RADON AND THORON STUDY IN AREAS OF ELEVATED BACKGROUND RADIATION IN PALONG, SEGAMAT, JOHOR

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To my beloved *mak* and *ayah*

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ABSTRACT

The study aims to present data on indoor and outdoor radon and thoron concentrations in areas of elevated background radiation in Palong, Segamat, Johor. The chosen area has the highest gamma background radiation in Johor. The measurements of equilibrium equivalent concentration of radon (EEC_{Rn}) and thoron (EEC_{Tn}) were carried out for periods of 12 hours from 7.00 am until 7.00 pm by using electronic radon dosimeter; DOSEman PRO. Terrestrial gamma radiations were measured and soil samples were collected in the area where radon and thoron monitoring took place. The results of radon and thoron concentrations were divided into three time intervals; morning (7.00 am – 11.00 am), afternoon (11.00 am – 3.00 pm) and evening (3.00 pm – 7.00 pm). The values of indoor and outdoor EEC_{Rn} varied from 2.6 to 69.3 Bq m^{-3} and 0.4 to 48.2 Bq m^{-3} respectively. While for thoron, the values varied from 0 to 20.6 Bq m^{-3} and 0 to 27.5 Bq m^{-3} respectively. Indoor and outdoor gamma dose rates varied from 169 to 397 nGy h^{-1} and 81 to 1007 nGy h^{-1} respectively. The concentrations of uranium, thorium and potassium in soils were 20.7 to 967.3 Bq kg^{-1}, 24.9 to 1003.8 Bq kg^{-1} and 4.5 to 4073.2 Bq kg^{-1} respectively. The populations in this area received annual effective dose between 0.54 mSv yr^{-1} to 7.52 mSv yr^{-1} due to terrestrial gamma and radon/ thoron exposure. The radiation dose is still within the normal range of 1-10 mSv yr^{-1} as stated by International Commission on Radiological Protection (ICRP).

ABSTRAK

Kajian ini bertujuan untuk membentangkan data kepekatan radon dan toron di dalam dan luar rumah di kawasan sinaran latar belakang tinggi di Palong, Segamat, Johor. Kawasan yang dipilih mempunyai sinaran gama latar belakang tertinggi di Johor. Pengukuran kepekatan kesetaraan keseimbangan bagi radon (EEC_{Rn}) dan toron (EEC_{Tn}) telah dilakukan dalam tempoh 12 jam dari pukul 7.00 pagi hingga 7.00 malam dengan menggunakan dosimeter radon elektronik; DOSEman PRO. Sinaran gama daratan diukur dan sampel tanah diambil di kawasan di mana pemantauan radon dan toron dibuat. Keputusan bacaan kepekatan radon dan toron dikelaskan kepada tiga sela masa iaitu pagi (7.00 pagi – 11.00 pagi), tengahari (11.00 pagi – 3.00 petang) dan petang (3.00 petang – 7.00 petang). Nilai EEC_{Rn} di dalam dan di luar rumah masing-masing berubah dari 2.6 hingga 69.3 Bq m^{-3} dan 0.4 hingga 48.2 Bq m^{-3}. Manakala bagi toron, nilainya masing-masing berubah dari 0 hingga 20.6 Bq m^{-3} dan 0 to 27.5 Bq m^{-3}. Nilai dos gama di dalam dan di luar rumah masing-masing berubah dari 169 hingga 397 nGy j^{-1} and 81 hingga 1007 nGy j^{-1}. Kepekatan uranium, torium dan kalium dalam tanah masing-masing bernilai 20.7 hingga 967.3 Bq kg^{-1}, 24.9 hingga 1003.8 Bq kg^{-1} dan 4.5 hingga 4073.2 Bq kg^{-1}. Penduduk di kawasan ini menerima dos berkesan tahunan antara 0.54 hingga 7.52 mSv $tahun^{-1}$ daripada pendedahan kepada sinar gama daratan dan juga radon/ toron. Dos sinaran ini masih di dalam julat normal 1-10 mSv $tahun^{-1}$ sebagaimana yang dinyatakan oleh Suruhanjaya Antarabangsa bagi Perlindungan Radiologi (ICRP).

