorium, where the correlation coefficient is 0.03 (R^2 = 0.0007) (Figure B3.26). The poor correlation indicates that individual results for any one radionuclide concentration in each pair are not, therefore, good predictors of individual values for the other (Narayana et al., 2001). In Figure B3.27 shows a very good correlation between ^{238}U and ^{226}Ra where the correlation coefficient is 0.99 (R^2 = 0.9759) which is almost 1:1 which we can infer that radioactive equilibrium within the uranium decay series was found to exist (Myrick et al., 1983).

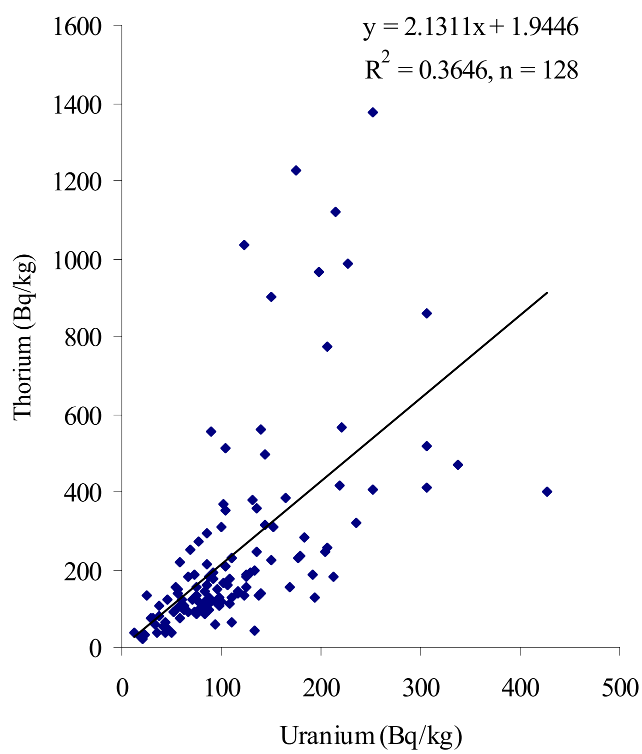

Figure B3.24 Correlation between uranium and thorium in soil

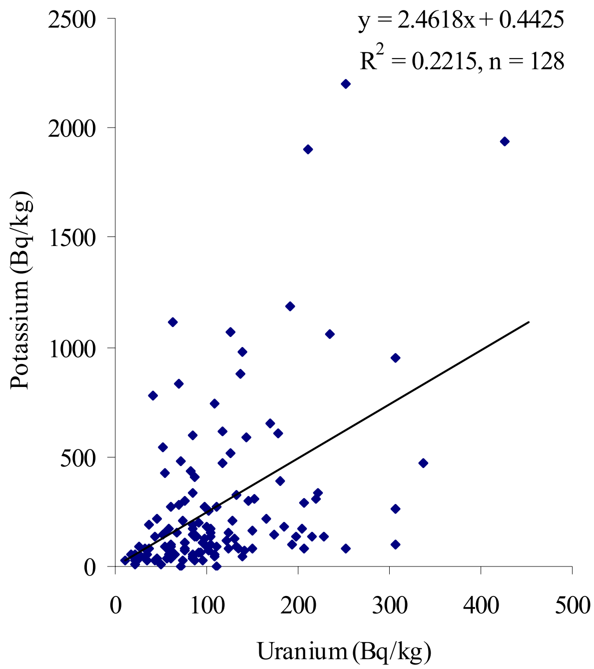

Figure B3.25 Correlation between uranium and potassium in soil

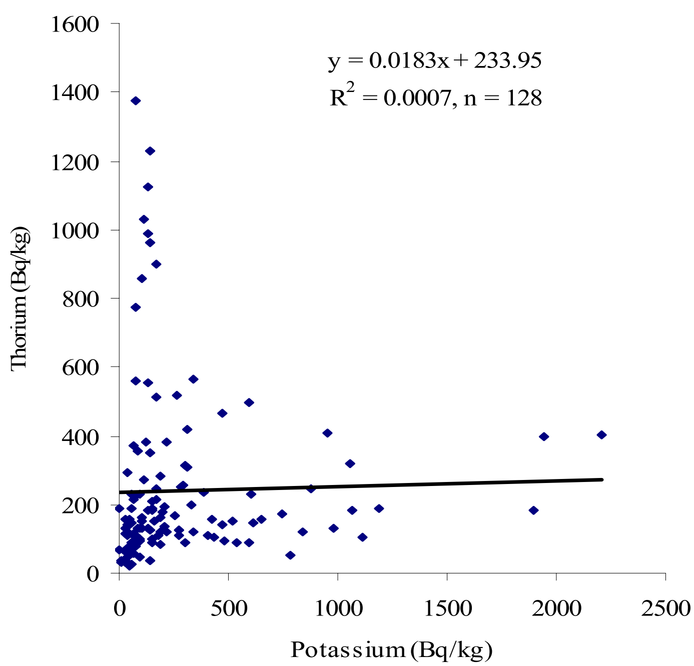

Figure B3.26 Correlation between potassium and thorium in soil

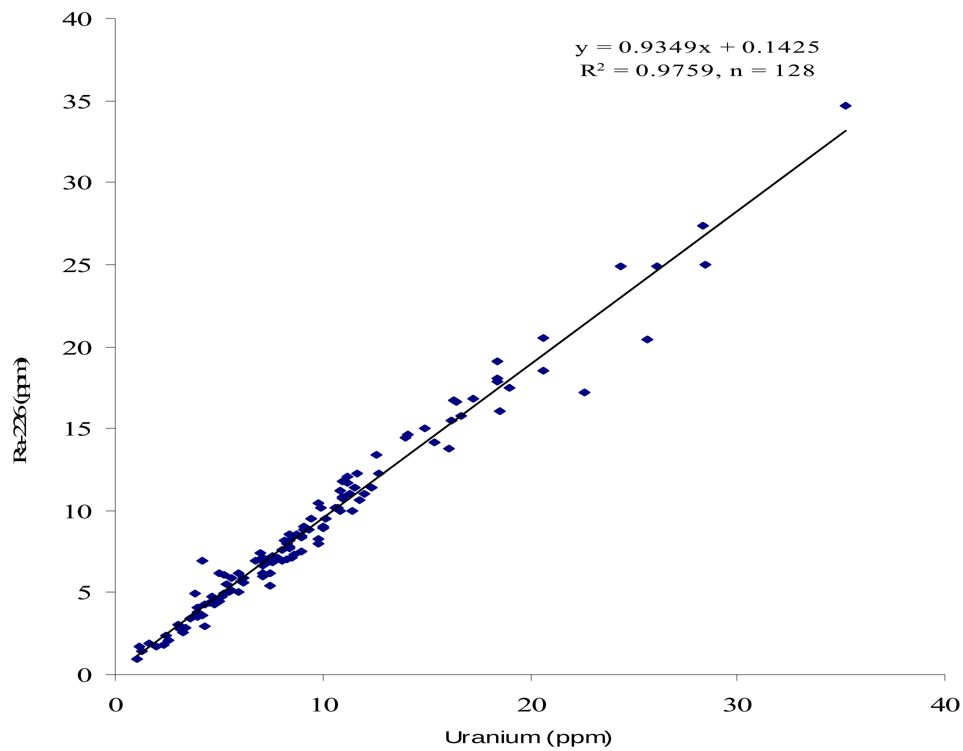

Figure B3.27 Correlation between ^{238}U and ^{226}Ra in soil

B3.16.3 Correlation between Gross Alpha, Gross Beta Activities and Dose Rate

The correlation coefficient between gross alpha activity, gross beta activity and total gross (alpha + beta) activity and dose rate are found to be 0.92 (R^2 = 0.8468) (Figure B3.28), 0.66 (R^2 = 0.4324) (Figure B3.29) and 0.89 (R^2 = 0.7951) (Figure B3.30) respectively. It is very interesting to see that both gross alpha activity and thorium activity have high correlation with dose rate. Their correlation coefficients are 0.92 and 0.94 respectively. For gross beta activity and uranium activity, their correlation coefficients are 0.66 and 0.63 respectively. The gross alpha and beta gross activity from the soil samples are the contribution from the thorium and uranium decay process.

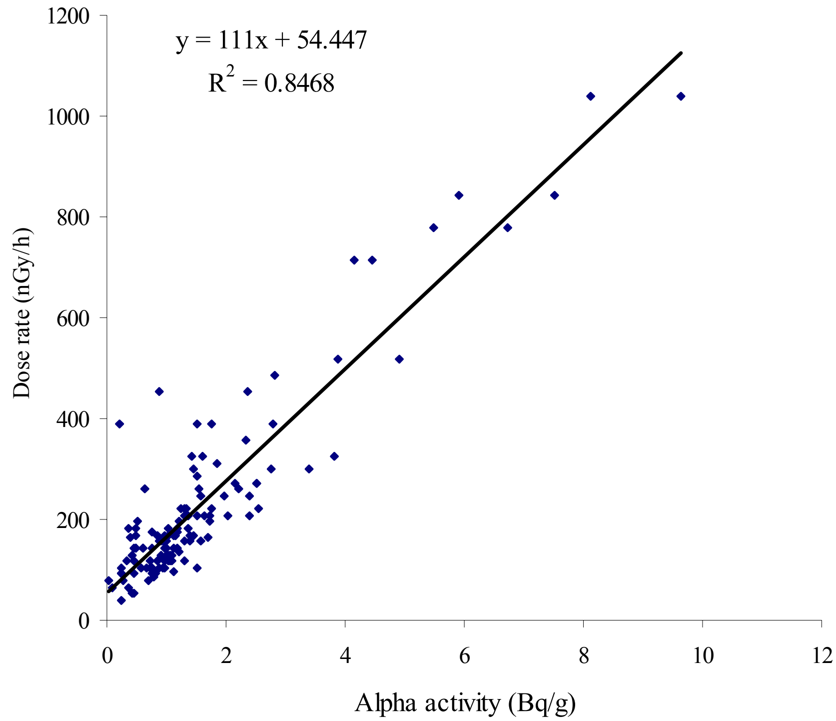

Figure B3.28 Correlation between gross alpha activity and dose rate

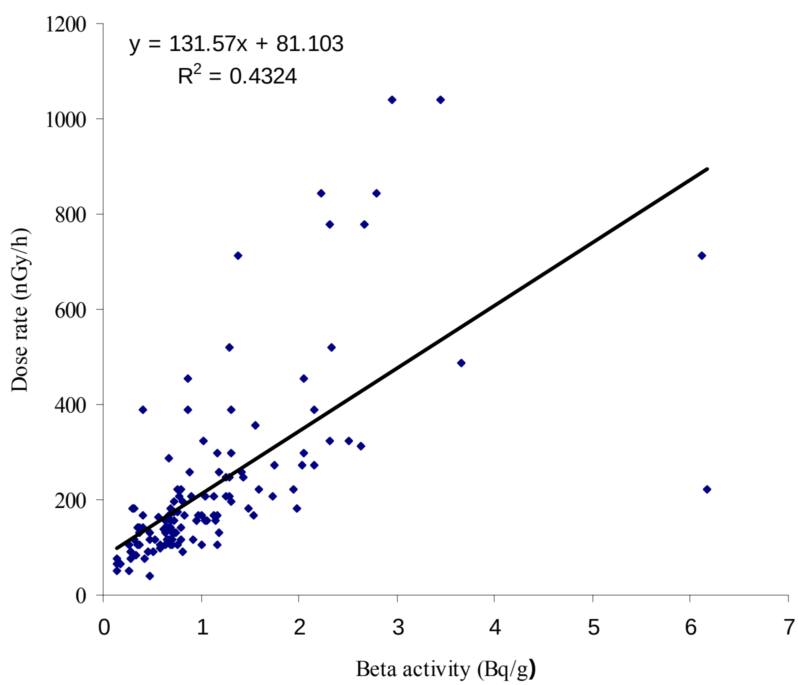

Figure B3.29 Correlation between gross beta activity and dose rate

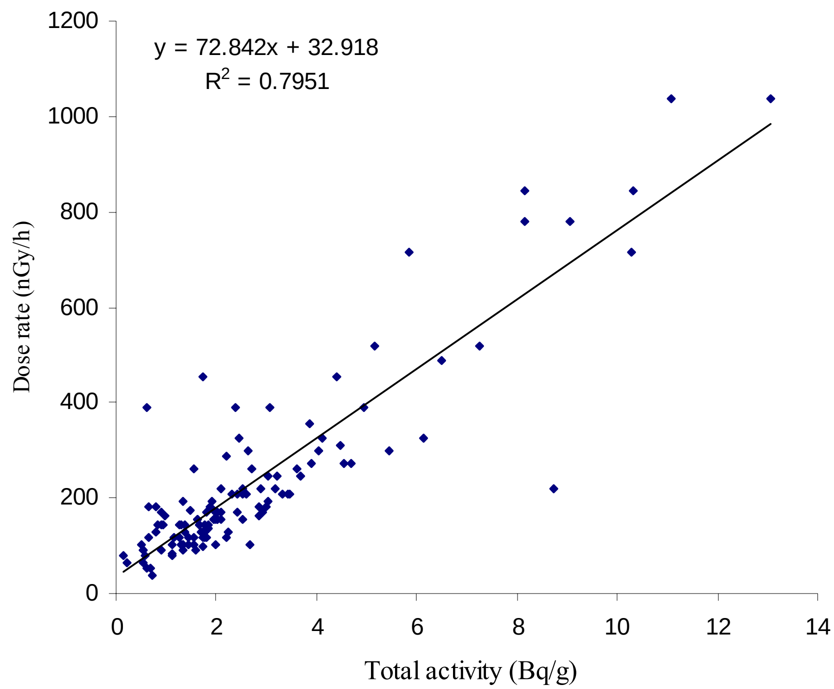

Figure B3.30 Correlation between total gross (alpha and beta) activity and dose rate

B3.17 Measurement of Radiation Levels at Amang Factories

We had visited several amang factories in the Kinta District in May and July 2003. We surveyed the factories and found that there is no proper place like office room. Amang by-products were ubiquitous. The compound was stored with piles of the by-products. The gamma radiation from these raw materials, monazite, zircon, ilmenite and waste sand were measured using the gamma-ray detector model 19, Micro R meter at a distance of about 30 cm away. All the upgrading plants visited are listed in Table B3.13, have background exposure rate readings between 260 nGy h^{-1} and greater than 50 μGy h^{-1} depending on the quantity and grade of the amang by-products.

Table B3.13 Amang plants in the Kinta District, Perak

Factory	Name of factory	Location
F1	BEH Mineral Sdn Bhd	Bukit Merah
F2	Sin Fook Lee & Co	Pusing
F3	Kim Yuan Amang Factory	Batu Gajah
F4	Sakuma Sdn Bhd	Tronoh
F5	Kilang Amang Tronoh	Tronoh
F6	Minex Amang Factory	Ipoh
F7	Ho Pak Yew	Batu Gajah
F8	Kinta Amang Dressing Plant Sdn Bhd	Kampar
F9	Syarikat Pendorong	Kampar
F10	Leong Sin Nam & Co	Kampar
F11	Kilang Amang Chee Ng Sdn Bhd	Kampar
F12	SEK Sdn Bhd	Kampar
F13	Kilang Hew Thian Fah & Sons	Kampar
F14	Kilang Amang Onn Sdn Bhd	Kampar
F15	Yoon Jaya Sdn Bhd	Kampar
F16	Hup Cheong Amang Retreatment Factory Sdn Bhd	Kampar
F17	TOR Mineral Sdn Bhd	Bukit Merah

The locations of the amang factories are shown in Figure B3.31. The exposure readings measured about 0.3 m from the monazite piles were greater than 50 μGy h^{-1}. These readings have exceeded the ICRP recommended value of 25 μGy h^{-1} for radiation worker. The workers used excavators to move the amang by-products for drying in the open sun. During the process the workers in the plants could be exposed to dangerously high levels of radiation. The radioactive gases, radon and thoron, are produced when uranium and thorium are present. The airborne particulates can cause inhalation hazards and lung cancer.

The thorium hydroxide is by-product obtain during the 'cracking' of monazite which is one of the associated minerals of tin. These thorium hydroxide stored outside the compound will seep into the ground water and contaminate the rivers in the Kinta District which would pose a danger to residents in the area (Sahabat Alam Malaysia, 1986).

During the visit, no workers wear any protective clothing or mask. Protective clothing and personnel monitor such as film badge should be worn. Proper shielding and storage are required at the plants. Continuous monitoring will ensure that ALARA is practice.

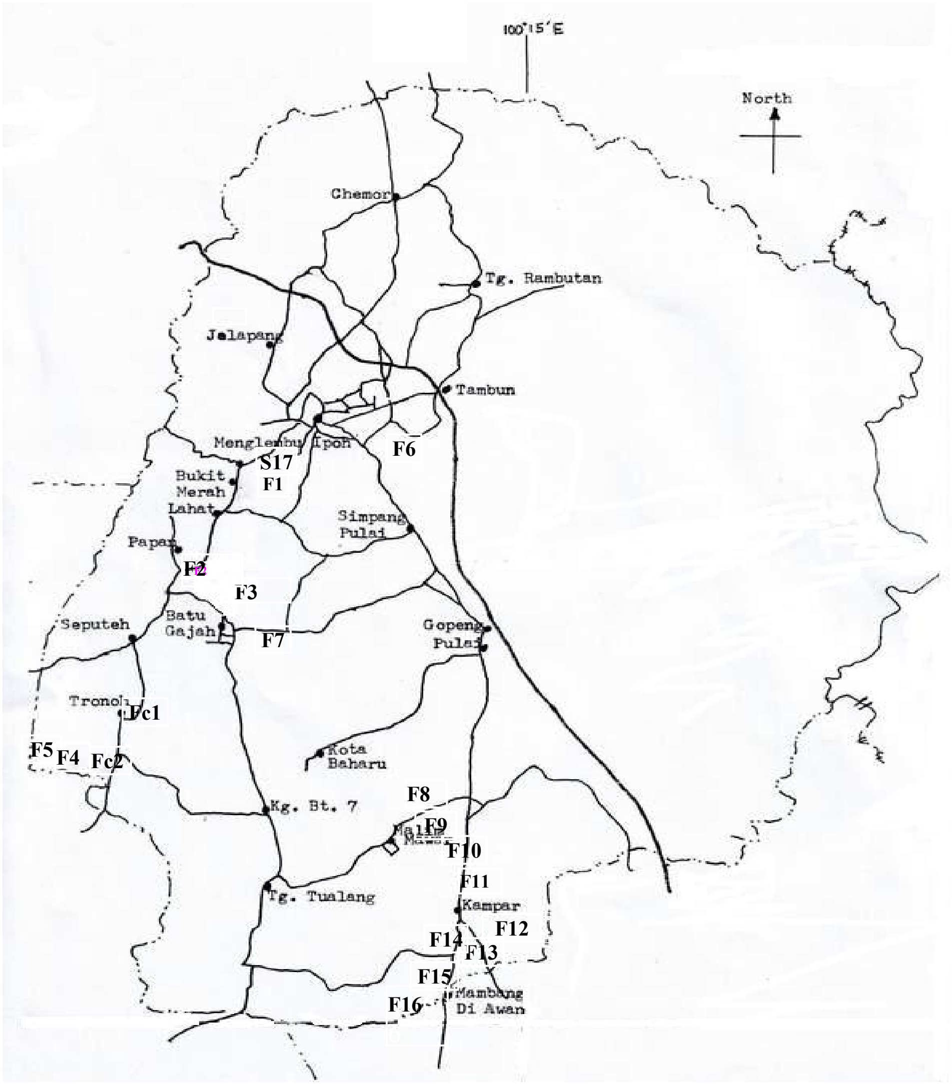

Figure B3.31 Location of Amang Factories

Legend:
F1 – BEH Mineral Sdn Bhd – Bukt Merah
F2 – Sin Fook Lee Co – Pusing
F3 – Kim Yuan Amang Factory – Batu Gajah
F4 – Sakuma Sdn Bhd – Tronoh
F5 – Kilang Amang Tronoh – Tronoh
F6 – Minex Amang Factory- Ipoh
F7 – Ho Pak Yew – Batu Gajah
F8 – Kinta Amang Dressing Plant Kampar
F9 – Syarikat Pendorong – Kampar
F10 – Leong Sin Nam & Co – Kampar
F11 – Kilang Amang Chee Ng Sdn Bhd –Kampar
F12 – SEK Sdn Bhd – Kampar
F14 – Kilang Amang Onn Sdn Bhd - Kampar
F15 – Yoon Jaya Sdn Bhd – Kampar
F16 – Hup Cheong Amang Retreatment Factory Sdn Bhd
F17 – TOR Mineral Sdn Bhd
Fc1 & Fc2 – Factories closed

B3.18 Measurement of Uranium and Thorium Concentrations in Amang Samples

Table B3.14 shows 38 samples were collected from 4 amang upgrading plants and a factory processing rutile from ilmenite.

Table B3.14 Samples collected from amang plants

Amang plants	Sample code	Number of sample
Sin Fook Lee & Co.	A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11 and A12	13
Sakuma Sdn Bhd	P1, P2, P3, and P4	4
Syarikat Kilang Amang Tronoh	B0, B1, B2, B3, B4 and B5	6
BEH Mineral Sdn Bhd	BM1, BM2, BM3, BM4, BM5, BM6, BM7, BM8, BM9, and BM10	10
TOR Mineral Sdn Bhd	T1, T2, T3, T4 and T5	5

The mineral has different grades as a result of different physical separation. The treatment involved and the radioactivity associated with each specimen depends on the grade of the minerals. The uranium activity level is deduced from the two ^{214}Pb peak at 352 keV and ^{214}Bi peak at 609 keV. The thorium activity level was obtained from the two clean peaks of ^{208}Tl at 583 keV and ^{228}Ac at 911 keV. The concentration of uranium and thorium ranges from 7 - 4025 ppm and 19 – 57949 ppm respectively (Table B3.15).

Table B3.15 Concentration of uranium and thorium from amang upgrading plants

Sample code	Description	Uranium, ppm	Thorium, ppm
A0	Raw amang	91 ± 8	232 ± 12
A1	Intermediate material (Large)	169 ± 12	668 ± 20
A2	Intermediate material (Medium)	207 ± 16	870 ± 25
A3	Intermediate material (Fine)	196 ± 15	1042 ± 28
A4	Combined intermediate material	276 ± 19	1336 ± 31
A5	Wet sand	21 ± 3	41 ± 7
A6	Ilmenite	148 ± 11	304 ± 12
A7	Zircon, low grade ilmenite	391 ± 27	2179 ± 45
A8	Zircon, monazite and xenotime	911 ± 59	5995 ± 96
A9	Monazite, less Zircon	1334 ± 85	11221 ± 158
A10	Zircon 62% interlock monazite	953 ± 60	350 ± 16
A11	Monazite	2343 ± 150	57949 ± 688
A12	Dry sand	51 ± 5	170 ± 11
P1	Raw amang	244 ± 17	399 ± 16
P2	Tin, zircon, monazite, etc	147 ± 11	315 ± 15
P3	Ilmenite	287 ± 20	552 ± 18
P4	Sand	38 ± 4	47 ± 6
T1	Raw Ilmenite	181 ± 13	163 ± 9
T2	Reduced ilmenite	220 ± 16	201 ± 10
T3	Leached ilmenite	57 ± 5	74 ± 8
T4	Iron oxide	320 ± 27	364 ± 34
T5	Synthetic rutile	49 ± 5	68 ± 8
B0	Raw amang	82 ± 7	166 ± 10
B1	Intermediate material	200 ± 14	546 ± 16
B2	Sand	78 ± 6	129 ± 8
B3	Monazite	4025 ± 244	9300 ± 134
B4	Ilmenite	211 ± 15	554 ± 16
B5	Zircon	1027 ± 65	340 ± 14
BM1	Raw amang	379 ± 25	1510 ± 33
BM2	Sand	97 ± 8	214 ± 10
BM3	More zircon , monazite, xenotime	1144 ± 72	9935 ± 139
BM4	More monazite, xenotime, zircon	1475 ± 92	16913 ± 221
BM5	Ilmenite	248 ± 17	341 ± 14
BM6	Monazite	2277 ± 146	55353 ± 666
BM7	Zircon	1179 ± 74	561 ± 21
BM8	Cassiterite	40 ± 4	65 ± 5
BM9	Rutile	71 ± 6	111 ± 8
BM10	Tourmaline	7 ± 2	19 ± 6

For radioactive minerals such as monazite and zircon from each plant in ppm are listed in Table B3.16 and kBq kg^{-1} in Table B3.17. Also included are ilmenite, iron oxide and rutile. Samples from different plants show that monazite and zircon samples have high concentration of uranium and thorium where as ilmenite, rutile and iron oxide have low concentration of uranium and thorium. The ilmenite, rutile and iron oxide are non-radioactive, the gamma activity measured is possibly due to the contamination of other radioactive minerals. Rutile (TiO_2) is obtained from processing ilmenite and has a very low gamma activity.

Table B3.16 Concentration of uranium and thorium from amang plants

Factory	Description	Uranium, ppm	Thorium, ppm
Sin Fook Lee & Co	Ilmenite Zircon Monazite	148 ± 11 953 ± 60 2343 ± 150	304 ± 12 350 ± 16 57949 ± 688
Syarikat Kilang Amang Tronoh	Ilmenite Zircon Monazite	211 ± 15 1027 ± 65 4025 ± 244	544 ± 16 340 ± 14 9300 ± 134
BEH Mineral Bhd	Ilmenite Zircon Monazite Rutile	248 ± 17 1179 ± 74 2277 ± 146 71 ± 6	341 ± 14 561 ± 21 55353 ± 666 111 ± 8
Sakuma Sdn Bhd	Ilmenite Tin, zircon, monazite	244 ± 17 287 ± 20	399 ± 16 552 ± 18
TOR Mineral Sdn Bhd	Ilmenite Iron Oxide Rutile	181 ± 13 320 ± 27 49 ± 5	163 ± 9 364 ± 34 68 ± 8

Comparing the mean of these results for thorium activity with Hu, (1984) in bracket, Monazite 164.8 (265.0) kBq kg^{-1}, Zircon 1.7 (33.0) kBq kg^{-1}, Ilmenite 1.6 (10.5) kBq kg^{-1} and for uranium are Monazite 35.4 (43.2) kBq kg^{-1}, Zircon 13.0 (18.2) kBq $kg^{-1}$and ilmenite 2.6 (8.2) kBq kg^{-1} . The results of this project shows the activity is comparatively lower could be due to the lower grade of the minerals.

Table B3.17 Specific activity of amang minerals

Factory	Description	Uranium, kBq kg^{-1}	Thorium, kBq kg^{-1}
Sin Fook Lee & Co	Ilmenite Zircon Monazite	1.8 ± 0.1 11.7 ± 0.7 22.8 ± 1.9	1.2 ± 0.1 1.4 ± 0.1 223.7 ± 2.8
Syarikat Kilang Amang Tronoh	Ilmenite Zircon Monazite	2.6 ± 0.2 12.6 ± 0.8 49.5 ± 3.0	2.2 ± 0.1 1.4 ± 0.1 37.5 ± 0.6
BEH Mineral Bhd	Ilmenite Zircon Monazite Rutile	3.0 ± 0.2 14.5 ± 0.9 28.0 ± 1.8 0.9 ± 0.1	1.4 ± 0.1 2.3 ± 0.1 223.2 ± 2.7 0.44 ± 0.1
Sakuma Sdn Bhd	Ilmenite Tin, zircon, monazite	3.5 ± 0.3 1.8 ± 0.1	2.2 ± 0.1 1.3 ± 0.1
TOR Mineral Sdn Bhd	Ilmenite Iron Oxide Rutile	2.22 ± 0.1 3.9 ± 0.3 0.6 ± 0.1	0.7 ± 0.1 1.5 ± 0.1 0.3 ± 0.1

Table B3.18 shows the average specific activity of the minerals. Monazite has the highest specific activity of 200.6 kBq kg^{-1}, zircon has a higher specific activity in uranium than thorium i.e. 13.0 compare to 1.7 kBq kg^{-1}, ilmenite has the low activity of 4.2 kBq kg^{-1} for thorium another major constituents of the amang by-products. Monazite has high Th/U ratio of 14.2. Zircon and Ilmenite have low Th/U ratios are due to low thorium content.

Table B3.18 Gamma activities of minerals from amang samples

Mineral	Activity (kBq kg^{-1})			Th/U
	Uranium	Thorium	Total	
Monazite	35.4 ± 2.2	164.8 ± 2.0	200.2 ± 2.9	4.7
Zircon	13.0 ± 0.8	1.7 ± 0.1	14.7 ± 0.8	0.1
Ilmenite	2.6 ± 0.1	1.6 ± 0.1	4.2 ± 0.1	0.6

The bar charts of Figures B3.32 and B3.33 show the distribution of the specific activity of uranium and thorium in ilmenite, zircon and monazite samples from three factories respectively. Specific activity of uranium is high in zircon and monazite samples. Very high specific activity of thorium is found in monazite sample and very low in ilmenite and zircon minerals.

