KAJIAN FIZIK KESIHATAN NEGERI SELANGOR, WILAYAH PERSEKUTUAN KUALA LUMPUR DAN PUTRAJAYA

MOHAMAD SYAZWAN MOHD SANUSI

Tesis ini dikemukakan
sebagai memenuhi syarat penganugerahan
Sarjana Sains (Fizik)

Fakulti Sains
Universiti Teknologi Malaysia

JULAI 2014

Untuk ibuku Zailani, bapaku Mohd Sanusi, insan tersayang Syazana, Syafiq, Amir,
Idayu, Fezrie, Nur Iman Widyan, Wafiyaa, Arraf
yang sentiasa mendoakan kejayaan ini dan bagi sokongan serta dorongan dalam
menyelesaikan kajian dan tesis ini.

PENGHARGAAN

Dengan Nama Allah Yang Maha Pengasih lagi Maha Penyayang, segala puji bagi-Nya, serta selawat dan salam kepada junjungan mulia Nabi Muhammad S.A.W. Syukur kehadrat Ilahi dengan limpah kurniaNya, dengan izinNya maka telah selesai penyelidikan dan penulisan tesis ini.

Ribuan ucapan penghargaan dan terima kasih kepada penyelia penyelidikan ini iaitu Prof. Dr. Ahmad Termizi Ramli, Prof. Madya Mohd Nor Said, Dr. Arien Heryanshah, Prof. Dr. Husin Wagiran, dan Prof. Dr. Muhamad Hisyam Lee diatas kerjasama, tunjuk ajar dan dorongan yang diberikan sepanjang tempoh penyelidikan.

Ucapan terima kasih juga ditujukan kepada pihak Lembaga Perlesenan Tenaga Atom, Kementerian Sains, Teknologi, dan Inovasi Malaysia yang menaja penyelidikan melalui kontrak perundingan yang ditadbir oleh Syarikat Uni-Technologies Sdn. Bhd. dan Global Technology and Innovation Management Sdn. Bhd. (GTIM). Ucapan terima kasih juga ditujukan kepada syarikat GTIM-UTM yang telah menjadi badan pengurusan penyelidikan ini . Seterusnya ucapan terima kasih disampaikan Jabatan Fizik, Fakulti Sains, Lembaga Perlesenan Tenaga Atom dan Agensi Nuklear Malaysia diatas kemudahan yang telah disediakan.

Penulis juga ingin mengucapkan terima kasih kepada rakan penyelidik dari Fakulti Sains iaitu En. Hamman Tukur Gabdo, En. Nurruddeen Nasiru Garba , Cik Nor Afifah Basri, Cik Nur Zati Hani. Tidak dilupakan juga pegawai dari Jabatan Mineral dan Geosains Negeri Perak, En. Arshad Mat Arib, En. Abdul Aziz Mohd Noor, Dr. Teng Yu Lin dari Lembaga Perlesenan Tenaga Atom dan En. Joseph Young yang telah banyak membantu semasa tempoh penyelidikan.

ABSTRAK

Sinaran gama daratan adalah salah satu sinaran latar belakang utama dan penyinarannya disebabkan oleh keradioaktifan daratan. Kajian fizik kesihatan telah dilakukan untuk mendapatkan data dasar status keradioaktifan dan aras sinaran gama daratan (TGR) alam sekitar di negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya. Kajian mengemukakan metodologi pensampelan tinjauan kadar dos TGR, D_m dan kaedah model regresi statistik bagi meramalkan kadar dos TGR, D_p berdasarkan hubungan linear pengaruh latar belakang geologi, D_g dan jenis tanah, D_s terhadap jumlah kadar dos TGR. Tinjauan kadar dos TGR, D_m telah dilakukan menggunakan pengesan sintilasi NaI (Tl) Model 19 *Micro R Meter Ludlum*. Kaedah pensampelan telah digunakan untuk penentuan titik tinjauan, D_m berdasarkan maklumat daripada peta tinjauan udara, peta geologi dan peta tinjauan jenis tanah. Bagi tujuan kawalan kualiti kadar dos TGR sensitif, D_m pada aras alam sekitar, teknik statistik interpolasi kecerunan antara kadar dos terhitung, D_c dan D_m telah dilakukan dengan memanfaatkan data keradioaktifan pemancar sinar - γ ^{238}U, ^{232}Th dan ^{40}K dalam sampel tanah bagi mendapatkan faktor pembetulan, C_f. Analisis kepekatan keradioaktifan radionuklid ^{238}U, ^{232}Th dan ^{40}K dalam sampel tanah telah dilakukan menggunakan spektrometer gama sepaksi hiper - tulen germanium (HPGe). Berdasarkan maklumat dari pengkalan data dasar kadar dos TGR kajian terdahulu (1995 - 2013), sebanyak 9884 data kadar dos TGR dari pengkalan data dasar tersebut telah dianalisis taburan kenormalannya menggunakan ujian statistik Shapiro - Wilk, Kolgomorov - Smirnov dan ujian Levene. Analisis hipotesis statistik Welch ANOVA dan Tamhane T2 dilakukan bagi pengesahan hubungan pengaruh latar belakang geologi dengan jenis tanah terhadap kadar dos TGR. Berdasarkan maklumat pengkalan data, model regresi linear telah dilakukan bagi meramalkan kadar dos TGR, D_p. Hasil kajian telah mendapati nilai purata tinjauan kadar dos TGR, D_m di lokasi kajian ialah (182 ± 81) nGy j^{-1} dan nilai ini melebihi tiga kali ganda nilai purata global serta dua kali ganda nilai purata di Malaysia dengan julat yang direkodkan ialah daripada 17.4 nGy j^{-1} - 500.0 nGy j^{-1}. Terbitan persamaan model regresi linear bagi jangkaan kadar dos TGR, D_p diberikan oleh $D_p = [0.664\ D_g + 0.414\ D_s - 12.134]$. Nilai p bagi ujian ANOVA model regresi ialah $p < 0.001$ dengan nisbah - F ($f_{(2, 983)}$ = 2177.0.64) dan nilai korelasi R Pearson model ialah $R = 0.903$. Pada aras signifikan 0.05, hipotesis nol ditolak dan dirumuskan bahawa kadar dos D_g dan D_s mempengaruhi nilai D_p dan terdapat korelasi kuat antara latar belakang geologi dan jenis tanah. Bagi pengesahan model dari segi kesahihan statistiknya, data D_m dan D_p telah dianalisis dengan ujian ANOVA dan nisbah F (0.004) yang diperoleh adalah lebih kecil daripada F - kritikal (4.08) dan H_0: $\mu_x = \mu_0$ diterima pada ($f_{cal} \leq f_{1,\ 40,\ 0.05} = 4.08$). Daripada model regresi yang dikemukakan dan tinjauan kadar dos TGR yang dilakukan, hasil data dasar telah diterjemahkan dalam bentuk peta isodos.

ABSTRACT

Terrestrial gamma radiation is one of the main constituents of background radiation and the irradiation is due to the terrestrial radioactivity. Health physics study were carried out to obtain the baseline data of radioactivity and terrestrial gama radiation (TGR) level in State of Selangor, Federal Territories of Kuala Lumpur and Putrajaya. The study provide a methodology of sampling for TGR dose rate survey and a statistical regression model for predicting the TGR dose rate based on linear relationship between total dose rate with geological background, D_g and soil types, D_s. The TGR dose rate survey, D_m has been conducted using scintillation detector Ludlum 19 micro R meter NaI (Tl). Based on airborne survey map, geological background map and soil survey map, the sampling method was used to determine survey point D_m. For quality control of the sensitive TGR dose rates, D_m at environmental level, a statistical interpolation of gradient between calculated dose rate, D_c and D_m have been carried out to obtain the correction factor, C_f using radioactivity data of γ - rays emitters ^{238}U, ^{232}Th and ^{40}K in soil samples. The analysis of radioactivity concentration of radionuclides ^{238}U, ^{232}Th and ^{40}K in soil samples were carried out using coaxial hyper-purity germanium (HPGe) gamma spectrometer. Based on baseline information of TGR dose rate data from previous research (1995 - 2013), 9884 data were analysed using Shapiro - Wilk, Kolgomorov - Smirnov and Levene statistical test for the normality distribution test. For verification of relationships of geological background and soil types on TGR dose rate, statistical hypothesis analysis of Welch's ANOVA and Tamhane T2 were carried out. Based on baseline information, statistical regression model was built to predict TGR dose rates, D_p. The study has found that the average value of TGR, D_m dose rate was (182 ± 81) nGy h^{-1} which is three times higher than global average value and two times higher than average value for Malaysia with measurements range within 17.4 nGy h^{-1} - 500.0 nGy h^{-1}. The derived equation for statistical regression model for predicting the TGR dose rate was given as $D_p = [0.664\ D_g + 0.414\ D_s - 12.134]$. The p value of ANOVA regression model analysis was $p < 0.001$ with F - ratio ($f_{(2, 983)} = 2341.053$) and Pearson's correlation value R is 0.903. At significant level of 0.05, null hypothesis was rejected and it is concluded that the dose rates of D_g and D_s influenced D_p value and there is a strong correlation between geological background and soil types. For statistical verification of the model validity, D_m and D_p data were analysed using ANOVA test and the F - ratio obtained (0.004) is smaller than F - critical (4.08) and H_0: $\mu_x = \mu_0$ were accepted at ($f_{cal} \leq f_{1,\ 40,\ 0.05} = 4.08$). Based on obtained regression model and the TGR dose rate survey, the baseline data are presented as an isodose map.