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LIST OF ABBREVIATIONS

AEDE	Annual effective dose equivalent
DCF	Dose conversion factor
EEC	Equilibrium equivalent concentration
EEC_{Rn}	Equilibrium equivalent concentration of radon
EEC_{Tn}	Equilibrium equivalent concentration of thoron
EPA	Environmental protection agency
GPS	Global positioning system
HBRA	High background radiation area
HPGe	Hyper pure germanium detector
IAEA	International atomic energy agency
NCRP	National council on radiation protection
OF	Occupancy factor
PAEC	Potential alpha energy concentration
ppm	Part per million
ROI	Region of interest
UNSCEAR	United nations scientific committee on the effects of atomic radiation
USNRC	United states nuclear regulatory commission
WL	Working level
WLM	Working level month

LIST OF SYMBOLS

A_s	-	Specific activity
A_U	-	Specific activity of uranium
A_{Th}	-	Specific activity of thorium
A_K	-	Specific activity of potassium
C_U	-	Concentrations of uranium
C_{Th}	-	Concentrations of thorium
C_K	-	Concentrations of potassium
R^2	-	Regression coefficient
Rn^{220}	-	Thoron
Rn^{222}	-	Radon
α	-	Alpha particle
β	-	Beta particle
γ	-	Gamma-rays
D	-	Absorbed dose

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Humans are constantly being exposed to ionizing radiation from natural sources since their existence on the earth. Natural radiation consists of radiation from radionuclides of terrestrial origin and high-energy cosmic rays hitting the earth's atmosphere. Radionuclides from terrestrial sources, mainly ^{238}U and ^{232}Th series and ^{40}K are the main contributor to external exposure due to gamma radiation and can be found everywhere in soils, rocks and underground water.

Uranium and thorium which has a very long half-life ultimately decay into ^{206}Pb and ^{208}Pb respectively. During the decaying process, they and their progenies emit numerous gamma rays, beta rays and alpha rays with different energies. The series produce variety daughter products including radon and thoron isotopes. Radon is an inert radioactive gas that occurs naturally. The two isotopes; ^{222}Rn and ^{220}Rn are the daughter product of ^{238}U and ^{232}Th respectively. The term “radon” denotes all the radon isotopes in general, but more specifically, radon denoted as Rn-222 whereas thoron denoted as Rn-220. The inhalation of short-lived radon and its progenies is the main source of natural internal exposure.

According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), inhalation of radon and thoron makes up to 52% of the total average worldwide exposure to natural radiation sources (UNSCEAR, 2000b). Whereas gamma radiation, cosmic radiation and radiation exposure from radionuclides present in water and food contributes 20%, 16% and 12% respectively. This data shows that radon and thoron play a very significant role in natural radiation exposure and it cannot be avoided by humans. From the typical total annual effective dose (1.25 mSv) due to both radon and thoron, inhalation of radon alone is responsible for 92% of it or 1.15 mSv (UNSCEAR 2000).

The respective doses contributed by the radon isotopes and its progeny largely depend on the local geology or the ratio of the concentration of ^{238}U and ^{232}Th in the soils (Bhatt, 2011). Therefore, the concentrations of radon and thoron parents are of great importance in predicting the radon or thoron activity concentration. According to the UNSCEAR (2000), the average global concentration of these radionuclides is 33 Bq kg^{-1} for ^{238}U and 45 Bq kg^{-1} for ^{232}Th. But there are some areas in the world that have elevated level of uranium and thorium.

Brazil, China, Iran, India, Spain and Australia are among the countries that have areas with high levels of background radiation. Numerous studies (Ramola et al., 2013; Mehdi and Mozhgan, 2005; Byju et al., 2012; Zuoyuan, 2002; Sainz et al., 2007) have been performed in these regions to access the radiation exposure and effective dose received by the inhabitants. This includes the study of radon and thoron and their progenies.

