RADIOACTIVE ANOMALY IN WEST COAST SABAH

ROLAND VOON GAH SENG

TESIS INI DIKEMUKAKAN UNTUK MEMENUHI SEBAHAGIAN DARIPADA SYARAT MEMPEROLEHI IJAZAH SARJANA MUDA SAINS DENGAN KEPUJIAN

PROGRAM FIZIK DENGAN ELEKTRONIK
SEKOLAH SAINS DAN TEKNOLOGI
UNIVERSITI MALAYSIA SABAH

2005

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS@

JUDUL: Radioactive Anomaly In West Coast Sabah.

Ijazah: Sarjanah Muda

SESI PENGAJIAN: 2001 - 2005

Saya ~~Roland Voon Gah~~ ROLAND VOON GAH SENG

(HURUF BESAR)

mengaku membenarkan tesis (LPS/Sarjana/Doktor Falsafah)* ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (/)

[/] SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

[ ] TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

[ ] TIDAK TERHAD

Disahkan oleh

(TANDATANGAN PENULIS) | (TANDATANGAN PUSTAKAWAN)

Alamat Tetap: ____________

Mr. ALVIE LO SIN VOI
Nama Penyelia

Tarikh: 4 April 2005

Tarikh: ____________

CATATAN: * Potong yang tidak berkenaan.

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

@ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (LPSM).

DECLARATION

I hereby declare that this piece of work is completely by myself except some reference information which had been stated their resources.

31 March 2005

ROLAND VOON GAH SENG

HS2002-4067

APPROVAL BY

1. SUPERVISOR Signature

(MR. ALVIE LO SIN VOI) 1/4/05

2. EXAMINOR 1 Signature

(DR. JEDOL DAYOU) 1. 4. 2005

3. EXAMINOR 2 Signature

(PN. FAUZIAH SULAIMAN) 01. 04. 05

4. DEAN Signature

(PROF. ASSOCIATE DR. AMRAN AHMED)

ACKNOWLEDGEMENT

I would like to use this opportunity to thank to my supervisor, Mr. Alvie Lo Sin Vui who guide me in working out this reearch. Besides of that, i also would like to thank to my both Co-supervisor, Prof. Dr. Sanudin Hj. Tahir dan Dr. Jedol Dayou. They have given me a direction to finish this research successfully

I also thank to any agency that help me in working out this research, such as *Jabatan Ukur Tanah*, lab assistances and office SST, *Jabatan Ukur Tanah* has provide me maps for certain places in West Coast Sabah. Lab assistances, Mr. Jalaludin Majalip and Mr. A. Kahim Ahmad have given me instruction to operate the instrument that used in this research. Office SST have help me ot finish this research fluently.

At last, i would like to thank to those who are direct or indirect for helping me to work out this research. Especially for Ko Ying Hao, my best friend, without whom there would be no data in this thesis.

ROLAND VOON GAH SENG

HS2002 - 4067

ABSTRAK

Radioaktif merupakan isu sedunia kerana radioaktif kerap wujud di sekitar kita dalam dunia ini, termasuk Sabah. Kajian ini dijalankan atas tujuan mengesan paras radioaktif di beberapa tempat tertentu di Pantai Barat Sabah. Tempat-tempat tersebut ialah Kota Kinabalu, Tuaran, Kota Belud, Papar, Ranau, Kelombong, Kinabalu Park dan Kundasang. Data-data tersebut amat berguna untuk membandingkan paras keselematan sedunia. Ini membolehkan kita memastikan tempat-tempat tersebut adalah di bawah paras keselamatan. Melalui kajian ini, terdapat dua faktor yang mempengaruhi paras radioaktif, iaitu sinar dari kosmos dan sinar dari tanah dan batu-batan. Kedua-dua faktor tersebut berupaya mempengaruhi perbezaan paras radioaktif pada waktu pagi dan petang. Selain itu, paras radioaktif bagi ketinggian yang berbeza juga dipengaruhi oleh kedua-dua faktor tersebut.