SENARAI KANDUNGAN

SENARAI JADUAL

SENARAI RAJAH

SENARAI SINGKATAN

ANOVA	-	*Analysis of Variance* Analisis Varians
FAO	-	*Food and Agriculture Organization* Pertubuhan Sedunia Makanan dan Pertanian Bangsa-Bangsa Bersatu
GPS	-	*Global Positioning System* Sistem Penentuan Kedudukan Global
IAEA	-	*International Atomic Energy Agency* Agensi Tenaga Atom Antarabangsa
ICRP	-	*International Commission on Radiological Protection* Suruhanjaya Antarabangsa untuk Perlindungan Radiologi
LPTA	-	Lembaga Perlesenan Tenaga Atom
NCRP	-	*National Council on Radiation Protection and Measurements* Dewan Nasional Pengukuran dan Perlindungan Sinaran
NIST	-	*National Institute of Standard in Techology* Institut Piawai dan Teknologi Kebangsaan
SS	-	*Sum of Square* *Hasil tambah kuasa dua*
SPSS	-	*Statistical Package for Social Science* Pakej Statistik untuk Sosial Sains
TENORM	-	*Technologically Enhances Naturally Occurring Radioactive Material* Bahan radioaktif tabii yang dipertingkatkan melalui teknologi
TLD	-	*Thermoluminescent Dosimetry* Dosimeter Termoluminesens
UNSCEAR	-	*United Nations Scientific Committee on the Effect of Atomic Radiation*

		Jawatankuasa Saintifik Pertubuhan Bangsa Bangsa Bersatu bagi Kesan Sinaran Atom
USDA	-	*United States Department of Agriculture* Jabatan Pertanian Amerika Syarikat

SENARAI SIMBOL

A	-	Nombor jisim
$\boldsymbol{b}$	-	Pemalar statistik regressi dos sinaran gama daratan daripada latar belakang geologi dan siri tanah
C	-	Kepekatan radionuklid
C_f	-	Faktor pembetulan
df	-	Darjah kebebasan
D	-	Dos terserap
D_c	-	Kadar dos sinaran gama daratan hasil kajian berasaskan kepekatan ^{238}U, ^{232}Th dan ^{40}K
$\mathrm{D}_{i,j}$		Dos sinaran gama daratan yang diukur daripada latar belakang geologi dan siri tanah
D_m	-	Dos sinar gama daratan yang diukur
D_p	-	Dos sinar gama jangkaan
D_s	-	Dos sinar gama daratan daripada sumbangan jenis tanah
E	-	Tenaga
F	-	Ujian F
G	-	Jenis latarbelakang geologi
G_r	-	Kebarangkalian risiko kanser
H	-	Dos setara
H_a	-	Hipotesis alternatif
H_E	-	Dos berkesan
H_{ex}	-	Indeks bahaya
H_o	-	Hipotesis nul
H_T	-	Dos setara pada tisu/organ
I_γ	-	Aras perwakilan indeks sinar gama
k	-	Jumlah kelompok
M	-	Jisim sampel
n	-	Banyaknya jumlah data

N_o	-	Jumlah radionuklid asal
N_t	-	Jumlah radionuklid yang mereput pada masa t
N_α	-	Bilangan bersih alfa
O	-	Unsur oksigen
$O.C$		Faktor kependudukan
p	-	Aras signifikan kebarangkalian
P_γ	-	Jumlah sinar gama per transformasi nukleus radionuklid
R	-	Nilai korelasi Pearsons
Ra_{eq}	-	Indeks kepekatan aktiviti setara radium
$\hat{R}_d$	-	Kesan kesihatan radiologi
S	-	Jenis tanah
t	-	Masa
$t_{½}$	-	Tempoh setengah hayat suatu radionuklid
W_R	-	Faktor pemberat sinaran
W_T	-	Faktor pemberat tisu/organ
X	-	Nukleus induk yang mengalami reputan
Z	-	Nombor atom
^{232}Th	-	Unsur torium - 232
^{238}U	-	Unsur uranium - 238
^{40}K	-	Unsur kalium - 40
α	-	Zarah alfa
α^3	-	Pekali kepencongan
α^4	-	Pekali keruncingan
β	-	Zarah beta
ε	-	Kecekapan pengesanan spectrometer gama
λ	-	Pemalar reputan
σ	-	Sisihan piawai
$\sigma_{i,j}$	-	Sisihan piawai latar belakang geologi dan siri tanah
γ	-	Sinar gama
μ	-	Nilai min
$\mu_{i,j}$	-	Min dos sinaran gama daratan daripada latar belakang geologi *i* dan siri tanah *j*

SENARAI LAMPIRAN

BAB 1

PENGENALAN

1.1 Latar Belakang

Setiap manusia terdedah kepada pelbagai jenis sumber sinaran mengion sama ada dari sinaran semulajadi (IAEA, 1989) dan buatan manusia (Grasty and LaMarre, 2004). Dedahan sinaran latarbelakang yang diterima manusia adalah wujud secara semulajadi (UNSCEAR, 2000; Achola et. al, 2012) dan merupakan sinaran yang berterusan (Jabbar et. al, 2008) serta tidak dapat dielakkan (Kannan et. al, 2002). Dos tahunan yang diterima manusia akibat dedahan sinaran semulajadi secara puratanya adalah 2.4 mSv (UNSCEAR, 2000). Sumbangan dedahan dos sinaran semulajadi didominasi oleh dua sumber utama (WHO, 1961) iaitu sinar kosmik dari luar angkasaraya dan sinaran gama daratan (ICRU, 2011; Khoshbinfar dan Moghaddam, 2010). Hentaman zarah bertenaga tinggi dari luar angkasaraya dengan elemen nukleus (Poje et. al, 2012) seperti O, N dan Ar yang terkandung dalam lapisan atmosfera akan menghasilkan rantaian interaksi dan produk sekunder (Tokuyama dan Igarashi, 1998) iaitu radionuklid kosmogenik yang memancarkan tenaga sinar kosmik (Vuković et. al, 2007). Dos sinaran gama daratan merupakan salah satu komponen dos sinaran latarbelakang yang diterima manusia (Kapdan, et. al, 2012). Dos dedahan akibat sinaran gama daratan kepada orang awam adalah berpunca daripada radionuklid primordial ^{238}U, ^{232}Th, and ^{40}K (Plant dan Saunders, 1996; Thorne, 2003). Proses nukleosintesis dalam teras bintang telah menghasilkan radionuklid primodial ini (Tzortzis et, al. 2003) yang mana ditemui berselerakan di seluruh tempat di dalam kerak bumi (Quindos, et. al, 1991; UNSCEAR, 2000). Pancaran dedahan sinaran gama daratan berpunca dari jarak 30 cm dalam tanah hingga ke permukaan tanah (UNSCEAR, 2000). Tenaga sinar gama akan diatenuasi oleh ketebalan tanah (Valkovic, 2001) dan selebihnya terpancar keluar sebagai sinaran gama daratan dengan julat tenaga sehingga 2.6 MeV (UNSCEAR, 2000).

Kajian sinaran gama daratan telah banyak dilakukan di kebanyakan negara di seluruh dunia, seperti di Cyprus (Tzortzis, 2003), Austria (Wallova et. al, 2012), Nigeria (Jibiri, 2007), Brunei (Lai, et. al, 1999), Oman (Goddard, 2002), Hong Kong (Tso and Li, 1992), Switzerland (Buchli and Burkart, 1989), Costa Rica (Mora, et. al, 2007), Syria (Aissa dan Jubeli,1997), Sweden (Kock dan Samuelsson, 2011), Rusia (Ramzaev, et. al 2006), Egypt (Ibrahim, et. al, 1993), Lebanon (Samad, et. al, 2013), Pakistan (Tufail, et. al. 2006), Brazil (Yoshimura, et. al, 2004), dan Spain (Quindos, et. al, 1993). Faktor utama kajian ini dilakukan adalah bagi mendapatkan data dasar status aras keradioaktifan dan sinaran tabii sesesuatu lokasi disebut sebagai aras rujukan (Ramli, et. al, 1997) khususnya untuk pelaksanaan akta dan undang-undang kawalan keradioaktifan (García-Talavera et. al, 2011). Kajian sebegini juga menjadi tumpuan khusus dalam mengenal pasti kawasan yang mempunyai aras dos sinaran latarbelakang dan keradioaktifan yang tinggi (Alencar dan Freitas, 2005) bagi tujuan pengkormersialan bahan nadir bumi dan mineral berat (Hu and Kandaiya, 1895; Udompornwirat, 1991 dan Hewson, 1996). Antara kawasan yang dikenalpasti mempunyai bacaan kadar dos sinaran gama daratan yang tinggi ialah di Pantai Guarapari, Brazil - 90, 000 nGy j^{-1}, Ramsar, Iran - 17, 000 nGy j^{-1}, Barat Daya Perancis - 10, 000 nGy j^{-1} (UNSCEAR, 2000), Orissa, India-5000 nGy j^{-1} (Mohanty, et. al, 2004), Kerala, India -3767 nGy j^{-1} (Ramasamy, et. al, 2013), dan New Zealand- 1100 nGy j^{-1} (UNSCEAR, 2000).

Kajian terdahulu oleh (Agocs dan Paton, 1958; Ramli et. al, 1997, 2001, 2003, 2005, 2007, 2009, 2013; Steinháusler dan Lettner, 1992; Tzortzis et, al. 2003; Bituh et. al, 2009; Ateba et. al, 2010; Wagiran et. al, 2013) telah membuktikan terdapat korelasi antara kadar dos sinaran gama daratan, jenis latarbelakang geologi dan jenis tanah. Secara dasarnya, perubahan kadar dos sinaran gama daratan di sesuatu kawasan dipengaruhi oleh jenis batuan geologi (Merdanoĝlu dan Altınsoy, 2006, Momčilović et, al. 2010), jenis tanah (Apriantoro, et. al. 2008; Adayrous et. al, 2010) dan faktor geografi kawasan tersebut (Karahan and Bayulken, 2000; Jibiri, 2001). Batuan igneus jenis intrusif granit secara semulajadinya menyumbangkan dedahan kadar dos sinaran gama yang tinggi (UNSCEAR, 2000) kerana kandungan radionuklid U dan Th yang tinggi di dalam batuan tersebut (Omar et. al, 2006) berbanding batuan endapan dan metamorfik (Tzortzis et, al. 2003) seperti batuan syal dan basalt (Kapdan, et. al, 2012).