1.2 Problem statement

In Malaysia, the study on radon, often known as "silent-killer", is quiet lacking as compared to European countries. The awareness on radon gas, as a source of energetic alpha radiation, which can contribute to long-term health problem has not been extensively highlighted. There are plenty of information and data on indoor and outdoor radon, but there is lack of representation from many tropical countries, especially on how elevated radioactivity in soil affects the radon concentration in these areas.

Radon and thoron are produced by radioactive decay of radium, decay products of uranium and thorium in rocks and soils. Theoretically, radon and thoron concentration is directly related to the uranium and thorium content of the mineral matter in the soils respectively. If the uranium content in these materials is high then the activity of radon gas will also be high (Hallenback, 1994). The measurement of these radionuclides in the soils will be used to provide information on radon and thoron concentration in the environment.

Palong is an area in the Segamat District in North Johor. The preliminary radiological study in this region have shown high concentration level of ^{238}U and ^{232}Th in soil samples whose concentration varied from 58.8 Bq kg^{-1} to 484.8 Bq kg^{-1} and 59.6 Bq kg^{-1} to 1204.0 Bq kg^{-1} respectively (Ramli et al., 2005). The values are higher than the worldwide average as stated by UNSCEAR (2000) which is 33 Bq kg^{-1} for ^{238}U and 45 Bq kg^{-1} for ^{232}Th respectively. Due to its high content of ^{238}U and ^{232}Th, this area is expected to have higher level of radon and thoron. Since no studies have been conducted in this area to determine radon/thoron levels and the associated dose rates, therefore it is pertinent to measure the radon and thoron levels in Palong.

The most significant element of human irradiation by natural radiation is radon exposure, and the most important mechanism of exposure is the inhalation of the short-lived decay products of ^{222}Rn (UNSCEAR, 1993). If these decay products are inhaled, they can deposit along the trachea and within the lungs. After the inhalation, it can cause significant damage to the internal cells of the bronchioles which may lead to the occurrence of lung cancer (Rahman et al., 2008). The populations of Palong are exposed to higher level of radiation from gamma exposure and from radon/thoron exposure as well. Thus the public dose from these exposures is considered in this study.

1.3 Objectives

The objectives of the study are as follows:

1) To measure the indoor and outdoor radon and thoron concentrations at different locations in Palong area.

2) To measure terrestrial gamma dose rates.

3) To measure the U^{238}, Th^{232} and K^{40} activity concentration in soil samples and correlate between uranium and thorium content in soils with radon and thoron levels.

4) To estimate annual effective doses to public from gamma, soil, radon and thoron exposures.

1.4 Scope

In order to achieve the stated objectives, this study was conducted within the scope as specified as follows:

1) The area of the study is Palong approximately bound by the latitude of 2º30’N to 2º50’N and the longitude of 102º40’E to 102º50’E.

2) DOSEman PRO supplied by Malaysian Nuclear Agency was used for radon and thoron measurements.

3) The absorbed gamma dose rates in air were measured in places where radon and thoron measurements were undertaken by using Ludlum 12S survey meter.

4) Soil samples were collected as well to measure its uranium and thorium concentration activity, by using gamma spectrometer.

5) The measurements were conducted during May to June 2013 involving 32 outdoor and six indoor measurements.

1.5 Significance of study

This study is significant as it provides preliminary data of radon and thoron in high background radiation area at Palong. No data on radon/thoron levels in this region is available previously. Radon and thoron concentration levels are used to estimate the dose due to inhalation, as stated by UNSCEAR (2000). On the average, inhalation of radon and thoron progenies contribute more than half of the total exposure received by humans due to natural radiation.

The results of the survey are expected to provide baseline data. Thus it will be useful in accessing public doses due to radiological accidents. Monitoring of radioactivity in air has been widely used as an early warning system for nuclear emergencies (Seftelis et al., 2007). These data will be important in accessing the effects of elevated background radiation on radon/thoron levels in the region.

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