ABSTRACT

Radioactive is a global issue because it always exists in our environment in this world, including Sabah. This research is carrying out to monitoring the radioactive level for certain places in West Coast Sabah. These places are Kota Kinabalu, Tuaran, Kota Belud, Papar, Ranau, Kelombong, Kinabalu Park and Kundasang. This set of data on the radioactive background is useful to compare to the global safety level. It can let us ensure that the radioactive levels in these places are below the safety level. From this research, there are two factors influence the radioactive level, which are radiation from cosmic rays and radiation from rocks and soils. These two factors can affect the different radioactive level in the morning and in the afternoon. Moreover, radioactive level for different altitude is also affected by these two factors.

TABLE OF CONTENT

	Page
DECLARATION	ii
APPROVAL BY	iii
ACKNOWLEDGEMENT	iv
ABSTRAK	v
ABSTRACT	vi
TABLE OF CONTENT	vii
LIST OF TABLE	xi
LIST OF FIGURE	xii
LIST OF SYMBOL AND NOTATION	xv
LIST OF APPENDIX	xvii
CHAPTER 1 INTRODUCTION	1
1.1 INTRODUCTION	1
1.2 RESEARCH GOAL	2
1.3 RESEARCH OBJECTIVE	3
1.4 SCOPE OF RESEARCH	3
CHAPTER 2 LITERATURE REVIEW	4
2.1 THE DISCOVERY OF RADIOACTIVITY	4
2.2 ATOM STRUCTURE	5
2.3 ISOTOPES	6