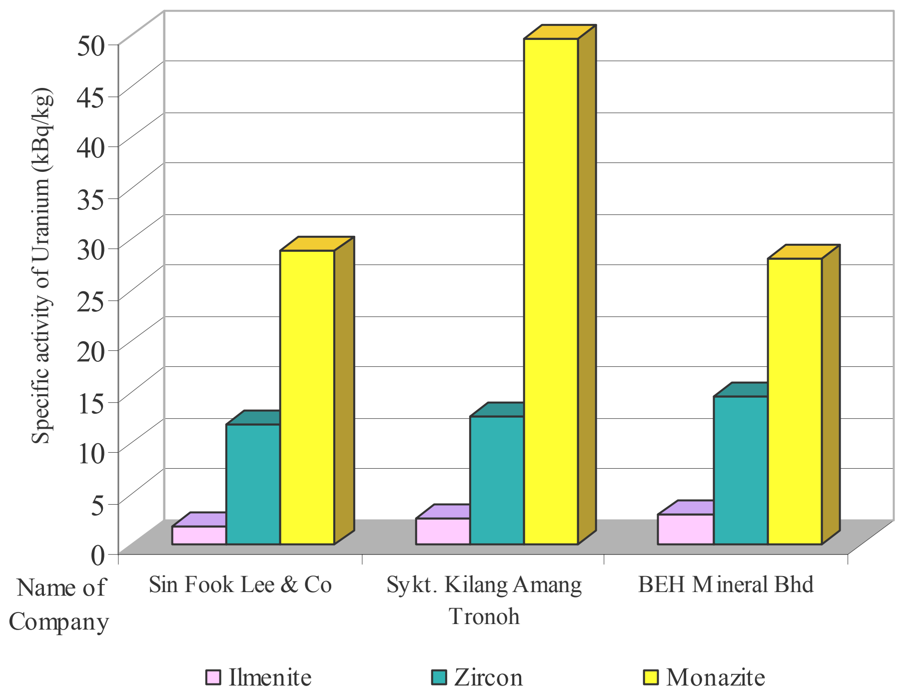

Figure B3.32 Specific activity of uranium in ilmenite, zircon and monazite samples

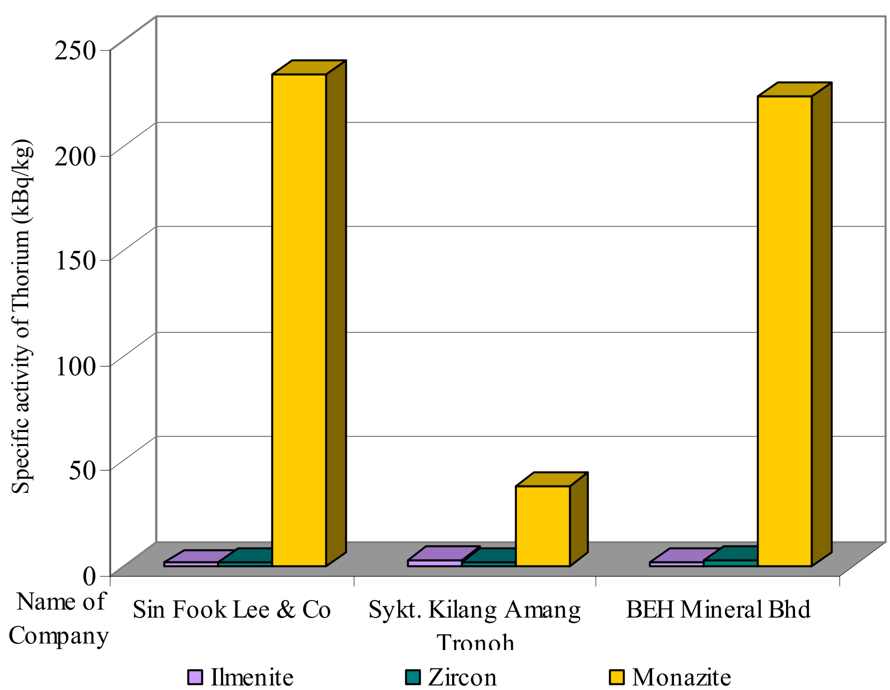

Figure B3.33 Specific activity of thorium in ilmenite, zircon and monazite samples

B3.19 Measurement of Gross Alpha and Gross Beta Activities from Minerals in Amang Samples

From Table B3.19 shows six different minerals taken from BEH Mineral Sdn were analyzed for gross alpha and gross beta activities. The bar chart of Figure B3.34 shows the distribution of the specific activities of gross alpha and gross beta among the minerals. The gross alpha and gross beta activities for monazite are about 11 and 9 times higher than zircon respectively. The rest of the minerals have extremely low radioactivity.

Table B3.19 Gross alpha and gross beta activities from minerals in amang samples

Minerals	Activity (kBq kg^{-1}) Gross alpha	Gross beta
Monazite	740	576
Zircon	62	60
Ilmenite	12	12
Cassiterite	4	3
Rutile	5	4
Tourmaline	1	0

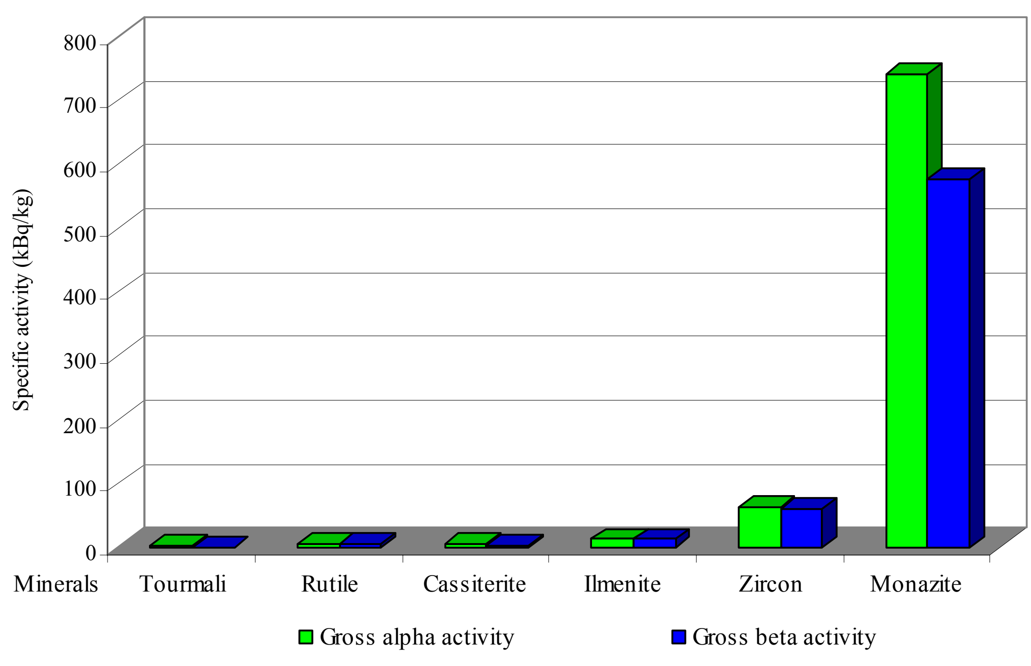

Figure B3.34 Bar chart of gross alpha and gross beta activities from minerals in amang samples

B3.20 Measurements at the Radioactive Waste Storage Site

We had visited the radioactive waste storage site at the Kledang Range in May 2003 together with some officers from Atomic Energy Licensing Board (AELB). Some measurements were taken around the building and on the flat roof top. The roof top is covered with soil and grass was grown on it. A total of 8 readings were taken are shown in Figure B4.35. I was told that some radioactive waste have been stored at the left hand corner of the building close to location #4. Measurements at locations from #1 - #3 are on the ground and #4 - #8 are at the roof top. Outside the gate, the dose rate was 195 nGy h^{-1}. The building was fenced up and some TLDs were seen placed at strategic locations by the AELB staff.

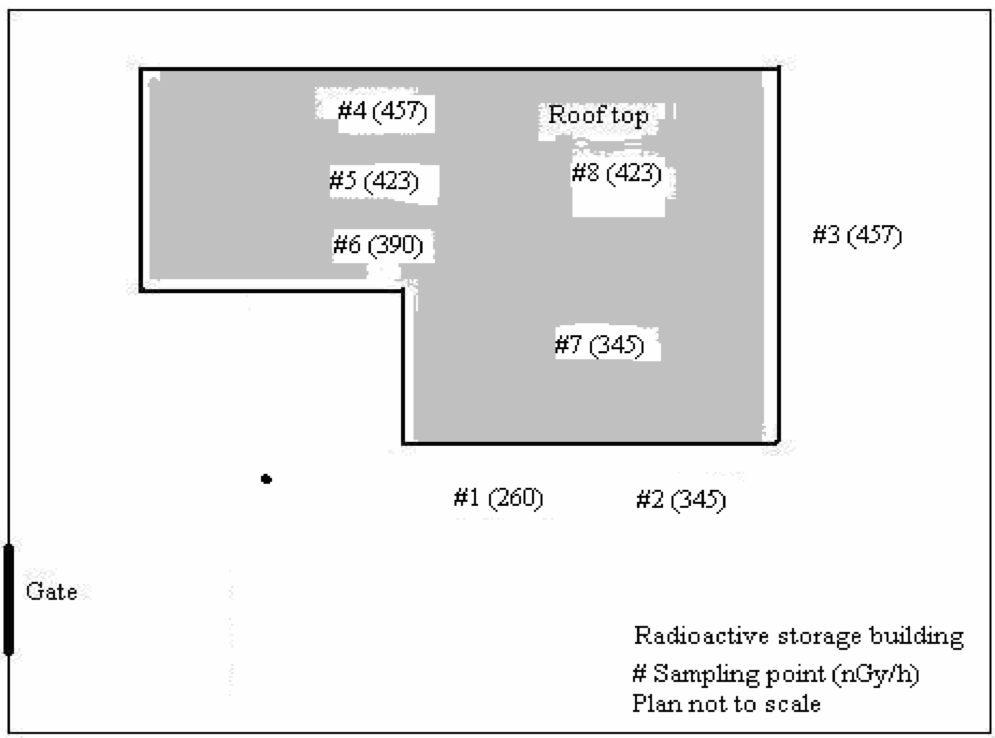

Figure B3.35 Storage building at the Kledang Range.

B3.21 Isodose Contour Map

The isodose contour map for dose rates was plotted using the SURFER software version 6. By overlapping the isodose contour on the geological map and soil map of the Kinta District are shown in Figures B3.36 and B3.37 respectively. It shows the dose rate contour lines at 50, 100, 150, 200, 250, 300, 400, 600, 800 and 1000 nGy h^{-1}. On the steep land at the Kledang Range on the west of the District, the contours lines run parallel along the slope. The two areas where the dose rates of 1039 nGy h^{-1} are located in areas of granitic basement rock in Kampung Sungai Durian. It is the highest dose rate recorded in Perak to date.

Figure B3.38 shows the 3D dose rate profile for the Kinta District. The height indicates the intensity of the dose rate. High dose rates areas in Tg. Tualang show some prominent peaks and for low dose rate areas are indicated by the lower ground or valley.

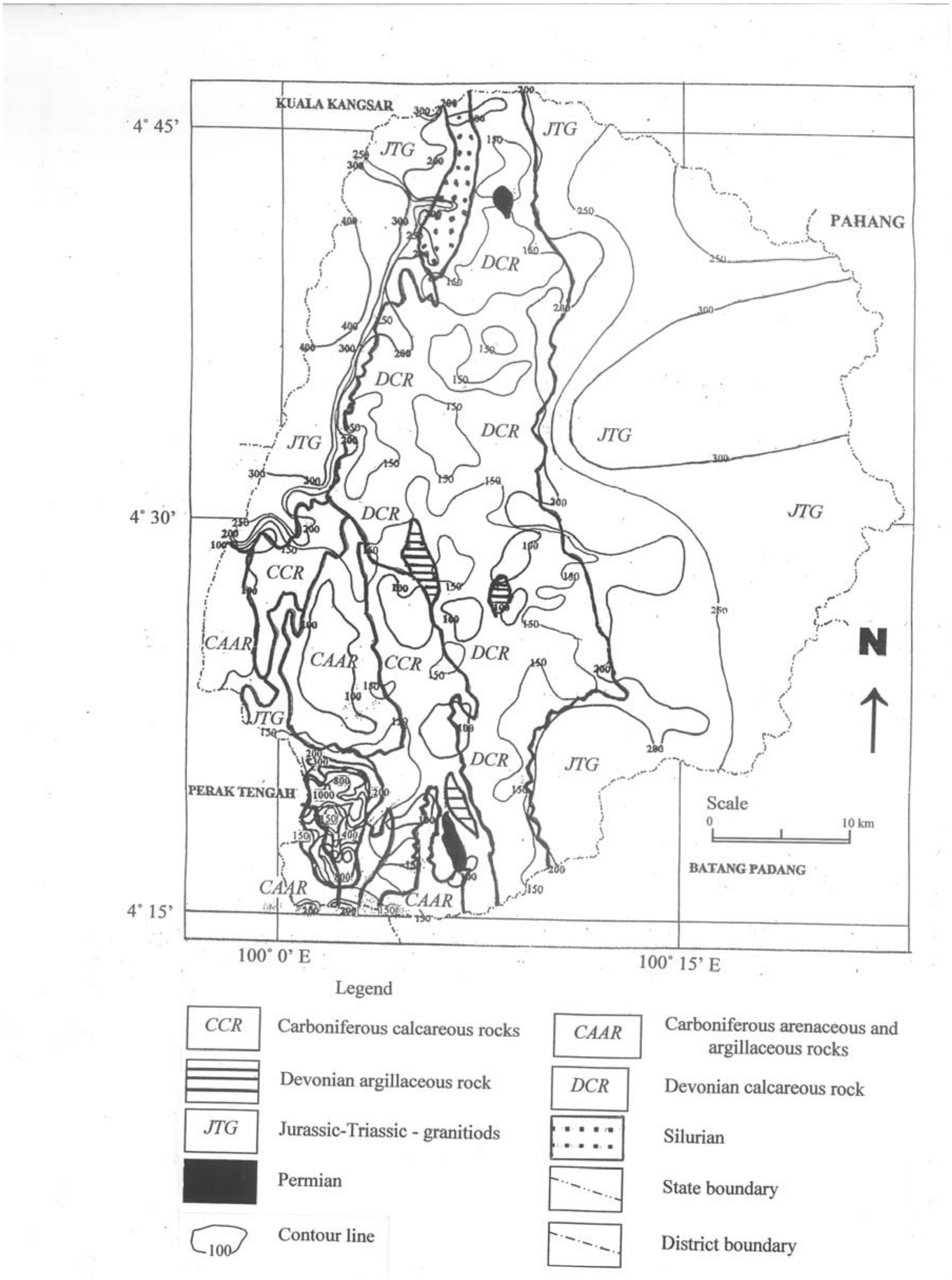

Figure B3.36 The isodose contour and geological types for the Kinta District

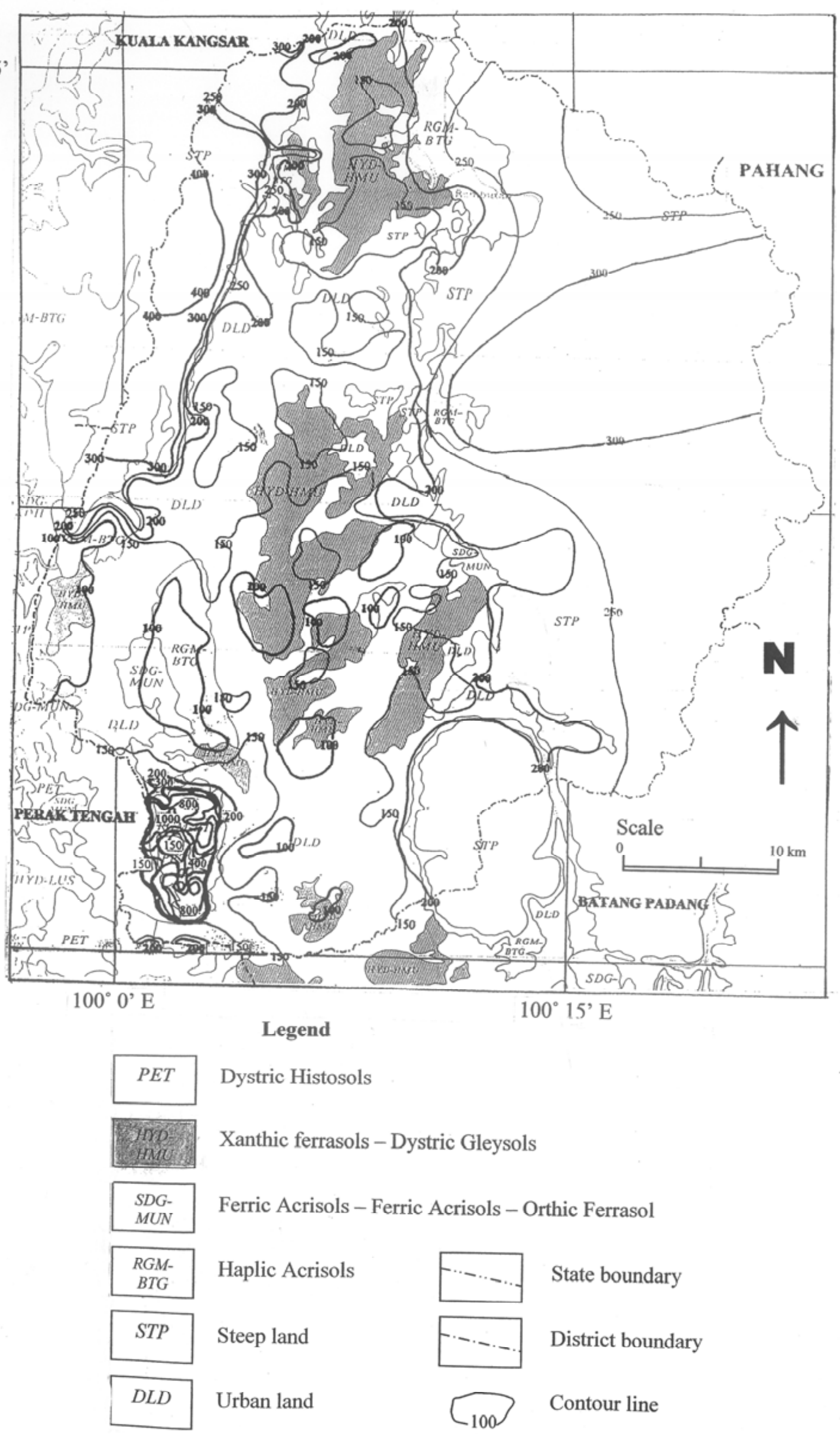

Figure B3.37 The isodose contour and soil types for the Kinta District

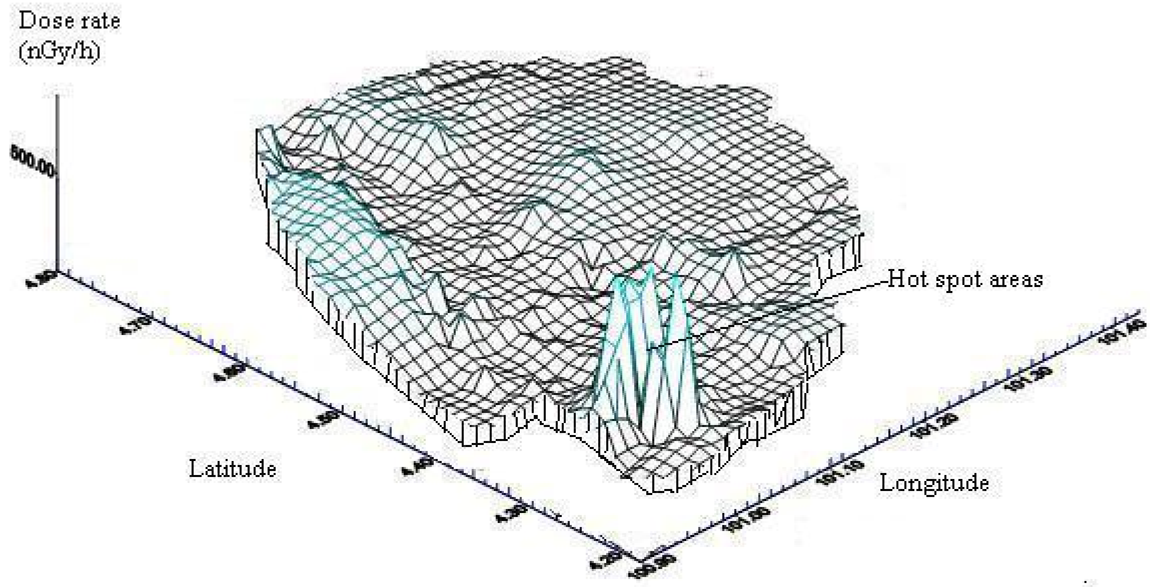

Figure B3.38 3D dose rate profile for the Kinta District

CHAPTER BIV

B4. CONCLUSIONS

B4.1 Conclusions

From the results obtained the following conclusions are made:

The gamma dose rates in the Kinta District are in the range from 39 to 1039 nGy h^{-1}; the wide range is mainly due to different soil types and geological types. Figure B3.38 shows the 3D dose rate profile for the Kinta District. The District is underlain by sedimentary rocks and the radiation level is lower than the granitic rocks from the Kledang Range and the Main Range. It is well known fact that metamorphic rocks are more radioactive than the sedimentary ones.

The average of the gamma dose rate in the Kinta District is 222 ± 191 nGy h^{-1} (1.36 mSv y^{-1}) which two times over the Malaysian average (92 nGy h^{-1}) and about 3 times over the world average (59 nGy h^{-1}).

The mean dose rate in *mukim* M3, M4 and M7 are lower than 1 mSv y^{-1} whereas *mukim* M1, M2, and M5 are slightly above 1mSv y^{-1}. *Mukim* M5, Tg. Tualang is 1.36 mSv y^{-1} are due to the ground materials are derived from different soil types and geological types. The mean population weighted dose rate for the Kinta District is 1.12 mSv y^{-1}.

The two high radiation areas or hot spots recorded 1039 nGy h^{-1} in Kampung Sungai Durian are due to the high activity of uranium and thorium. The lowest dose rate of 39 nGy h^{-1} was located at *Ladang Lembah Kinta* near Chenderong town in *mukim* Tg. Tualang. Technologically enhanced radiation is excluded.

From the data obtained, except for soil type 10, the mean dose rates for soil type 48 > soil type 49 > soil types18 and 50 > soil type 31. Different geological types exhibit different values of the mean dose rates with Jurassic-Triassic > Silurian > Devonian > Carboniferous > Permian. From the results obtained, it is possible to predict the gamma dose rates based on the soil types and geological types. We conclude that the dose rate varies with the geology of the surface soil.

The results of activity of naturally occurring radionuclides in soil samples in the Kinta District vary significantly from place to place are given in Table B3.11. For the measured gamma ray spectra from soil samples, activity concentrations were determined for ^{238}U (range from 12 to 426 Bq kg^{-1}), ^{232}Th (from 19 to 1377 Bq kg^{-1}) and ^{40}K (from less than 19 to 2204 Bq kg^{-1}). Kinta District average concentrations of 112 ± 18, 246 ± 21, and 277 ± 127 Bq kg^{-1} are for ^{238}U, ^{232}Th, and ^{40}K respectively. The ^{40}K is low compared to the world average. World average concentrations of 33, 45, and 420 Bq kg^{-1} are for ^{238}U, ^{232}Th, and ^{40}K respectively (UNSCEAR, 2000). It should be noted that none of the 128 soil samples analyzed, ^{137}Cs peak at 662 keV was found.

The calculated absorbed dose rate and the measured dose rates are linear. The correlation coefficient is found to be 0.94. This shows that the gamma absorbed dose rate in air calculated using the results of activity concentration of ^{238}U, ^{232}Th and ^{40}K are found to compare well with that of the direct measurement.

The results of analyses of soil samples showed that the contents of radionuclides in soils of high natural background dose rates were significantly higher than those in lower natural background dose rates.

It is very interesting to see that the gross alpha activity and thorium activity are closely related to the dose rate. Their correlation coefficients are 0.92 and 0.94 respectively. From the graph obtained we can successfully predict the alpha activity and thorium activity in soil samples from the dose rate measurements. It can also be said that for gross beta activity and uranium activity. Their correlation coefficients are 0.66 and 0.63 respectively.

The activity of gross alpha and gross beta from the soil samples are contributions from uranium and thorium decay series. The mean gross alpha activity of 1558 ± 121 Bq kg^{-1} is higher than the mean gross beta activity of 1112 ± 32 Bq kg^{-1} for the soil samples.

Measurements carried out at the amang factory sites showed that the radiation levels in the mineral processing factories could be significant in the case of long term occupation exposure. Monazite should be kept in store room with proper containers. Effluents discharge to the rivers should be checked.

Survey meters are necessary to measure the radiation level in any area and hence can be used to indicate how safe any area is. It is most important to choose the correct instrument according to the type of measurement to be made and the radiation to be measured and detected. Again it is most important to test that any instrument is functioning properly, i.e. send to The Malaysian Institute for Nuclear Technology Research (MINT) for calibration yearly. The present work will be a valuable guide for future survey to be carried in other states in the country.

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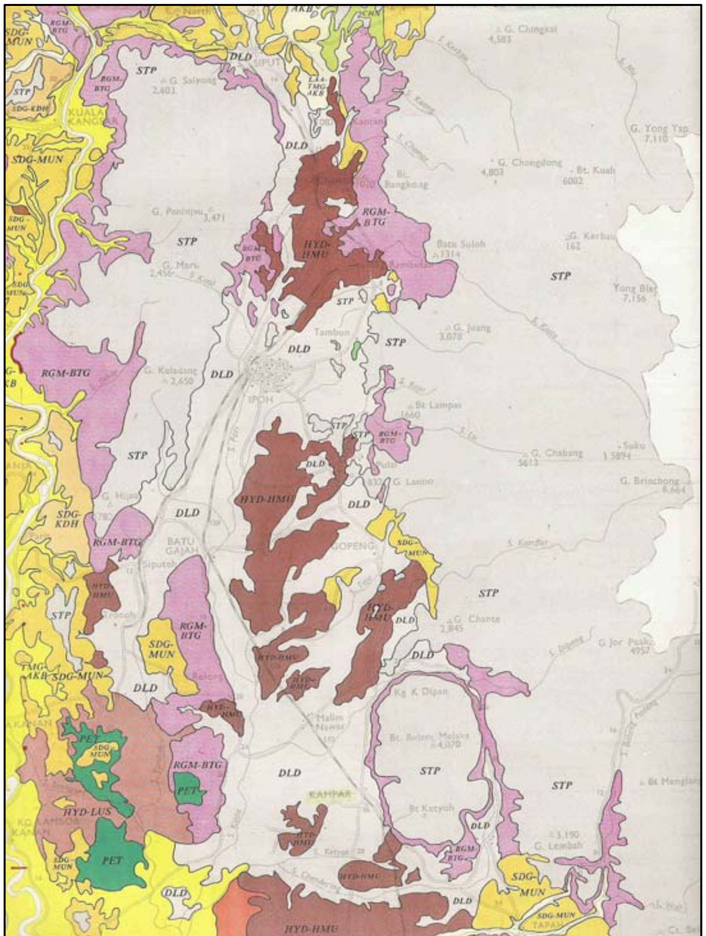
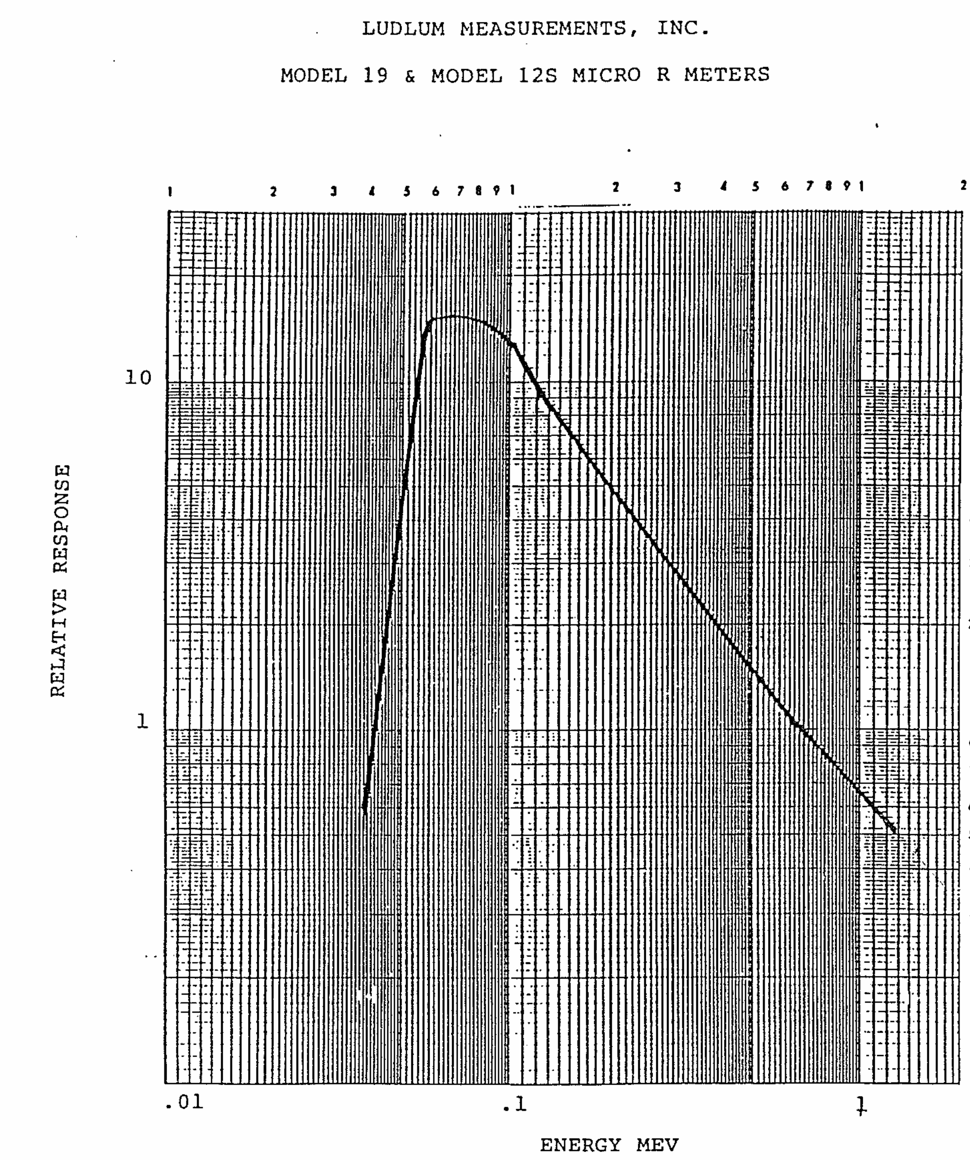
LIST OF APPENDIES

APPENDIX A : Soil Types Found in the Kinta District

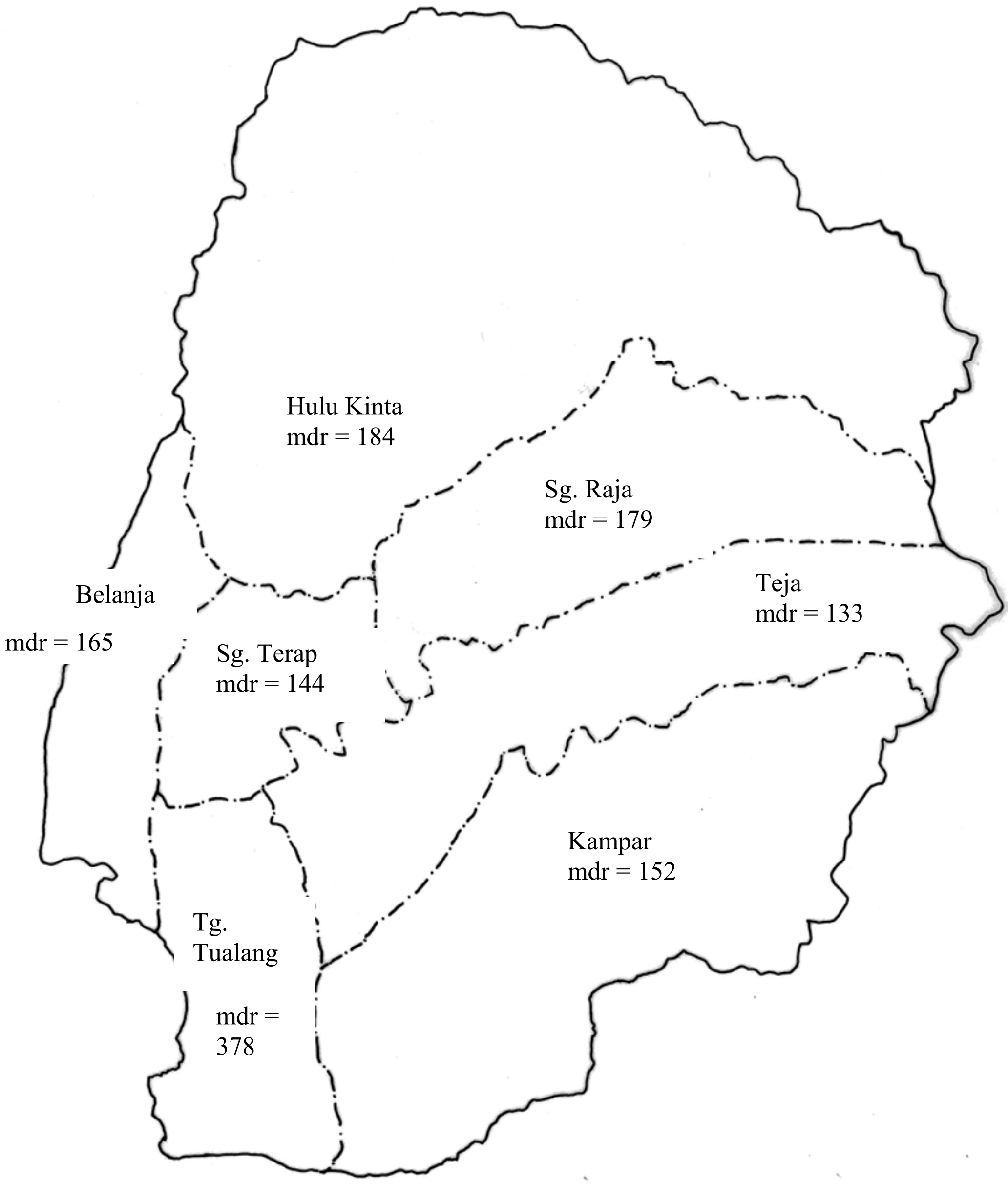


Parent Material	Soil Type	Soil Mapping Unit	Map Symbol
Organic Deposits	10	Peat	PET
Subrecent and Older Alluvium	18	Holyrood-Harimau	HYD-HMU
Shales, Sandstones and Schists	31	Serdang-Munchong	SDG-MUN
Granites	48	Rengam-Bukit-Temiang	RGM-BTG
Miscellaneous Land Units	49	Disturbed Land	DLD
	50	Steep Land	STP

APPENDIX B: Energy Response of Model 19 Micro R Meters.