Tanah ditakrifkan sebagai siri bahan agregat longgar yang terhasil akibat daripada proses luluhawa semulajadi melalui air, haba dan angin (Strahler, 1987) pada batuan induk dari pelbagai jenis latarbelakang geologi (Plummer et. al, 2007). Hampir 99% tanah di kebanyakan tempat di dunia ini terhasil daripada proses reputan batuan mineral seperti induk igneus (Henry, 1990), batuan metamorfik dan batuan endapan (Jabatan Pertanian Semenanjung Malaysia, 1993). Kelimpahan radionuklid dalam tanah bergantung kepada geologi latarbelakang sesuatu kawasan (Huy and Luyen, 2006). Siri tanah jenis Renggam atau secara saintifiknya dikenali sebagai *Paleudults* (USDA, 1999) merupakan antara siri tanah yang memberikan bacaan kadar dos sinaran gama daratan yang tinggi akibat kandungan uranium dan torium yang tertinggi berbanding jenis tanah gambut (Ramli, et. al, 2003; 2007) yang terhasil akibat daripada proses pereputan tumbuhan dan organisma (Henry, 1990).

Siri tanah Renggam ini terhasil akibat daripada proses pereputan batuan induk jenis granit (Wong, 1970). Ramli et. al, 2003 telah mengemukakan model jangkaan statistik kadar dos berdasarkan pengaruh latarbelakang geologi dan jenis tanah di negeri Johor. Kajian tersebut telah melaporkan pemalar sumbangan kadar dos akibat pengaruh Geo-Soil adalah 50:50. Apriantoro, 2008 dalam kajian radiologi di negeri Perak telah mengemukakan model sama dan mendapati kadar dos sinaran gama daratan disumbangkan oleh 59% dari pengaruh latarbelakang geologi dan 41% dari pengaruh jenis tanah. Model linear regressi yang telah dikemukan ini terbukti sah dan telah diuji keabsahan statistiknya dengan data survei in-situ kadar dos di lapangan. Ujian hipotesis statistik menunjukan tiada perbezaan yang signifikan antara kadar dos yang diukur dan kadar dos yang kira berdasarkan model tersebut.

Dalam konteks perlindungan radiologi alam sekitar, data dasar bagi sesuatu kawasan adalah penting untuk tujuan penilaian status keradioaktifan (Mora et. al, 2007; Papp, 2010) dan sinaran tabii (Ramli et. al, 1997, 2001, 2003, 2005, 2007, 2013). Selain itu, data dasar juga amat bermanfaat bagi tujuan melaksanakan undang-

undang perlindungan dan keselamatan sinaran, polisi dan penguatkuasaan akta yang melibatkan amalan fizik kesihatan (AELB, 1984). Pendokumentasian data dasar aras dos sinaran gama daratan dalam bentuk peta isodos adalah suatu pendekatan yang ideal dan amat berguna. Metodologi ini telah banyak dilaporkan dalam kajian-kajian terdahulu bagi mengemukakan data survei yang melibatkan maklumat geospatial (Agocs dan Paton, 1958; Ramli et. al, 1997, 2003, 2005, 2007, 2013; Steinháusler dan Lettner, 1992; IAEA, 2003; Grasty, R.L. dan LaMarre, J.R. 2004; Ismail et. al, 2005; Dowdall et. al, 2005; Mora, et. al. 2007; Van der Graaf et. al, 2007; Apriantoro, et. al. 2008; Lee et. al, 2009; Ateba et. al, 2010; Khoshbinfar, and Vahabi Moghaddam, 2010; García-Talavera et. al, 2011; Dimovska et. al, 2011; Ruqiang dan Jin, 2012; Kapdan, et. al, 2012; Poje et. al, 2012; Zhao et. al, 2012; Muneer et. al, 2013; dan Caro et. al, 2013).

Kebiasaannya, pemetaan isodos sinaran gama daratan adalah sah sekiranya survei kadar dos di lapangan dilakukan secara intensif. Namun, kajian sebegini akan melibatkan titik survei yang banyak, memerlukan tempoh masa yang panjang dan amat sukar dilaksanakan apabila faktor topografi lokasi kajian menyukarkan seperti hutan tebal, cerun yang curam dalam dan kawasan bergunung. Metodologi persampelan merupakan kaedah statistik yang telah diaplikasi dalam kajian melibatkan survei alam sekitar (Ramli, 2007). Kaedah ini secara saintifiknya dilakukan dengan memilih sebilangan titik persampelan berbanding pemilihan keseluruhan titik populasi pembolehubah (Ramachandran and Tsokos, 2009).

Teknik persampelan rawak (*random sampling*) dikatakan akan mematuhi pola taburan diskriptif statistik sepertimana mengikut populasinya. Persampelan 20 titik survei daripada sejumlah besar titik survei dalam satu-satu populasi akan memberikan hasil keputusan yang sama berdasarkan kepada taburan Gaussian data pembolehubah. Teknik sebegini boleh diuji keabsahan statistiknya berdasarkan ujian kenormalan Kilmogorov-Smirnov (Dowdall et. al, 2005).

1.2 Pernyataan Masalah

Amalan fizik kesihatan khususnya melibatkan kajian sinaran gama daratan dan implikasi radiologi alam sekitar di sesuatu lokasi merupakan suatu kajian dasar yang penting (Kucukomeroglu et. al, 2012) dalam mengemukakan data saintifik aras keradioaktifan dan sinaran tabii semulajadi (Ramli *et. al*, 1997, 2003). Penilaian aras keradioaktifan sinaran tabii penting (Mandić dan Dragović, et. al, 2010) bagi penilaian menyeluruh implikasi radiologi alam sekitar (Reddy et. al, 2003) sekiranya berlaku kemalangan nuklear (Quindos et. al, 1991), amalan nuklear lain yang tidak terkawal seperti kemalangan luruhan nuklear global (Pálsson et. al, 2013; Hamzah et. al, 2012; Ahmad et. al, 2010) dan industri TENORM (Merdanoĝlu dan Altınsoy, 2006; Ateba et. al, 2010). Penilaian peningkatan aras dos sinaran relatif kepada sinaran tabii akibat kemalangan nuklear boleh dibuat berdasarkan kepada aras rujukan sinaran tabii (Mora et. al, 2007).

Di Negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya, mempunyai kepadatan populasi yang tertinggi di Malaysia (Jabatan Perangkaan Malaysia, 2011), oleh itu data dasar mengenai aras keradioaktifan dan sinaran mengion wajarlah diwujudkan. Data dasar yang dikemukan setakat ini hanya melibatkan kajian implikasi radiologi akibat industri TENORM (Hu, et. al, 1981; Chong et. al 1978; Hamzah dan Mahmood, 1985; Meor Sulaiman, 1988; Sharif dan Ghazali, 1987; Udompornwirat, 1991; Roberts, 1995; Hewson, 1996; Omar and Hassan, 2002; Bahari et. al, 2007;; Hu and Kandaiya, 1985a,b; Meor Sulaiman dan Muslimin, 2010; dan Yusof et. al, 2001). Data dasar sebegini tidak menyeluruh dan tidak mencukupi sebagai data dasar. Ia hanya bersifat kajian setempat.

Perkembangan industri TENORM yang pesat (AELB, 1991) khususnya melibatkan aktiviti pemerosesan amang (Hu, *et. al* 1984) dan perlombongan bijih timah (SEATRAD, 1991) merupakan antara penyebab kajian sebegini dilakukan. Latarbelakang geologi dan pemineralan di Timur negeri Selangor (Flinter et. al, 1963) pada Banjaran Titiwangsa (*The Main Granite Range*) merupakan perangsang perkembangan industri TENORM (AELB, 1991) yang boleh meningkatkan aras dos sinaran latarbelakang (Ramli, 2007, Agocs dan Paton, 1958).

Untuk memastikan jaminan sumber tenaga jangka panjang pada alaf baru (Ismail dan Roston, 2012), Malaysia sedang dalam perancangan pembangunan tenaga nuklear (Basri dan Ramli, 2012). Pemilihan tapak loji tenaga nuklear adalah merupakan satu perkara asas yang perlu dipertimbangkan (Basri dan Ramli, 2012). Data dasar status aras keradioaktifan dan sinaran tabii merupakan salah satu keperluan dalam pemilihan tapak loji nuklear (Muneer et. al, 2013).

Penyediaan data dasar aras status keradiokatifan dan sinaran tabii merupakan satu kajian yang mencabar. Survei aras keradioaktifan dan sinaran gama daratan melibatkan beberapa faktor halangan seperti batasan capaian kepada sesuatu lokasi, permukaan topografi hutan tebal tropikal, cerun curam dan melibatkan keluasan yang besar (Ramli et. al, 2013). Satu pembaharuan dari segi metodologi survei aras dos sinaran tabii diperlukan. Kajian ini dilakukan bagi mencadangkan satu metodologi persampelan yang meminimumkan jumlah titik survei. Pengesahan keabsahan dari segi statistik metodologi ini akan menerbitkan satu model regressi jangkaan kadar dos yang akan lebih memudahkan kajian seumpamanya pada masa hadapan.