2.4 UNITS FOR RADIATION DOSE AND RADIOACTIVITY 7

2.5 PROPERTIES OF NUCLEAR RADIATION 8

2.5.1 Alpha Particle Radiation (α) 9

2.5.2 Beta Particle Radiation (β) 11

2.5.3 Gamma Particle Radiation (γ) 12

a. The Photoelectric Effect 13

b. Compton Scattering 13

c. Pair Production 14

2.6 TYPE OF RADIATION 15

2.6.1 Non-ionizing Radiation 15

2.6.2 Ionizing Radiation 15

a. Directly Ionizing Radiation 15

b. Indirectly Ionizing Radiation 16

2.7 RATE OF RADIOACTIVE DECAY 16

2.8 HALF LIFE 18

2.9 RADIOANUCLIDE DECAY SERIES 18

2.10 SOURCE OF RADIATION 19

2.10.1 Natural Source Radiation 20

a. Cosmic Radiation 21

b. Terrestrial Radiation 23

2.10.2 Man-made Source of Radiation 24

CHAPTER 3 METHODOLOGY 25

3.1 RESEARCH LOCATION 25

3.2 RADIOACTIVE LEVEL MEASUREMENT 29

3.2.1 Geiger-muller Detector 29

3.2.2 Global Positioning System (GPS) 32

3.3 DATA ANALYSIS 34

3.3.1 Radioactive Anomaly In Each Place 34

3.3.2 Compare The Radioactive Level In The Morning and In The Afternoon 34

3.3.3 Compare The Radioactive Level Among The Places 35

3.3.4 Compare To the worldwide Average Annual Effective Dose And The Range Of Radioactive Safety Level 35

CHAPTER 4 RESULT 36

4.1 AVERAGE RADIOACTIVE DOSE RATE FOR KOTA KINABALU 36

4.2 AVERAGE RADIOACTIVE DOSE RATE FOR KOTA BELUD 39

4.3 AVERAGE RADIOACTIVE DOSE RATE FOR RANAU 41

4.4 AVERAGE RADIOACTIVE DOSE RATE FOR KELOMBONG 43

4.5 AVERAGE RADIOACTIVE DOSE RATE FOR KINABALU PARK 46

4.6 AVERAGE RADIOACTIVE DOSE RATE FOR KUNDASANG 48

CHAPTER 5 DISCUSSION 50

5.1 RADIOACTIVE DOSE RATE FOR KOTA KINABALU 51

5.1.1 Percentage And Range of Radioactive Dose Rate For Kota Kinabalu 54

5.2 RADIOACTIVE DOSE RATE FOR KOTA BELUD 55

5.2.1 Percentage And Range of Radioactive Dose Rate fFor Kota Bebud 56

5.3 RADIOACTIVE DOSE RATE FOR RANAU 58

5.3.1 Percentage And Range of Radioactive Dose Rate For Ranau 61

5.4 RADIOACTIVE DOSE RATE FOR KELOMBONG 62

5.4.1 Percentage And Range of Radioactive Dose Rate For Kelombong 63

5.5 RADIOACTIVE DOSE RATE FOR KINABALU PARK 65

5.5.1 Percentage And Range of Radioactive Dose Rate For Kinabalu Park 66

5.6 RADIOACTIVE DOSE RATE FOR KUNDASANG 68

5.6.1 Percentage And Range of Radioactive Dose Rate For Kundasang 69

5.7 DOSE RATE FOR PLACES IN THE MORNING AND THE AFTERNOON 71

5.8 AVERAGE RADIOACTIVE DOSE RATE FOR PLACES IN WEST COAST SABAH 74

5.9 COMPARE TO THE WORLDWIDE AVERAGE EFFECTIVE DOSE AND THE RANGE OF RADIOACTIVE SAFETY LEVEL 79

CHAPTER 6 CONCLUSION 80

REFERENCES 83

APPENDIX 86

LIST OF TABLE

Table No.		Page
2.1	Major properties of the three sub-atomic particles	6
2.2	Values of Quality factor, Q for different radiations	7
2.3	Units for radiation dose and radioactivity	8
2.4	First member and the last member of the four series	19
2.5	Average radiation doses at year 2000 from natural and man-made sources of radiation	20
2.6	Average radiation dose from natural sources	21
3.1	The main functions of the GPS	33
4.1	Average dose rate for Kota Kinabalu	34
4.2	Average dose rate for Kota Belud	37
4.3	Average dose rate for Ranau	39
4.4	Average dose rate for Kelombong	41
4.5	Average dose rate for Kinabalu Park	44
4.6	Average dose rate for Kundasang	46
5.1	Range of altitude of the certain places in the West Coast Sabah	77
5.2	Average annial effective dose in a year for certain places in West Coast Sabah	79

LIST OF FIGURE

Figure No.		Page
2.1	Simple β-particle energy E*max* and $\overline{E}$	12
2.2	Illustration of the photoelectric absorption process where a γ-ray photon is absorbed and a characteristic X-ray is emitted	13
2.3	Illustration of the Compton process. The incoming photon interacts with an electron and is scattered at an angle θ, whereas the electron recoils forward at angle Φ; λ_1 and λ_2 are the wavelengths for the incident and the scattered photons	14
2.4	A schematic representation of the exponential nature of radioactive decay	17
2.5	Relation between half-life and radioactivity	18
2.6	Component of the dose equivalent from cosmic rays in the atmosphere	23
3.1	Territories in west coast Sabah	28
3.2	Geiger Muller Detector	30
3.3	Schematic diagram of a end-window Geiger-muller tube	30
3.4	Garmin GPS 12	32
3.5	Processes to operate the GPS 12	33
4.1	Average dose rate for Kota Kinabalu (Unit in ± 7.0% $\mu Svhr^{-1}$)	38
4.2	Average dose rate for Kota Belud (Unit in ± 7.0% $\mu Svhr^{-1}$)	40
4.3	Average dose rate for Ranau (Unit in ± 7.0% $\mu Svhr^{-1}$)	42

4.4	Average dose rate for Kelombong (Unit in ± 7.0% $\mu Svhr^{-1}$)	45
4.5	Average dose rate for Kinabalu Park (Unit in ± 7.0% $\mu Svhr^{-1}$)	47
4.6	Average dose rate for Kundasang (Unit in ± 7.0% $\mu Svhr^{-1}$)	49
5.1	Average dose rate for Kota Kinabalu (Unit in ± 7.0% $\mu Svhr^{-1}$)	53
5.2	Percentage and range of appearance radioactive dose rate for Kota Kinabalu	55
5.3	Average dose rate for Kota Belud (Unit in ± 7.0% $\mu Svhr^{-1}$)	57
5.4	Percentage and range of appearance radioactive dose rate for Kota Belud	58
5.5	Average dose rate for Ranau (Unit in ± 7.0% $\mu Svhr^{-1}$)	60
5.6	Percentage and range of appearance radioactive dose rate for Ranau	61
5.7	Average dose rate for Kelombong (Unit in ± 7.0% $\mu Svhr^{-1}$)	64
5.8	Percentage and range of appearance radioactive dose rate for Kelombong	65
5.9	Average dose rate for Kinabalu Park (Unit in ± 7.0% $\mu Svhr^{-1}$)	67
5.10	Percentage and range of appearance radioactive dose rate for Kinabalu Park	68
5.11	Average dose rate for Kundasang (Unit in ± 7.0% $\mu Svhr^{-1}$)	70
5.12	Percentage and range of appearance radioactive dose rate for Kundasang	71
5.13	Radioactive level for certain places in West Coast Sabah in the morning and in the afternoon (Unit in ± 7.0% $\mu Svhr^{-1}$)	73