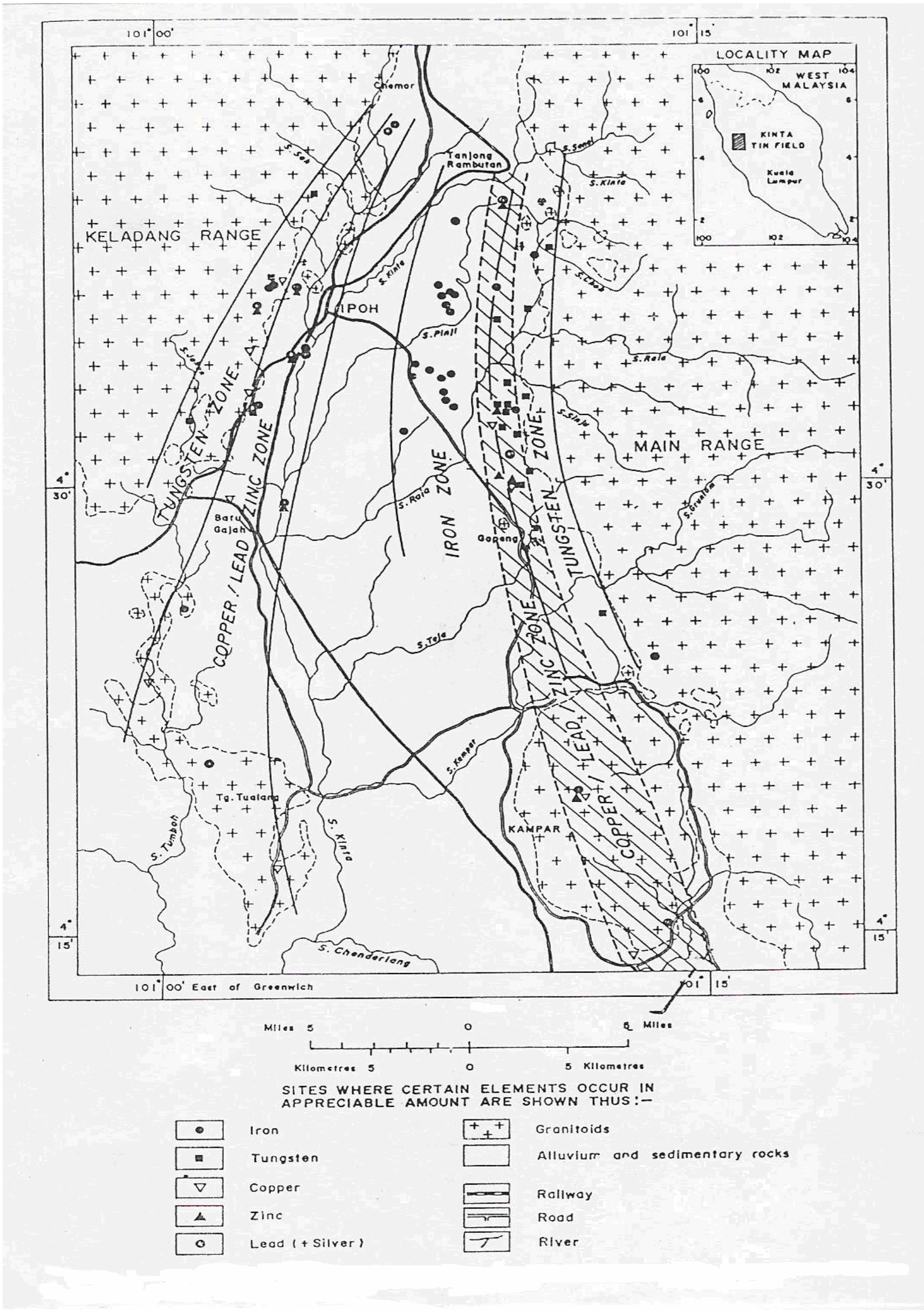


APPENDIX C: **Mean dose rate for each *mukim***



mdr = mean dose rate (nGy h^{-1})

APPENDIX D: Mineral Map of the Kinta District



APPENDIX E: Dose rate measurements

No.	Longitude	Latitude	Measured dose rate μR h^{-1}	nGy h^{-1}	Corrected dose rate nGy h^{-1}
1	E 101° 08.203’	N 04° 32.132’	26	226	169
2	E 101° 10.428’	N 04° 33.015’	38	331	247
3	E 101° 14.912’	N 04° 34.319’	46	400	299
4	E 101° 20.011’	N 04° 34.013’	36	313	234
5	E 101° 01.068’	N 04° 22.770’	16	139	104
6	E 101° 01.963’	N 04° 22.211’	18	157	117
7	E 101° 02.967’	N 04° 14.932’	28	244	182
8	E 101° 02.503’	N 04° 15.040’	42	365	272
9	E 101° 02.684’	N 04° 19.238’	120	1044	779
10	E 101° 01.971’	N 04° 19.057’	28	244	182
11	E 101° 02.160’	N 04° 19.030’	34	296	221
12	E 101° 02.356’	N 04° 19.006’	90	783	585
13	E 101° 02.729’	N 04° 19.471’	80	696	520
14	E 101° 03.290’	N 04° 19.695’	60	522	390
15	E 101° 04.441’	N 04° 16.820’	28	244	182
16	E 101° 07.188’	N 04° 16.729’	12	104	78
17	E 101° 06.727’	N 04° 16.242’	14	122	91
18	E 101° 05.718’	N 04° 38.490’	18	157	117
19	E 101° 06.151’	N 04° 39.081’	22	191	143
20	E 101° 06.866’	N 04° 39.928’	28	244	182
21	E 101° 07.244’	N 04° 40.941’	28	244	182
22	E 101° 07.332’	N 04° 42.231’	22	191	143
23	E 101° 07.250’	N 04° 43.331’	28	244	182
24	E 101° 07.176’	N 04° 44.114’	30	261	195
25	E 101° 06.945’	N 04° 45.400’	32	278	208
26	E 101° 08.900’	N 04° 43.229’	22	191	143
27	E 101° 09.297’	N 04° 42.511’	24	209	156
28	E 101° 09.671’	N 04° 42.267’	34	296	221
29	E 101° 09.046’	N 04° 42.251’	20	174	130
30	E 101° 09.763’	N 04° 40.660’	30	261	195
31	E 101° 10.347’	N 04° 41.180’	36	313	234
32	E 101° 11.069’	N 04° 41.513’	70	609	455
33	E 101° 11.058’	N 04° 41.518’	50	435	325
34	E 101° 11.677’	N 04° 41.616’	44	383	286
35	E 101° 09.399’	N 04° 40.220’	30	261	195
36	E 101° 09.835’	N 04° 39.275’	22	191	143
37	E 101° 10.631’	N 04° 39.676’	30	261	195
38	E 101° 11.898’	N 04° 40.113’	22	191	143
39	E 101° 11.661’	N 04° 40.320’	26	226	169

40	E 101° 12.060’	N 04° 40.632’	38	331	247
41	E 101° 12.111’	N 04° 40.715’	32	278	208
42	E 101° 10.224’	N 04° 39.020’	24	209	156
43	E 101° 10.368’	N 04° 38.337’	42	365	272
44	E 101° 10.402’	N 04° 38.074’	30	261	195
45	E 101° 10.711’	N 04° 38.086’	18	157	117
46	E 101° 08.644’	N 04° 30.878’	34	296	221
47	E 101° 08.790’	N 04° 30.998’	28	244	182
48	E 101° 08.786’	N 04° 30.437’	38	331	247
49	E 101° 09.138’	N 04° 30.327’	22	191	143
50	E 101° 09.259’	N 04° 30.432’	34	296	221
51	E 101° 10.647’	N 04° 27.929’	26	226	169
52	E 101° 11.321’	N 04° 27.633’	28	244	182
53	E 101° 11.632’	N 04° 27.373’	34	296	221
54	E 101° 12.441’	N 04° 27.523’	48	418	312
55	E 101° 12.808’	N 04° 27.308’	44	383	286
56	E 101° 12.799’	N 04° 27.351’	28	244	182
57	E 101° 13.157’	N 04° 27.714’	20	174	130
58	E 101° 13.699’	N 04° 28.149’	26	226	169
59	E 101° 13.306’	N 04° 27.941’	26	226	169
60	E 101° 11.384’	N 04° 27.325’	24	209	156
61	E 101° 10.971’	N 04° 26.784’	24	209	156
62	E 101° 11.347’	N 04° 26.447’	20	174	130
63	E 101° 11.609’	N 04° 26.680’	26	226	169
64	E 101° 10.157’	N 04° 26.878’	22	191	143
65	E 101° 10.194’	N 04° 26.056’	24	209	156
66	E 101° 10.650’	N 04° 25.853’	26	226	169
67	E 101° 11.069’	N 04° 25.455’	22	191	143
68	E 101° 11.242’	N 04° 24.988’	30	261	195
69	E 101° 10.272’	N 04° 24.652’	10	87	65
70	E 101° 09.604’	N 04° 22.740’	30	261	195
71	E 101° 10.762’	N 04° 23.295’	22	191	143
72	E 101° 09.121’	N 04° 30.145’	28	244	182
73	E 101° 09.458’	N 04° 30.118’	40	348	260
74	E 101° 10.045’	N 04° 30.313’	36	313	234
75	E 101° 10.229’	N 04° 30.607’	30	261	195
76	E 101° 07.948’	N 04° 32.474’	10	87	65
77	E 101° 07.876’	N 04° 32.320’	30	261	195
78	E 101° 07.876’	N 04° 32.475’	10	87	65
79	E 101° 09.094’	N 04° 32.288’	26	226	169
80	E 101° 10.155’	N 04° 33.315’	44	383	286
81	E 101° 10.490’	N 04° 33.395’	38	331	247
82	E 101° 10.124’	N 04° 33.428’	48	418	312
83	E 101° 10.675’	N 04° 33.432’	42	365	272
84	E 101° 11.455’	N 04° 33.653’	30	261	195

85	E 101° 12.675’	N 04° 34.039’	40	348	260
86	E 101° 14.881’	N 04° 34.317’	46	400	299
87	E 101° 14.995’	N 04° 34.553’	50	435	325
88	E 101° 17.972’	N 04° 33.257’	28	244	182
89	E 101° 18.361’	N 04° 33.274’	22	191	143
90	E 101° 15.169’	N 04° 34.415’	36	313	234
91	E 101° 11.418’	N 04° 33.539’	32	278	208
92	E 101° 10.156’	N 04° 33.249’	32	278	208
93	E 101° 08.025’	N 04° 31.872’	26	226	169
94	E 101° 06.956’	N 04° 32.161’	20	174	130
95	E 101° 07.213’	N 04° 32.354’	26	226	169
96	E 101° 09.488’	N 04° 29.455’	12	104	78
97	E 101° 09.888’	N 04° 29.701’	10	87	65
98	E 101° 10.246’	N 04° 29.664’	34	296	221
99	E 101° 10.245’	N 04° 29.468’	18	157	117
100	E 101° 10.218’	N 04° 28.997’	22	191	143
101	E 101° 10.451’	N 04° 28.566’	22	191	143
102	E 101° 10.910’	N 04° 28.141’	14	122	91
103	E 101° 11.245’	N 04° 28.619’	20	174	130
104	E 101° 11.279’	N 04° 28.453’	18	157	117
105	E 101° 10.863’	N 04° 27.990’	44	383	286
106	E 101° 10.433’	N 04° 28.000’	18	157	117
107	E 101° 09.644’	N 04° 22.667’	28	244	182
108	E 101° 10.461’	N 04° 22.744’	28	244	182
109	E 101° 10.963’	N 04° 23.404’	22	191	143
110	E 101° 11.816’	N 04° 23.619’	22	191	143
111	E 101° 12.461’	N 04° 24.258’	46	400	299
112	E 101° 11.981’	N 04° 24.051’	46	400	299
113	E 101° 11.878’	N 04° 25.567’	34	296	221
114	E 101° 12.269’	N 04° 24.591’	30	261	195
115	E 101° 12.113’	N 04° 23.289’	26	226	169
116	E 101° 13.004’	N 04° 22.900’	26	226	169
117	E 101° 09.449’	N 04° 21.163’	28	244	182
118	E 101° 08.767’	N 04° 20.215’	20	174	130
119	E 101° 09.132’	N 04° 19.500’	22	191	143
120	E 101° 08.667’	N 04° 19.756’	24	209	156
121	E 101° 08.640’	N 04° 20.022’	24	209	156
122	E 101° 10.028’	N 04° 27.166’	34	296	221
123	E 101° 09.469’	N 04° 21.538’	32	278	208
124	E 101° 10.001’	N 04° 22.437’	30	261	195
125	E 101° 12.661’	N 04° 23.297’	30	261	195
126	E 101° 13.093’	N 04° 23.436’	60	522	390
127	E 101° 13.477’	N 04° 23.482’	30	261	195
128	E 101° 12.907’	N 04° 23.316’	46	400	299
129	E 101° 12.780’	N 04° 23.181’	28	244	182

130	E 101° 13.438’	N 04° 22.521’	28	244	182
131	E 101° 13.955’	N 04° 22.429’	20	174	130
132	E 101° 14.547’	N 04° 22.321’	24	209	156
133	E 101° 14.932’	N 04° 22.287’	28	244	182
134	E 101° 13.940’	N 04° 21.824’	22	191	143
135	E 101° 14.218’	N 04° 20.953’	32	278	208
136	E 101° 09.950’	N 04° 17.048’	24	209	156
137	E 101° 09.845’	N 04° 18.095’	44	383	286
138	E 101° 09.925’	N 04° 17.603’	38	331	247
139	E 101° 09.812’	N 04° 17.605’	22	191	143
140	E 101° 08.909’	N 04° 19.166’	22	191	143
141	E 101° 08.309’	N 04° 19.560’	26	226	169
142	E 101° 08.763’	N 04° 23.838’	20	174	130
143	E 101° 09.353’	N 04° 23.757’	34	296	221
144	E 101° 06.047’	N 04° 34.191’	18	157	117
145	E 101° 08.054’	N 04° 31.096’	20	174	130
146	E 101° 07.863’	N 04° 31.343’	26	226	169
147	E 101° 08.014’	N 04° 30.319’	22	191	143
148	E 101° 09.369’	N 04° 29.039’	18	157	117
149	E 101° 09.326’	N 04° 28.768’	8	70	52
150	E 101° 08.996’	N 04° 29.241’	8	70	52
151	E 101° 08.861’	N 04° 28.980’	8	70	52
152	E 101° 08.048’	N 04° 28.856’	20	174	130
153	E 101° 08.336’	N 04° 27.999’	12	104	78
154	E 101° 07.994’	N 04° 27.724’	16	139	104
155	E 101° 07.594’	N 04° 27.027’	18	157	117
156	E 101° 07.247’	N 04° 26.468’	12	104	78
157	E 101° 08.185’	N 04° 26.467’	24	209	156
158	E 101° 07.812’	N 04° 25.413’	22	191	143
159	E 101° 06.850’	N 04° 25.212’	14	122	91
160	E 101° 06.872’	N 04° 25.809’	14	122	91
161	E 101° 07.656’	N 04° 26.527’	18	157	117
162	E 101° 10.158’	N 04° 26.406’	24	209	156
163	E 101° 09.318’	N 04° 17.760’	18	157	117
164	E 101° 09.017’	N 04° 17.309’	22	191	143
165	E 101° 07.978’	N 04° 17.493’	18	157	117
166	E 101° 07.336’	N 04° 17.022’	16	139	104
167	E 101° 07.002’	N 04° 16.498’	14	122	91
168	E 101° 05.991’	N 04° 16.265’	22	191	143
169	E 101° 05.363’	N 04° 16.424’	20	174	130
170	E 101° 04.992’	N 04° 16.697’	26	226	169
171	E 101° 04.558’	N 04° 16.798’	24	209	156
172	E 101° 04.023’	N 04° 16.865’	26	226	169
173	E 101° 03.476’	N 04° 16.952’	24	209	156
174	E 101° 03.057’	N 04° 17.000’	26	226	169

175	E 101° 03.198’	N 04° 16.538’	26	226	169
176	E 101° 03.108’	N 04° 16.006’	26	226	169
177	E 101° 02.926’	N 04° 15.509’	20	174	130
178	E 101° 09.003’	N 04° 16.443’	16	139	104
179	E 101° 03.183’	N 04° 17.578’	30	261	195
180	E 101° 03.440’	N 04° 18.688’	26	226	169
181	E 101° 03.064’	N 04° 18.286’	60	522	390
182	E 101° 02.605’	N 04° 17.912’	60	522	390
183	E 101° 01.992’	N 04° 17.908’	70	609	455
184	E 101° 01.470’	N 04° 18.008’	50	435	325
185	E 101° 00.929’	N 04° 18.106’	80	696	520
186	E 101° 01.154’	N 04° 17.922’	26	226	169
187	E 101° 01.366’	N 04° 18.333’	42	365	272
188	E 101° 02.003’	N 04° 18.509’	24	209	156
189	E 101° 01.482’	N 04° 18.609’	26	226	169
190	E 101° 01.031’	N 04° 18.691’	110	957	714
191	E 101° 00.866’	N 04° 18.565’	120	1044	779
192	E 101° 02.891’	N 04° 18.709’	130	1131	844
193	E 101° 03.444’	N 04° 19.046’	24	209	156
194	E 101° 02.969’	N 04° 19.732’	90	783	585
195	E 101° 02.744’	N 04° 19.387’	100	870	649
196	E 101° 02.195’	N 04° 18.914’	34	296	221
197	E 101° 01.964’	N 04° 19.001’	22	191	143
198	E 101° 01.790’	N 04° 19.514’	160	1392	1039
199	E 101° 01.495’	N 04° 19.447’	150	1305	974
200	E 101° 01.358’	N 04° 19.000’	140	1218	909
201	E 101° 02.446’	N 04° 18.911’	50	435	325
202	E 101° 03.301’	N 04° 19.695’	70	609	455
203	E 101° 03.102’	N 04° 16.855’	30	261	195
204	E 101° 09.021’	N 04° 16.620’	18	157	117
205	E 101° 08.536’	N 04° 16.486’	18	157	117
206	E 101° 08.546’	N 04° 16.270’	20	174	130
207	E 101° 09.002’	N 04° 16.376’	20	174	130
208	E 101° 02.955’	N 04° 17.086’	90	783	585
209	E 101° 02.892’	N 04° 17.181’	140	1218	909
210	E 101° 02.181’	N 04° 17.369’	50	435	325
211	E 101° 01.971’	N 04° 17.363’	30	261	195
212	E 101° 01.779’	N 04° 17.281’	130	1131	844
213	E 101° 01.479’	N 04° 17.398’	140	1218	909
214	E 101° 01.224’	N 04° 17.462’	28	244	182
215	E 101° 01.002’	N 04° 17.511’	16	139	104
216	E 101° 00.708’	N 04° 17.577’	18	157	117
217	E 101° 01.203’	N 04° 17.362’	80	696	520
218	E 101° 00.993’	N 04° 17.324’	18	157	117
219	E 101° 00.586’	N 04° 17.389’	16	139	104

220	E 101° 01.498’	N 04° 17.220’	40	348	260
221	E 101° 01.708’	N 04° 17.175’	140	1218	909
222	E 101° 01.827’	N 04° 17.108’	140	1218	909
223	E 101° 02.032’	N 04° 17.194’	90	783	585
224	E 101° 02.507’	N 04° 17.254’	160	1392	1039
225	E 101° 02.593’	N 04° 17.090’	160	1392	1039
226	E 101° 02.952’	N 04° 16.943’	34	296	221
227	E 101° 03.117’	N 04° 16.575’	34	296	221
228	E 101° 02.973’	N 04° 16.458’	54	470	351
229	E 101° 02.967’	N 04° 16.457’	100	870	649
230	E 101° 02.775’	N 04° 16.506’	130	1131	844
231	E 101° 02.628’	N 04° 16.729’	140	1218	909
232	E 101° 02.594’	N 04° 16.786’	140	1218	909
233	E 101° 02.297’	N 04° 16.814’	140	1218	909
234	E 101° 02.221’	N 04° 16.745’	150	1305	974
235	E 101° 02.387’	N 04° 16.489’	150	1305	974
236	E 101° 02.484’	N 04° 16.056’	100	870	649
237	E 101° 02.489’	N 04° 15.731’	14	122	91
238	E 101° 02.155’	N 04° 15.979’	100	870	649
239	E 101° 02.049’	N 04° 16.059’	100	870	649
240	E 101° 01.984’	N 04° 16.533’	24	209	156
241	E 101° 01.472’	N 04° 15.058’	22	191	143
242	E 101° 01.573’	N 04° 15.539’	20	174	130
243	E 101° 01.155’	N 04° 16.002’	18	157	117
244	E 101° 01.089’	N 04° 16.178’	20	174	130
245	E 101° 01.095’	N 04° 16.525’	16	139	104
246	E 101° 01.092’	N 04° 17.002’	18	157	117
247	E 101° 00.978’	N 04° 17.247’	20	174	130
248	E 101° 00.492’	N 04° 17.330’	18	157	117
249	E 101° 00.117’	N 04° 17.315’	18	157	117
250	E 101° 00.119’	N 04° 17.063’	18	157	117
251	E 101° 00.116’	N 04° 16.470’	22	191	143
252	E 101° 00.225’	N 04° 16.283’	24	209	156
253	E 101° 00.331’	N 04° 16.532’	18	157	117
254	E 101° 00.443’	N 04° 16.496’	22	191	143
255	E 101° 00.453’	N 04° 16.155’	18	157	117
256	E 101° 01.005’	N 04° 16.154’	20	174	130
257	E 101° 01.507’	N 04° 16.149’	22	191	143
258	E 101° 01.801’	N 04° 16.158’	44	383	286
259	E 101° 01.798’	N 04° 16.353’	80	696	520
260	E 101° 01.749’	N 04° 16.507’	110	957	714
261	E 101° 01.745’	N 04° 16.783’	90	783	585
262	E 101° 01.634’	N 04° 17.014’	90	783	585
263	E 101° 01.504’	N 04° 17.150’	130	1131	844
264	E 101° 01.354’	N 04° 17.176’	120	1044	779

265	E 101° 01.044’	N 04° 17.225’	14	122	91
266	E 101° 01.511’	N 04° 16.629’	20	174	130
267	E 101° 00.488’	N 04° 16.824’	18	157	117
268	E 101° 03.363’	N 04° 16.496’	38	331	247
269	E 101° 03.999’	N 04° 16.291’	20	174	130
270	E 101° 03.992’	N 04° 16.001’	32	278	208
271	E 101° 03.864’	N 04° 15.486’	18	157	117
272	E 101° 03.805’	N 04° 15.326’	22	191	143
273	E 101° 03.650’	N 04° 15.350’	22	191	143
274	E 101° 04.091’	N 04° 16.491’	18	157	117
275	E 101° 05.097’	N 04° 16.477’	20	174	130
276	E 101° 05.030’	N 04° 16.050’	20	174	130
277	E 101° 04.691’	N 04° 16.095’	18	157	117
278	E 101° 05.640’	N 04° 16.204’	18	157	117
279	E 101° 05.538’	N 04° 15.978’	20	174	130
280	E 101° 04.979’	N 04° 15.353’	20	174	130
281	E 101° 05.057’	N 04° 15.043’	32	278	208
282	E 101° 05.817’	N 04° 15.017’	20	174	130
283	E 101° 06.671’	N 04° 16.014’	18	157	117
284	E 101° 06.693’	N 04° 15.533’	18	157	117
285	E 101° 07.015’	N 04° 16.155’	16	139	104
286	E 101° 07.827’	N 04° 17.367’	16	139	104
287	E 101° 07.700’	N 04° 17.005’	16	139	104
288	E 101° 07.550’	N 04° 16.866’	18	157	117
289	E 101° 06.093’	N 04° 16.003’	16	139	104
290	E 101° 05.919’	N 04° 15.684’	22	191	143
291	E 101° 06.736’	N 04° 16.517’	18	157	117
292	E 101° 06.726’	N 04° 16.931’	16	139	104
293	E 101° 06.519’	N 04° 17.067’	20	174	130
294	E 101° 06.036’	N 04° 16.869’	18	157	117
295	E 101° 06.073’	N 04° 16.360’	20	174	130
296	E 101° 05.132’	N 04° 16.736’	18	157	117
297	E 101° 05.016’	N 04° 17.078’	24	209	156
298	E 101° 04.949’	N 04° 17.537’	42	365	272
299	E 101° 05.118’	N 04° 18.010’	20	174	130
300	E 101° 05.214’	N 04° 18.541’	14	122	91
301	E 101° 05.570’	N 04° 19.026’	14	122	91
302	E 101° 05.902’	N 04° 19.053’	16	139	104
303	E 101° 05.595’	N 04° 20.034’	22	191	143
304	E 101° 05.460’	N 04° 20.038’	22	191	143
305	E 101° 04.946’	N 04° 19.864’	26	226	169
306	E 101° 03.916’	N 04° 19.897’	60	522	390
307	E 101° 03.709’	N 04° 19.761’	38	331	247
308	E 101° 03.458’	N 04° 19.102’	24	209	156
309	E 101° 03.870’	N 04° 17.042’	20	174	130

310	E 101° 07.028’	N 04° 16.941’	12	104	78
311	E 101° 06.807’	N 04° 17.009’	16	139	104’
312	E 101° 06.588’	N 04° 17.177’	18	157	117
313	E 101° 04.381’	N 04° 19.406’	32	278	208
314	E 101° 01.789’	N 04° 19.053’	28	244	182
315	E 101° 01.813’	N 04° 18.881’	18	157	117
316	E 101° 01.799’	N 04° 19.189’	85	740	552
317	E 101° 01.823’	N 04° 19.230’	120	1044	779
318	E 101° 01.827’	N 04° 19.370’	150	1305	974
319	E 101° 01.826’	N 04° 19.410’	150	1305	974
320	E 101° 01.878’	N 04° 19.624’	135	1175	877
321	E 101° 01.940’	N 04° 19.845’	110	957	714
322	E 101° 01.728’	N 04° 19.543’	160	1392	1039
323	E 101° 01.436’	N 04° 19.377’	140	1218	909
324	E 101° 01.875’	N 04° 19.159’	95	827	617
325	E 101° 01.861’	N 04° 19.090’	26	226	169
326	E 101° 02.576’	N 04° 18.959’	120	1044	779
327	E 101° 02.597’	N 04° 19.260’	90	783	585
328	E 101° 03.397’	N 04° 19.001’	35	305	228
329	E 101° 03.183’	N 04° 19.059’	100	870	649
330	E 101° 03.161’	N 04° 19.116’	110	957	714
331	E 101° 03.122’	N 04° 19.286’	120	1044	779
332	E 101° 03.124’	N 04° 19.337’	120	1044	779
333	E 101° 03.039’	N 04° 19.283’	130	1131	844
334	E 101° 03.064’	N 04° 19.293’	125	1088	812
335	E 101° 03.089’	N 04° 19.167’	125	1088	812
336	E 101° 03.118’	N 04° 19.069’	120	1044	779
337	E 101° 03.173’	N 04° 18.818’	115	1001	747
338	E 101° 03.229’	N 04° 18.756’	100	870	649
339	E 101° 03.212’	N 04° 18.642’	115	1001	747
340	E 101° 03.132’	N 04° 18.680’	115	1001	747
341	E 101° 03.097’	N 04° 18.763’	120	1044	779
342	E 101° 02.704’	N 04° 19.225’	120	1044	779
343	E 101° 02.700’	N 04° 19.077’	140	1218	909
344	E 101° 02.698’	N 04° 19.150’	125	1088	812
345	E 101° 02.693’	N 04° 19.367’	125	1088	812
346	E 101° 02.763’	N 04° 19.667’	120	1044	779
347	E 101° 02.660’	N 04° 19.619’	110	957	714
348	E 101° 02.515’	N 04° 19.342’	105	914	682
349	E 101° 03.475’	N 04° 18.423’	26	226	169
350	E 101° 04.010’	N 04° 18.455’	22	191	143
351	E 101° 04.115’	N 04° 18.433’	18	157	117
352	E 101° 04.222’	N 04° 18.089’	22	191	143
353	E 101° 04.017’	N 04° 18.168’	14	122	91
354	E 100° 58.862’	N 04° 22.113’	18	157	117