1.3 Skop Kajian

Kajian ini melibatkan seluruh negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya. Penyelidikan ini meliputi daratan seluas 8,104 km^2 yang mempunyai penduduk yang seramai 7, 209, 175 yang dilaporkan pada tahun 2010 (Department of Statistics, 2011). Kajian ini memberikan tumpuan khusus pada penilaian status aras dos sinar gama daratan berdasarkan dua kaedah berbeza iaitu kaedah survei di lapangan dan kaedah model regressi linear statistikal jangkaan. Teknik persampelan telah digunakan bagi tujuan survei kadar dos sinaran gama daratan di lapangan. Ujian hipotesis statistikal ANOVA telah dilakukan bagi menguji keabsahan model regressi linear jangkaan kadar dos. Pembinaan model ini berdasarkan maklumat pengkalan data yang melibatkan 9884 data in-situ kadar dos sinaran gama daratan di semua negeri di Semenanjung Malaysia, yang dikumpul semenjak 1995-2013 (Ramli dan Jasman, 1995; Ramli et al 1997; 2001; 2003; 2005. ;2007; 2009; 2013 dan Apriantoro, 2008). Ujian hipotesis statistik- *t*, *z*, ujian korelasi Pearson, ujian kenormalan Levene, Shapiro-Wilk, Kolgomorov-Smirnov, dan ujian *Pos Hoc* Tukey's dan Fisher's telah digunakan bagi membuktikan terdapat korelasi yang kuat diantara pengaruh latarbelakang geologi dan jenis tanah terhadap kadar dos sinar gama.

Instrumen pengukuran aras dos sinaran yang digunakan semasa aktiviti di lapangan ialah jenis pengesan sintillasi sinar gama jenis Ludlum 19 $\mu R\ j^{-1}$ (*micro Rontgen per hour*) dan dengan bantuan alat navigasi GPS serta peta topografi semenanjung Malaysia. Setiap pengukuran dos dilakukan satu meter dari tanah iaitu setara paras sistem gonad manusia iaitu sistem genting terhadap sinaran mengion. Bagi tujuan kawalan kualiti kadar dos survei sinaran gama, sebanyak 41 sampel tanah (*top soil*) telah diambil secara rawak di negeri Pahang, Perlis, Kedah, P. Pinang dan Selangor. Analisis kepekatan kandungan ^{238}U, ^{232}Th, and ^{40}K telah dilakukan di Makmal Nuklear, Fakulti Sains dan di Agensi Nuklear Malaysia dengan menggunakan spektrometer gama HPGe. Kaedah kawalan kualiti ini menggunakan teknik interpolasi kecerunan antara pembolehubah kadar dos terkira, D_c daripada analisis kepekatan ^{238}U, ^{232}Th, and ^{40}K dengan pembolehubah kadar dos yang diukur, D_m. Teknik ini digunakan bagi mendapatkan pemalar pekali pembetulan kadar dos, C_f daripada korelasi kecerunan graf pembolehubah.

Hasil data survei yang telah direkodkan dari di lapangan dan hasil kaedah statistikal jangkaan kadar dos sinaran gama daratan akan diterjemahkan dalam bentuk peta isodos dengan menggunakan sofwer Arcgis 9.3. Analisis geospatial kadar dos sinaran gama daratan ini dibina berdasarkan teknik Kriging iaitu satu kaedah interpolasi data secara statistik.

1.4 Objektif Kajian

Objektif kajian ini disusun seperti berikut :-

1. Kajian ini bertujuan untuk menghasilkan data dasar status aras dos sinaran gama daratan semulajadi dan membangunkan satu metodologi persampelan dalam amalan fizik kesihatan serta kaedah statistik model regressi linear jangkaan kadar dos berdasarkan pengaruh ciri geologi dan jenis tanah.di negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya
2. Mengemukakan hasil kajian kesahihan statistik hubungan pengaruh latarbelakang geologi dan jenis tanah terhadap kadar dos sinaran gama daratan.
3. Mengenalpasti kawasan yang mempunyai aras keradioaktifan luar biasa berbanding dengan aras normal global dan aras dos sinaran gama tabii yang tinggi.
4. Menjangkakan risiko impak kesihatan radiologi kepada orang awam.
5. Membina peta isodos sinaran mengion bagi negeri Selangor, Wilayah Persekutuan Kuala Lumpur dan Putrajaya.

1.5 Kepentingan Kajian

1. Menghasilkan kaedah baru bagi penilaian aras dos sinaran gama daratan dengan pendekatan jangkaan statistik dan persampelan yang meminimumkan titik survei dos sinaran gama daratan.
2. Mengemukakan rumusan kesan implikasi radiologi alam sekitar di negeri Selangor berdasarkan data dasar keradioaktifan dan sinaran gama daratan yang telah diperolehi.
3. Mengemukakan data dasar sebagai rujukan untuk kegunaan keselamatan, penguatkuasaan kawalan sisa dan pencemaran radioaktif dari industri TENORM.

4. Memberi maklumat saintifik untuk penilaian impak radiologi dalam situasi genting yang melibatkan kebocoran reaktor nuklear atau pencemaran radioaktif yang meningkatkan aras dos sinaran kepada populasi umum.
5. Data saintifik ini memainkan peranan sebagai bukti dalam hal berkaitan dengan keselamatan amalan sinaran untuk dalam meyakinkan rakyat bahawa negara mempunyai maklumat saintifik mengenai hal tersebut.
6. Bermanfaat bagi tujuan penggubalan dasar dan polisi yang melibatkan keselamatan pekerjaan dan orang awan akibat daripada amalan yang melibatkan penggunaan bahan radioaktif atau tenaga nuklear.
7. Memberikan data tentang kawasan yang mempunyai aras dos sinaran dan tahap keradioaktifan tabii yang tinggi berbanding dengan aras purata dunia dan ini diperlukan dalam proses pemilihan lokasi loji tenaga nuklear.

RUJUKAN

Abbady, G.E.A. (2004). Estimation of radiation hazard indices from sedimentary rocks in Upper Egypt. Applied Radiation and Isotopes. 60 (1) 111 – 114

Abbady, G.E.A. (2004). Estimation of radiation hazard indices from sedimentary rocks in Upper Egypt. Applied Radiation and Isotopes. 60 (1) 111 – 114

Abdul Ghaffar Ramli (1991). Keradioaktifan Asas dan Penggunaan, Dewan Bahasa dan Pustaka, Kuala Lumpur.

Abdul Rahman, A.T, Ramli, A.T., Wood, A.K., (2004). Analysis of the concentrations of natural radionuclides in rivers in Kota Tinggi District, Malaysia. Journal Of Nuclear And Related Technologies. 1 (1), 34.

Abdullah Mokhtar (1994). Regression Analysis, 1^{st} ed., chapter 1; simple linear regression model, pp-3, Dewan Bahasa dan Pustaka, Kuala Lumpur.

Abiama, P. E., Ben-Bolie, G. H., Amechmachi, N., Najib, F., El Khoukhi, T., and Ateba, O. (2012). Annual intakes of ^{226}Ra, ^{228}Ra and ^{40}K in staple foodstuffs from a high background radiation area in the southwest region of Cameroon. Journal of Environmental Radioactivity. 110, 59- 63.

Abu, M. S. dan Tasir, Z. (2001). Pengenalan kepada analisis data berkomputer SPSS 10 for Window. 1^{st}. ed. Venton Publishing, Kuala Lumpur, Malaysia.

Achola, S.O, Patel, J.P., Mustapha, A.O., dan Angeyo, H.K. (2012). Natural Radioactivity and External Dose in the High Background Radiation Area of Lambwe East, Southwestern Kenya. 1- 6.

AELB (1984). Akta Perlesenan Tenaga Atom (Akta 304), Undang-Undang Malaysia. Lembaga Perlesenan Tenaga Atom Malaysia, Dengkil, Selangor.

AELB (1991). Radiological hazards assessment at mineral processing plants in Malaysia. Atomic Energy Licensing Board of Malaysia. LEM/LST/ I6

Agbalagba, E.O., Avwiri, G.O., Chad-Umoreh, Y.E. (2012). γ-Spectroscopy measurement of natural radioactivity and assessment of radiation hazard indices in soil samples from oil fields environment of Delta State, Nigeria. Journal of Environmental Radioactivity 109, 64 – 70.

Agocs, W.B and Paton, J. R., 1958. Airborne Magnetometer and Scintillation Counter Survey of Kedah, Perak, Selangor, Terengganu, Pahang, dan Johor. Department of Geological Survey, Ipoh, Malaysia,

Ahmad, Z., Wo, Y.M., Abu Bakar, A.S.,dan Shahar, H. (2010). Spatial distributions of ^{137}Cs and $^{239+240}Pu$ in surface seawater within the Exclusive Economic Zone of East Coast Peninsular Malaysia. Applied Radiation and Isotopes. 68 (9), 1839 – 1845.

Aissa, M., dan Jubeli, Y.M. (1997). Carborne gamma-ray spectrometric survey of an area East of Homs, Central Syria Applied Radiation and Isotopes. 48 (1), 135 – 142.

Amstrong, M., 1998. Basic Linear Geostatistics. Springer-Verlag Berlin Heidelberg, German.

Azkeskin, E.K., Güven, G., Güral, M., dan Sezer, T. (2013). Parenting styles: parents with 5-6 year old children. Journal of Educational and Instructional Studies in The World. 3 (1), 9.

Alencar, A.S., dan Freitas, A.C. (2005). Reference levels of natural radioactivity for the beach sands in a Brazilian southeastern coastal region Radiation Measurements. 40, 76 – 83.

Al-Hamarneh, I.F., dan Awadallah, M. I. (2009). Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan. Radiation Measurements. 44, 102–110.

Alias, M. Hamzah, Z., Saat, A., Omar, M., dan Kadir, A. (2004). An Assessment Of Absorbed Dose And Radiation Hazard Index From Natural Radioactivity. 12 (1).