LIST OF SYMBOL AND NOTATION

α	Alpha radiation
β	Beta radiation
γ	Gamma radiation
λ	Decay constant
Φ	Angle of recoil electron
θ	Angle of scatter electron
^{3}H	Tritium
A	Atomic mass number
B	Dose rate from Geiger-Muller
Bi	Bismuth
Bq	Becquerel
C	Carbon
Ci	Curie
CF	Consideration factor
D	Real dose rate
eV	Electron volt
E	Energy
E_e	Recoil electron
$\overline{E}$	Average of energy
Gy	Gray
He	Helium
J	Joule

J_{CF}	Range correction factor
mSv	miliSievert
Pu	Neptunium
Pb	Plumbum
Q	Quality factor
Sv	Sievert
Sq. Km	Square meter
t	Time
$T_{1/2}$	Half-life of radioactivity
Th	Thorium
u	Atomic mass unit
U	Uranium
υ	Antineutrino
μSv	microSievert
X	Atom symbol
Z	Atomic number

LSIT OF APPENDIX

Appendix No.		Page
A	Dose rate for Kota Kinabalu in the morning and the afternoon	86
B	Dose rate for Kota Belud in the morning and the afternoon	90
C	Dose rate for Ranau in the morning and the afternoon	94
D	Dose rate for Kelombong in the morning and the afternoon	98
E	Dose rate for Kinabalu Park in the morning and the afternoon	103
F	Dose rate for Kundasang in the morning and the afternoon	107
G	Dose rate for Papar in the morning and the afternoon	110
H	Dose rate for Tuaran in the morning and the afternoon	114
I	Average dose rate for Papar	118
J	Average dose rate for Tuaran	119
K	*Sijil Tentukuran* Geiger-muller with serial: 44081	120

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Radioactive is a universal phenomenon that has established from the beginning of time but our human are not realize in it until the year of 1896 when Henri Becquerel evidenced ionizing radiation from Uranium salts. Pierre and Marie Curie had discovered the phenomenon of radioactivity in 1899 and identified radioactive elements, polonium and radium in 1903. Their researches had successfully opened a new era of artificial radioactivity. As a result, many studies dealing with measurement of environment radioactivity are started in the early 1900. In 1900, Geitel and Wilson investigated independently the radioactivity in air (Vandecasteele, 2004). Hess discovered the cosmic ray by measurements the altitude with a balloons (Cooper, Randle & Sokhi, 2002). Following by that, many determination investigation in the radioactivity in soils and rocks, seawater and waters from hot and mineral springs were collected (Vandecasteela, 2004). Thus environment monitoring in radioactive anomaly has work out thought the world.

1.3 RESEARCH OBJECTIVES

1. Measure the radioactive level in certain places in West Coast Sabah.
2. Analysis the radioactive anomaly within a place in West Coast Sabah.
3. Compare the radioactive level in the morning and afternoon.
4. Compare the radioactive anomaly among the places in West Coast Sabah.
5. Compare the radioactive level for certain places in West Coast Sabah with the safety radioactive level.

1.4 SCOPE OF RESEARCH

The research is only focus on the measurement of radioactive anomaly in the eight places in West Coast Sabah. These eight places are Kota Kinabalu, Kota Belud, Papar, Tuaran, Ranau, Kelombong, Kinabalu Park and Kundasang.