355	E 100° 58.887’	N 04° 22.542’	24	209	156
356	E 100° 58.908’	N 04° 23.119’	26	226	169
357	E 101° 06.556’	N 04° 31.002’	22	191	143
358	E 101° 06.439’	N 04° 30.489’	22	191	143
359	E 101° 06.317’	N 04° 30.334’	22	191	143
360	E 101° 06.275’	N 04° 31.076’	24	209	156
361	E 101° 06.606’	N 04° 31.494’	26	226	169
362	E 101° 06.671’	N 04° 31.797’	28	244	182
363	E 101° 06.083’	N 04° 31.081’	24	209	156
364	E 101° 06.061’	N 04° 31.527’	20	174	130
365	E 101° 06.092’	N 04° 31.844’	20	174	130
366	E 101° 05.990’	N 04° 31.024’	24	209	156
367	E 101° 05.926’	N 04° 31.479’	24	209	156
368	E 101° 05.847’	N 04° 30.251’	26	226	169
369	E 101° 05.520’	N 04° 30.495’	24	209	156
370	E 101° 05.354’	N 04° 30.081’	22	191	143
371	E 101° 05.312’	N 04° 29.561’	22	191	143
372	E 101° 04.814’	N 04° 29.268’	20	174	130
373	E 101° 04.965’	N 04° 31.066’	22	191	143
374	E 101° 04.455’	N 04° 31.648’	26	226	169
375	E 101° 05.100’	N 04° 31.856’	24	209	156
376	E 101° 04.208’	N 04° 32.168’	22	191	143
377	E 101° 03.710’	N 04° 31.773’	24	209	156
378	E 101° 03.464’	N 04° 31.993’	20	174	130
379	E 101° 03.383’	N 04° 31.427’	26	226	169
380	E 101° 03.249’	N 04° 30.995’	22	191	143
381	E 101° 02.937’	N 04° 30.427’	24	209	156
382	E 101° 02.817’	N 04° 29.759’	60	522	390
383	E 101° 03.021’	N 04° 29.551’	26	226	169
384	E 101° 03.134’	N 04° 28.959’	22	191	143
385	E 101° 03.251’	N 04° 28.529’	24	209	156
386	E 101° 03.304’	N 04° 29.067’	24	209	156
387	E 101° 03.300’	N 04° 29.500’	24	209	156
388	E 101° 03.382’	N 04° 30.002’	24	209	156
389	E 101° 03.435’	N 04° 30.495’	30	261	195
390	E 101° 03.598’	N 04° 30.997’	24	209	156
391	E 101° 03.941’	N 04° 31.504’	24	209	156
392	E 101° 03.860’	N 04° 31.885’	24	209	156
393	E 101° 00.319’	N 04° 23.432’	20	174	130
394	E 101° 00.119’	N 04° 23.995’	18	157	117
395	E 101° 00.243’	N 04° 24.155’	16	139	104
396	E 101° 00.490’	N 04° 24.011’	14	122	91
397	E 101° 01.388’	N 04° 22.954’	14	122	91
398	E 101° 01.071’	N 04° 22.789’	14	122	91
399	E 101° 01.501’	N 04° 22.224’	16	139	104

400	E 101° 01.433’	N 04° 22.063’	16	139	104
401	E 101° 01.458’	N 04° 21.478’	18	157	117
402	E 101° 04.049’	N 04° 29.266’	16	139	104
403	E 101° 04.059’	N 04° 28.636’	18	157	117
404	E 101° 04.243’	N 04° 28.496’	20	174	130
405	E 101° 02.464’	N 04° 27.515’	18	157	117
406	E 101° 02.618’	N 04° 26.321’	18	157	117
407	E 101° 02.043’	N 04° 26.953’	16	139	104
408	E 101° 01.818’	N 04° 26.935’	17	148	110
409	E 101° 02.430’	N 04° 26.081’	17	148	110
410	E 101° 02.761’	N 04° 24.875’	18	157	117
411	E 101° 02.941’	N 04° 24.253’	16	139	104
412	E 101° 02.502’	N 04° 24.140’	6	52	39
413	E 101° 02.190’	N 04° 24.175’	12	104	78
414	E 101° 02.052’	N 04° 24.142’	12	104	78
415	E 101° 01.533’	N 04° 23.607’	18	157	117
416	E 101° 01.763’	N 04° 24.674’	8	70	52
417	E 101° 02.037’	N 04° 24.396’	8	70	52
418	E 101° 02.103’	N 04° 24.502’	10	87	65
419	E 101° 02.140’	N 04° 24.233’	14	122	91
420	E 101° 02.698’	N 04° 23.515’	14	122	91
421	E 101° 02.847’	N 04° 23.397’	16	139	104
422	E 101° 02.965’	N 04° 22.970’	17	148	110
423	E 101° 02.457’	N 04° 23.486’	14	122	91
424	E 101° 02.602’	N 04° 23.080’	10	87	65
425	E 101° 03.416’	N 04° 22.007’	12	104	78
426	E 101° 03.252’	N 04° 21.735’	12	104	78
427	E 101° 02.213’	N 04° 22.065’	18	157	117
428	E 101° 02.117’	N 04° 21.818’	18	157	117
429	E 101° 05.988’	N 04° 34.363’	29	252	188
430	E 101° 06.479’	N 04° 33.199’	38	331	247
431	E 101° 06.764’	N 04° 32.813’	22	191	143
432	E 101° 06.247’	N 04° 33.176’	19	165	123
433	E 101° 06.314’	N 04° 33.700’	19	165	123
434	E 101° 05.840’	N 04° 33.250’	20	174	130
435	E 101° 05.497’	N 04° 33.071’	22	191	143
436	E 101° 05.734’	N 04° 38.629’	22	191	143
437	E 101° 05.681’	N 04° 39.056’	22	191	143
438	E 101° 06.060’	N 04° 39.506’	26	226	169
439	E 101° 05.634’	N 04° 39.843’	38	331	247
440	E 101° 06.275’	N 04° 40.114’	22	191	143
441	E 101° 06.275’	N 04° 40.567’	22	191	143
442	E 101° 06.609’	N 04° 40.076’	24	209	156
443	E 101° 06.576’	N 04° 39.366’	22	191	143
444	E 101° 07.322’	N 04° 40.613’	24	209	156

445	E 101° 06.945’	N 04° 40.915’	24	209	156
446	E 101° 06.594’	N 04° 40.741’	26	226	169
447	E 101° 07.381’	N 04° 41.889’	29	252	188
448	E 101° 06.540’	N 04° 41.955’	39	339	253
449	E 101° 07.207’	N 04° 42.877’	41	357	266
450	E 101° 07.598’	N 04° 42.656’	15	131	98
451	E 101° 07.620’	N 04° 42.062’	24	209	156
452	E 101° 07.915’	N 04° 42.024’	24	209	156
453	E 101° 08.252’	N 04° 41.578’	21	183	137
454	E 101° 08.200’	N 04° 41.946’	19	165	123
455	E 101° 07.552’	N 04° 41.462’	21	183	137
456	E 101° 08.026’	N 04° 41.419’	22	191	143
457	E 101° 08.460’	N 04° 41.390’	24	209	156
458	E 101° 09.099’	N 04° 40.901’	17	148	110
459	E 101° 08.528’	N 04° 40.805’	10	87	65
460	E 101° 08.101’	N 04° 40.372’	19	165	123
461	E 101° 08.162’	N 04° 40.452’	16	139	104
462	E 101° 07.062’	N 04° 39.851’	16	139	104
463	E 101° 07.545’	N 04° 39.709’	20	174	130
464	E 101° 07.138’	N 04° 39.111’	22	191	143
465	E 101° 08.257’	N 04° 29.984’	24	209	156
466	E 101° 08.147’	N 04° 29.717’	20	174	130
467	E 101° 07.760’	N 04° 29.951’	24	209	156
468	E 101° 07.367’	N 04° 30.032’	23	200	149
469	E 101° 07.417’	N 04° 29.511’	21	183	137
470	E 101° 07.280’	N 04° 29.572’	23	200	149
471	E 101° 06.852’	N 04° 29.370’	14	122	91
472	E 101° 06.533’	N 04° 28.977’	23	200	149
473	E 101° 06.313’	N 04° 28.495’	28	244	182
474	E 101° 06.423’	N 04° 27.982’	25	218	163
475	E 101° 06.350’	N 04° 27.468’	18	157	117
476	E 101° 06.281’	N 04° 27.055’	20	174	130
477	E 101° 06.440’	N 04° 26.489’	12	104	78
478	E 101° 06.993’	N 04° 26.252’	12	104	78
479	E 101° 07.100’	N 04° 25.492’	13	113	84
480	E 101° 06.643’	N 04° 27.485’	25	218	163
481	E 101° 06.132’	N 04° 28.662’	26	226	169
482	E 101° 05.339’	N 04° 28.519’	33	287	214
483	E 101° 04.295’	N 04° 28.371’	13	113	84
484	E 101° 04.496’	N 04° 27.955’	17	148	110
485	E 101° 05.007’	N 04° 27.943’	18	157	117
486	E 101° 05.521’	N 04° 28.238’	20	174	130
487	E 101° 04.857’	N 04° 27.702’	16	139	104
488	E 101° 04.623’	N 04° 27.372’	20	174	130
489	E 101° 05.019’	N 04° 27.124’	14	122	91

490	E 101° 05.213’	N 04° 26.491’	15	131	98
491	E 101° 05.622’	N 04° 26.269’	18	157	117
492	E 101° 05.676’	N 04° 26.764’	20	174	130
493	E 101° 05.714’	N 04° 27.520’	20	174	130
494	E 101° 05.974’	N 04° 27.732’	27	235	175
495	E 101° 06.074’	N 04° 28.015’	27	235	175
496	E 101° 05.641’	N 04° 28.525’	25	218	163
497	E 101° 05.615’	N 04° 28.516’	19	165	123
498	E 101° 04.681’	N 04° 28.438’	41	357	266
499	E 101° 04.259’	N 04° 27.913’	17	148	110
500	E 101° 04.188’	N 04° 27.995’	18	157	117
501	E 101° 04.184’	N 04° 27.495’	14	122	91
502	E 101° 04.165’	N 04° 26.995’	10	87	65
503	E 101° 04.308’	N 04° 26.474’	14	122	91
504	E 101° 04.151’	N 04° 25.924’	14	122	91
505	E 101° 03.754’	N 04° 26.057’	23	200	149
506	E 101° 03.500’	N 04° 26.543’	19	165	123
507	E 101° 03.268’	N 04° 27.029’	19	165	123
508	E 101° 02.855’	N 04° 27.619’	18	157	117
509	E 101° 02.764’	N 04° 28.023’	39	339	253
510	E 101° 03.538’	N 04° 28.392’	29	252	188
511	E 101° 03.826’	N 04° 28.012’	23	200	149
512	E 101° 04.653’	N 04° 27.010’	19	165	123
513	E 101° 04.704’	N 04° 26.681’	12	104	78
514	E 101° 04.820’	N 04° 26.074’	15	131	98
515	E 101° 04.930’	N 04° 26.270’	14	122	91
516	E 101° 05.033’	N 04° 26.112’	12	104	78
517	E 101° 05.303’	N 04° 26.107’	14	122	91
518	E 101° 03.520’	N 04° 25.986’	21	183	137
519	E 101° 03.027’	N 04° 26.984’	21	183	137
520	E 101° 03.163’	N 04° 26.473’	21	183	137
521	E 101° 03.301’	N 04° 25.988	23	200	149
522	E 101° 03.447’	N 04° 25.465’	26	226	169
523	E 101° 03.601’	N 04° 24.973’	18	157	117
524	E 101° 03.735’	N 04° 24.482’	19	165	123
525	E 101° 03.988’	N 04° 23.987’	17	148	110
526	E 101° 04.104’	N 04° 23.474’	26	226	169
527	E 101° 04.180’	N 04° 22.998’	22	191	143
528	E 101° 04.396’	N 04° 22.393’	20	174	130
529	E 101° 04.485’	N 04° 22.002’	24	209	156
530	E 101° 04.557’	N 04° 21.473’	28	244	182
531	E 101° 04.978’	N 04° 21.003’	18	157	117
5632	E 101° 04.949’	N 04° 20.672’	29	252	188
533	E 101° 02.808’	N 04° 27.533’	26	226	169
534	E 101° 02.616’	N 04° 26.983’	19	165	123

535	E 101° 03.011’	N 04° 26.853’	26	226	169
536	E 101° 02.663’	N 04° 26.343’	22	191	143
537	E 101° 03.024’	N 04° 25.781’	16	139	104
538	E 101° 02.883’	N 04° 25.436’	13	113	84
539	E 101° 03.175’	N 04° 24.495’	16	139	104
540	E 101° 03.497’	N 04° 24.373’	14	122	91
541	E 101° 03.215’	N 04° 23.629’	17	148	110
542	E 101° 03.630’	N 04° 23.296’	36	313	234
543	E 101° 03.981’	N 04° 22.029’	16	139	104
544	E 101° 01.432’	N 04° 21.196’	24	209	156
545	E 101° 01.463’	N 04° 21.291’	15	131	98
546	E 101° 02.016’	N 04° 21.048’	21	183	137
547	E 101° 02.549’	N 04° 20.968’	20	174	130
548	E 101° 03.015’	N 04° 21.048’	30	261	195
549	E 101° 03.218’	N 04° 20.606’	28	244	182
550	E 101° 03.280’	N 04° 19.853’	65	566	423
551	E 101° 03.403’	N 04° 20.009’	45	392	293
552	E 101° 03.100’	N 04° 20.434’	55	479	358
553	E 101° 02.968’	N 04° 20.499’	85	740	552
554	E 101° 02.706’	N 04° 20.473’	110	957	714
555	E 101° 03.606’	N 04° 22.238’	22	191	143
556	E 101° 02.945’	N 04° 22.506’	20	174	130
557	E 101° 02.944’	N 04° 22.641’	20	174	130
558	E 101° 02.387’	N 04° 22.521’	15	131	98
559	E 101° 02.628’	N 04° 22.670’	15	131	98
560	E 101° 01.495’	N 04° 22.518’	15	131	98
561	E 101° 02.928’	N 04° 20.704’	30	261	195
562	E 101° 02.553’	N 04° 20.841’	28	244	182
563	E 101° 02.997’	N 04° 20.561’	67	583	435
564	E 101° 02.913’	N 04° 20.585’	90	783	585
565	E 101° 02.761’	N 04° 20.336’	110	957	714
566	E 101° 03.037’	N 04° 20.366’	100	870	649
567	E 101° 03.180’	N 04° 20.327’	70	609	455
568	E 101° 03.117’	N 04° 20.283’	100	870	649
569	E 101° 03.121’	N 04° 19.965’	120	1044	779
570	E 101° 03.302’	N 04° 19.919’	75	653	487
571	E 101° 03.242’	N 04° 19.949’	120	1044	779
572	E 101° 03.233’	N 04° 19.948’	120	1044	779
573	E 101° 03.258’	N 04° 19.943’	75	653	487
574	E 101° 03.317’	N 04° 19.911’	60	522	390
575	E 101° 03.211’	N 04° 20.203’	95	827	617
576	E 101° 03.220’	N 04° 20.204’	85	740	552
577	E 101° 03.240’	N 04° 20.206’	75	653	487
578	E 101° 03.105’	N 04° 20.235’	95	827	617
579	E 101° 03.434’	N 04° 20.005’	35	305	228

580	E 101° 03.406’	N 04° 19.991’	75	653	487
581	E 101° 03.409’	N 04° 19.970’	55	479	358
582	E 101° 03.000’	N 04° 19.897’	95	827	617
583	E 101° 02.893’	N 04° 19.990’	115	1001	747
584	E 101° 02.352’	N 04° 19.291’	145	1262	942
585	E 101° 02.120’	N 04° 19.408’	120	1044	779
586	E 101° 02.562’	N 04° 19.526’	120	1044	779
587	E 101° 02.565’	N 04° 19.889’	115	1001	747
588	E 101° 02.461’	N 04° 20.012’	115	1001	747
589	E 101° 02.456’	N 04° 20.283’	115	1001	747
590	E 101° 02.413’	N 04° 20.539’	120	1044	779
591	E 101° 02.344’	N 04° 20.133’	115	1001	747
592	E 101° 02.136’	N 04° 20.306’	115	1001	747
593	E 101° 01.965’	N 04° 20.190’	100	870	649
594	E 101° 01.847’	N 04° 20.153’	39	339	253
595	E 101° 01.605’	N 04° 20.026’	39	339	253
596	E 101° 01.399’	N 04° 19.969’	115	1001	747
597	E 101° 01.451’	N 04° 19.952’	125	1088	812
598	E 101° 01.148’	N 04° 20.110’	40	348	260
599	E 101° 01.302’	N 04° 20.517’	90	783	585
600	E 101° 01.168’	N 04° 20.640’	23	200	149
601	E 101° 01.000’	N 04° 20.799’	45	392	293
602	E 101° 00.883’	N 04° 21.329’	30	261	195
603	E 101° 06.963’	N 04° 37.859’	20	174	130
604	E 101° 06.404’	N 04° 38.987’	26	226	169
605	E 101° 06.768’	N 04° 39.620’	26	226	169
606	E 101° 07.034’	N 04° 40.057’	26	226	169
607	E 101° 07.365’	N 04° 41.250’	28	244	182
608	E 101° 07.435’	N 04° 42.047’	26	226	169
609	E 101° 07.368’	N 04° 43.037’	38	331	247
610	E 101° 07.269’	N 04° 44.072’	24	209	156
611	E 101° 07.082’	N 04° 45.100’	30	261	195
612	E 101° 07.196’	N 04° 43.093’	28	244	182
613	E 101° 06.080’	N 04° 42.616’	24	209	156
614	E 101° 05.229’	N 04° 41.041’	44	383	286
615	E 101° 04.334’	N 04° 39.660’	22	191	143
616	E 101° 04.259’	N 04° 38.828’	28	244	182
617	E 101° 03.762’	N 04° 37.809’	34	296	221
618	E 101° 03.511’	N 04° 36.784’	26	226	169
619	E 101° 03.102’	N 04° 36.798’	42	365	272
620	E 101° 02.603’	N 04° 35.911’	50	435	325
621	E 101° 02.386’	N 04° 34.911’	36	313	234
622	E 101° 07.375’	N 04° 36.252’	24	209	156
623	E 101° 07.790’	N 04° 36.462’	18	157	117
624	E 101° 07.236’	N 04° 36.567’	28	244	182

625	E 101° 08.843’	N 04° 37.185’	24	209	156
626	E 101° 09.135’	N 04° 37.995’	28	244	182
627	E 101° 09.630’	N 04° 38.888’	20	174	130
628	E 101° 09.775’	N 04° 39.806’	22	191	143
629	E 101° 09.810’	N 04° 40.531’	30	261	195
630	E 101° 09.534’	N 04° 41.442’	26	226	169
631	E 101° 09.018’	N 04° 42.266’	20	174	130
632	E 101° 08.828’	N 04° 43.144’	20	174	130
633	E 101° 08.136’	N 04° 43.577’	24	209	156
634	E 100° 58.830’	N 04° 23.441’	22	191	143
635	E 100° 58.817’	N 04° 23.754’	12	104	78
636	E 100° 59.330’	N 04° 25.079’	16	139	104
637	E 100° 59.779’	N 04° 27.150’	16	139	104
638	E 101° 00.465’	N 04° 29.007’	42	365	272
639	E 101° 01.375’	N 04° 30.536’	28	244	182
640	E 101° 02.243’	N 04° 32.438’	32	278	208
641	E 101° 03.334’	N 04° 33.686’	26	226	169
642	E 101° 03.071’	N 04° 33.570’	16	139	104
643	E 101° 03.371’	N 04° 33.465’	22	191	143
644	E 101° 02.693’	N 04° 33.033’	20	174	130
645	E 101° 02.846’	N 04° 32.994’	28	244	182
646	E 101° 02.639’	N 04° 32.891’	24	209	156
647	E 101° 02.590’	N 04° 32.730’	44	383	286
648	E 101° 02.853’	N 04° 32.498’	22	191	143
649	E 101° 02.633’	N 04° 32.412’	32	278	208
650	E 100° 58.294’	N 04° 23.426’	20	174	130
651	E 100° 58.523’	N 04° 23.427’	40	348	260
652	E 100° 58.884’	N 04° 23.293’	24	209	156
653	E 100° 59.100’	N 04° 24.041’	16	139	104
654	E 100° 59.766’	N 04° 25.630’	18	157	117
655	E 100° 59.993’	N 04° 26.081’	18	157	117
656	E 100° 59.918’	N 04° 26.949’	16	139	104
657	E 100° 59.833’	N 04° 27.992’	24	209	156
658	E 101° 00.055’	N 04° 28.695’	28	244	182
659	E 101° 00.824’	N 04° 30.019’	28	244	182
660	E 101° 03.050’	N 04° 32.542’	18	157	117
661	E 101° 04.069’	N 04° 32.521’	24	209	156
662	E 101° 04.540’	N 04° 33.050’	24	209	156
663	E 101° 04.781’	N 04° 34.112’	24	209	156
664	E 101° 01.900’	N 04° 30.971’	28	244	182
665	E 101° 07.020’	N 04° 33.395’	32	278	208
666	E 101° 06.853’	N 04° 33.415’	30	261	195
667	E 101° 07.375’	N 04° 32.532’	24	209	156
668	E 101° 07.689’	N 04° 32.231’	28	244	182
669	E 101° 07.746’	N 04° 31.727’	24	209	156

670	E 101° 06.961’	N 04° 31.491’	24	209	156
671	E 101° 06.458’	N 04° 30.947’	24	209	156
672	E 101° 05.869’	N 04° 30.971’	24	209	156
673	E 101° 05.392’	N 04° 30.899’	22	191	143
674	E 101° 04.975’	N 04° 30.477’	18	157	117
675	E 101° 04.607’	N 04° 29.949’	24	209	156
676	E 101° 04.234’	N 04° 28.923’	16	139	104
677	E 101° 03.765’	N 04° 28.456’	22	191	143
678	E 101° 02.910’	N 04° 28.465’	30	261	195
679	E 101° 01.550’	N 04° 28.090’	18	157	117
680	E 101° 00.887’	N 04° 28.092’	20	174	130
681	E 100° 59.952’	N 04° 28.123’	20	174	130
682	E 101° 00.961’	N 04° 30.798’	32	278	208
683	E 101° 00.247’	N 04° 29.867’	44	383	286
684	E 101° 00.593’	N 04° 29.802’	24	209	156
685	E 101° 01.009’	N 04° 29.647’	30	261	195
686	E 101° 02.031’	N 04° 29.135’	24	209	156
687	E 101° 02.681’	N 04° 27.889’	22	191	143
688	E 101° 02.598’	N 04° 26.975’	18	157	117
689	E 101° 02.756’	N 04° 25.855’	22	191	143
690	E 101° 02.949’	N 04° 25.022’	18	157	117
691	E 101° 03.295’	N 04° 24.497’	16	139	104
692	E 101° 03.032’	N 04° 23.966’	18	157	117
693	E 101° 03.436’	N 04° 22.966’	18	157	117
694	E 101° 03.771’	N 04° 21.969’	18	157	117
695	E 101° 04.006’	N 04° 20.946’	28	244	182
696	E 101° 03.970’	N 04° 19.946’	44	383	286
697	E 101° 02.949’	N 04° 22.199’	14	122	91
698	E 101° 01.973’	N 04° 22.215’	16	139	104
699	E 101° 01.169’	N 04° 22.354’	16	139	104
700	E 101° 00.764’	N 04° 21.980’	20	174	130
701	E 101° 00.900’	N 04° 21.050’	18	157	117
702	E 101° 01.007’	N 04° 23.038’	14	122	91
703	E 101° 00.473’	N 04° 23.735’	18	157	117
704	E 101° 00.403’	N 04° 23.524’	28	244	182
705	E 100° 59.976’	N 04° 23.545’	36	313	234
706	E 100° 59.520’	N 04° 24.030’	18	157	117
707	E 101° 00.668’	N 04° 27.135’	16	139	104
708	E 101° 05.297’	N 04° 28.585’	22	191	143
709	E 101° 05.649’	N 04° 29.050’	20	174	130
710	E 101° 06.107’	N 04° 29.172’	26	226	169
711	E 101° 07.198’	N 04° 29.597’	18	157	117
712	E 101° 08.038’	N 04° 30.014’	20	174	130
713	E 101° 08.980’	N 04° 29.973’	42	365	272
714	E 101° 09.584’	N 04° 28.865’	34	296	221

715	E 101° 09.917’	N 04° 27.780’	18	157	117
716	E 101° 09.055’	N 04° 27.546’	16	139	104
717	E 101° 08.362’	N 04° 26.994’	22	191	143
718	E 101° 08.149’	N 04° 25.958’	18	157	117
719	E 101° 07.007’	N 04° 25.000’	20	174	130
720	E 101° 05.877’	N 04° 24.674’	22	191	143
721	E 101° 05.030’	N 04° 24.103’	22	191	143
722	E 101° 04.649’	N 04° 22.924’	22	191	143
723	E 101° 06.174’	N 04° 22.007’	14	122	91
724	E 101° 06.962’	N 04° 21.019’	18	157	117
725	E 101° 07.611’	N 04° 21.731’	24	209	156
726	E 101° 07.483’	N 04° 21.643’	18	157	117
727	E 101° 08.021’	N 04° 22.032’	22	191	143
728	E 101° 09.031’	N 04° 22.584’	32	278	208
729	E 101° 09.721’	N 04° 24.924’	20	174	130
730	E 101° 09.535’	N 04° 23.954’	36	313	234
731	E 101° 09.474’	N 04° 23.015’	26	226	169
732	E 101° 09.456’	N 04° 21.962’	24	209	156
733	E 101° 08.466’	N 04° 21.444’	22	191	143
734	E 101° 08.353’	N 04° 20.979’	16	139	104
735	E 101° 07.992’	N 04° 20.808’	16	139	104
736	E 101° 07.807’	N 04° 20.197’	22	191	143
737	E 101° 09.488’	N 04° 20.954’	30	261	195
738	E 101° 09.453’	N 04° 20.091’	28	244	182
739	E 101° 09.428’	N 04° 18.391’	22	191	143
740	E 101° 09.694’	N 04° 17.978’	30	261	195
741	E 101° 09.079’	N 04° 16.974’	26	226	169
742	E 101° 09.062’	N 04° 17.017’	32	278	208
743	E 101° 08.953’	N 04° 17.018’	38	331	247
744	E 101° 08.802’	N 04° 17.054’	22	191	143
745	E 101° 09.091’	N 04° 17.290’	22	191	143
746	E 101° 08.627’	N 04° 27.307’	22	191	143
747	E 101° 08.136’	N 04° 27.154’	26	226	169
748	E 101° 07.890’	N 04° 26.061’	18	157	117
749	E 101° 07.472’	N 04° 25.181’	26	226	169
750	E 101° 06.313’	N 04° 24.820’	22	191	143
751	E 101° 06.280’	N 04° 24.828’	24	209	156
752	E 101° 04.913’	N 04° 24.280’	22	191	143
753	E 101° 11.126’	N 04° 27.815’	24	209	156
754	E 101° 11.277’	N 04° 27.169’	26	226	169
755	E 101° 10.994’	N 04° 28.162’	16	139	104
756	E 101° 09.981’	N 04° 28.667’	26	226	169
757	E 101° 05.694’	N 04° 30.878’	24	209	156
758	E 101° 05.204’	N 04° 30.960’	20	174	130
759	E 101° 04.722’	N 04° 29.976’	24	209	156

760	E 101° 04.252’	N 04° 28.463’	20	174	130
761	E 101° 04.966’	N 04° 28.558’	16	139	104
762	E 101° 02.341’	N 04° 26.510’	18	157	117
763	E 101° 01.712’	N 04° 26.969’	14	122	91
764	E 101° 02.501’	N 04° 24.150’	6	52	39
765	E 101° 02.676’	N 04° 23.500’	14	122	91
766	E 101° 02.946’	N 04° 22.627’	16	139	104
767	E 101° 01.059’	N 04° 22.777’	15	131	98
768	E 101° 00.625’	N 04° 23.978’	20	174	130
769	E 101° 00.137’	N 04° 24.700’	18	157	117
770	E 101° 00.856’	N 04° 23.595’	12	104	78
771	E 100° 58.207’	N 04° 25.296’	10	87	65
772	E 100° 57.523’	N 04° 24.992’	14	122	91
773	E 100° 57.488’	N 04° 24.473’	12	104	78
774	E 100° 58.606’	N 04° 25.892’	14	122	91
775	E 100° 58.534’	N 04° 26.526’	8	70	52
776	E 100° 58.412’	N 04° 26.609’	10	87	65
777	E 100° 59.554’	N 04° 25.860’	40	348	260
778	E 100° 59.843’	N 04° 26.503’	16	139	104
779	E 100° 58.931’	N 04° 26.222’	14	122	91
780	E 100° 59.613’	N 04° 25.395’	22	191	143
781	E 100° 59.795’	N 04° 27.919’	28	244	182
782	E 100° 59.036’	N 04° 27.666’	14	122	91
783	E 100° 58.321’	N 04° 27.522’	12	104	78
784	E 100° 57.786’	N 04° 27.476’	10	87	65
785	E 100° 57.243’	N 04° 27.090’	12	104	78
786	E 101° 00.237’	N 04° 28.846’	20	174	130
787	E 101° 09.103’	N 04° 37.789’	34	296	221
788	E 101° 09.436’	N 04° 38.581’	30	261	195
789	E 101° 10.353’	N 04° 39.572’	22	191	143
790	E 101° 11.820’	N 04° 40.236’	40	348	260
791	E 101° 10.083’	N 04° 39.557’	22	191	143
792	E 101° 09.469’	N 04° 39.781’	22	191	143
793	E 101° 09.127’	N 04° 41.492’	32	278	208
794	E 101° 09.234’	N 04° 41.954’	28	244	182
795	E 101° 08.234’	N 04° 42.231’	22	191	143
796	E 101° 08.211’	N 04° 42.216’	22	191	143
797	E 101° 08.459’	N 04° 42.186’	23	200	149
798	E 101° 08.629’	N 04° 42.175’	26	226	169
799	E 101° 08.709’	N 04° 42.223’	25	218	163
800	E 101° 08.298’	N 04° 43.344’	18	157	117
801	E 101° 08.215’	N 04° 43.014’	20	174	130
802	E 101° 08.986’	N 04° 43.611’	22	191	143
803	E 101° 09.453’	N 04° 43.911’	24	209	156
804	E 101° 09.173’	N 04° 44.631’	24	209	156