Alias, M., Hamzah, Z., Saat, A., Omar, M., dan Wood, A.K. (2008). An Assessment of Absorbed Dose and Radiation Hazard Index from Natural Radioactivity. The Malaysian Journal of Analytical Sciences. 12 (1).

Almayahi, B.A., Tajuddin, A.A, dan Jaafar, M.S. (2012). Effect of the natural radioactivity concentrations and $^{226}Ra/^{238}U$ Disequilibrium on cancer diseases in Penang, Malaysia. Radiation Physics and Chemistry. 81 (10, 1547-1558.

Almayahi, B.A., Tajuddin, A.A, dan Jaafar, M.S. (2014). Measurements of natural radionuclides in human teeth and animal bones as markers of radiation exposure from soil in the Northern Malaysian Peninsula. Radiation Physics and Chemistry. 97, 56–67.

Merdanoğlu, B. dan Altinsoy, N. (2006). Radioactivity Concentrations and Dose Assessment for Soil Samples from Kestanbol Granite Area, Turkey. Radiation Protection Dosimetry. 121 (4), 399 – 405.

Apriantoro, N. H. (2008). Kajian Radiologi di Negeri Perak dan Impak Radiologi di Daerah Kinta, Tesis Ijazah Doktor Falsalah. Universiti Teknologi Malaysia.

Asghar, M., Tufail, M. Javied, S., Abid, A., dan Waqas, M. (2008). Radiological implications of granite of northern Pakistan. Journal Radiological Protection. 28, 387–399.

Ateba, J.F.B., Ateba, P.O., Ben-Bolie, G.H., Ele Abiama, P., Abega, C.R., dan Mvondo, S. (2010). Natural Background Dose Measurements in South Cameroon. Radiation Protection Dosimetry. 140 (1), 81 – 88.

Aydarous, A.Sh., Zeghib, S. dan Al-Dughmah, M. (2010). Measurements of Natural Radioactivity and the Resulting Radiation Doses from Commercial Granites. Radiation Protection. 142 (2 - 4), 363 – 368. 1.

Basri, N. A. ,Ramli, A. T.,2012.Selection of possible candidate area for NuclearPower Plant In Johor, Malaysia. Journal Nuclear & Related Technolology, 9 (1), 56–63.

Bahari, I., Othman, M., and Soong, H. F. (2000). Effect of tin dredging on the environmental concentration of arsenic, chromium and radium -226 in soils and water. Journal of Nuclear Sciences Malaysia, 18(1), 107-116.

Bahari, I., Monawarah, N.M.Y, Hng, P.W., dan Sharifah Mastura, S.A. (2005). Environmental External Gamma Radiation Isodose Map Of Kinta & Batang Padang Districts, Perak. Journal of Nuclear and Related Technologies. 2 (1).

Bahari, I., Mohsen, N., and Abdullah, P. (2007). Radioactivity and radiological risk associated with effluent sediment containing technologically enhanced naturally occurring radioactive materials in amang (tin tailings) processing industry. Journal of Environmental Radioactivity (95), 161-170.

Beretka, J., dan Mathew, P.J. (1985). Natural radioactivity of Australian building materials, industrial wastes and by-products. *Health Physics.* 48, 87–95.

Bituh, T., Marovic, G., Petrinec, B., Sencar, J. dan Franulovic, I. (2009). Natural Radioactivity of ^{226}Ra and ^{228}Ra In Thermal and Mineral waters In Croatia. Radiation Protection Dosimetry. 133 (2), 119 – 123.

Buchli, R. dan Burkart, W. (1989). Correlation Among the Terrestrial Gamma Radiation, the Indoor Air ^{222}Rn, and the Tap Water ^{222}Rn in Switzerland. Health Physics. 57 (5)

Caro, A., Legarda, F., Romero, L., Herranz, M., Barrera, M., Valiño, F., Idoeta, R., dan Olondo, C. (2013). Map on predicted deposition of Cs-137 in Spanish soils from geostatistical analyses. Journal of Environmental Radioactivity. 115, 53 – 59.

Carver, R. H. and Nash, J. G. (2000). Doing data analysis with SPSS 10.0. 1st ed., Duxbury publication, USA.

Clouvas, A., Xanthos, S., Antonopoulos-Domis, M., dan Silva, J. (2000). Monte carlo calculation of dose rate conversión factors for external exposure to photon emitters in soils. Health Physics. 78, 295–302.

Cohen, Y. and Cohen, J. Y. (2008). Statistics and data with R; an application approach through examples. 1st ed., John Wiley & Son, London, UK.

Colgan, P.A., Organo, C., Hone, C., and Fenton, C. (2008). Radiation doses received by the Irish population. Radiological Protection Institute of Ireland (RPII).

Chen, D., Liu, Z., Ma, X. and Hua, D. (2005). Selecting Genes by Test Statistics Journal of Biomedicine and Biotechnology. 2, 132 – 138.

Chong, C.S., Hu, S.J. and Subas. S (1978). Gamma counting on samples of tin ores and amang by-products. Newsletter of The Geological Society of Malaysia. (4), No. 3. 75-79.

de Smith, M. J., Goodchild, M.F. and Longley, P. A. (2007). Geospatial Analysis, 2nd ed.: a comprehensive guide to principles, techniques and software tools; regressions method in chapter 5; data exploration and spatial distribution. pp 239-241. The Winchelsea press, Leicester, UK.

Department of Agriculture Peninsular Malaysia, (2002). Map of Soil Types in Peninsular Malaysia. Department of Agriculture, Peninsular Malaysia, Kuala Lumpur, Malaysia.

Department of Agriculture Peninsular Malaysia, (1993). A Guideline for main soils series in Peninsular Malaysia. Department of Agriculture, Peninsular Malaysia, Kuala Lumpur, Malaysia.

Department of Geological Survey, Malaysia, (1985). Map of Geological Features in Peninsular Malaysia. Department of Geological Survey, Ipoh, Malaysia.

Department of National Mapping, Malaysia, (1989). Topography map of Peninsular Malaysia. Department of Survey and Mapping Malaysia, Kuala Lumpur, Malaysia.

Department of Statistics, (2011). Annual book of Statistics Malaysia 2011. National Printed Malaysia Berhad, Kuala Lumpur.

Dimovska, S., Traje Stafilov, T. and Šajn, R. (2011). Radioactivity in Soil from the City Of Kavadarci (Republic Of Macedonia) and Its Environs. Radiation Protection Dosimetry, 2011, 107 – 120.

Dowdall, M., Gerland, S., Karcher, M., Gwynn, J.P., Rudjord, A.L. dan Kolstad, A.K. (2005). Optimisation of sampling for the temporal monitoring of technetium-99 in the Arctic marine environment. Journal of Environmental Radioactivity. 84, 111 – 130.

El-Arabi, A.M. (2007).Ra, Th, K concentrations in igneous rocks from eastern desert Egypt and its radiological implications. Radiation Measurement. 42, 94–100.

El-Shershaby, A. (2002). Study of radioactivity levels in granite of Gable-Gattar II in the north eastern desert of Egypt. Applied Radiation Isotopes. 57, 131–5.

Evans, M.A. (1993). Ore Geology and Industrial Minerals: An Introduction, 3rd ed. Blackwell Publishing. Oxford, UK.

Flinter, B.H., Butler, J.R., dan Harral, G.M. (1963). A study of alluvial monazite from Malaya. The American Mineralogist. (48).

García-Talavera, M. Matarranz, J.L., Martínez, M., Salas, R. dan Ramos, L. (2007). Natural Ionizing Radiation Exposure of the Spanish Population. Radiation Protection Dosimetry (2007). 124 (4), 353 – 359.

Garmin, (2000). Chartplotting receiver owner's manual and reference guide. Garmin Corporation, Ins. Kansas, US.

Goddard, C.C (2002). Measurement of Outdoor Terrestrial Gamma Radiation in the Sultanate of Oman. Health Physics. 82 (6), 869 – 874.

Grasty, R.L. dan LaMarre, J.R. (2004). The annual estimation effective dose from natural sources of ionizing radiation in Canada. Radiation Protection Dosimetry. 108 (3), 215 – 226.

Grogan, K.P., Fjeld, R.A, Kaplan, D., Devol, T.A., dan Coates, J.T. (2010). Distributions of radionuclide sorption coefficients (Kd) in sub-surface sediments and the implications for transport calculations. Journal of Environmental Radioactivity. 101, 847 – 85.

Hamzah, N.M., Yahaya, R. Majid, A.,Yasir, M.S., dan Bahari, I. (2010). Contribution Of Selangor And Johor Clay Bricks Towards The Natural Radioactivity Exposure To Dweller. Journal of Nuclear and Related Technology. 7 (1).

Hamzah, M. S., and Mahmood, C. S. (1985). Determination of uranium in mineral samples by neutron activation analysis techniques. Journal of Nuclear Sciences Malaysia, 3 (2), 71-74.

Hamzah, Z., Abd. Rahman, S. A., Saat, A., Agos, S. S., and Ahmad, Z., (2010). Measurement of ^{226}Ra in river water using liquid scintillation counting technique. Journal of Nuclear and Related Technologies. 7 (2).

Hamzah, Z., Saat, A., Riduan, S.D, dan Amirudin, C.Y (2012). Assessment of ^{137}Cs Activity Concentration in Soil from Tea Plantantion Areas in Cameron Highlands. Journal of Nuclear and Related Technologies. 9 (1).

Harder, D. L., Hurd, C. L., dan Speck, T. (2006). Effect of thyroid function on COPD exacerbation. American Journal of Botany, 93 (10),1426 – 1322.

Hartung, J. dan Argaç D. (2001). Testing For Homogeneity In Combining Of Two-Armed Trials With Normally Distributed Responses. The Indian Journal of Statistics. 63 (3), 298 – 310.