CHAPTER 2

LITERATURE REVIEW

2.1 THE DISCOVERY OF RADIOACTIVE

In 1895, while Wilherm Rountgen studying cathode rays from electrical discharges through tubes which containing a rarefied gas, he noticed that across the room a screen coated with barium platinocyanide gently glowed. The rays responsible for this phenomenon were quickly shown to pass through materials opaque to ordinary light. So, Wilhem Routgen has discovered the X-ray (Cooper, Randle & Sokhi, 2002).

In March 1896, Henri Becquerel discovered an invisible, penetrating radiation emitted spontaneously by uranium. He showed that these uranic rays made an imprint on photographic plates and made air conduct electricity (Lowenthal & Airey, 2001). Pierre and Marie Curie discovered two other elements that emitted similar radiations. They baptized the first Polonium in July 1898 and the second Radium in December of the same year. Pierre and Marie Curie characterized the phenomenon that produces these radiations and called it radioactivity. They discovered that a given mass of radium, which is the most active of all the radioactive elements, emits 1.4 million times more radiation than the same mass of uranium (Cooper, Randle & Sokhi, 2002).

In 1899, Rutherford characterized helium nuclei as an alpha particle. In 1900, Villard characterized another type of radiation: the uncharged, penetrating gamma rays. The law of radioactive decay was established by 1903 by Rutherford and Soddy, and by 1912 the concept of isotopes had been developed to explain the phenomenon of isotopes (Cooper, Randle & Sokhi, 2002).

2.2 ATOM STRUCTURE

Atom structure contains 3 elements, which are photon, neutrons and electrons. Protons are much larger and heavier than electrons and have the opposite charge. protons have a positive charge. Neutrons are large and heavy like protons; however neutrons have no electrical charge. Electrons are tiny, very light particles that have a negative electrical charge. The properties of the sub-atomic particles are shown in Table 2.1.

Table 2.1 Major properties of the three sub-atomic particles (Cooper, Randle & Sokhi, 2002).

Particle	Symbol	Charge (C)	Mass (Kg)
Proton	p	1.602×10^{-19}	1.673×10^{-27}
Neutron	n	0	1.675×10^{-27}
Electron	e	-1.602×10^{-19}	9.110×10^{-31}

The electron volt (eV) is a unit to express atomic and nuclear energies. It defined as the energy gained by an electron when passing through an electrical potential of a volt. The relationship between SI unit of energy, joule (J) and the electron volt is given as below:

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

2.3 ISOTPES

An element may have a number of different nuclides which are called isotopes (Cooper, Randle & Sokhi, 2002). When the nuclides of an atom of a specific element have the same number of protons but a different number of neutrons, it is called an isotope of that element (Bomberger and Dannenfelser, 1984).

An isotope is express in term as below:

$$^{A}_{Z}X$$

Where X is the chemical symbol of the atom. Z is the atomic number. Atomic number is the numbers of protons in a nucleus of atom and determines the chemical properties of the atom and hence its position in the Periodic Table. A is the atomic mass number. The atomic mass is the mass of an atom relative to one twelfth of the mass of an atom of carbon-12 (Cooper, Randle & Sokhi, 2002).

2.4 UNIT FOR RADIATION AND RADIOACTIVE

The basic quantity used to express the exposure of material such as the human body is the absorbed dose, for which the unit is the Gray (Gy). One gray is equal to an absorbed dose of 1 Joule/kilogram. Rad is the special unit of absorbed dose. One rad is equal to an absorbed dose of 0.01 gray. However the biological effect per unit of absorbed dose varies with the type of radiation and the part of the body exposed. To take account of those variations, a weighted quantity called the effective dose is used, for which the unit is the Sievert (Sv). The dose equivalent in sievert is equal to the absorbed dose in grays multiplied by the quality factor,Q (Table 2.2). Rem is the special unit quantity to express the dose equivalent. Rem originally defined as 'roentgen equivalent man'. The dose equivalent in rems is equal to 0.01 sievert (UNSCEAR, 2000).