805	E 101° 09.011’	N 04° 44.963’	22	191	143
806	E 101° 09.668’	N 04° 45.212’	50	435	325
807	E 101° 09.827’	N 04° 45.111’	38	331	247
808	E 101° 09.663’	N 04° 44.866’	46	400	299
809	E 101° 09.179’	N 04° 45.526’	26	226	169
810	E 101° 08.531’	N 04° 46.012’	48	418	312
811	E 101° 08.236’	N 04° 46.702’	22	191	143
812	E 101° 09.066’	N 04° 46.499’	38	331	247
813	E 101° 09.240’	N 04° 46.469’	38	331	247
814	E 101° 08.372’	N 04° 46.504’	26	226	169
815	E 101° 08.989’	N 04° 46.242’	26	226	169
816	E 101° 07.794’	N 04° 46.235’	22	191	143
817	E 101° 07.896’	N 04° 45.892’	32	278	208
818	E 101° 07.281’	N 04° 45.394’	34	296	221
819	E 101° 07.035’	N 04° 45.913’	22	191	143
820	E 101° 07.833’	N 04° 41.447’	24	209	156
821	E 101° 08.379’	N 04° 41.414’	28	244	182
822	E 101° 07.880’	N 04° 42.334’	18	157	117
823	E 101° 07.784’	N 04° 42.214’	18	157	117
824	E 101° 08.085’	N 04° 41.889’	26	226	169
825	E 101° 08.215’	N 04° 41.965’	16	139	104
826	E 101° 08.666’	N 04° 40.312’	22	191	143
827	E 101° 08.120’	N 04° 45.519’	18	157	117
828	E 101° 07.718’	N 04° 44.020’	32	278	208
829	E 101° 08.146’	N 04° 44.224’	22	191	143
830	E 101° 08.346’	N 04° 45.023’	50	435	325
831	E 101° 08.400’	N 04° 45.128’	42	365	272
832	E 101° 08.472’	N 04° 45.219’	24	209	156
833	E 101° 08.563’	N 04° 44.610’	24	209	156
834	E 101° 08.533’	N 04° 44.503’	24	209	156
835	E 101° 07.831’	N 04° 44.647’	24	209	156
836	E 101° 07.828’	N 04° 45.298’	22	191	143
837	E 101° 10.088’	N 04° 41.797’	34	296	221
838	E 101° 09.352’	N 04° 40.974’	32	278	208
839	E 101° 06.365’	N 04° 42.933’	34	296	221
840	E 101° 04.582’	N 04° 42.331’	50	435	325
841	E 101° 04.844’	N 04° 41.948’	42	365	272
842	E 101° 05.203’	N 04° 40.874’	30	261	195
843	E 101° 03.780’	N 04° 40.204’	50	435	325
844	E 101° 05.167’	N 04° 41.021’	38	331	247
845	E 101° 04.567’	N 04° 39.763’	32	278	208
846	E 100° 59.480’	N 04° 28.183’	20	174	130
847	E 100° 58.856’	N 04° 28.500’	24	209	156
848	E 100° 59.975’	N 04° 28.723’	22	191	143
849	E 101° 03.808’	N 04° 21.740’	18	157	117

850	E 101° 01.215’	N 04° 15.122’	34	296	221
851	E 100° 07.376’	N 04° 17.294’	12	104	78
852	E 101° 05.510’	N 04° 16.327’	16	139	104
853	E 101° 05.709’	N 04° 15.791’	18	157	117
854	E 101° 10.123’	N 04° 18.495’	32	278	208
855	E 101° 09.449’	N 04° 18.824’	32	278	208
856	E 101° 09.276’	N 04° 19.330’	30	261	195
857	E 101° 09.533’	N 04° 25.246’	20	174	130
858	E 101° 09.339’	N 04° 26.423’	26	226	169
859	E 101° 09.247’	N 04° 26.021’	16	139	104
860	E 101° 09.213’	N 04° 25.488’	20	174	130
861	E 101° 08.876’	N 04° 25.068’	20	174	130
862	E 101° 09.415’	N 04° 24.625’	22	191	143
863	E 101° 08.529’	N 04° 26.321’	14	122	91
864	E 101° 09.007’	N 04° 26.786’	14	122	91
865	E 101° 07.409’	N 04° 24.474’	16	139	104
866	E 101° 07.994’	N 04° 24.159’	14	122	91
867	E 101° 07.510’	N 04° 23.722’	24	209	156
868	E 101° 07.514’	N 04° 22.990’	16	139	104
869	E 101° 07.656’	N 04° 22.471’	16	139	104
870	E 101° 06.604’	N 04° 43.583’	28	244	182
871	E 101° 06.550’	N 04° 44.043’	24	209	156
872	E 101° 06.028’	N 04° 44.068’	32	278	208
873	E 101° 05.847’	N 04° 43.891’	26	226	169
874	E 101° 05.621’	N 04° 43.455’	34	296	221
875	E 101° 05.563’	N 04° 43.552’	38	331	247
876	E 101° 05.187’	N 04° 42.892’	16	139	104
877	E 101° 06.252’	N 04° 45.051’	30	261	195
878	E 101° 05.655’	N 04° 45.407’	42	365	273
879	E 101° 05.725’	N 04° 45.127’	24	209	156
880	E 101° 05.741’	N 04° 45.905’	75	653	487
881	E 101° 05.771’	N 04° 45.790’	55	479	357
882	E 101° 06.127’	N 04° 45.979’	26	226	169
883	E 101° 06.823’	N 04° 45.601’	28	244	182
884	E 101° 08.382’	N 04° 39.747’	22	191	143
885	E 101° 07.049’	N 04° 38.608’	20	174	130
886	E 101° 08.141’	N 04° 37.688’	28	244	182
887	E 101° 07.040’	N 04° 37.531’	26	226	169
888	E 101° 06.883’	N 04° 36.735’	18	157	117
889	E 101° 06.643’	N 04° 36.173’	14	122	91
890	E 101° 06.253’	N 04° 35.746’	22	191	143
891	E 101° 05.625’	N 04° 35.578’	22	191	143
892	E 101° 06.045’	N 04° 35.108’	22	191	143
893	E 101° 04.764’	N 04° 34.631’	24	209	156
894	E 101° 04.903’	N 04° 35.020’	26	226	169

895	E 101° 04.407’	N 04° 35.805’	24	209	156
896	E 101° 04.617’	N 04° 35.999’	38	331	247
897	E 101° 05.487’	N 04° 35.464’	24	209	156
898	E 101° 06.420’	N 04° 34.865’	22	191	143
899	E 101° 06.745’	N 04° 35.275’	26	226	169
900	E 101° 07.779’	N 04° 34.944’	18	157	117
901	E 101° 08.533’	N 04° 35.428’	22	191	143
902	E 101° 09.123’	N 04° 35.764’	18	157	117
903	E 101° 08.671’	N 04° 36.080’	24	209	156
904	E 101° 08.499’	N 04° 36.373’	20	174	130
905	E 101° 07.609’	N 04° 35.311’	24	209	156
906	E 101° 07.795’	N 04° 35.610’	26	226	169
907	E 101° 07.026’	N 04° 34.833’	22	191	143
908	E 101° 07.586’	N 04° 34.641’	30	261	195
909	E 101° 04.070’	N 04° 38.972’	34	296	221
910	E 101° 03.660’	N 04° 39.224’	60	522	390
911	E 101° 04.081’	N 04° 38.643’	26	226	169
912	E 101° 03.406’	N 04° 38.567’	60	522	390
913	E 101° 02.501’	N 04° 37.892’	70	609	455
914	E 101° 03.134’	N 04° 37.978’	60	522	390
915	E 101° 02.743’	N 04° 37.519’	70	609	455
916	E 101° 02.725’	N 04° 36.587’	60	522	390
917	E 101° 02.665’	N 04° 37.044’	60	522	390
918	E 101° 02.482’	N 04° 35.966’	60	522	390
919	E 101° 01.930’	N 04° 34.520’	60	522	390
920	E 101° 02.132’	N 04° 35.086’	50	435	325
921	E 101° 01.988’	N 04° 33.370’	60	522	390
922	E 101° 01.786’	N 04° 33.040’	50	435	325
923	E 101° 01.745’	N 04° 32.173’	40	348	260
924	E 101° 01.407’	N 04° 32.423’	50	435	325
925	E 101° 01.590’	N 04° 31.604’	36	313	234
926	E 101° 01.473’	N 04° 31.621’	50	435	325
927	E 101° 01.430’	N 04° 31.257’	70	609	455
928	E 101° 01.330’	N 04° 30.232’	28	244	182
929	E 101° 01.123’	N 04° 29.684’	42	365	273
930	E 101° 00.965’	N 04° 29.138’	44	383	286
931	E 100° 59.627’	N 04° 27.306’	18	157	117
932	E 100° 59.709’	N 04° 26.611’	22	191	143
933	E 101° 00.172’	N 04° 25.474’	18	157	117
934	E 101° 00.929’	N 04° 25.356’	16	139	104
935	E 100° 59.641’	N 04° 25.027’	18	157	117
936	E 100° 59.208’	N 04° 22.844’	20	174	130
937	E 100° 59.619’	N 04° 22.067’	16	139	104
938	E 100° 58.689’	N 04° 22.762’	14	122	91
939	E 100° 58.372’	N 04° 23.539’	20	174	130

940	E 100° 58.041’	N 04° 23.474’	16	139	104
941	E 100° 57.499’	N 04° 23.455’	14	122	91
942	E 100° 58.801’	N 04° 25.189’	14	122	91
943	E 101° 00.266’	N 04° 29.129’	18	157	117
944	E 100° 59.981’	N 04° 29.955’	42	365	273
945	E 101° 00.074’	N 04° 30.307’	40	348	260
946	E 101° 00.238’	N 04° 29.790’	46	400	299
947	E 101° 00.494’	N 04° 29.807’	30	261	195
948	E 101° 00.484’	N 04° 32.076’	46	400	299
949	E 101° 00.163’	N 04° 32.295’	46	400	299
950	E 101° 00.705’	N 04° 30.701’	28	244	182
951	E 100° 59.905’	N 04° 31.338’	46	400	299
952	E 101° 00.498’	N 04° 30.912’	30	261	195
953	E 101° 00.387’	N 04° 30.347’	26	226	169
954	E 101° 02.300’	N 04° 30.532’	24	209	156
955	E 101° 02.787’	N 04° 30.994’	20	174	130
956	E 101° 03.042’	N 04° 32.599’	18	157	117
957	E 101° 02.796’	N 04° 31.942’	20	174	130
958	E 101° 02.608’	N 04° 31.598’	20	174	130
959	E 101° 04.026’	N 04° 35.065’	32	278	208
960	E 101° 03.434’	N 04° 34.181’	18	157	117
961	E 101° 03.454’	N 04° 33.579’	22	191	143
962	E 101° 02.981’	N 04° 33.540’	18	157	117
963	E 101° 02.608’	N 04° 33.021’	20	174	130
964	E 101° 02.660’	N 04° 33.704’	22	191	143
965	E 101° 02.318’	N 04° 34.525’	24	209	156
966	E 101° 03.171’	N 04° 35.101’	26	226	169
967	E 101° 03.420’	N 04° 35.888’	22	191	143
968	E 101° 03.502’	N 04° 36.695’	26	226	169
969	E 101° 03.719’	N 04° 37.127’	32	278	208
970	E 101° 03.814’	N 04° 37.549’	34	296	221
971	E 101° 04.389’	N 04° 36.854’	34	296	221
972	E 101° 04.765’	N 04° 37.316’	30	261	195
973	E 101° 04.897’	N 04° 38.138’	24	209	156
974	E 101° 05.644’	N 04° 37.367’	26	226	169
975	E 101° 04.736’	N 04° 38.672’	26	226	169
976	E 101° 05.554’	N 04° 37.633’	26	226	169
977	E 101° 05.644’	N 04° 37.370’	26	226	169
978	E 101° 06.038’	N 04° 35.094’	22	191	143
979	E 101° 05.028’	N 04° 34.219’	22	191	143
980	E 101° 04.099’	N 04° 33.244’	26	226	169
981	E 101° 03.753’	N 04° 33.690’	28	244	182
982	E 101° 05.073’	N 04° 36.473’	26	226	169
983	E 101° 05.447’	N 04° 36.319’	24	209	156
984	E 101° 06.031’	N 04° 36.651’	22	191	143

985	E 101° 06.533’	N 04° 36.816’	22	191	143
986	E 101° 07.225’	N 04° 36.189’	24	209	156
987	E 101° 06.301’	N 04° 35.891’	20	174	130
988	E 101° 05.916’	N 04° 34.934’	24	209	156
989	E 101° 07.024’	N 04° 24.679’	16	139	104
990	E 101° 06.917’	N 04° 24.261’	16	139	104
991	E 101° 06.489’	N 04° 24.530’	30	261	195
992	E 101° 05.878’	N 04° 24.064’	24	209	156
993	E 101° 05.464’	N 04° 23.374’	16	139	104
994	E 101° 05.576’	N 04° 22.922’	16	139	104
995	E 101° 08.737’	N 04° 17.295’	18	157	117
996	E 101° 08.440’	N 04° 17.705’	18	157	117
997	E 101° 08.794’	N 04° 18.081’	20	174	130
998	E 101° 08.039’	N 04° 17.509’	16	139	104
999	E 101° 07.552’	N 04° 17.650’	16	139	104
1000	E 101° 07.017’	N 04° 17.507’	20	174	130
1001	E 101° 06.654’	N 04° 17.469’	16	139	104
1002	E 101° 04.969’	N 04° 42.462’	26	226	169
1003	E 101° 05.850’	N 04° 44.800’	12	104	78
1004	E 101° 00.110’	N 04° 32.080’	60	522	390
1005	E 101° 00.540’	N 04° 32.040’	40	348	260
1006	E 101° 00.490’	N 04° 32.140’	30	261	195
1007	E 101° 02.170’	N 04° 33.060’	25	218	163

1 $\mu R\ h^{-1} = 8.7\ nGy\ h^{-1}$, correction factor = 0.746

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Concentration of Uranium and Thorium in the Product and by-Product of Amang and Ilmenite Tailings Process

(Kepekatan Uranium dan Torium dalam Hasil dan Hasil Sampingan proses Tahi Timah Amang dan Ilmenit)

HUSIN WAGIRAN, LIM SAY ENG, LEE SIAK KUAN & MOHAMAD YASIN SUDIN

ABSTRACT

Amang are by-products obtained when tin tailings are processed into concentrated ores and other economical products such as monazite, (Ce,La,Th)PO_4; zircon, $ZrSiO_4$; ilmenite, $FeTiO_3$; struverit; and xenotime, YPO_4. Its could be extracted from amang for further usage. Tailings from these ores may have a significant potential to cause elevated radiation exposures. This project was carried out to measure the concentration of uranium and thorium in the waste and products produced after the processing of the amang and ilmenite ore. The concentration of uranium and thorium was determined using gamma ray spectrometer with HPGe detector. The concentration of uranium was determined by measuring the intensity of gamma ray emitted from its daughter nuclei ^{214}Pb at 352 keV and ^{214}Bi at 609 keV while the concentration of thorium was determined by measuring the intensity of gamma rays emitted from its daughter nuclei ^{228}Ac at 911 keV and ^{208}Tl at 583 keV. The concentration of uranium and thorium in ppm obtained in this study are as follows: raw amang (83 – 383) and (174 - 1566); ilmenite (149 – 290) and (301 – 575); monazite (2303 – 4070) and (9641 – 60061); zircon (963 – 1192) and (353 – 583) and waste (22 – 98) and (44 – 223) respectively. Rutile and iron oxide was obtained from ilmenite. The concentration of uranium and thorium in rutile was 50 and 72 ppm and from iron oxide was 336 and 379 ppm respectively. These values are considered high compare to normal sand and could pose danger to the surrounding.

Keywords: Amang, Uranium, Thorium, Ilmenite

ABSTRAK

Amang adalah hasil sampingan yang diperoleh semasa pengekstrakan tahi timah kepada logam tulennya. Pelbagai hasil yang berekonomi seperti monazit, (Ce,La,Th)PO_4; zirkon, $ZrSiO_4$; ilmenit, $FeTiO_3$; struverit; dan xenotim, YPO_4 boleh diekstrak daripada amang bagi kegunaan seterusnya. Pemprosesan tahi bijih ini berkeupayaan mendatangkan pendedahan sinaran yang tidak diingini. Kajian ini dijalankan untuk menentukan kandungan uranium dan torium yang terkandung dalam sisa dan hasil yang dikeluarkan semasa pemprosesesan amang dan ilminit. Kepekatan kandungan uranium dan torium ditentukan menggunakan spkltrometer sinar gama dengan pengesan HPGe. Kandungan uranium ditentukan dengan mengukur keamatan sinar gama yang dipancarkan daripada nukleus anaknya, iaitu ^{214}Pb pada tenaga 352 keV dan ^{214}Bi pada tenaga 609 keV, manakala kandunagan torium ditentukan dengan mengukur keamatan sinar gama yang dipancarkan oleh nukleus anaknya, iaitu ^{228}Ac pada tenaga 911 keV dan ^{208}Tl pada 583 keV. Kandungan uranium dan torium dalam ppm yang diperoleh daripada kajian ini masing-masing adalah seperti berikut: amang mentah (83 – 383) dan (174 - 1566); ilmenit (149 – 290) dan (301 – 575); monazit (2303 – 4070) dan (9641 – 60061); zirkon (963 – 1192) dan (353 – 583,) dan sisa (22 – 98) dan (44 – 223). Kandungan uranium dan torium dalam rutilmasing-masing ialah 50 and 72 ppm, manakala dalam ferum oksida ialah 336 dan 379 ppm. Nilai yang diperolehi ini adalah tinggi berbanding dengan pasir biasa semula jadi dan berpotensi mendatangkan kemudaratan kepada persekitaran.

Kata kunci: Amang, Ilmenit, Uranium, Torium

INTRODUCTION

The total number of mines in Malaysia at the end of the year 2002 was 66. The main minerals produced include tin ore, raw gold, iron ore, coal, bouxite, mica, silica and kaolin. Rare earth minerals such as zircon, ilminite and struverite were produced as by-products of tin mining, amang (Minerals and Geosciences Department Malaysia, 2002).

The mining and processing of ores for the production of metals and minerals generate large quantities of residual bulk solid and liquid wastes. Because the minerals of value make up only a small fraction of the ore, most of these bulk minerals has no direct use. Depending on the original ores and processing methods, some of these wastes contain elevated concentration of TENORM (Technologically Enhanced Naturally Occurring Radioactive Material). It has been reported that some of the more uncommon metals have highly radioactive waste products. Some processes associated with metal extraction appear to concentrate certain radionuclides and enhance their environmental mobility (Cohen et al. 1993).

In Malaysia, mining tin ore has left large areas of radioactively contaminated spoil heap. Amang is a general term for the by products obtained when tin tailings are processed into concentrated ores. It includes minerals such as monazite, Ce,La,Th)PO_4; zircon, $ZrSiO_4$; ilminite, FeTiO$_3$; rutile, TiO$_2$; struverit and xenotime, YPO$_4$. Tailings from these ores may have a significant potential to cause elevated radiation exposures (Cohen et al. 1993). This radioactivity represents a potential health hazard to the dense population of this region (Hu et al. 1981).

Ilminite is one of the products in amang tailing. It was treated in a local factory to produce rutile, TiO$_2$, which is used in paint industry.

In this study, the concentration of uranium and thorium in various types of product and by-product during amang tailings and ilminite tailings were investigated. The samples were collected from several amang processing factories located in the state of Perak.

EXPERIMENT

A total of 40 samples has been collected. The samples were collected from four amang tailings factories and one ilminite talings factory, which are located in the Kinta Valley. Perak. The detail description of the samples is shown in Appendix 1. The measured samples were dried in the oven at 110 °C, pulverized, sieved through 200 micron, weighted, sealed in polyethylene of 20 ml vials and stored for four weeks before counting in order to allow the in-growth of uranium and thorium decay products and achievement of equilibrium for ^{238}U and ^{232}Th with their respective progeny (Myrich et al. 1983).

In this study, the concentration of uranium and thorium in the samples were determined using gamma-ray spectrometer with HPGe detector. The concentration of uranium was determined by measuring the intensity of gamma ray emitted from its daughter nuclei ^{214}Pb at 352 keV and ^{214}Bi at 609 keV while the concentration of thorium was determined by measuring the intensity of gamma rays emitted from its daughter nuclei ^{228}Ac at 911 keV and ^{208}Tl at 583 keV (Myrich et al. 1983). Figure 1 shows the arrangement of electronic devices in gamma-ray spectrometer used in this study.

The calibration curve was used to determine the concentration of uranium and thorium in the samples. Standard sample S-15 supplied by IAEA was prepared in four different masses. The activities or the number of counts, N in the sample is proportional to the mass, M of uranium or thorium in the sample and given by

$$N \propto M$$

or

$$N = kM,$$

where k is the slope of the graph. The intercept of the curve was set to be zero. The mass of uranium and thorium in the sample were determined by

$$M = \frac{N}{k}.$$

The concentration of uranium and thorium in the sample then be determined by

$$C = \frac{M}{W},$$

where C is the concentration of uranium and thorium in the sample in ppm (mg/g) and W is the mass of the sample in g. The calibration curves for determination of uranium and thorium content are shown in Figure 2 and Figure 3 respectively.

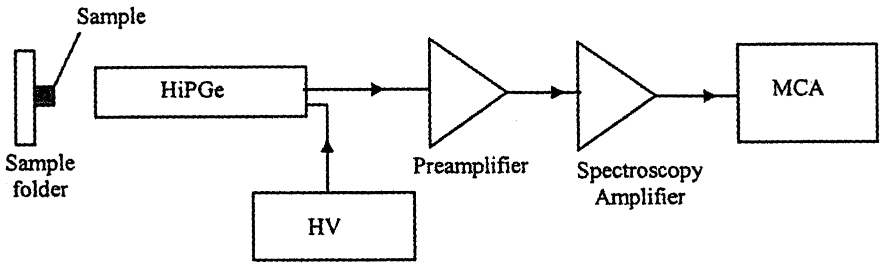

FIGURE 1. The arrangement of electronic devices in gamma-ray spectrometer

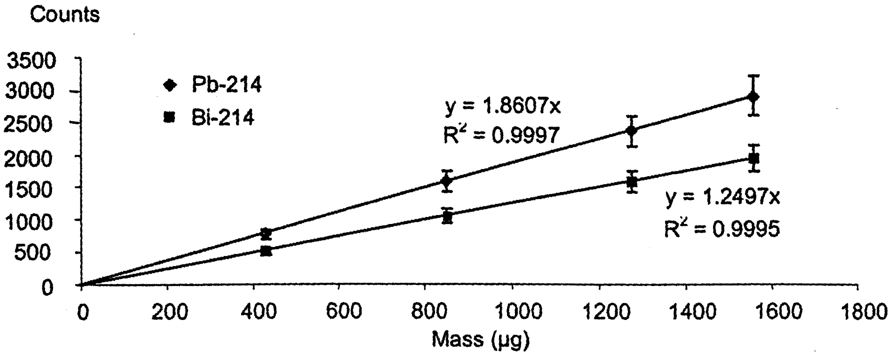

FIGURE 2. Calibration curve for determination of uranium

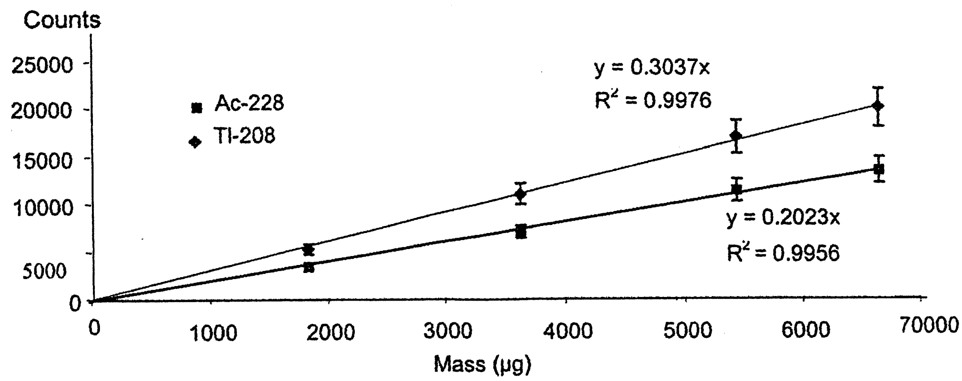

FIGURE 3. Calibration curve for determination of thorium

RESULTS AND DISCUSSION

Based on the process of amang tailings, the samples collected from the amang factories were grouped into four categories. Those were raw material, intermediate material, product material and waste product. Samples collected from amang factories, S0, P1, B0 and BM1 were the raw materials. Samples S1, S2, S3, S4, P2 and B1 were the intermediate materials, that is the sand removed materials during wet process in amang tailings. Samples S7, S8, S9, BM3 and BM4 were the intermediate materials during dry process in amang tailings. The samples grouped as product materials were ilminite, monzite, zircon, cassiterite, rutile and tourmaline. The ilminite samples were S6, P3, B4 and BM5. Monazite samples were S11, B3 and BM6 while zircon samples were S10, B5 and BM7. Cassiterite, rutile snd tourmaline samples were BM8, BM9 and BM10 respectively. The waste samples were S5, S12, P4, B2 and BM2.

The concentration of uranium and thorium in the samples collected from four amang tailings factories obtained in this study are shown in Table 1. The concentration of uranium and thorium in raw amang samples are in the range of (83 – 383) ppm and (174 – 1556) ppm respectively. For intermediate materials during wet process of amang tailings, the concentration of uranium and thorium were in the range of (148 – 279) and (327 – 1393) ppm respectively while for intermediate materials during dry process in amang tailings, the concentrations are in the range of (396 – 1491) ppm for uranium and (2259 – 17529) ppm for thorium.

The concentration of uranium and thorium in the products materials of amang tailings process are (1.49 – 290) and (301 – 575) ppm for alminite samples, (2303 – 4070) ppm and (9641 – 60061) ppm for monazite samples and (963 – 1192) ppm and (353 – 583) ppm for zircon samples. Cassiterite produced from amang tailings has 41 ppm of uranium and 67 ppm of thorium. The concentration of uranium and thorium in rutile are 8 ppm and 24 ppm recpectively.

The concentration of uranium and thorium in waste products of amang tailings are (22- 98) ppm and (44 – 223) ppm respectively. The natural sand samples which were collected from other places around Kinta Valley, far away from the factories contain (3 – 5) ppm of uranium and (7 – 10) ppm of thorium. These results clearly show that the sand samples produced from amang processing industries contain more uranium and thorium compared to natural sand.

From the study, it could be seen that after the tailings process, the product materials such as monazite and zircon have high concentration of uranium and thorium. Ilminite, cassiterite, rutile, tourmaline and waste sand have lower concentration of uranium and thorium compare with raw materials after amang tailing process. Other products have low concentration of uranium and thorium.

For ilminite tailings process, the samples were collected from one factory only. The samples also grouped into raw material, intermediate material, product material and waste product. Table 2 shows the concentration of uranium and thorium in the samples collected from ilminite tailings factory.

From the table, it is shown that the raw material, elminite contains 170 ppm uranium and 183 ppm thorium. The concentrations of uranium in reduced ilminite and leached ilminite sample are 222 ppm and 57 ppm, while the concentrations of thorium are 210 ppm and 79 ppm respectively. The product of ilminite tailing process, rutile contains 50 ppm uranium and 72 ppm thorium. The waste product of ilminite tailings process, iron oxide contains 336 ppm uranium and 379 ppm thorium.

CONCLUSION

In amang tailings process, the concentration of uranium increases in most samples except ilminite, cassiterite, rutile, toumaline and sand. Only monazite is concentrated with thorium during amang tailings process. The highest uranium concentration was found in the monazite samples (2369 – 4070) ppm. The results show that the there are a potential to extract uranium from the monazite for further usage as fuel in nuclear reactor. Normally, 1000 ppm of uranium concentration in the sample was good enough to extract uranium for nuclear reactor fuel.

Ilminite produced from amang tailings process has to be processed again to produce titanium oxide to be used as a raw material in paint industry. The waste product of this process, iron oxide has high concentration of uranium and thorium and therefore it cannot be used for other purposes like construction materials.