Hauri, D. D., Huss, A., Zimmermann, F., Kuehni, C. E., dan Röösli, M. (2012). A prediction model for assessing residential radon concentration in Switzerland. Journal of Environmental Radioactivity. 112, 83 – 89,

Health Canada (2009) Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Radiological Parameters. Radiation Protection Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario, Canada.

Heide, T.V.D., Roijackers, R.M.M, Peeters E.T.H.M and Nes, E.H.V. (2006). Experiments with duckweed–moth systems suggest that global warming may reduce rather than promote herbivory. Freshwater Biology. 51, 110 – 116.

Henry, D.F., Fundamental of Soil Science, 2nd ed. John Wiley & Sons, New York, 1990.

Hocking, R.R. (1996). Methods and Apllications of Linear Models. Regression and the analysis of variance. 1st ed. John Wiley and Sons, New York, USA.

Houmani, M.Z.M., Majid, A. A. dan Radiman, S. dan Ahmad, Z. (2012). Effects of physico-chemical soil properties on the adsorption and transport of ^{137}Cs in rengam and selangor soil series. The Malaysian Journal of Analytical Sciences. 16 (2), 94 – 102.

Hu, S. J.,and Kandaiya, S. (1985b). Radium-226 and Th-232 concentration in Amang. Health Physics, 49 (5), 1003 - 1007.

Hu, S. J., Koo, W. K. and Tan, K. T. (1984). Radioctivity associated with amang upgrading plants. Health Physics, 46 (2), 452-455.

Hu, S. J. and Koo, W. K. (1981). Measurement of ThB (Pb212) concentration in Amang Plants. Health Physics 41, 391-393.

Hu, S.J. and Kandaiya, S. (1985a). Health and safety problems among amang workers in the tin industry in Malaysia. Journal of Nuclear Sciences Malaysia, 3(2), 1-4.

Hu, S.J., Chong, C.S. and Subas. S. (1981). U238 and Th232 in Cassiterites Samples and Amang By-Products. Health Physics (40), 248-250.

Hewson, G. S. (1996). Overview of Radiation Safety in the Tin By-Product (amang) Industry of South East Asia. Health Physics, 72 (2), 225-234.

Huy, N. Q.; and Luyen, T. V., (2006). Study on external exposure doses from terrestrial radioactivity in Southern Vietnam. Radiation Protection Dosimetry, 118 (3), 331–336.

IBM (2011). IBM SPSS statistics online help: Algorithm: Post Hoc Tests for Unequal Variances. Copyright IBM Corporation 1989. http://www. pic.dhe.ibm.com/infocenter/spssstat.

Ibrahim, N.M., Abd El Ghani, A.H., Shawky, E.M., Ashraf, E.M., dan Farouk, M.A. (1993). Measurement of radioactivity levels in soils in the Nile Delta and Middle Egypt. Health Physics, 64 (6), 620–627.

International Atomic Energy Agency, (1989). Measurement of radionuclides in food and the environment in food and the environment. Technical Report Series 295, a guidebook. IAEA.

International Atomic Energy Agency, (2003). Guidelines for radioelement mapping using gamma ray spectrometry data. TECDOC 1363, IAEA. Vienna, Austria.

International Atomic Energy Agency, (2004). Method for assessing occupational radiation doses due to the intakes of radionuclides. Safety Report Series, 37. IAEA. Vienna, Austria.

International Commission on Radiological Protection ICRP 60, (1990). Recommendations of the international commission on radiological protection. In: ICRP Publication 60, Annals of the ICRP. Pergamon Press, Oxford.

Isinkaye, M.O. dan Ajayi, I.R. (2006). Natural Background Dose and Radium Equivalent Measurements at Ikogosi Warm Spring, Nigeria. Radiation Protection Dosimetry. 1 – 3.

Ismail, M.A. dan Zakaria, M. R. (2012). Revisiting uranium resources in Malaysia. Jurnal Sains Nuklear Malaysia. 24 (1), 1-8.

Jabbar, T., Khan, K., Subhani, M.S., Akhter, P. dan Jabbar, A. (2008). Environmental Gamma Radiation Measurement In District Swat, Pakistan. Radiation Protection Dosimetry (2008). 132 (1), 88–93.

Jibiri, N.N., (2001), Assessments of health risk levels associated with terrestrial gamma radiation dose rates in Nigeria. Environment International, 21, 21-26.

Joshua, E.O, Ademola, J.A., Akpanowo, M.A., Oyebanjo O.A.,dan Olorode, D.O., (2009). Natural radionuclides and hazards of rock samples collected from Southeastern Nigeria. Radiation Measurements. 44, 401–404.

Kannan, V., Rajan M.P., Iyengar, M. A. R., and Ramesh, R. (2002). Distribution of natural and anthropogenic radionuclides in soil and beach sand samples of Kalpakkam (India) using hyper pure germanium (HPGe) gamma ray spectrometry. Applied Radiation and Isotopes. 57, 109–119.

Kapdan, E.; Varinlioglu, A. and Karahan, G., (2012). Outdoor radioactivity and health risks in Balikesir, Northwestern Turkey, Radiation Protection Dosimetry, 148 (3), 301–309.

Karahan, G., and Bayulken, A. (2000). Assessment of gamma dose rates around Istanbul (Turkey). Journal of Environmental Activity. 47, 213-221.

Khoshbinfar, S. and M. Vahabi Moghaddam, M.V. (2010). Terrestrial Outdoor Exposures in the South-West Caspian Region. Radiation Protection Dosimetry (2010). 142 (2-4), 332 – 338.

Knoll, G. F. (2000). Radiation Detection and Measurement, 3rd Ed , John Wiley & Sons.Inc. New York.

Kock, P., dan Samuelsson, C. (2011). Comparison of airborne and terrestrial gamma spectrometry measurements - evaluation of three areas in southern Sweden. Journal of Environmental Radioactivity. 102 (6), 605 – 613.

Kucukomeroglu, B. Maksutoglu, F. Damla, N., Cevik, U. dan Celeb, N. (2012). A Study of Environmental Radioactivity Measurements In The Samsun Province, Turkey. Radiation Protection Dosimetry. 1–7.

Krishnamoorthy, K., Lua, F., dan Mathew, T. (2007). A parametric bootstrap approach for ANOVA with unequal variances: Fixed and random models. Computational Statistics & Data Analysis. 51, 5731 – 5742.

Lai, K.K., Hu, S.J., Minato, S., Kodaira, K., dan Tan, K.S. (1999). Terrestrial gamma ray dose rates of Brunei Darussalam. Applied Radiation and Isotopes. 50 (3), 599-608.

Larson, M.G. (2008). Analysis of Variance. Circulatio: Journal of American Heart Association. 117, 115 – 121.

Lee, S. K., Ramli, A.T, Wagiran, H., Apriantoro, N.H., Wood, A.K. (2009). Radiological monitoring: terrestrial natural radionuclides in Kinta District, Perak, Malaysia. Journal of Environmental Radioactivity. 100, 368–374.

Lenka, P., Jha, S.K., Gothankar, S.R., Tripathi, M., dan Puranik, V.D. (2009). Suitable gamma energy for gamma-spectrometric determination of ^{238}U in surface soil samples of a high rainfall area in India. Journal of Environmental Radioactivity. 100, 509–514.

Lillierfors, H.W. (1967). On the Kolmogorov-Smirnov Test for Normality with Mean and Variance Unknown. Journal of the American Statistical Association. 62 (318). 399-402.

Ludlum, (1993). Instruction Manual of Ludlum Model 19 Micro R Meter. Texas :Ludlum Measurements, Inc.

M.O. Schwartz, M.O., Rajah, S.S., Askury, A.K., Putthapiban, P. and Djaswadi, S. (1995). The Southeast Asian Tin Belt. Earth-Science Reviews. 38, pp 95-293.

Mandić, L.J. dan Dragović, S. (2010). Assessment of Terrestrial Gamma Exposure to the Population of Belgrade (Serbia). Radiation Protection Dosimetry (2010). 140 (44), 369 – 377.

Mann, B.W., Ayres, R.L. and Garfinkel, S.B. (1980). Radioactivity and its Measurement, 2^{nd} Ed., Pergamon Press., Oxdford, United Kingdom.

Martin, A., Harbison, S.A., (1986). An Introduction to Radiation Protection, third ed. Chapman and Hall, London, UK.

Mickey, M.R., Dunn, J.O. dan Clark. A.V. (2004). Applied statistics: Analysis of Variance and Regression. 3^{rd} ed. John Wiley and Sons, New Jersey, USA.

Merdanoĝlu dan Altınsoy, (2006). Radioactivity Concentrations and Dose Assessment for Soil Samples from Kestanbol Granite Area, Turkey. Radiation Protection Dosimetry, 121, (4) 399 – 405.

Meor Sulaiman, M. S. (1988). The use of room temperature phosphorescence for the determination of uranium in tin-tailings mineral samples. Journal of Nuclear Sciences Malaysia, 6 (2), 81 – 87.hamed, C. A. R., Ahmad, Z. dan Theng, T. L. (2006). ^{210}Po and ^{210}Pb in cockle tissues in west coast of peninsula Malaysia. Journal of Nuclear and Related Technologies. 3 (1), 69 – 75.

Meor Sulaiman, M. Y. and Muslimin Masliana (2010). Quantitative Analysis of Uranium And Thorium In Local Zircon And Tin Slag By The EDXRF Technique. Journal of Nuclear and Related Technology (7), No. 1

Mohamed, C. A. R., Ahmad, Z. dan Yew, N. S. (2008). Aktiviti ^{226}Ra dan ^{228}Ra pada permukaan sedimen Bagan Lalang, Selangor. The Malaysian Journal of Analytical Sciences. 12 (1).

Mohamed, C. A. R., Sabuti, A. A., dan Ahmad, Z. (2010). Radioactivity of ^{210}Po in the environmental samples from Kapar, Malaysia. Journal of Nuclear and Related Technology. 7 (1).