Table 2.2 Values of Quality factor, Q for different radiations (Tsipenyuk, 1997)

Type of radiation	Quality factor, Q
x-ray and γ radiation	1
Electrons, positrons, β-radiation	1
Protons with energy less than 10 MeV	10
Thermal neutrons	2.3
Neutrons with energy less than 20 keV but > 0.025 eV	3
Neutrons with energy 0.1 – 10 MeV	10
α-radiation with energy less than 10 MeV	20
Heavy recoil nuclei	20

A radioactive source is described by its activity, which is the number of nuclear disintegrations per unit of time. The unit of activity is the Becquerel (Bq). One Becquerel is defined as one disintegration per second (UNSCEAR, 2000). Curie (Ci) is majority used in medicine and for many industrial applications (Lowenthal & Airey, 2001). The units for radiation dose and radioactivity rearrange in Table 2.3.

Table 2.3 Units for radiation dose and radioactivity (Ismail & Mohd. Yusoft, 2004)

Unit	Type of unit	Expression	Relationship
Gray (Gy)	Unit SI	Absorbed dose	1 Gy = 1 joule/kilogram
Rad	Special unit	Absorbed dose	1 Rad = 0.01 Gy
Sievert (Sv)	Unit SI	Effective dose	1 Sv = Gy/Quality factor
Rem	Special unit	Effective dose	1Rem = 0.01 Sv
Becquerel (Bq)	Unit SI	Radioactivity	1 Bq = 1 disintegration/second
Curie (Ci)	Special unit	Radioactivity	1 Curie = 3.7×10^{10} Bq

2.5 PROPERTIES OF NUCLEAR RADIATION

Radioactivity is the phenomenon where certain substances are known to spontaneously give out energetic radiations. Nuclei, which are subject to such decay, are termed radioactive (Tsipenyuk, 1997). When a radionuclide decays to form a more stable atom, the process result in the emission of one or more of the following types of nuclear radiation:

REFERENCES

Aswathanarayana, A., 1995. *Geoenvironment An Introduction.* A.A. Balkema Publishers, Brookfield.

Bomberger, A.S. and Dannenfelser, B.A., 1984. *Radiation And Health: Principle And Practice In The Therapy And Disaster Preparedness.* An Aspen Publication, Maryland.

Cigna, A.A., Roosi, L.C., Sgorbini, S. and Zurlini, G., 1987. Environment study of fallout plutonium in soils from the Piemonte region (North-West Italy). *Journal of Environment Radioactive* **5**, 71-81.

Cooper, J.R., Randle, K. and Sokhi, R.S, 2002. *Radioactive Release In The Environment: Impact and Assessment.* John Wiley & Sons Ltd, England.

Garmin Corporation, 1999. *GPS 12: Owner's Manual And Reference.* Garmin Internatinal, Inc., USA.

Husin Wagiran, 1992. *Fizik Nukleus.* Dewan Bahasa dan Pustaka, Kuala Lumpur.

International Atomic Energy Agency (IAEA), 2004. *Radiation, People and the Environment.* IAEA, Vienna.

International Commission On Radiological Protection (ICRP), 1993. Protection Against Radon-222 At Home And At Work. *Annual Of The ICRP23(2)*, ICRP, New York

Ismail Bahari and Mohd. Yusof Mohd. Ali (eds), 2004. *National Committee For The Certification Of Radiation Protection Officers Atomic Energy Licensing Board: Guide Notes For Radiation Officers.* McGraw-Hill, Kuala Lumpur.

Lowenthal, G.C. and Airey, P.L., 2001. *Practical Application Of Radioactivity And Nuclear Radiations.* University Press, Cambridge.

Singh, S., Sharma, D.K. and Kumar, A., 20004. Short communication: environment radon studies using solid state nuclear track detectors. *Journal Of Environment Radioactivity* **76**, 369-376.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000. *Reports Of The United Nations Scientific Committee On The Effects Of Atomic Radiation To The General Assembly Volume 1: Source.* UNSCEAR, New York.

Tsipenyuk, Y.M., 1997. *Fundamental And Applied Nuclear Physics Series: Nuclear Method In Science And Technology.* Institute Of Physics Publishing, London.

Vandecasteela, C.M., 2004. Environment monitoring and radioecology: a necessary synergy. *Journal of Environment Radioactive* **72**, 17-23.

Wang, C.H., Willis, D.L. and Loveland, W.D., 1975. *Radiotracer Methodology In The Biological, Environment, And Physical Sciences.* Prentice-Hall, New Jersey.