TABLE 1. The concentration of uranium and torium in the samples collected from amang tailings factories

Sample description	Sample	Name of Factory	Uranium (ppm)	Thorium (ppm)
Raw Amang	S0	Sin Fook Lee and Co	92 ± 8	239 ± 19
	P1	Sakuma Sdn Bhd	248 ± 20	361 ± 26
	B0	Syarikat Kilang Amang Tronoh	83 ± 7	174 ± 15
	BM1	BEH Meneral Sdn Bhd	383 ± 29	1566 ± 88
		Range of concentration	*83 - 383*	*174 - 1556*
Intermediate Material (reduced amang in wet process)	S1	Sin Fook Lee and Co	171 ± 14	694 ± 43
	S2	Sin Fook Lee and Co	209 ± 17	902 ± 56
	S3	Sin Fook Lee and Co	199 ± 17	1088 ± 66
	S4	Sin Fook Lee and Co	279 ± 22	1393 ± 81
	P2	Sakuma Sdn Bhd	148 ± 13	327 ± 25
	B1	Syarikat Kilang amang Tronoh	202 ±	567 ± 36
		Range of concentration	*148 - 279*	*327 - 1393*
Intermediate Material (reduced amang in dry process)	S7	Sin Fook Lee and Co	396 ± 31	2259 ± 125
	S8	Sin Fook Lee and Co	921 ± 69	6214 ± 317
	S9	Sin Fook Lee and Co	1349 ± 99	11630 ± 572
	BM3	BEH Meneral Sdn Bhd	1156 ± 84	10297 ± 506
	BM4	BEH Meneral Sdn Bhd	1491 ± 108	17529 ± 846
		Range of concentration	*392 - 1491*	*2259 - 17529*
Imenite (product of amang in tailing process)	S6	Sin Fook Lee and Co	149 ± 12	301 ± 22
	P3	Sakuma Sdn Bhd	290 ± 23	573 ± 38
	B4	Syarikat Kilang amang Tronoh	214 ± 17	575 ± 35
	BM5	BEH Meneral Sdn Bhd	250 ± 20	354 ± 26
		Range of concentration	*149 – 290*	*301 – 575*
Monazite (product of amang in tailing process)	S11	Sin Fook Lee and Co	2369 ± 174	6006 ± 2829
	B3	Syarikat Kilang amang Tronoh	4070 ± 287	9641 ± 479
	BM6	BEH Meneral Sdn Bhd	2303 ± 170	57368 ± 2710
		Range of concentration	*2303 - 4070*	*6006 - 57368*
Zircon (product of amang in tailing process)	S10	Sin Fook Lee and Co	963 ± 70	364 ± 28
	B5	Syarikat Kilang amang Tronoh	1039 ± 76	353 ± 26
	BM7	BEH Meneral Sdn Bhd	1192 ± 87	583 ± 41
		Range of concentration	*963 - 1192*	*353 - 583*
Cassiterite (product of amang in tailing process)	BM8	BEH Meneral Sdn Bhd	41 ± 4	67 ± 8
Rutile (product of amang in intailing process)	BM9	BEH Meneral Sdn Bhd	73 ± 7	117 ± 12
Tourmaline (product of amang in tailing process)	BM 10	BEH Meneral Sdn Bhd	8 ± 2	24 ± 6
Sand (waste of amang tailing process)	S5	Sin Fook Lee and Co	22 ± 3	44 ± 8
	S12	Sin Fook Lee and Co	51 ± 5	184 ± 17
	P4	Sakuma Sdn Bhd	42 ± 4	53 ± 7
	B2	Syarikat Kilang Amang Tronoh	82 ± 8	129 ± 12
	BM2	BEH Meneral Sdn Bhd	98 ± 8	223 ± 17
		Range of concentration	*22 - 82*	*44 - 184*
Natural Sand	A2-1	Kinta Valley	5 ± 2	10 ± 8
	A2-2	Kinta Valley	3 ± 1	7 ± 8
		Range of concentration	*3 - 5*	*7 - 10*

TABLE 2. The concentration of uranium and torium in the samples collected from ilminite tailings factory

Sample description	Sample	Name of Factory	Uranium (ppm)	Thorium (ppm)
Raw ilminite	T1		183 ± 15	170 ± 14
Reduced ilminite	T2		222 ± 18	210 ± 16
Leached ilminite	T3	TOR Mineral Sdn. Bhd	57 ± 5	79 ± 9
Synthetic rutile	T4		50 ± 5	72 ± 8
Iron oxide	T5		336 ±	379 ± 45

APPENDIX 1. Description of the samples

Name of Factory	Sample	Description of the sample
Sin Fook Lee and Co	S0	Raw amang
	S1	Intermediate material (large)
	S2	Intermediate material (medium)
	S3	Intermediate material (fine)
	S4	Combined intermediate material
	S5	Wet sand
	S6	Ilminite
	S7	Zircon, low grade ilminite
	S8	Zircon, monazite, xenotime
	S9	Monazite, < zirconium
	S10	Zirconium 62% interlock monazite
	S11	Monazite
	S12	Dry sand
Sakuma Sdn. Bhd.	P1	Raw amang
	P2	Tin, zircon, monazite etc
	P3	Ilminite
	P4	Sand
Syarikat Kilang Amang Tronoh	B0	Raw amang
	B1	Intermediate material
	B2	Sand
	B3	Monazite
	B4	Ilminite
	B5	Zircon
BEH Mineral Sdn. Bhd.	BM1	Raw amang
	BM2	Sand
	BM3	> zircon and monazite, Xenotime
	BM4	> Monazite, Xenotime, Zircon
	BM5	Ilminite
	BM6	Monazite
	BM7	Zircon
	BM8	Cassiterite
	BM9	Rutile
	BM10	Tourmaline
TOR Mineral Sdn. Bhd	T1	Raw ilminite
	T2	Reduced ilminite
	T3	Leached ilminite
	T4	Iron oxide
	T5	Synthetic rutile
Kinta Valley Area	A2-1	Sand
	A2-2	Sand

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NATURAL GAMMA BACKGROUND RADIATION DOSE RATE AND ITS RELATIONSHIP WITH GEOLOGICAL BACKGROUND IN THE KINTA DISTRICT, PERAK, MALAYSIA

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ABSTRACT

A survey of natural gamma background radiation (NGBR) levels in the Kinta District was carried out for three years between 2003 and 2005. Dose rates were measured from 1007 locations by using a portable gamma-ray survey meter manufactured by Ludlum, Model 19 MicroR Meter. The measured dose rates ranged from 39 to 1039 nGy h^{-1}. It has a mean dose rate of 222 ± 191 nGy h^{-1}. Small areas of hot spot around Kampung Sungai Durian with dose rates up to 1039 ± 104 nGy h^{-1}. This is the highest recorded in Perak to date. Geological type G5 is Jurassic – Triassic, the rock type is mainly granites. It exhibits the highest mean dose rate of 432 ± 259 nGy h^{-1}. The dose rates range from 91 to 1039 nGy h^{-1}. The lowest recorded was on sandstones, the dose rate is 39 nGy h^{-1}. The mean population weighted dose rate for the Kinta District is 1.12 mSv y^{-1}. Gamma isodose map for the Kinta District was plotted.

Keywords: NGBR, dose rate, hot spot, population, isodose

1. INTRODUCTION

Environmental gamma activities results from potassium, uranium, thorium, and their daughters in various rocks and soils; estimates of such activities at a height of about 1 m over granite areas are typically on the order of 1600 μGy y^{-1} and over limestone on the order of 200 μGy y^{-1} (Henry,1969). The dose rate depends on the geological location (Ramli, 1997; Martin and Harbison, 1972).

Nation-wide survey of natural gamma background radiation has been carried out in many countries and to establish a baseline data of natural radiation levels (Ramli et al., 2001; Ibrahiem et al., 1993; Quindos et al., 1994; Mireles et al., 2003). In several high background areas in the world, such as in Brazil, Iran, India and China the radiation levels that the local inhabitants are exposed to, are similar to or above those received by the workers of the nuclear industry (UNSCEAR 1993). The baseline data will be used as reference information to assess any changes in the radiation background level due to various processes or any fallout in the near future. The measurement will also help in the development of standards and guidelines for use and management of radioactive materials (Quindos et al., 1994).

The Kinta District is located between latitude 4º 45"N and 4º 15"N and longitude 101º 15"E and 101º 00"E. It is divided into 7 *mukims*. The main objectives of this project are to establish a baseline data of natural gamma radiation levels and to identify areas where the dose rate are high.

2. GEOLOGICAL FEATURE

The geology map of the Kinta District (Ingham and Bradford, 1960) is produced in Figure 1. The Kinta District is an extensive area located in a valley flanked by granites to the east and west. The Kinta District is underlain by a sequence of sedimentary rocks ranging in age from Silurian to Permian, which have been intruded by granitoids and associated late phase minor intrusive of probable Jurassic to Triassic age. Most of the sedimentary rocks in the valley are Devonian in age. Rocks of Silurian age are present in the northern part, whereas rocks of carboniferous underline areas in the south western part of the valley. Alluvium covers almost the entire valley. Its thickness varies considerably; in the valley, the thickness increases southward from 6 m near Ipoh to more than 30 m in the southern part (Rajah, 1979).

Granite is the major igneous rock that is abundantly available in Peninsular Malaysia. The ages of the granites range from Permian to Cretaceous; with the majority of Triassic age (Bignell and Snelling, 1977).

Rocks of the Calcareous Series are believed to be of carboniferous age i.e. between 280 and 345 million years (Inghan and Bradford, 1960). The sedimentary rocks underlying the Kinta District is chiefly calcareous. They comprise relatively pure limestone, dolomite and ferroandolomite and occupy about 673 sq km of the valley. Generally, the limestone has recrystalline to form crystalline marble. The resulting calcite crystals show great variation in grain size. Locally, the calcareous rocks may be interbedded with argillaceous beds. The limestone, with irregular pinnacles and forming a karts topography, has commonly been in mines working on stanniferous alluvium. In Kinta, limestone hills arising from the alluvial plain and forming a striking topographical feature occur particularly in the eastern portion of the valley. Permian limestone is known to be present north of Tanjung Rambutan and west of Kampar (Rajah, 1979).

The argillaceous rocks consist essentially of shale, phyllite and schist with subordinate siltstone and sandstone (quartize). The argillaceous strata are well exposed in numerous parts of the valley. The largest outcrops extend from Batu Gajah to Tanjung Tualang and form a stretch of undulating country. The arenaceous rocks are composed mainly of sandstone (quartize) with minor interbeds of conglomerate, siltstone and shale. These rocks are found mainly in the west and southwest of the valley. Granitic rocks, in the shape of a giant horse-shoe, encircle the sedimentary strata that form the basement of the valley. They underlie an area of about 738 sq km i.e. about half the area of Kinta District (Rajah, 1979).

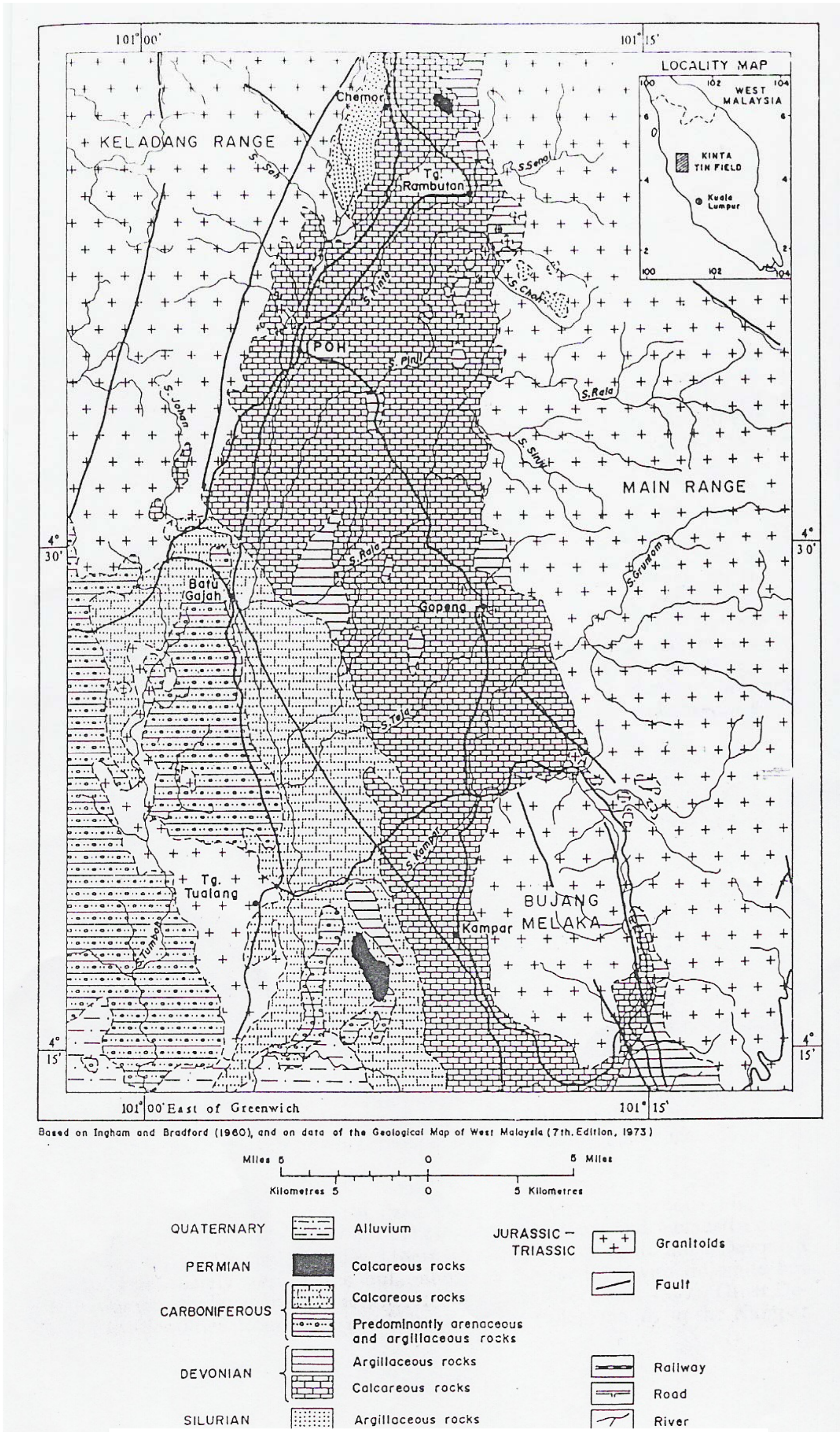

Figure 1 Geology of the Kinta District

3 METHODS AND MATERIAL

Dose rate measurements in the Kinta District were performed by a portable survey meter manufactured by Ludlum (Model 19 Micro R Meter, USA). The equipment uses a 2.54 cm x 2.54 cm NaI crystal doped with thallium [NaI(Tl)] to offer an optimum performance in counting low-level gamma radiation. The NaI scintillator is energy sensitive. This instrument had a reported accuracy of ± 10%. (Ludlum Measurements, Inc. 1993). The detection of gamma rays from cosmic sources is negligible due to the low response of the instrument to high energy gamma radiation. This was observed when radiation level was measured on board of a ferry far away from land. It detected a reading of only half a division on the smallest scale 1 μR h^{-1}(~ 8.7 nGy h^{-1}). The NaI(Tl) detector is the most widely used device for all kinds of gamma ray surveys due to its efficiency (IAEA 1979).

The survey meter was placed on the floor in the back seat; the car was driven throughout Kinta District. Dose measurements were done at approximately every 1 km (more frequently if significant change in the radiation level was detected) when ever access is possible by road. The following procedure was complied with at each measuring point:

(i) The car was driven off the road surface, usually into the nearby field.
(ii) The survey meter was held 1 m above the ground.
(iii) After 60 seconds warm-up an average of the radiation levels was recorded.
(iv) Take another two readings about 5 meters away from each other.
(v) The actual measurement data will be the average of the three readings.

For each location, the latitude and the longitude were checked by using global positioning system (Garmin GPS 12XL) with an accuracy of about 100 meters. A total of 1007 measurements were taken (Figure 2). The grounds at the measurement locations were unpaved and generally covered by grass. Measurements were taken at relatively close distance to determine whether significant variation occur within the same area and to determine the representative result for larger area. In some areas where access was restricted no dose rates were measured e.g. on the eastern part of the Kinta District which is near to the border of Pahang. These areas are mainly Bukit Kinta Forest Reserve and have a very low population density. Locations chosen were flat ground away from obstacles, outcrops, and buildings (Goddard, 2002).

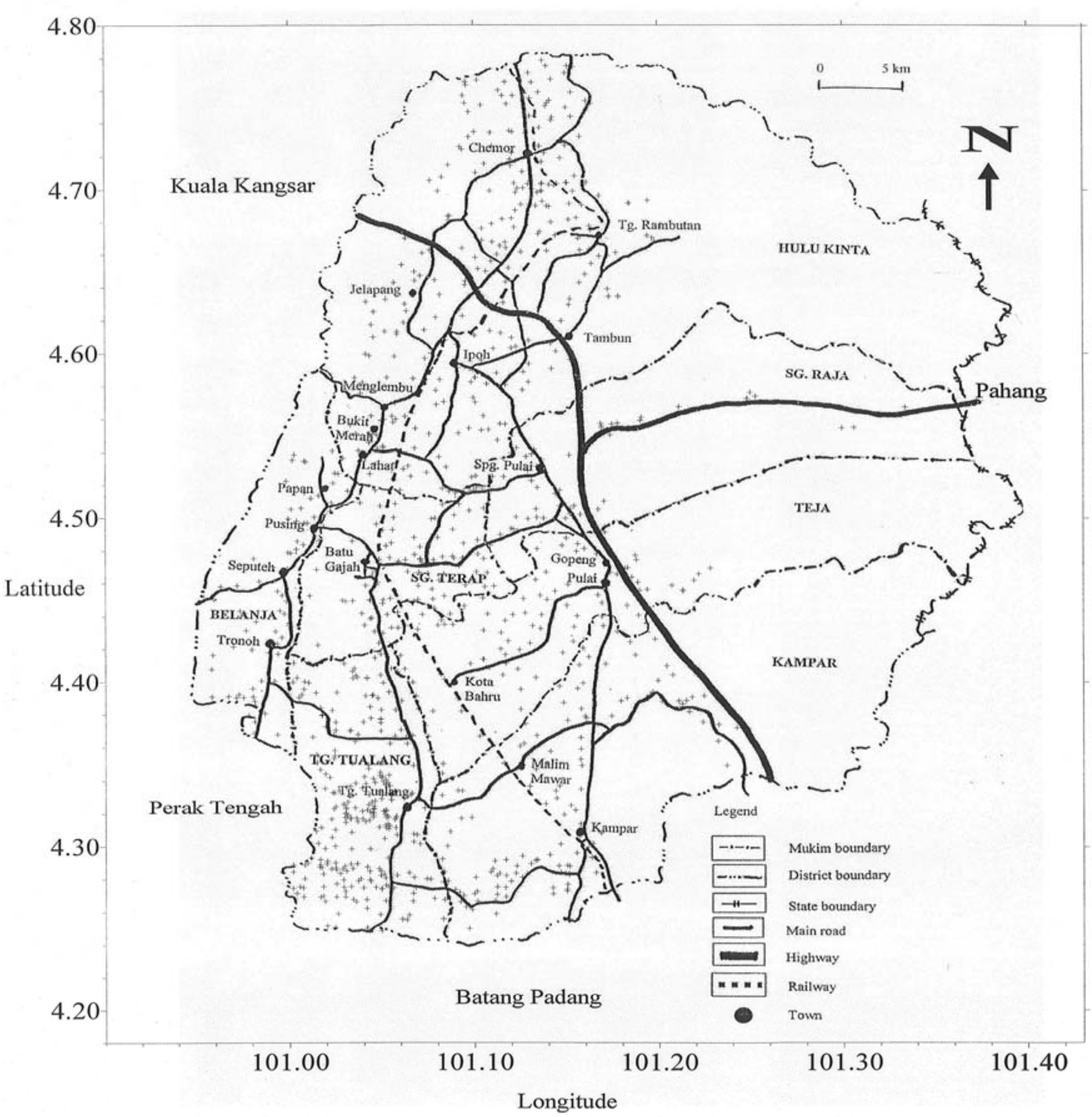

Figure 2 locations of dose measurement.

4 RESULTS AND DISCUSSION

4.1 Evaluation of Gamma-Ray Data

The distribution of the gamma-ray dose data is presented by histogram in Figure 3. The histogram of the gamma-ray dose data is skewed to the right. The most frequently recorded values were between 100 and 200 nGy h^{-1}. The frequency histogram becomes more symmetrical after the dose readings were transformed using natural logarithmic transformation, as shown in Figure 4.

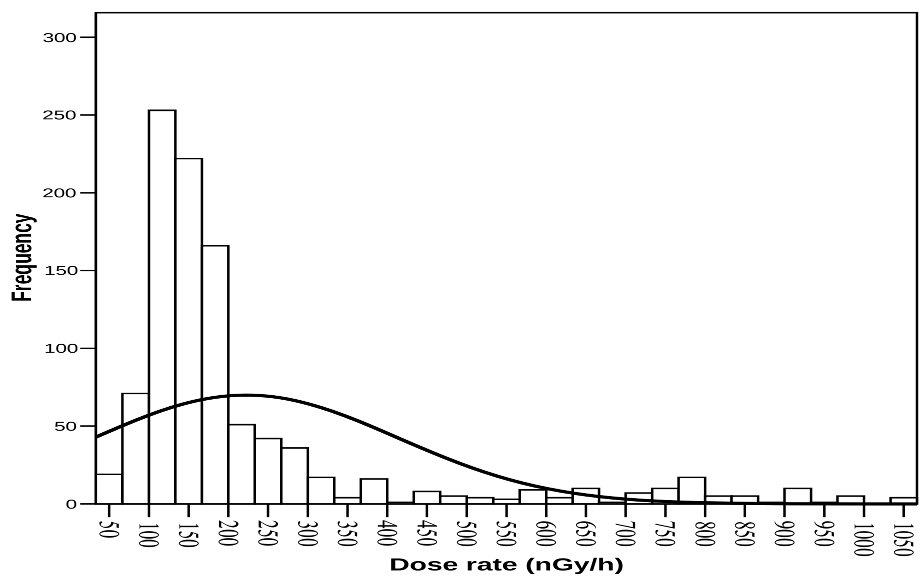

Figure 3 Frequency histogram of gamma radiation dose measurements

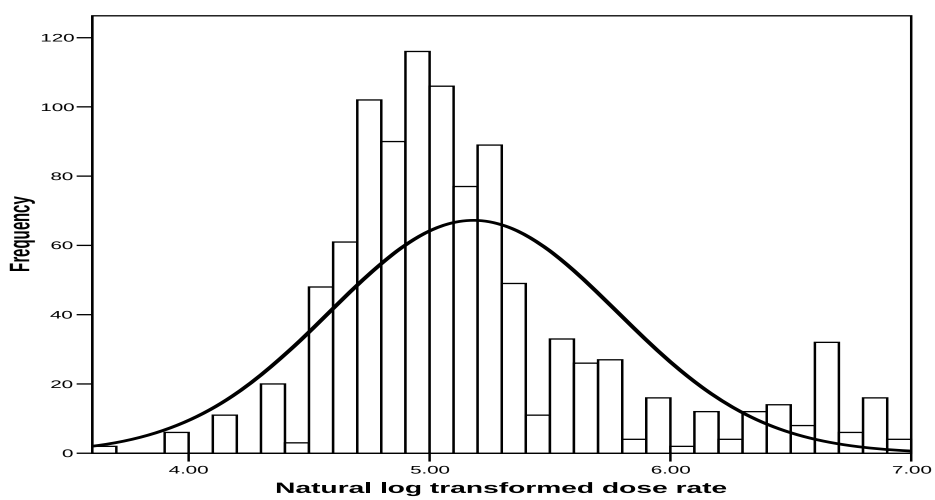

Figure 4 Frequency histogram of the log-transformed data shown in Figure 3

4.2 Geological Type and Gamma-Ray Dose Rate Distribution

In the Kinta District there are 7 different geological types as shown in Table 1. Geological types G1 and G2 are carboniferous. Geological types G3 and G4 are Devonian. The geological types are differentiated by difference types of rocks. For geological type G1, the rocks are arenaceous and argillaceous, the dose rate readings range are bigger than geological type G2, calcareous rock. From Table 2, the mean dose rate for geological types G1 and G2 are 133 ± 89 nGy $h^{-1}$and 134 ± 41 nGy h^{-1} respectively. For geological types G3 and G4, they have the same mean dose rate of 153 ± 38 nGy h^{-1}. The rock types are argillaceous and calcareous respectively.

Table 1 Geological features with rock types and number of readings taken

Code	Geological features and rock types			Number of Readings
G1	CAAR	Carboniferous	– Predominantly Arenaceous and Argillaceous	173
G2	CCR	Carboniferous	– Calcareous rocks	131
G3	DAR	Devonian	– Argillaceous rocks	22
G4	DCR	Devonian	– Calcareous rocks	384
G5	JTG	Jurassic-Triassic	– Granitods	271
G6	PCR	Permian	– Calcareous rocks	7
G7	SAR	Silurian	– Argillaceous rocks	19

Geological type G5 is Jurassic – Triassic, the rock type is granitiods. Geological type G5 exhibits the highest mean dose rate of 432 ± 259 nGy h^{-1}. The dose rates range from 91 to 1039 nGy h^{-1}. Geological type G6 is Permian. Permian limestone are present in the north of Tanjung Rambutan and west of Kampar has the lowest mean dose rate of 104 ± 17 nGy h^{-1}. Geological type G7 is Silurian, has the second highest mean dose of 176 ± 43 nGy h^{-1}. For geological types G3, G6 and G7, the areas covered are small and the number of readings taken was considered small ($n < 30$) are 22, 7 and 19 respectively. The results indicated that different geological types exhibit different values for the mean dose rates with Jurassic-Triassic > Silurian > Devonian > Carboniferous > Permian.

The mean gamma-ray dose measured under individual geological units for all locations varied from 104 ± 17 nGy h^{-1} measured under calcareous rock to 432 ± 259 nGy h^{-1} measured under granite. Granite has relatively higher content of radioactive materials (Omar and Hassan, 1990; Omar et al.,1991; Wong 1985).

Table 2 Statistical summary and 95% Confidence limit for the mean gamma-ray dose for various geological types.

Geology	Dose rate (nGy h^{-1})				95 % confidence intervals for mean
	Mean	Std. Deviation	Range	Std. Error	
G1	133	89	39 – 779	7	120 – 146
G2	134	41	65 – 390	4	127 – 142
G3	153	37	65 – 266	8	137 – 169
G4	153	39	52 – 325	2	149 – 157
G5	432	259	91 – 1039	16	401 – 463
G6	104	17	78 – 130	6	88 – 120
G7	176	43	78 – 253	10	155 – 199
Total	222	191	39 – 1039	6	210 - 234

The box plot in Figure 4 shows the variability and distribution of the data for each geological type. Gamma-ray dose distribution are almost symmetrical for geological types G2 and G4, but are skewed for G5 and G7. For geological types G1, G2, G3 and G4 extreme values were recorded.

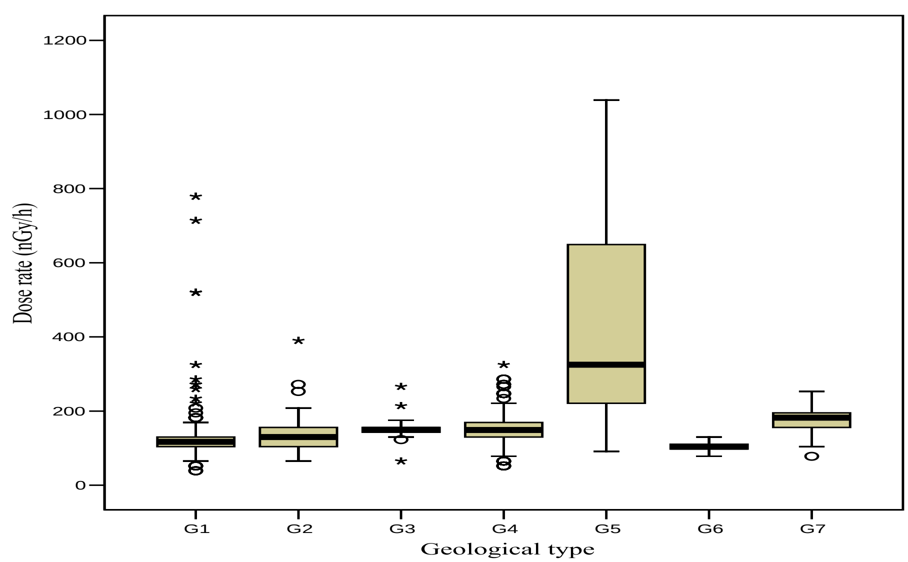

Figure 4 Box plot showing the distribution and the variability of gamma-ray dose for each geological type (* represents extreme values, and o represents outliers) (Triola, 2005).

4.3 Gamma-Ray Dose Rate Distribution

Table 3 shows the mean gamma-ray dose for each *mukim* (parish) in the Kinta District. The highest mean dose of 378 ± 301 nGy h^{-1} which is 6 times the world average of 59 nGy h^{-1} was in *mukim* Tg. Tualang, M5. The dose rate ranges from 39 nGy h^{-1} to 1039 nGy h^{-1}. The lowest mean dose of 133 ± 46 nGy h^{-1} was in *mukim* Teja, M3 which is 2 times over the world average. The dose rate ranges from 52 nGy h^{-1} to 312 nGy h^{-1}. The mean gamma-ray dose rate for the rest of the *mukims* range from 133 to 184 nGy h^{-1}, which are lower than mean value of 222 ± 191 nGy h^{-1}.

The mountainous regions are in *mukim* M1, Hulu Kinta. It is situated in the north-eastern part of the District, *mukim* M2, Sg. Raja, *mukim* M3, Teja and *mukim* M4, Kampar that are on the eastern part of the District. Only a few readings were taken here, that is along the highway to Cameron Highland. Most of the area is Bukit Kinta Forest Reserve. There are some rubber and oil palm plantations. The population involved is very small. The measurements taken here would not be representative of the dose received by the population as a whole.

Table 3 Statistical summary and 95% confidence limit for the mean gamma-ray dose for each *mukim* (SPSS Output).

Label – *Mukim*	Dose rate (nGy h^{-1})				95 % confidence intervals for mean
	Mean	Std. Deviation	Range	Std. Error	
M1 – Hulu Kinta	184	71	65 – 487	4	176 – 192
M2 – Sg. Raja	179	59	65 – 325	7	165 – 194
M3 – Teja	133	46	52 – 312	5	124 – 143
M4 – Kampar	152	51	65 – 390	4	1143 – 161
M5 – Tg. Tualang	378	301	39 – 1039	18	342 – 413
M6 – Belanja	165	85	52 – 455	11	143 – 186
M7 – Sg. Terap	144	48	65 – 390	5	134 – 153
Total	222	191	39 - 1039	6	210 – 234

Figure 5 shows the distribution of dose measurement for each *mukim*. The distributions of the dose rate are skewed towards the higher end for *mukim* M1, M2, M4, M5, and M6. *Mukim* M3 and M7 which are almost symmetric. *Mukim* M1, M4 and M7 have outliers and extreme values. *Mukim* M3 and M6 have outliers. These outliers affect the values of the mean and standard deviations.

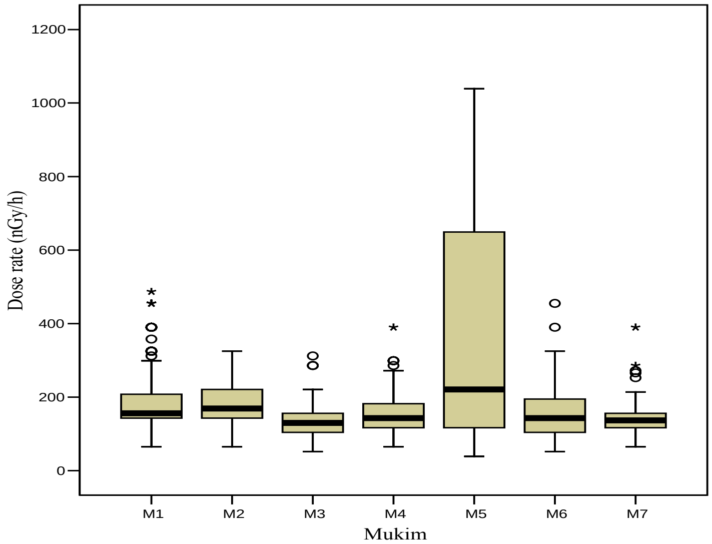

Figure 5 Box plot showing the distribution and the variability of gamma-ray dose for each *mukim* (* represents extreme values, and O represents outliers).

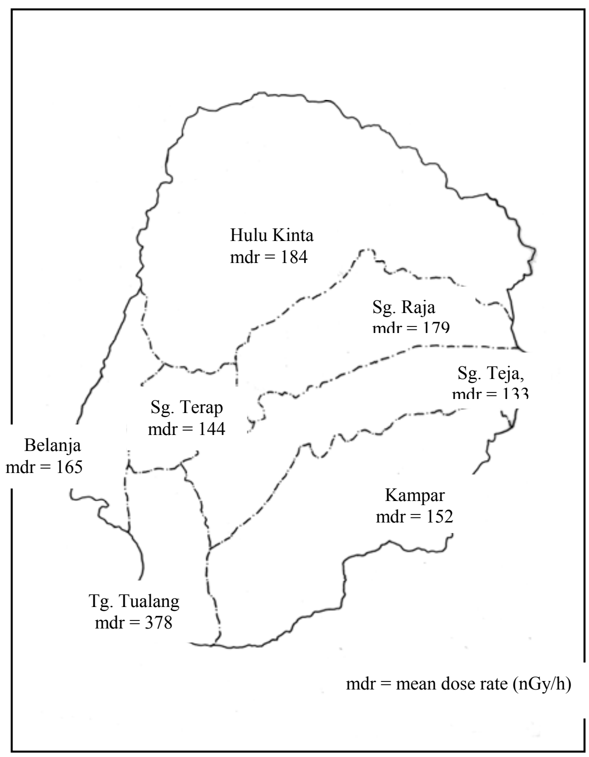

Figure 6 Map of Kinta District showing the 7 mukims with their respective mean dose rate

Figure 6 shows the 7 *mukims* with their respective dose rate. *Mukim* Tg. Tualang, M5 shows the highest mean dose rate of 378 nGy h^{-1}. The rest of the *mukims* have the mean dose less than half of *mukim* M5. *Mukim* M3 exhibits the lowest mean dose of 133 nGy h^{-1}. *Mukims* M3, M4 and M7 have the mean dose rate that is lower than 1 mSv y^{-1}.

