

**NATURAL BACKGROUND RADIATION IN THE
KINTA DISTRICT, PERAK, MALAYSIA**

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**A thesis submitted in fulfillment of the
requirements for the award of the degree of
Master of Science (Physics)**

**Faculty of Science
Universiti Teknologi Malaysia**

NOVEMBER 2007

To my dear mother, my late father, brothers, sister, my wife and sons.

ACKNOWLEDGEMENT

I would like to thank the Atomic Energy Licensing Board (Vot. no. 68876) for funding this research. I also like to express deep gratitude to UTM, Physics Department and Institute Ibnu Sina for providing various facilities.

My sincere thank to my supervisors Prof. Dr. Husin Wagiran and Prof. Dr. Ahmad Termizi Ramli for their encouragement, and support throughout the course of this research work.

Special thanks go to En. Mohamad Yasin Sudin, En. Ahmad Abu Bakar, En. Mohamad, staff from AELB for the assistant during field survey and visit to the amang factories in the Kinta District. I thank Associate Professor Dr. Shaharom Noordin from Faculty of Education, UTM for allowing me to attend his lectures on Statistics. I also wish to express my appreciation to En. Abdul Kahar Embi from Department of Geosciences in Ipoh to use his SURFER software in this project. I thank Dr. Abdul Khalid Wood, En. Md. Suhaimi Elias and other staff from MINT for the assistance in analyzing the NAA samples. I would also like to thank Prof. Dr. Noorddin Ibrahim for sending my samples to MINT and get analyzed, helpful discussions and suggestions. I also would like to take this opportunity to thank the entire academic and laboratory staff from Physics Department and Pn. Wanny from Institute Ibnu Sina for the cooperation they have given me. I thank my research partner En. Nursama Heru Apriantoro for the cooperation during field survey.

I also take great pride in thanking my wife, Teo Poh Choo, and my sons Sing Han and Sing Sian for their help and encouragement. I wish to acknowledge my appreciation to all those who had assisted in this project.

ABSTRACT

Measurement of natural background radiation levels in the Kinta District was carried out between 2003 and 2005. Gamma 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 ²³⁸U, ²³²Th and ⁴⁰K were analyzed by using a HPGe detector. The ranges are 12 – 426 Bq kg⁻¹ for ²³⁸U, 19 – 1377 Bq kg⁻¹ for ²³²Th and from less than 19 – 2204 Bq kg⁻¹ for ⁴⁰K. 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_{eq}) 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. The isodose map is the most recent and can be used as a reference.

ABSTRAK

Pengukuran bagi aras sinaran latar belakang semulajadi di daerah Kinta telah dijalankan antara tahun 2003 hingga 2005. Kadar dos telah diukur di 1007 lokasi dengan menggunakan meter survei sinaran gama, *Model 19 Micro R Meter* buatan syarikat Ludlum. Julat bagi kadar dos yang diukur ialah 39 hingga 1039 nGy h⁻¹ dan nilai min kadar dos ialah 222 ± 191 nGy h⁻¹ (1.36 mSv y⁻¹). Sekitar Kampung Sungai Durian terdapat dua kawasan kecil mempunyai kadar dos yang tinggi iaitu 1039 nGy h⁻¹. Sehingga kini, kadar dos ini merupakan yang tertinggi di negeri Perak. Sebanyak 128 sampel tanah telah diambil dan dianalisis untuk menentukan keaktifan radionuklid semulajadi, keaktifan alfa dan beta. Kepekatan ²³⁸U, ²³²Th dan ⁴⁰K telah dianalisis dengan menggunakan alat pengesan HPGe. Julat bagi ²³⁸U ialah 12 – 426 Bq kg⁻¹, 19 – 1377 Bq kg⁻¹ bagi ²³²Th dan kurang daripada 19 – 2204 Bq kg⁻¹ bagi ⁴⁰K. Berdasarkan kepada aras keaktifan yang dikira, kadar dos terserap sinaran gama di udara pada jarak 1 m dari atas tanah telah ditentukan menggunakan prosedur UNSCEAR 2000. Jumlah kadar dos yang dikira dan kadar dos yang diukur menunjukkan pekali korelasi yang baik iaitu 0.94. Aktiviti setara radium (Ra_{eq}) yang dikira berada dalam julat 0.14 hingga 6.01 mSv setahun. Keaktifan alfa bagi sampel tanah didapati berada dalam julat 15 hingga 9634 Bq kg⁻¹ dan min dosnya ialah 1558 ± 121 Bq kg⁻¹. Keaktifan beta berada dalam julat 142 hingga 6173 Bq kg⁻¹ dan min dosnya ialah 1112 ± 32 Bq kg⁻¹. Min kadar dos pemberat populasi bagi daerah Kinta ialah 1.2 mSv setahun. Peta isodos sinar gama bagi daerah Kinta telah diplotkan. Peta isodos ini adalah yang terkini dan boleh digunakan sebagai rujukan.