Mohanty, A.K., Sengupta, D., Das, S.K., Saha, S.K., Van, K.V. (2004). Natural radioactivity and radiation exposure in the high background area at Chhatrapur beach placer deposit of Orissa, India. Journal of Environmental Radioactivity. 75 (1), 15-33.

Mohsen, N., Bahari, I., Abdullah, P., and Jaafar, A. (2007). Gamma hazards and risk associated with norm in sediment from amang processing recycling ponds. The Malaysian Journal Of Analytical Sciences, (11) No 1, 314 -323.

Møller, A.P. and Jennions, M.D (2002). How much variance can be explained by ecologists and evolutionary biologists. Ecologia. 132, pp 492 – 500.

Momčilović, M., Kovačević, J., and Dragović, S. (2010). Population doses from terrestrial exposure in the vicinity of abandoned uranium mines in Serbia. Radiation Measurements. 45, 225-230.

Montgomery, C.W. (1993). Physical Geology, third ed. Wm.C publishers, Illinois, USA.

Mora, P., Picado, E., and Minato, S. (2007). Natural radiation doses for cosmic and terrestrial components in Costa Rica. Applied Radiation and Isotopes. 65

Muneer, A.S., Ramli, A.T., Yasser A., Aliyu, A.B.S. (2013). Assessment of environmental ^{226}Ra, ^{232}Th and ^{40}K concentrations in the region of elevated radiation background in Segamat District, Johor, Malaysia. Journal of Environmental Radioactivity. 124, 130-140.

Myers, R. H. (1986). Classical and modern regression with applications, 1st ed., chapter; The simple linear regression model, pp 9 – 10, PWS publishers, Boston, USA.

Navas, A., Gaspar, L., López-Vicente, M., dan Machín, J. (2011). Spatial distribution of natural and artificial radionuclides at the catchment scale (South Central Pyrenees). Radiation Measurements. 46, 261 – 269.

NCRP. National Council on Radiation Protection and Measurements (1976). Environmental Radiation Measurement, NCRP Report No. 50, 1976.

Omar, M. (2009). γ-ray interference and emission probability selection in the determination of natural radionuclide concentration using γ-spectrometry. Journal of Nuclear and Related Technologies. 6 (2).

Omar, M. and Hassan, A. (2002). The occurrence of high concentration of natural radionuclides in black sands of Malaysian beaches. Journal of Nuclear Sciences Malaysia, 20 (1 & 2), 30 – 36.

Omar, M. dan Laili, Z. (2008). The Presence of ^{60}Co in Solid Wastes from Crude Oil Production Industri. Journal of Nuclear and Related Technologies. 5 (1).

Omar, M., Hassan, A., dan Sulaiman, I. (2007). Radiation exposure during travelling in Malaysia. Technical Notes. *Radiation Protection Dosimetry*. 121(4), 456-460.

Omar, M., Hamzah, M. S., and Wood, A. K. (2008). Radioactive Disequilibrium and Total Activity Concentration of Norm Waste. Journal Nuclear And Related Technology. 5 (2).

Osborne, J. W. (2010). Improving your data transformations: Applying the Box-Cox transformation. Electronic journal of practical assessment, research & evaluation. 15 (12).

Pálsson, S.E., Howard, B.J., Bergan, T.D., Paatero, J. Isaksson, M. dan Nielsen, S.P. (2013). A simple model to estimate deposition based on a statistical reassessment of global fallout data. Journal of Environmental Radioactivity. 121, 75 – 86.

Paramanathan, S. (1998). Malaysian Soil Taxonomy: A Proposal for the Classification of Malaysian Soils. Selangor : Malaysian Society of Soil Science

Plant, J.A. dan Saunders, A.D. (1996). The Radioactive Earth. Radiation Protection Dosimetry, 68, 1, 25-36.

Plummer, C. C.; Carlson, D. H.; and McGeary, T. L. D. (2007). Physical Geology, 11th ed. McGraw-Hill, New York,.

Poje, M., Vukovic´, B., Radolic´, V., Miklavčic´, I., Faj, D.,Pajtler, M.V., dan Planinić, J. (2012). Mapping of cosmic radiation dose in Croatia. Journal of Environmental Radioactivity. 103, 30 – 33.

Quindós, L.S., Fernández, P.L., Soto, J. dan Rodenas, C. (1991). Terrestrial gamma radiation levels outdoors in Cantabria, Spain. Journal of Radiological Protection. 11 (2), 127-130.

Quindos, L.S., Fernandez, P.L., dan Soto, J. (1993). Exposure to natural sources of radiation in Spain. Nuclear Tracks and Radiation Measurements. 21 (2), 295 – 298.

Quindos, L.S., Fernández, P.L., Ródenas, C., Gómez, A.J., dan Arteche, J. (2004). Conversion factors for external gamma dose derived from natural radionuclides in soils. *Environmental Radioactivity* 71(2), 139-145.

Ramachandran, M. K. and Tsokos, C. P. (2009). Mathematical statistics with application, 1st ed; Analysis of variance in chapter 10, pp 501 – 503, Elsevier Academic Press, San Diego, US.

Ramasamy, V.; Sundarrajan M.; Paramasivam, K.; Meenakshisundaram, V.; Suresh. G. (2013). Assessment of spatial distribution and radiological hazardous nature of radionuclides in high background radiation area, Kerala, India, *Applied Radiation and Isotopes*, 73, 21–31.

Ramli, A. T. (1997). Environmental Terresterial Gamma Radiation Dose and its Relationship with Soil Type and Underlying Geological Formation in

Pontian District, Malaysia. Applied Radiation and Isotopes. Volume 48(3) : 407-412

Ramli, A. T., and Jasman, Y. (1995). Determination of the Natural Radiation Dose Level in the State of Johor by Thermoluminescence Dosimetry Method. Proceedings of Radiation and Occupational Health Symposium, Malaysian Institute of Physics, pp. 79 - 91, July.

Ramli, A. T., Kajian Radiologi Ke Atas Kesan Amang di Negeri Perak (2007). Final report research Vot 68876, Universiti Teknologi Malaysia and Atomic Energy License Boarding (AELB).

Ramli, A.T, Wagiran, H., Lee, S.K., Apriantoro, N.H., Wood, A.K. (2009). Health Risk Implications of High Background Radiation Dose Rate in Kampung Sungai Durian, Kinta District, Perak, Malaysia. Global Journal of Health Sciences. 1, 2.

Ramli, A.T, Wagiran, H., Sahrone, S. (2005). Terrestrial gamma radiation dose study to determine the baseline for environmental radiological health practices in Melaka state. Malaysia. Journal of Radiological Protection. 25, 435–450.

Ramli, A.T. (1993). *Biofizik Sinaran*. Kuala Lumpur : Dewan Bahasa dan Pustaka Kementerian Pendidikan Malaysia.

Ramli, A.T. (2007). Radiology study on effect of amang in Perak State. Final report of research project Vot. 68876, UTM-AELB.

Ramli, A.T., Abdel Wahab, M.A., and Lee, M.H., (2001). Geological influence on terrestrial gamma ray dose rate in the Malaysian state of Johore. Applied Radiation and Isotopes. 54, 327–333

Ramli, A.T., Abdul Rahman, A.T., dan Lee, H.M. (2003). Statistical prediction of terrestrial gamma radiation dose rate based on geological features and soil types in Kota Tinggi district, Malaysia. Applied Radiation and Isotopes. 59, 6, 393-405.

Ramli, A.T., Sanusi, M.S.M., and Basri, A. (2013). Laporan akhir khidmat perundingan: Pemetaan Isodos Sinaran Gama Daratan Semenanjung Malaysia, Universiti Teknologi Malaysia and Atomic Energy License Boarding (AELB).

Ramzaev, V., Yonehara, H., Hille, R., Barkovsky, A., Mishine, A., Sahoo, S.K., Kurotaki, K., Masafumi, U. (2006). Gamma-dose rates from terrestrial and Chernobyl radionuclides inside and outside settlements in the Bryansk Region, Russia in 1996 – 2003. Journal of Environmental Radioactivity. 85, 205 – 227.

Ranade, A. K., Pandey, M., and Datta, D. (2012). Estimation of factors from natural and anthropogenic radioactivity present in the surface soil and comparison with DCF values Radiation Protection Dosimetry. pp. 1–

Rani, A., dan Singh, S. (2005). Natural radioactivity levels in soil samples from some areas of Himachal Pradesh, India using γ-ray spectrometry, Atmospheric Environment. 39 (34), 6306-6314.

Reddy, K.V.K, Reddy, B.S, Reddy, M.S., Reddy, C.H., Reddy, P.Y.M dan Redyy, K.R. (2003). Baseline studies of radon/thoron concentration levels in and around the Lambapur and Peddagattu areas in Nalgonda district, Andhra Pradesh, India. Radiation Measurements. 36, 419 – 423.

Roberts, P. D. (1995). Radiometric Measurements, Soil and Water Sampling In Tin Mining Areas of Malaysia. British Geology Surveys. Technical Reports WC/95/62. Overseas Geology Series.

Ruqing, D., dan Jin, Y. (2012). Application of Ordinary Kriging Method in Data Processing of Magnetic Survey. The 7th International Conference on Computer Science & Education (ICCSE 2012), July 14-17, 2012, Melbourne, Australia.

Saat, A., Hamzah, Z., Abu Bakar, Z., Munir, A. Z., Sumari, S. M., and Hassan, M. (2010) Some Remarks On Diurnal Radon Concentration At Various Locations In Peninsular Malaysia. Journal of Nuclear and Related Technology (7), No. 1.