4.4 Mean Population Weighted Dose Rate

The mean population weighted dose rate was obtained from the summation of all the products of the mean dose rate and population for each *mukim* and then divided by the total population. The mean population weighted dose rate for Kinta District was 1.12 mSv y^{-1}.

4.5 High Radiation Areas in Tg. Tualang

High natural gamma background radiation (HNGBR) areas in the Kinta District were located in *mukim* Tg. Tualang, (M5). Small areas of hot spots were located on higher ground with a dose rate of 1039 nGy h^{-1}. The hot spot areas are separated by a valley. These areas are cultivated with oil palms and rubber. Within the hot spot area, there were some residential houses in Kg. Sungai Durian. In this area the dose rates range from 143 – 714 nGy h^{-1}.

4.6 Comparison of Gamma Dose Rates in Air

The gamma dose rates in air in the Kinta District are compared with the values reported in Table 4.

Table 4 Comparison of gamma dose rates in air

District/State	Mean dose rate (nGy h^{-1})	Range (nGy h^{-1})	Reference
Kinta District	222 ± 191	39 – 1039	Present study
Kota Tinggi District	180 ± 20	45 – 630	Ahmad Taufek (2004)
Johor State	163 ± 122	9 – 1262	Wahab (1998)
Pontian District	67*	50 – 230	Ramli (1997)
Malaysia	92*	55 – 130	UNSCEAR (2000)
World	59*	-	UNSCEAR (2000)

* Average dose rate

4.7 Isodose Contour Map

The terrestrial gamma dose rate at each sampling was plotted by using the SURFER software version 6. Figure 7 shows the dose rate contour lines at 50, 100, 150, 200, 250, 300, 400, 600, 800 and above 1000 nGy h^{-1}. The hot spot areas where the dose rates up to 1039 nGy h^{-1} were in areas of granites basement rock at Kampung Sungai Durian near Tg. Tualang is the highest in Perak to date. Figure 8 shows the 3D dose profile for the Kinta District.

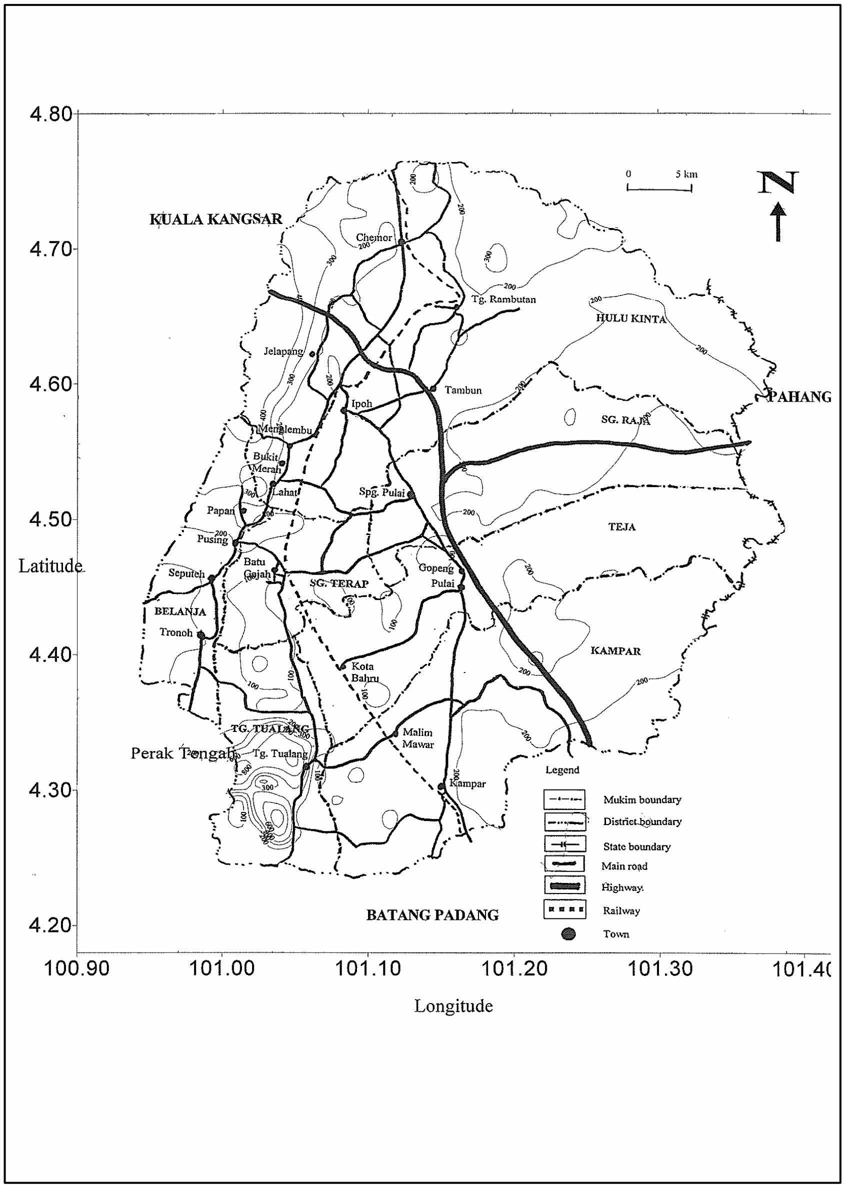

Figure 7 The isodose contour map for the Kinta Valley

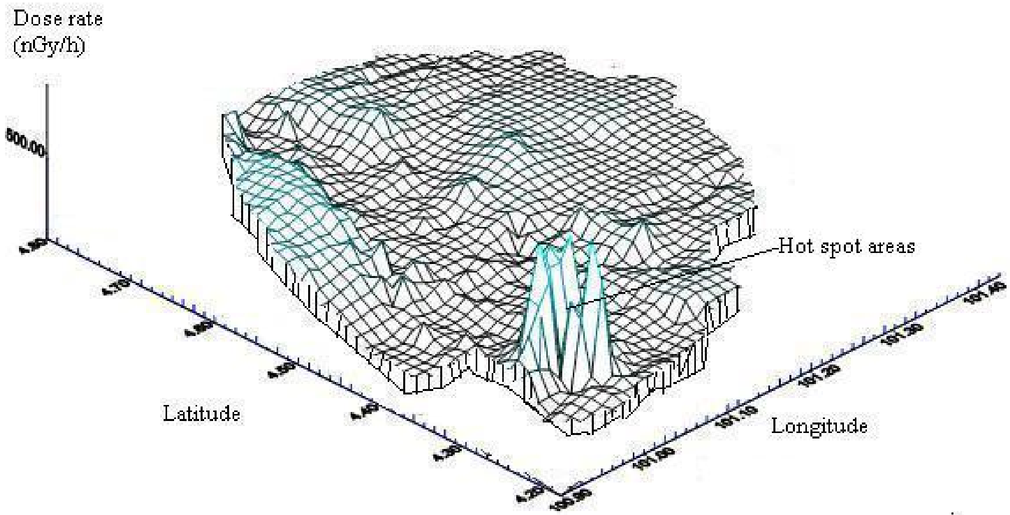

Figure 8 shows the 3D dose rate profile for the Kinta District

5. CONCLUSIONS

The gamma dose rate in the Kinta Valley ranged from 39 to 1039 nGy h^{-1}. The mean gamma dose rate is 222 ± 191 nGy h^{-1} (1.36 mSv y^{-1}) which is higher than the Johor State (165 nGy h^{-1}); about two times the Malaysian average and about 3 times over the world average (UNSCEAR 2000). High radiation areas or hot spots were recorded in Sungai Durian with dose rate of 1039 nGy h^{-1}. Geological type G5 is Jurassic –Triassic, the rock type is mainly granites. It exhibits the highest mean dose rate of 432 ± 259 nGy h^{-1}. The dose rates range from 91 to 1039 nGy h^{-1}. The lowest recorded was on sandstones, the dose rate is 39 nGy h^{-1}.

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Environmental Radiological Studies for Health Physics Practices in Kinta District, Perak, Malaysia

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Abstract

A study of natural gamma background radiation (NGBR) and radioactivity levels was carried out from 2003 to 2005 in Kinta District, Perak, Malaysia for health Physics purposes. A total of 1,007 dose rate measurements were recorded. The dose rate ranged from 39 to 1,039 nGy h^{-1}. The mean dose rate was 222 ± 191 nGy h^{-1}. Small areas of hot spots were located having the dose rates of up to 1,039 ± 104 nGy h^{-1}. A total of 128 soil samples were collected. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K were analyzed by using a hyper pure gamma spectrometer. The ranges are 12 – 426 Bq kg^{-1} for ^{238}U, 19 – 1,377 Bq kg^{-1} for ^{232}Th and <19 – 2,204 Bq kg^{-1} for ^{40}K. Based on the radioactivity levels determined, the gamma absorbed dose rates in air at 1 meter above the ground were calculated using the procedure applied by UNSCEAR 2000. The calculated dose rates and measured dose rates have a good correlation coefficient, R of 0.94. The gross alpha activity of the soil samples range from 15 to 9,634 Bq kg^{-1}. It has a mean value of 1,558 ± 121 Bq kg^{-1}. The gross beta activity range from 142 to 6,173 Bq kg^{-1}. It has a mean value of 1,112 ± 32 Bq kg^{-1}. The mean population weighted terrestrial gamma radiation dose rate for the Kinta District is 1.12 mSv y^{-1}. Isodose map for the Kinta District was plotted.

Key words: Terrestrial gamma isodose map, ^{238}U, ^{232}Th and ^{40}K, radioactivity in soil, mean population dose

INTRODUCTION

The Kinta District was the largest producer of tin in the world. Over a century of tin mining has produced large amount of tin tailing or “amang”, a by-product of tin mining. “Amang” is a Malaysian term. It contain to a group of heavy minerals which occur together with the tin ore recovered from the alluvium. The constituents of amang are monazite, ilmenite, zircon, xenotime, rutile, and some other minerals. The Amang industry involves the processing of these minerals. Amang contents especially monazite, and xenotime which have substantial amounts of thorium and uranium are radioactive and pose high external radiation levels in the work place, storage room and to the environment (Hu et. al, 1981, 1984a, 1984b, Gangadharam et. al 1981). Radioactive gases, radon and thoron, are produced when uranium and thorium are present (Hu et. al, 1983). In order to manage the radiation hazard resulting from activities involving amang it is very important to conduct radiological studies to determine the relevant baseline data.

Measurement of natural background radiation and radioactivity in soil has been carried out in many countries to establish baseline data of natural radiation levels (Ibrahiem et al. 1993; Quindos et al. 1994; Mireles et al. 2003). The baseline data can be used to assess any changes in the radioactivity background level due to various activities involving radioactive materials or any fallout in the near future. The measurement will also help in the development of standards and guidelines for use and management of these materials.

In this study, the concentration of ^{238}U, ^{232}Th and ^{40}K in soil samples were analyzed. Based on the radioactivity levels determined, the gamma absorbed dose rates in air at 1 meter above the ground were calculated using the procedure applied by UNSCEAR 2000. Correlation between measured and calculated dose rates was obtained. Based on the results obtained, the measured dose rates were corrected.

Geological features of the Kinta District

The geology map of the Kinta District is produced in Fig. 1 (Ingham and Bradford 1960, Geological map of West Malaysia, 7th Edition, 1973). The Kinta District is an extensive area flanked by granites to the east and west. Kinta District is underlined by a sequence of sedimentary rocks ranging in age from Silurian to Permian, which have been intruded by granitoids and associated late phase minor intrusive of probable Jurassic to Triassic age. Most of the sedimentary rocks in the valley are Devonian in age. Rocks of Silurian age are present in the northern part, whereas rocks of Carboniferous underline areas in the southwestern part of the District. Alluvium covers almost the entire valley part of the District. Its thickness varies considerably; in the valley, the thickness increases southward from 6 m near Ipoh to more than 30 m in the southern part (Rajah, 1979).

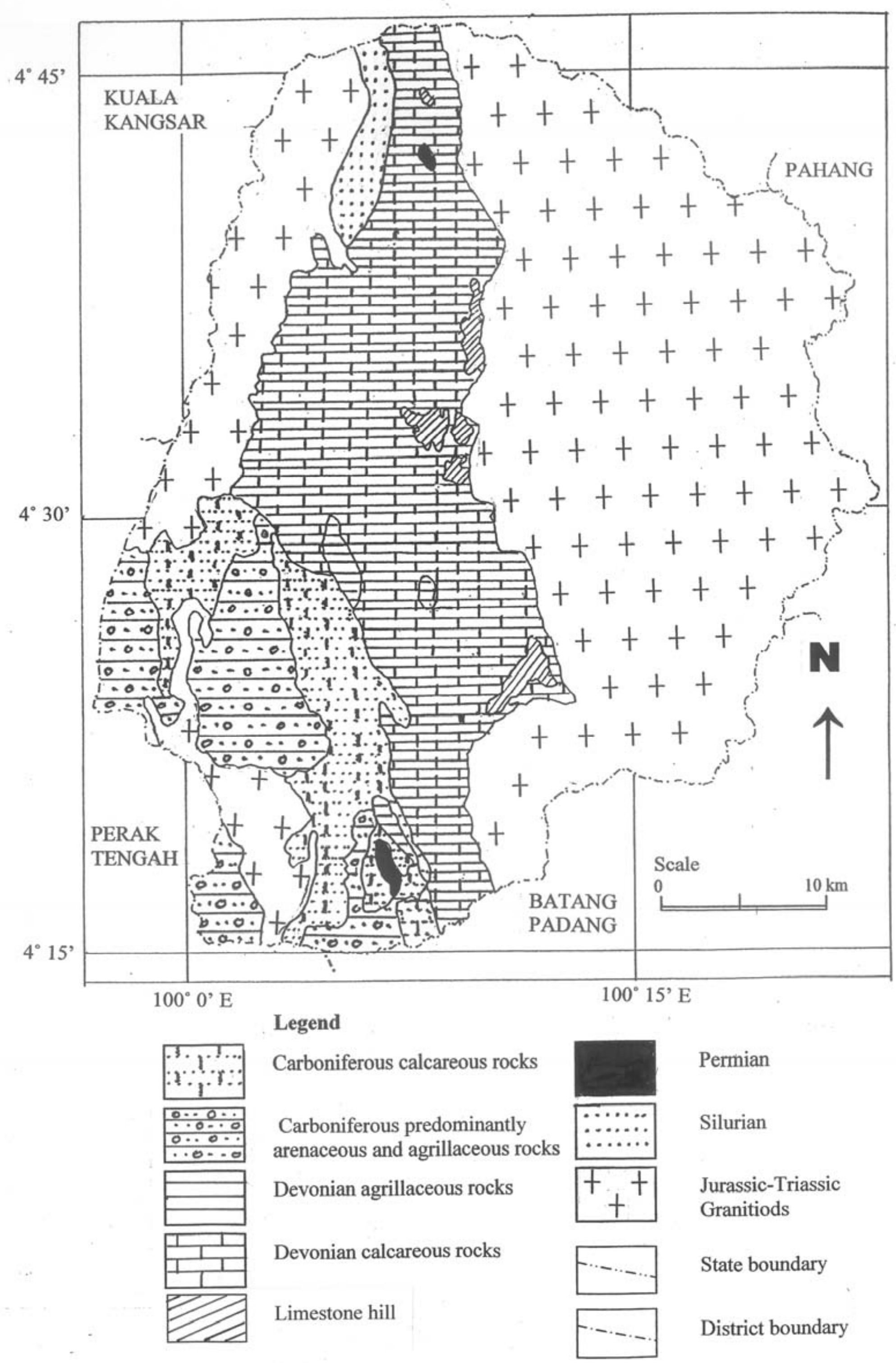

Fig. 1. Geology of the Kinta District

Soil types in the Kinta District

The types of soil found in the Kinta District are shown in Fig. 2. They are five different types of soil namely Dystric Histosols, Xanthic Ferrasols-Dystric Gleysols, Ferric Acrisols-Ferric Acrisols-Orthic Ferrasol, Haplic Acrisols, Steep land and Urban land. Table 1 shows the total number of readings taken for each type of soil.

Table 1. Soil types(FAO/UNESCO) and number of readings taken.

Soil type number	Soil type	Map symbol (Local name)	Parent material	Total number of readings
10	Dystric Histosols	PET (Peat)	Organic deposit	5
18	Xanthic Ferrasols-Dystric Gleysols	HYD-HMU (Holyrood-Harimau)	Subrecent and older alluvium	233
31	Ferric Acrisols-Ferric Acrisols-Orthic Ferrasol	SDG-MUN (Serdang-Munchong)	Shale, sandstones and schists	47
48	Haplic Acrisols	RGM-BTG (Rengam-Bukit-Temiang)	Granites	249
49	Steep land	STP (Steep land)	Miscellaneous land units	55
50	Urban land	DLD (Disturbed land)	Miscellaneous land units	418

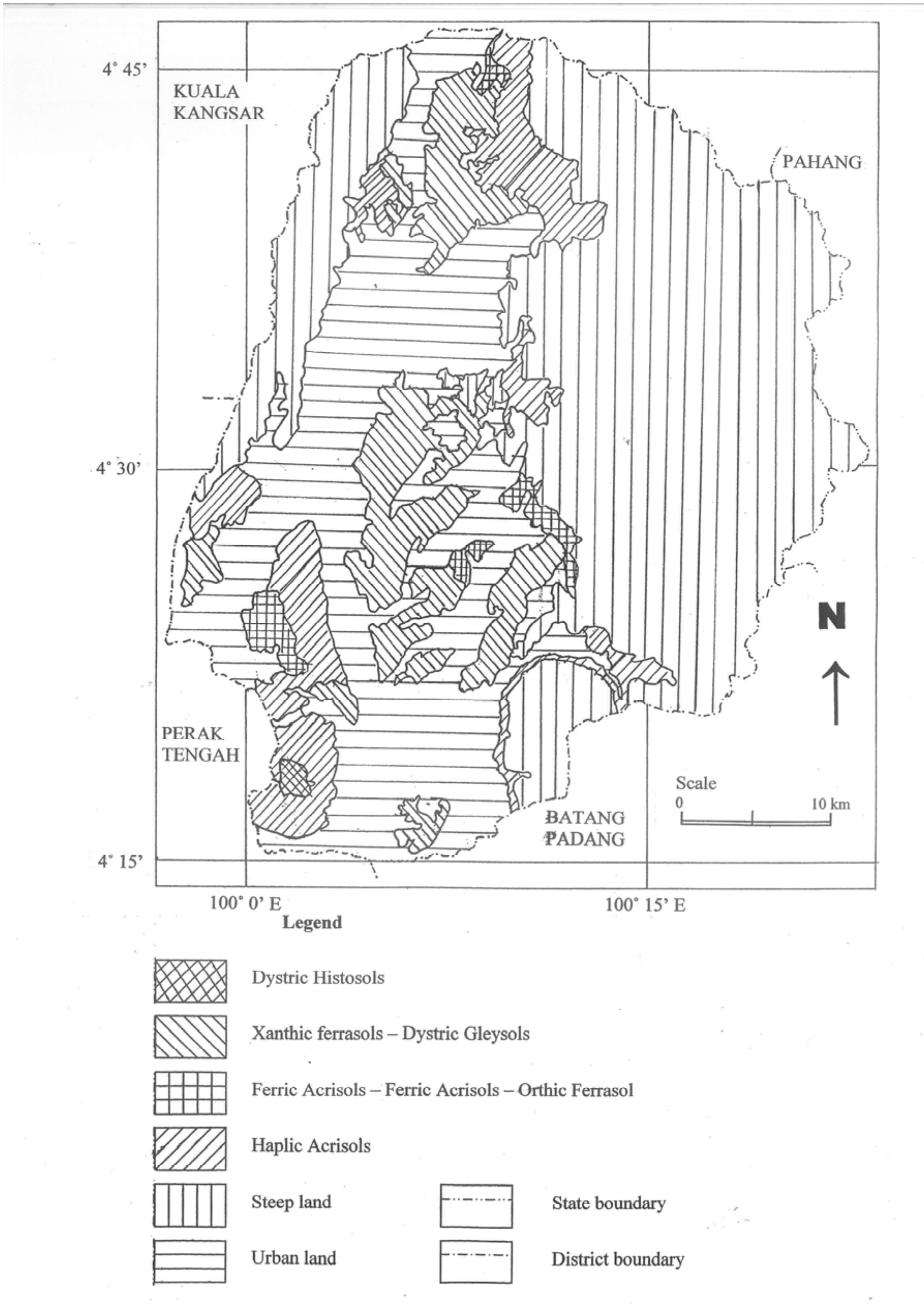

Fig. 2. Soil types for the Kinta District

METHODS AND MATERIAL

Gamma dose rate measurements were performed by a portable survey meter manufactured by Ludlum (Model 19 Micro R Meter, USA). The equipment uses a 2.54 cm x 2.54 cm NaI crystal doped with thallium [NaI(Tl)] to offer an optimum performance in counting low-level gamma radiation. The NaI scintillator is energy sensitive. This instrument had a reported accuracy of ± 10%. (Ludlum Measurements, Inc. 1993). The detection of gamma rays from cosmic sources is negligible due to the low response of the instrument to high energy gamma radiation. This was observed when radiation level was measured on board of a ferry far away from land. It detected a reading of only about half a division on the smallest scale of 1 μR h^{-1}(~ 8.7 nGy h^{-1}). The NaI(Tl) detector is the most widely used device for all kinds of gamma ray surveys due to its efficiency (IAEA 1979). This instrument was calibrated for the higher count rates by Malaysian Nuclear Agency (MNA) an IAEA recognized secondary standard calibration laboratory.

Dose measurements were done at approximately every 1 km (more frequently if significant change in radiation level was detected), wherever access is possible by road throughout the District. At some of the locations soil samples were also collected. The position of the locations were determined by using global positioning system, GPS Garmin Model 12X (Garmin Corporation, 1988) which has practical accuracy of ± 50m. Dose measurements were conducted and soil samples were collected according to established procedures (Mireles, 2003; Goddard, 2002).

Soil samples were collected from areas with different soil types and geological background. Soil samplings were conducted at 128 locations as shown in Fig. 3. About 2 to 3 kg of soil was placed in each plastic bag. The samples were dried at 110 °C for 2 to 3 days in an oven. Dried samples were pulverized and sifted through a 325 micron sieve. About 0.5 kg of the soil was weighted and put in a Marinelli beaker. It is stored for 4 weeks to achieve equilibrium for ^{238}U and ^{232}Th with their respective progeny (Myrick et al. 1983).

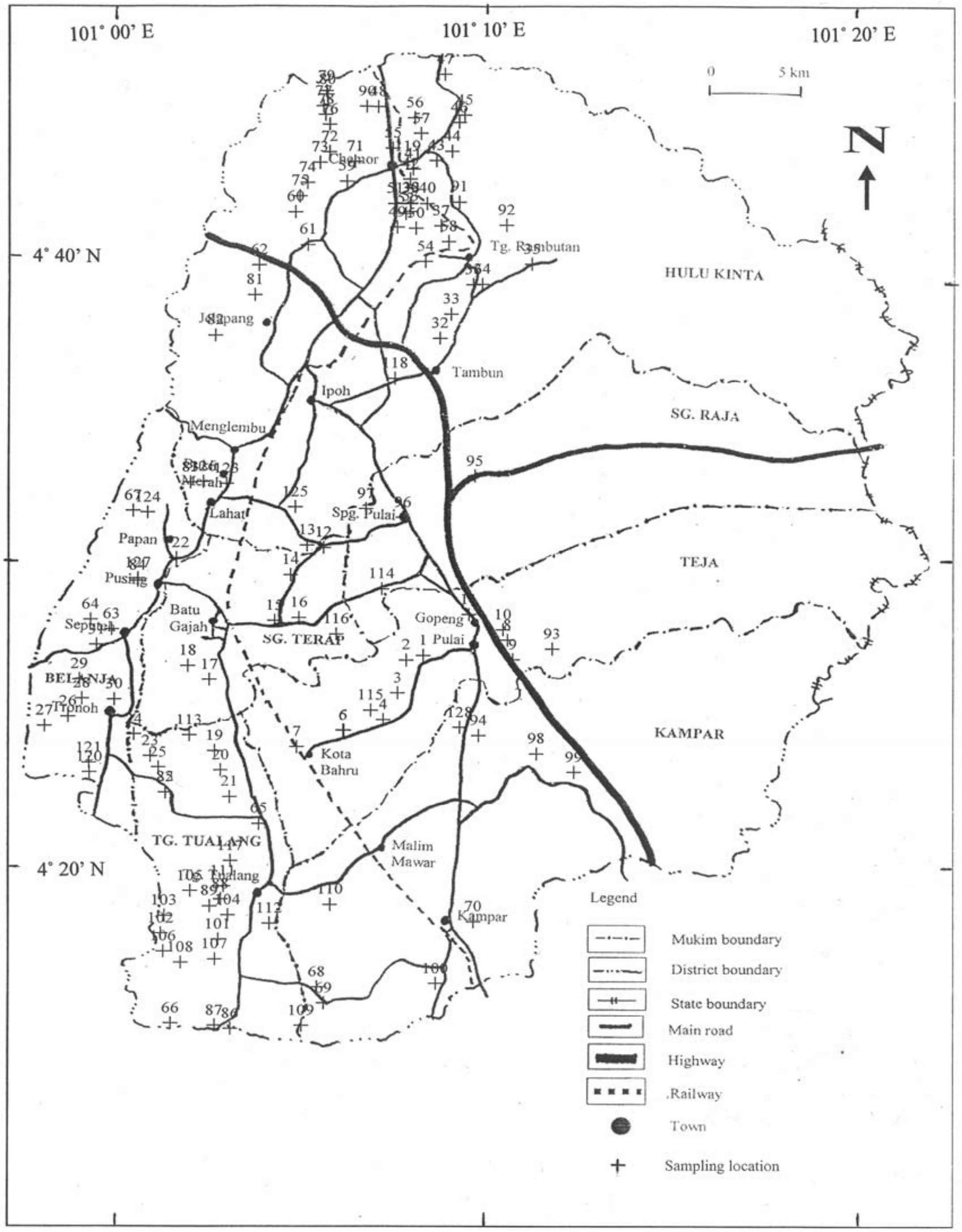

Fig. 3. Locations of soil samples

The ^{232}Th concentration was determined from the average concentration of ^{208}Tl using 583 keV peak and ^{228}Ac by using 911 keV peak. ^{238}U was determined from the average concentrations of the ^{214}Pb by using 352 keV peak and ^{214}Bi by using 609 keV peak (Hamby and Tynybekov, 2000) and the 1460 keV peak for ^{40}K. Each sample was put into a shielded HPGe detector and measured for 3 hours. Gamma background was determined with an empty Marinelli beaker under identical conditions, and was subtracted from the spectra of each sample. Comparison method was used to calculate the specific activity. The IAEA standard samples used as reference materials were S-14 and SL-2. The results obtained were found to be comparable to those by neutron activation analysis performed by Malaysia Nuclear Agency.

Gamma-ray spectrometry

A hyperpure germanium (HPGe) detector manufactured by Ortec with an efficiency of 20% and a resolution of 1.8 keV at 1332 keV was used for the measurement of the gamma energy spectrum. Advanced Analyzer (MCA) emulation software (MAESTRO-32) enables data acquisition, storage and display of the acquired spectra. The detector is surrounded by lead shield to reduce background radiation (Tsoulfanidis, 1995).

RESULTS AND DISCUSSION

The mean annual dose to population

Fig. 4 shows the histogram of dose rate ranges versus frequency. About 64% of the dose rate measurements are in the range of 101 – 200 nGy h^{-1}.

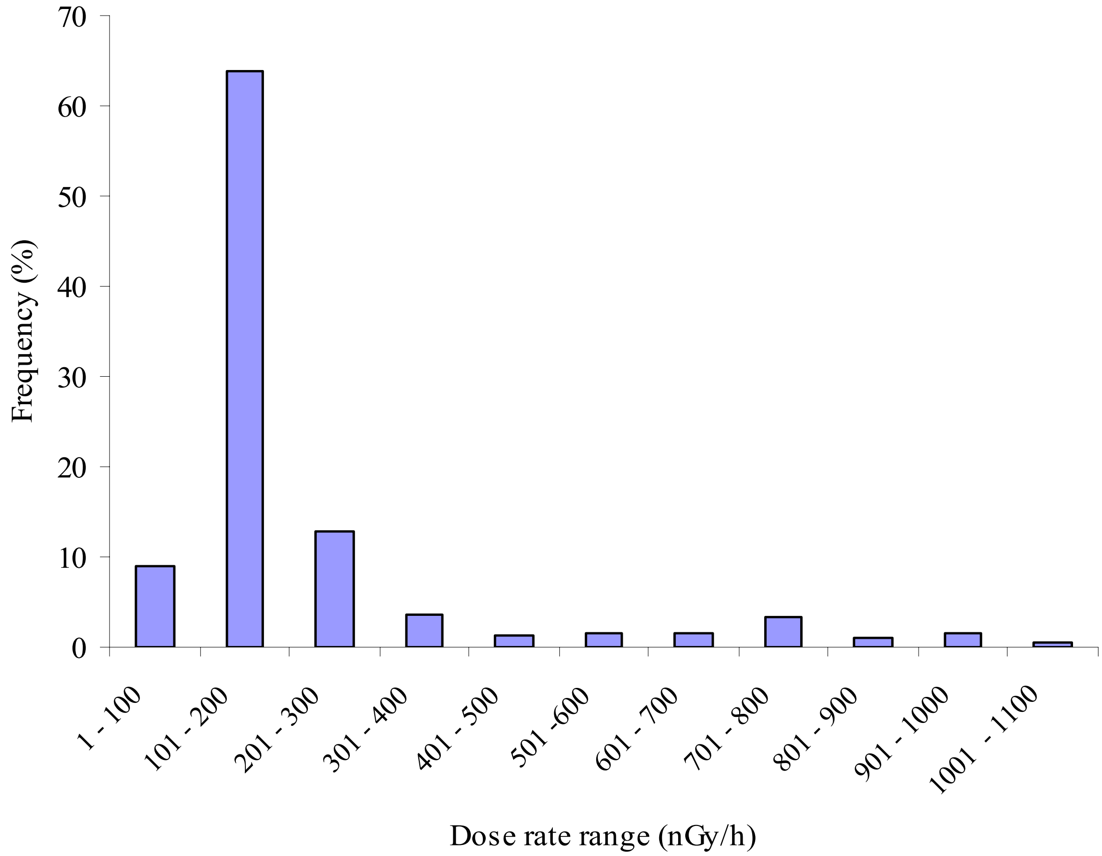

Fig. 4. Shows the bar chart where the highest frequency of 64 % is in the range of 101 – 200 nGy h^{-1}

Table 2 shows the population of the *mukims*. *Mukim* Tg. Tualang, M5 shows the highest mean dose rate of 378 nGy h^{-1}. The rest of the *mukims* have the mean dose less than half of *mukim* M5. *Mukim* M3 exhibits the lowest mean dose rate of 133 nGy h^{-1} with a population of 23,998. *Mukims* M3, M4 and M7 have the mean annual gamma dose lower than 1 mSv. The mean population weighted gamma annual dose for Kinta District is 1.12 mSv.