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LIST OF ABBREVIATIONS/SYMBOLS

C	-	Coulombs
J	-	Joules
M	-	Molecular weight of sample
N	-	Number of atom
R	-	Roentgen
X	-	X-ray
g	-	Gram
m	-	Meter
p	-	Pico
u	-	Atomic mass unit
s	-	Second
ALARA	-	As low as reasonable achievable
DF	-	Distribution factor
FAO	-	Food and Agriculture Organization
GPS	-	Geographical positioning system
HPGe	-	High purity Germanium
IAEA	-	International Atomic Energy Agency
ICRP	-	International Commission on Radiological Protection
MCA	-	Multi-channel Analyzer
MINT	-	Malaysian Institute of Nuclear Technology Research
NAVISTAR	-	Navigation Satellite Receiver
NBRL	-	Natural background radiation level

PSI	-	Pound per square inch
QF	-	Quality factor
SPSS	-	Statistical Package for Social Sciences
TLD	-	Thermoluminescent dosimeter
UNSCEAR	-	United Nations Scientific Committee on the effects of Atomic Radiation
USA	-	United States of America
cpm	-	Counts per minute
eV	-	Electron volt
keV	-	Kiloelectron volt
kW	-	kilowatt
km	-	Kilometer
rad	-	Radiation absorbed dose
rem	-	Roentgen equivalent man
Ar	-	Argon
A_v	-	Avogadro's number
Bq	-	Becquerel
Ci	-	Curie
CH ₄	-	Methane
E_{BE}	-	Binding energy
E_e	-	Kinetic energy
E_γ	-	Gamma energy
F_α	-	Calculated activity of the standard sample for alpha particles
F_β	-	Calculated activity of the standard sample for beta particles
Gy	-	Gray
KCl	-	Potassium chloride
keV	-	Kiloelectron volt
kW	-	kilowatt
MeV	-	Megaelectron volt
Sv	-	Sievert

α	-	Alpha particle
β	-	Beta particle
γ	-	Gamma radiation
ε	-	Efficiency
λ	-	Disintegration constant
^{40}K	-	Potassium-40
^{239}Np	-	Neptunium-239
^{233}Pa	-	Protactinium-233
^{226}Ra	-	Radium-226
^{228}Ra	-	Radium-228
^{234}U	-	Uranium-234
^{235}U	-	Uranium-235
^{238}U	-	Uranium-238
^{232}Th	-	Thorium-232
U_3O_8	-	Uranium trioxide

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CHAPTER I

INTRODUCTION

1.1 Introduction

When the earth was formed four billion years ago, it contained many radioactive isotopes (Wang et. al. 1975 and Foster, 1985). Since then, all the shorter-lived isotopes have decayed. Only those isotopes with 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.

Everyone is inevitably exposed to background radiation, which varies from place to place and from time to time in both amount and type. Some of this exposure is caused by external radiations that come from both cosmic rays and radioactive materials in the ground. Cosmic radiation of concern is principally a result of protons and the products of their interaction with various nuclei. Exposure resulting from such radiation depends on the latitude and the altitude. The dose rate of radiation from cosmic rays ordinarily measures 0.28 mGy y^{-1} when tested at 70° , sea level; appropriate corrections may be made for other latitudes and altitudes (Henry, 1969).

Environmental gamma activities result 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 in the order of 1.5 mGy y^{-1} and over limestone in 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 environment quality, monitor continuously the air gamma radiation level for 24 hours and detect the abnormality, 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 to 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.

In addition to the natural background radiation, there are several other sources of human exposure which are peculiar to the last few decades. These sources are: diagnostic radiology, therapeutic radiology, use of isotopes in medicine, radioactive waste, fall-out from nuclear tests, and occupational exposures from nuclear reactors and accelerators.

1.2 Research Objectives

Research objectives are:

- i. to establish a baseline data of natural background radiation levels in the Kinta District.
- ii. to identify the hot spot areas.
- 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 plot the isodose contour map of gamma dose rate.

1.3 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 human activities or any artificial influences due to fallout (Goddard, 2000; Ibrahiem et. al., 1993; Quindös 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 present 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.

1.4 Statement of Hypotheses.

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

1.5 Scope of Study

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

Kinta District has 12 major towns namely 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 km² 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 °C (Shaari, 2003).

1.6 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 ²³⁸U, ²³²Th and ⁴⁰K in the soil samples were measured by using HPGe gamma-ray spectrometry. Among by-products were analyzed for ²³⁸U and ²³²Th.

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

Statistical data analysis was performed using SPSS and Excel programs. Data was presented as mean, standard deviation, standard error and 95% confidence intervals. Frequency histogram of the gamma dose rate was plotted. Box plot was used to show the variability and the distribution of the gamma dose rate for various parameters such as geological types, soil types and *mukims*. Excel program

was used in the correlation coefficient analysis of the data.

The isodose contour map for the dose rates was plotted using the Surfer software version 6.

1.7 Thesis Outlines

This thesis consists of 5 chapters. The first chapter consists of introduction, research objectives, importance of this research, and scope of study and research methodology. Chapter two is the literature review. It covers the work of relevant studies carried out. Chapter three explains the methods and equipment used in the experimental work. Chapter four shows the data obtained from the field measurements, statistical presentation of data using box plots, histograms, high radiation areas, analysis of soil samples using direct method and neutron activation analysis (NAA) method, correlation coefficient between dose rate and radionuclides and gamma isodose contour plot. Finally chapter five presents the conclusions of the project and the suggestions.

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