Saat, A., Kassim, N., Hamzah, Z., Farisz, A. (2005). Determination of Surface Radiation Dose And Concentrations of Uranium and Thorium in Soil At Uitm Perhilitan Research Station Kuala Keniam, Taman Negara, Pahang. Journal of Nuclear and Related Technologies.7 (2).

Saito, K., dan Jacob, P. (1995). Gamma ray fields in the air due to sources in the ground. *Radiation Protection Dosimetry*. 58, 29-45.

Samad, O.E., Baydoun, R., Nsouli., B., Darwish., T. (2013). Determination of natural and artificial radioactivity in soil at North Lebanon province. Journal of Environmental Radioactivity. 125, 36 – 39.

Schwartz, M.O., Rajah, S.S., Askury, A.K., Putthapiban, P., and Djaswadi, S. (1995). The Southeast Asian Tin Belt. Earth Sciences-Review. 38, 95 – 293.

SEATRAD (1991). Annual Report of Southeast Asia Tin Research And Development Centre. 12 – 51.

Steinháusler, F. dan Lettner, H. (1992). Radiometric Survey in Namibia. Radiation Protection Dosimetry. 45(1/4). 553-555.

Strahler, A. N. and Strahler, A. H. (1987). Modern Physical Geography 3^{rd}, John Wiley and Sons, New York.

Szegvarya, T.,Conena, F., Stöhlker, U., Duboisc, G., Bossewc, P., dan de Vries, G. (2007). Mapping terrestrial *γ*-dose rate in Europe based on routine monitoring data. Radiation Measurements. 42, 1561 – 1572.

Sharif, J. and Ghazali, Z. (1987). Fluometric determination of uranium in monazites. Journal of Nuclear Sciences Malaysia, 5(1), 29-34.

Shiraishi, T. (1993). Statistical procedures based on signed ranks in k samples with unequal variances. Ann. Inst. Statist. Math. 45 (2), 265 – 278.

Shweikani, R., Al-Masri, M.S., Hushari, M., Raja, G., Aissa, M., dan Al-Hent, R. (2012). Natural radiation background in the ancient city of Palmyra. Radiation Measurements. 47, 557 – 560.

Tajuddin, A.A., Hu, S.J., dan Sakanoue, M., (1994). Continuous measurement of radiation levels along the west coast Highway of Peninsular Malaysia . Applied Radiation Isotopes. 45, 1117–1119.

The International Commission on Radiation Units and Measurements, ICRU (2011). Quantification and Reporting Of Low-Dose and Other Heterogeneous Exposures. ICRU report no.68. Journal of ICRU. 11 (2).

Theng, T. L. dan Mohamed, C. Abd. R. (2004). Activities of ^{210}Po and ^{210}Pb in the water column at Kuala Selangor, Malaysia. Journal of Environmental Radioactivity. 80, 273–286.

Thompson, G. R. and Turk, J. (1997). Introduction to physical geology. 2nd ed. Brooks Cole, UK.

Thorne, M.C., (2003). Background radiation: natural and man-made. Journal Radiological Protection, (23), 29–42.

Tokuyama, H. dan Igarashi, S. (1998). Seasonal Variation in the Environmental Background Level of Cosmic-Ray-Produced ^{22}Na at Fukui City, Japan. Journal of Environmental Radioactivity. 38 (2), 147 – 161.

Tso, M. Y.W. dan Li, C. C. (1992). Terrestrial Gamma Radiation Dose in Hong Kong. Health Physics. 62 (1).

Tufail, M., Akhtar, N., dan Waqas, M. (2006). Measurement of terrestrial radiation for assessment of gamma dose from cultivated and barren saline soils of Faisalabad in Pakistan Radiation Measurements. 41 (4).

Turner, J. E. (2007). Atoms Radiation and Radiation Detection. 3rd Ed. Wiley-Vch, Weinheim, German.

Tzortzis, M., Tsertos, H., Christofides, S., and Christodoulides., G., (2003). Gamma-ray measurements of naturally occurring radioactive samples from Cyprus characteristic geological rocks. Radiation Measurements. 37, 221-229.

Tzortzis, M., Tsertos, H., Christofides, S., Christodoulides, G., 2003. Gamma radiation measurements and dose rates in commercially-used natural tiling rocks (granites). J. Environ. Radioact. 70, 223–235.

Udompornwirat, S. (1991). Overview of Radioactivity Problems In Relation To the Recovery of By-Product of Tin- Mining. SETRAD Report of investigation No.82. Project No. ENV 3.1.

Udompornwirat, S. (1993). A Review Of Radiological Hazards Associated With Tin-By Product Mineral Processing Industry In The SEATRAD Centre Member Countries. Proceedings of The First International Symposium On: Radiation Protection In The Mining, Milling And Downstream Processing Of Mineral Sands, Bunbury, Western Australia. 18 – 20 March 1993, Part 2, Vol 11 No. 3

UNSCEAR. United Nations Scientific Committee on the Effect Atomic Radiation (2000). *Sources and Effects of Ionizing Radiation*. UNSCEAR Report on The General Asembly. New York : United Nations

USDA, United States Department of Agriculture, (1999). Soil Taxonomy, a Basic System of Soil Classification for Making and Interpreting Soil Surveys, second ed. Agriculture Handbook 436, Washington, USA.

Ulasli, S. S., Bozbas, S.S., Ozen, Z.E., Ozyurek B. E., dan Ulubay, G. (2013). Effect of thyroid function on COPD exacerbation frequency: a preliminary study. Multidisciplinary Respiratory Medicine. 8 (64).

van der Graafa, E.R., Koomansb, R.L., Limburg, J., dan de Vries, K. (2007). In situ radiometric mapping as a proxy of sediment contamination: Assessment of the underlying geochemical and -physical principles. Applied Radiation and Isotopes. 65, 619 – 633.

Vasques, G.M., Grunwald, S., Comerford, N.B. dan Sickman, J.O. (2010). Regional Modelling of Soil Carbon at multiple depths within a subtropical watershed. Geoderma 156, 326 – 336.

Vijarnsorn, P. and Fehrenbacher, J.N., (1975). Characteristics and classification of three granite-derived soils in peninsular Thailand. Soil Science for Agricultural Development in Third Asean Conference, 26 Nov. – 5 Dec., Kuala Lumpur, Malaysia.

Vlado Valkovic (2001). Radioactivity in the environment, Elsevier Science B.V., Amsterdam.

Vukovic´, B., Radolic´, V., Miklavčic´, I., Poje, M. Varga, M. dan Planinic´, J. (2007). Cosmic radiation dose in aircraft - a neutron track etch detector. Journal of Environmental Radioactivity. 98, 264 – 273.

Wagiran, H., Maxwell, O., Ibrahim, N. Lee, S.K. and, Sabri, S. (2013) Comparison of activity concentration of ^{238}U, ^{232}Th and ^{40}K in different Layers of subsurface Structures in Dei-Dei and Kubwa, Abuja, North Central Nigeria. Radiation Physics and Chemistry. 91, 70–80.

Wallova, G. Kandler, N. and Wallner, G. (2012). Monitoring of radionuclides in soil and bone samples from Austria. Journal of Environmental Radioactivity. 107, 4450

Wallova, G. Kandler, N. and Wallner, G. (2012). Monitoring of radionuclides in soil and bone samples from Austria. Journal of Environmental Radioactivity. 107, 4450

Wang, Z., (2002). Natural radiation environment in China. International Congress Series. 1225, 39– 46.

Weiss, C. A. (2008). Introductory Statistics. 8^{th} ed. Pearson Education, Boston, USA.

Welch B.L. (1951). On the comparison of several mean values: An alternative approach. *Biometrika.* 38, 330–336.

Withanage, A.P., and Mahawatte P. (2012). Radioactivity of beach sand in the South Western Coast of Sri Lanka. Radiation Protection Dosimetry, 1–6.

Wo, Y. M. dan Ahmad, Z. (2004). Determination of ^{137}Cs in seawater surrounding peninsular Malaysia - A Case Study. Journal of Nuclear and Related Technologies. 1 (2).

Wo, Y. M. dan Mohamad, N. (2007). Concentration of radiocaesium ^{137}Cs and ^{134}Cs in sediments of the Malaysian marine environment. Applied Radiation and Isotopes, 65, 1389–1395.

Wong, I.F.T., (1970). Reconnaissance Soil Survey of Selangor. Divison of Agriculture. Ministry of Agriculture and Land, Malaysia.

World Health Organization, WHO (1961). Ionizing Radiation and Health. Geneva, Switzerland.

Yasir, S. M., Majid, A. Abd., Ibrahim, F., Tap, S. Q. M., and Abidin, M. R. Z. (2006). Analysis of U238,Th232,Ra226 and K40 in amang, soil dan water samples at Dengkil, Selangor using gamma spectrometry. Malaysia Journal of Analytical Sciences, (10)1, 35-40.

Yoshimura, E.M., Otsubo, S.M., dan Oliveira, R.E.R. (2004). Gamma ray contribution to the ambient dose rate in the city of São Paulo, Brazil. Radiation Measurements. 38 (1) 51 – 57.

Yusof, A.M., Mahat, M.N., Omar, N., and Wood, A.K.H. (2001). Water quality studies in an aquatic environment of disused tin-mining pools and in drinking water. Ecological Engineering (16), 405–414.

Zhao, Y., Yan, D., Zhang, Q., Zhan, J., dan Hua, H. (2012). Spatial distributions of ^{137}Cs in surface soil in Jing-Jin-Ji Region, North China. Journal of Environmental Radioactivity. 113, 1 – 7.

Zim, H.S., Shaffer, P.R. dan Perlman, R. (1962). Rocks and Minerals; A Guide to minerals, gems,and rocks, 1st ed. Golden Press, New York. USA.

Zhang, S. (1998). Fourteen homogeneity of variance tests: when and how to use them. Annual Meeting of the American Educational Research Association April 13-17, San Diego, California.