Table 2. Statistics for dose rate (nGy h^{-1}) distribution in the Kinta District.

Mukim →	M1 Hulu Kinta	M2 Sungai Raja	M3 Teja	M4 Kampar	M5 Tg. Tualang	M6 Belanja	M7 Sungai Terap
No. of readings	281	68	97	134	273	63	91
Mean dose rate	184	179	133	152	378	165	144
Standard deviation	71	59	46	51	301	85	48
Mean dose (mSv y^{-1})	1.13	1.10	0.82	0.93	2.32	1.01	0.88
Range	65-487	65-325	52-312	65-390	39-1,039	52-455	65-390
Population[a]	533,493	19,094	23,998	57,389	17,830	12,210	39,434

[a] Data from Department of Statistics, Malaysia 2003. (Population census in 2000).

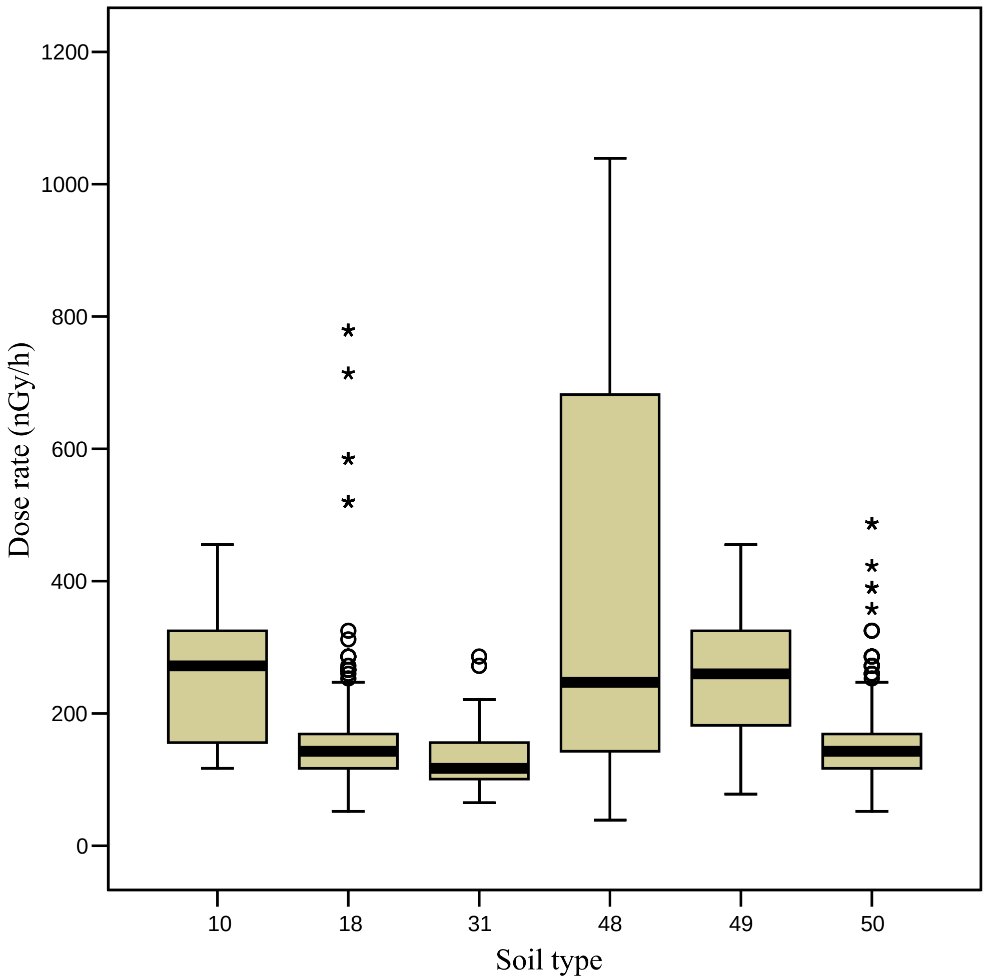

Fig. 5. Box plot showing the distribution and the variability of gamma ray dose for each soil type (* represents extreme values, and o represents outliers)

The box plot in Fig. 5 shows the variability and the distribution of the data for each type of soil type. It consists of a line extending from the minimum value to the maximum value, and a box with lines drawn at the first quartile, a line in the box at the median value, and the third quartile. An outlier ‘o’ is a value that is located very far away from almost all of the other values. Relative to the other data, an outlier is an extreme ‘*’ value (Triola, 2005).

The distributions of the dose rate are skewed for soil types 10, 31 and 48. Dose rate distribution for soil types 18, 49 and 50 are almost symmetric. Soil types 18 and 50 have outliers and extreme values. Soil type 31 has outliers. These outliers affect the values of the mean and standard deviations. Soil types 10 and 49 have no outliers.

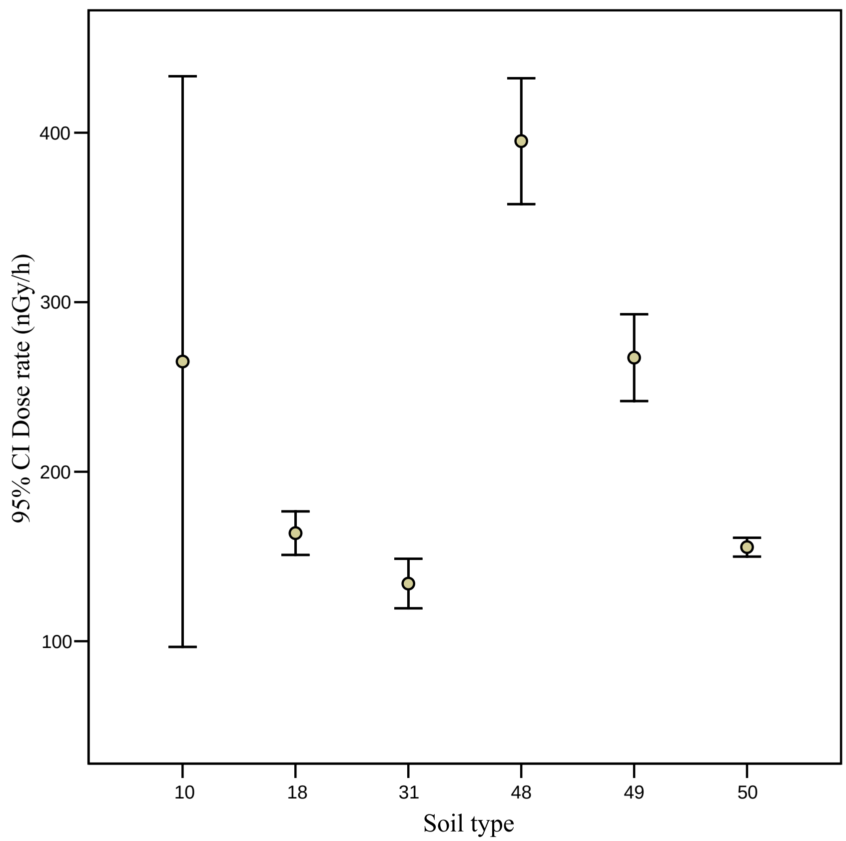

Fig. 6. Mean dose rate and 95% confidence interval for the mean for the various soil type. (SPSS output)

Fig. 6 shows the mean dose rate and 95% confidence intervals for mean for each soil type. The mid-points of the vertical lines are the mean values and their lengths represent the 95% confidence limit for the mean. Soil type 48 shows the highest mean dose rate of 395 nGy h^{-1} with 95% confidence limit dose rate range from 358 – 432 nGy h^{-1}. Soil type 49, steep land exhibits lower dose rate readings than granitic range from 242 – 293 nGy h^{-1}. Soil type 10 covers a small area, 5 readings were taken which shows a wide range from 97 to 433 nGy h^{-1}. The data is too small where number of readings is less than 30. It has a mean dose rate of 265 nGy h^{-1}. Except for soil type 10, each soil type shows a different range of readings. The 95% confidence limit for the mean dose rate range for soil type 18 (151 – 177 nGy h^{-1}) and soil type 50 (150 – 161 nGy h^{-1}). These two soil types can be grouped together (Wahab 1988). The mean dose rate for soil types 18 and 50 are 164 and 155 nGy h^{-1} respectively. Soil type 31 that shows the lowest dose rate range from 119 – 149 nGy h^{-1} mainly made up of shale, sandstones and schists. From Fig. 6, the 95% confidence intervals for mean gamma-ray dose clearly shows that the dose rate for soil type 48 > soil type 49 > soil types18 and 50 > soil type 31. It shows that the mean dose rates are associated with the soil types.

Alpha and beta activities

Gross alpha and gross beta specific activities were determined to study the trends in the concentration of radionuclides in the soil samples. The gross alpha activity range from 15 to 9,634 Bq kg^{-1}. It has a mean value of 1,558 ± 121 Bq kg^{-1} .The gross beta activity range from 142 to 6,173 Bq kg^{-1}. It has a mean value of 1,112 ± 32 Bq kg^{-1}. From Fig. 7, the data confirmed that ^{40}K is not the major contributor to the gross beta activity where the correlation coefficient, R was 0.29 (R^2 = 0.084). The other beta contributors are members of the uranium and thorium decay series. Radionuclides from the thorium and uranium series are responsible for the majority of the alpha activity.

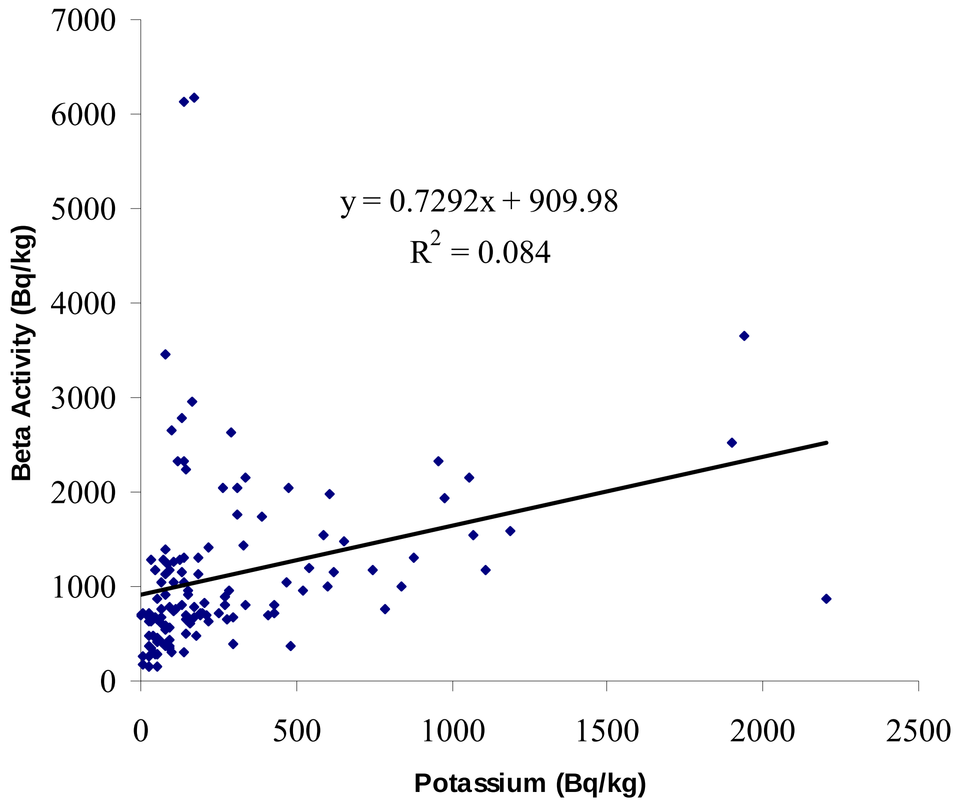

Fig. 7. Correlation between potassium and beta activity

Uranium, thorium and potassium concentration

The ^{238}U concentration ranges from 12 to 426 Bq kg^{-1}, a mean value of 112 ± 18 Bq kg^{-1}, which is three times higher than the world average. ^{232}Th concentration ranges from 19 to 1,377 Bq kg^{-1}, it has a mean value of 246 ± 21 Bq kg^{-1} that is about seven times world average and ^{40}K concentration ranges from less than 19 to 2,204 Bq kg^{-1} and the mean value is 277 ± 127 Bq kg^{-1} which is less than the world average. World average concentrations are 35 Bq kg^{-1} and 45 Bq kg^{-1} for ^{226}Ra and ^{232}Th, respectively; and typical ranges are 16 – 116 Bq kg^{-1} for ^{226}Ra and 7-50 Bq kg^{-1} for ^{232}Th. The world average concentration is 420 Bq kg^{-1} for ^{40}K, and the typical range is 100-700 Bq kg^{-1} for ^{40}K (UNSCEAR 2000). It should be noted that none of the 128 soil samples analyzed, ^{137}Cs peak at 662 keV was found.

Table 3. Summary of activity concentration and gamma dose rates of natural radioisotopes in soil samples in the Kinta District and other parts of the world (UNSCEAR 1998).

Region/Country	^{238}U Bq kg^{-1}		^{232}Th Bq kg^{-1}		^{40}K Bq kg^{-1}		Dose rate nGy h^{-1}	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Kinta District[b]	12-426	112	19-1,377	246	1-2,204	277	39-1,039	222
Malaysia	49-86	66	63-110	82	170-430	310	55-130	92
China	2-690	84	1-360	41	9-1,800	440	2-340	62
India	7-81	29	14-160	64	38-760	400	20-1,100	56
Japan	2-59	29	2-88	28	15-990	310	21-77	53
United States	4-140	35	4-130	35	100-700	370	14-118	47
Egypt	6-120	37	2-96	18	29-650	320	8-93	22
Greece	1-240	25	1-190	20	12-1,570	360	30-109	56
Portugal	26-82	49	22-100	51	220-1,230	840	4-230	84
Russia	0-67	19	2-79	30	100-1,400	520	12-102	65
Spain	-	-	2-210	33	25-1,650	470	40-120	76
World[c]	16-116	33	7-50	45	100-700	420	-	59

[b] (present study), [c] (UNSCEAR 2000)

Table 3 summarized the natural radioactivity levels and dose rates obtained in some of world regions and from this study. The mean activity for ^{238}U and ^{232}Th are higher but for ^{40}K has the lowest value. The dose rate recorded is many times higher ranged from two to ten times.

Validity of measurement by NaI(Tl) detector

The response of NaI(Tl) detector is highly energy dependent, so the question of validity of its measurement given the wide variation of energy of the gamma-rays emitted by the radionuclide involved. A statistical comparison between the measured values obtained by using Ludlum Model 19 and the calculated values was conducted.

The activity concentrations of ^{238}U and ^{232}Th series and ^{40}K measured in Bq kg^{-1} were used to calculate dose rate D_c in nGy h^{-1} at a height of 1 m above the ground using the following relationship (UNSCEAR 2000).

$$D_c = 0.462A[^{238}U] + 0.604A[^{232}Th] + 0.0417A[^{40}K] \qquad (1)$$

The statistical validity of the measured value was established. The non-zero intercept from Fig. 8 could be interpreted as the dose contribution from high energy cosmic rays. The correlation coefficient of R = 0.94 indicates good general agreement between measured and calculated dose rates.

The total absorbed dose rates calculated from the concentrations of the radionuclides range from 24 to 977 nGy h^{-1} while the corrected measured dose rates range from 39 to 1,039 nGy h^{-1}. In situ measurement of dose rate is more representative of the area under consideration compared to laboratory analyses of soil sample. A survey meter placed about 1 m above the earth detects gamma radiation from a larger area. This represents a large volume of soil compared to the size of a small sample usually taken for laboratory analysis. The difference might be due to calibration factor used in the instrument's calibration. The gradient of the graph is not 45º. Therefore a correction factor needs to be introduced to reconcile the difference between the measured and the calculated values. All the measured readings were then corrected.

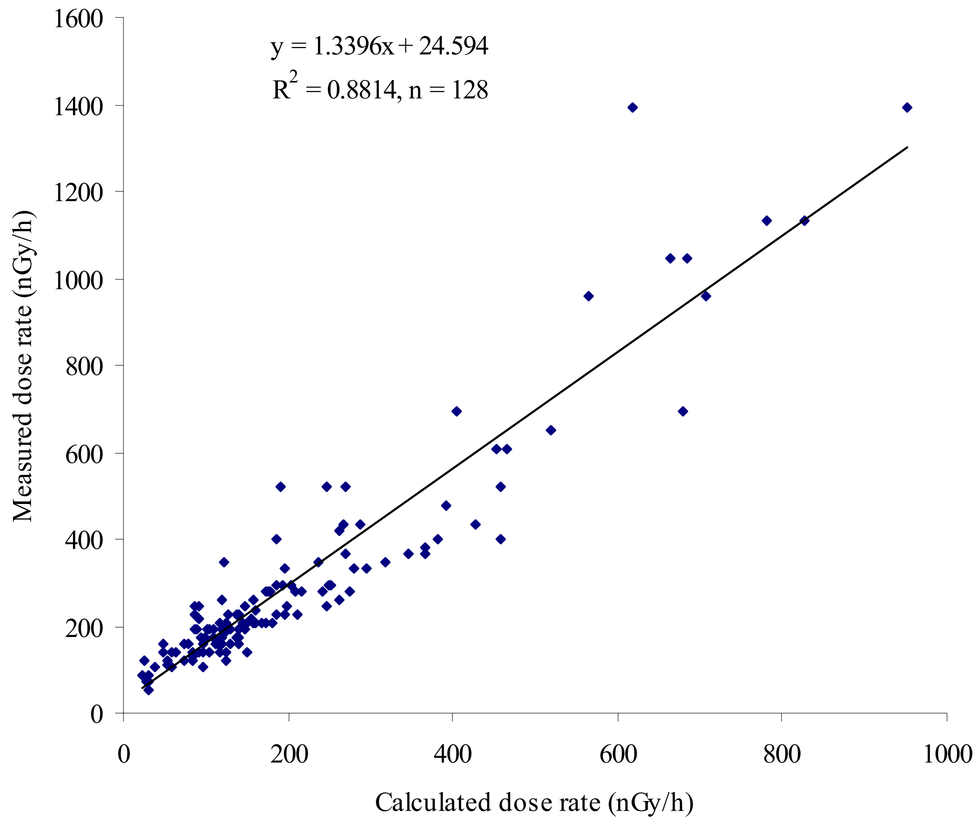

Fig. 8. Calculated dose rate versus measured dose rate (nGy h^{-1})

Gamma dose rate isodose map

The terrestrial gamma dose rate at each sampling was plotted using the SURFER software version 6. Fig. 9 and Fig. 10 show the dose rate contour lines at 50, 100, 150, 200, 250, 300, 400, 600, 800 and 1,000 nGy h^{-1} are superimposed on the geological and soil maps respectively. The computer generated isodose contour lies was then adjusted according to the soil type and geological features boundaries (Wahab, 1998; Ramli et al, 2004) to take into account their known influence in producing the gamma isodose map. Fig. 11 shows the 3D plot of the gamma isodose map of the Kinta District.

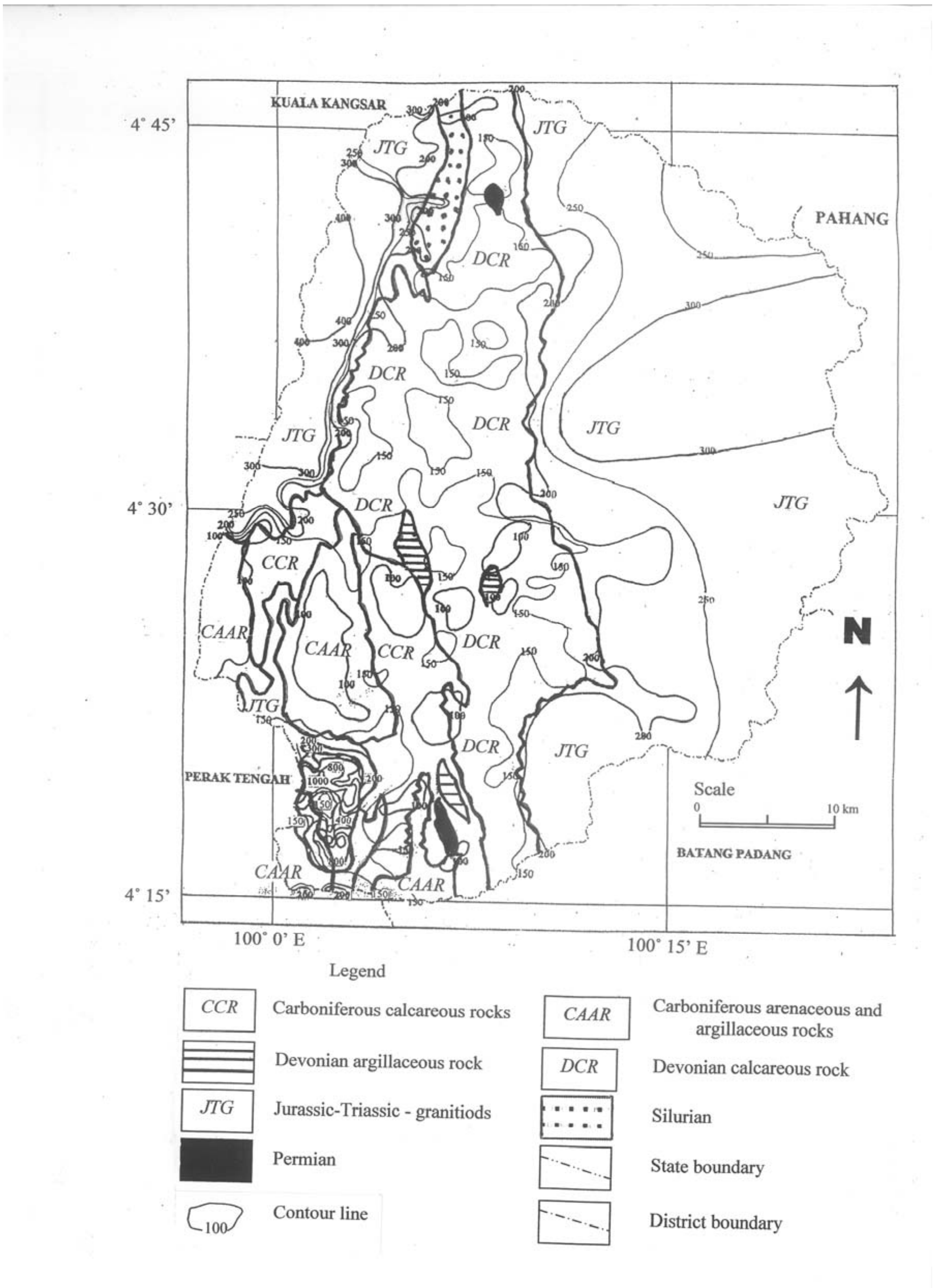

Fig. 9. The isodose contour is superimposed with the geological types

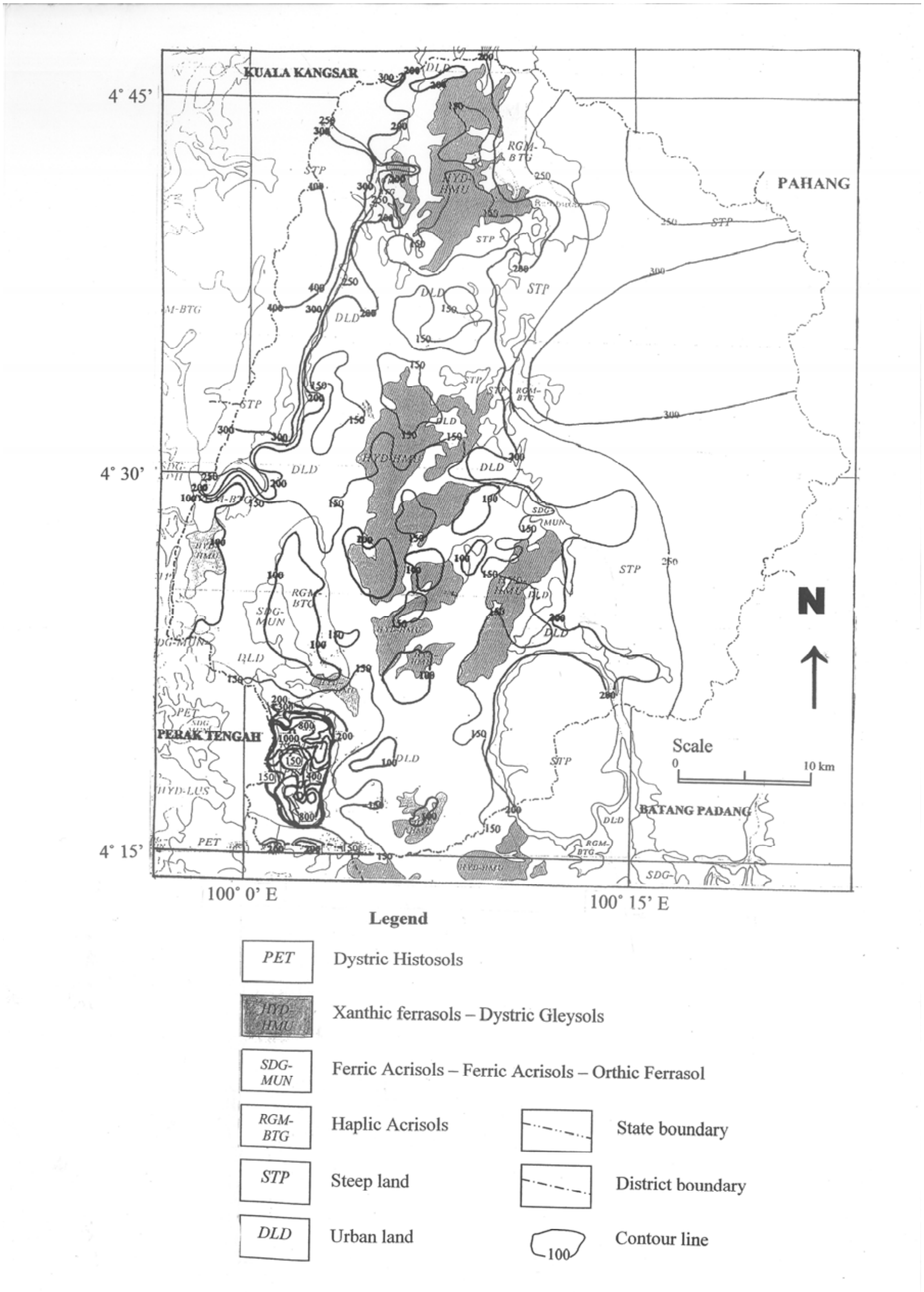

Fig. 10. The isodose contour is superimposed with the soil types

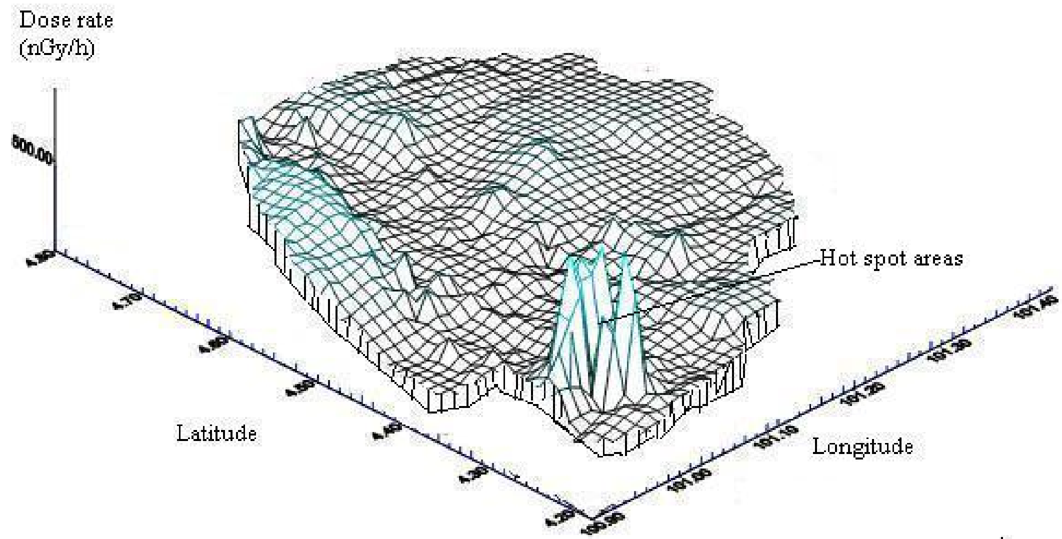

Fig. 11. The 3D plots of gamma isodose map of the Kinta District

CONCLUSIONS

The gamma dose rate in the Kinta District ranged from 39 to 1,039 nGy h^{-1}. The mean of gamma dose rate is 222 ± 191 nGy h^{-1} (1.36 mSv y^{-1}) which is about twice the Malaysian average and about 4 times the world average (59 nGy h^{-1}). The highest recorded in Sg. Durian is 1,039 ± 104 nGy h^{-1}. The lowest level recorded is 39 ± 4 nGy h^{-1} on the sandstones in Tg. Tualang District. The mean population weighted gamma annual dose for the terrestrial source is 1.12 mSv. Activity concentrations in the soil samples were for ^{238}U range from 12 to 426 Bq kg^{-1}, ^{232}Th from 19 to 1,377 Bq kg^{-1} and ^{40}K range from less than 19 to 2,204 Bq kg^{-1}). Kinta District average concentrations for ^{238}U, ^{232}Th, and ^{40}K are 112, 246, and 277 Bq kg^{-1} respectively. World average concentrations for ^{238}U, ^{232}Th, and ^{40}K are 35, 30, and 370 Bq kg^{-1} respectively (UNSCEAR 1998). The ^{40}K concentration is low compared to the world average. The calculated and measured dose rates have a very good coefficient of correlation $R = 0.94$. This shows that it is statistically valid to use NaI(Tl) detector for environmental gamma measurement even though subjected to suitable correction factor. The NaI(Tl) detector even though is highly energy dependent. The gross alpha activity of the soil samples range from 15 to 9,634 Bq kg^{-1}. It has a mean value of 1,558 ± 121 Bq kg^{-1}. The gross beta activity range from 142 to 6,173 Bq kg^{-1}. It has a mean value of 1,112 ± 32 Bq kg^{-1}.

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Footnotes

[a] Data from Department of Statistics, Malaysia 2003. (Population census in 2000).
[b] (present study)
[c] (UNSCEAR 2000)