LEM/TEK/15
December, 1988

RADON, THORON AND THEIR DAUGHTERS

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TABLE OF CONTENTS

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1. INTRODUCTION

In Malaysia radon, thoron and their daughters are always associated with tin mining industry especially, which involves activities such as milling, storing and processing of amang and monazite. The purpose of preparing this brochure is to provide brief explanation on radon, thoron and their daughters, and it may be useful to those who deal with tin mining industry whether directly or indirectly.

2. What is Radon, Thoron and their daughters?

The characteristics of radon, thoron and their daughters are specified in detail in the Periodic Table of elements.

Radon is an element which possesses 86 proton (atomic number) and its mass number (neutron + proton) varies from 200 to 222. Brief explanation on radon, thoron and their daughters are as follows:

(a) Radon

Radon is an isotope which possesses an atomic number (Z) of 86 and a mass number (number of neutron plus proton) of 222 (Rn-222).

(b) Thoron

Thoron is an isotope which possesses an atomic number (Z) of 86 and a mass number (neutron plus proton) of 220 (Rn-220).

Both radon and thoron in their normal conditions are in gaseous state and radioactive in nature with half-lives of 3.8 days and 55.6 seconds respectively.

(c) Radon daughters

Because it is radioactive in nature, radon (Rn-222) will disintegrate to yield radon daughters which eventually become stable nuclides (refer to fig. 1). radon daughters include 2111po, 214Pb, 214 Bi, and 214po.

(d) Thoron daughters

Thoron (Rn-220) is also radioactive in nature, and will disintegrate to yield thoron daughters which eventually become stable nuclides (refer to figure 2). Thoron daughters include ^{216}Po, ^{212}Pb, ^{212}Bi, and ^{212}Po.

3. How Radon and Thoron gases could exist?

Normally if there are uranium and thorium in a particular place, there are also radon and thoron gases.

(a) Radon gas (Rn-222) is formed when radium-226 with half-life equal to 1600 years, disintegrates according to uranium-238 decay series;

(b) Thoron gas (Rn-220) is formed when radium-224 with half-life equal to 3.64 days disintegrates, in thorium-232 decay series.

Therefore in areas such as tin mining areas, where there are uranium or thorium, most likely there will be radon or thoron in the air (airborne). If there is insufficient ventilation in an area, the concentration of radon, thoron and their daughters in that area, will increase.

4. What are the applicable limits and units?

(a) Limit

The applicable limits as specified in the Radiation Protection (Basic Safety Standard) Regulations 1988 are as follows:

Quote: "Radon daughters: Short-lived decay products of ^{222}Rn: "^{218}Po (RaA), ^{218}At, ^{214}Pb (RaB) ' ^{214}Bi (RaC), ^{214}P0 (RaC') and ^{210}TI (RaC").

The annual limit on intake (ALI) for radon (^{222}Rn) daughters is 0.02 Joules of inhaled potential alpha energy. This value corresponds to

(i) a derived air concentration (DAC) of 8.3 microjoules per cubic meter (0.4 Working Level); or

(ii) an annual limit of exposure (ALE) of 0.017 J.h.m^{-3} (5 Working level Months).

Thoron daughters: Short-lived decay products of ^{22O}Rn: ^{216}Po (ThA), ^{212}Pb (ThB), ^{212}Bi (ThC'), ^{212}P0 (ThC') and ^{208}TI (ThC').

The annual limit of intake (ALI) for thoron (22'Rn) daughters is 0.06 Joules of inhaled potential alpha energy. This value corresponds to (i) a derived air concentration (DAC) of 25 microjoules per cubic metre (1.2 Working Level); or (ii) an annual limit of exposure (ALE) of 0.05 J.h.m^{-3} (15 Working Level Months)."

(b) Unit

Unit normally used for limits and measurements of radon, thoron and their daughters are:

i. Working level (WL); and
ii. Working level month (WLM)

(c) Definition Working Level (WL)

Any combination of radon or thoron daughters in 1 litre (1000 cc) of airs which produces ultimate emission of alpha energy equal to 1.3 x 10^5 MeV. In SI unit, WL is equivalent to 2.1 x 10^{-5} J.m^{-3}.

Working Level Month (WLM)

1 WLM is an exposure unit against radon or thoron daughters. One Working Level Month (1 WLM) is equal to 3.54 mJ.h.m^{-3} or 170 WL.h.

Because the dose from radon and thoron gases are insignificant as compared with the doses from radon daughters and thoron daughters, therefore only doses from radon daughters and thoron daughters are considered.

(d) **Relationship between WL and WLM**

1 WL is equivalent to 2.10 x 10^{-5} J.m^{-3}

1 WLM is equivalent to 3.54. mJ.h.m^{-3} or 170 WL.h

i. 1 WL 1.3 x 105 MeV (Alpha Energy)m^{-3}
1 MeV 1.602 X 10^{-13} joules

Therefore 1 WL = 1.3 x 10^1 x 1.602 x 10^{-13} joules m^{-3}
= 2.0826 x 10^{-5} joules.m^{-3}

1 WL = 2.10 x 10^{-5} joules.m^{-3}

ii. From the definition:

1 WLM = 170 WL.h

From (i):
1 WLM = 170 x 2.1 x 10^{-5} Joules.m-3.h = 3.57 rnJ.h.m^{-1} The value given in the definition of WLM is 3.54 mJ.h.m^{-3}
Therefore:

1 WLM = 3.54 mJ.h.m^{-3}

(e) For Radon Daughters

i. ALI (annual limit on intake) for radon daughters (for radiation workers) 0.02 joules.

Breathing rate = 0.02 m^3 per minute = 0.02 x 60 m^3 per hour = 1.2 m^3 per hour

The volume of the breathed air in a year is equivalent to
0.02 x 60 x 2000 = 2,400 M3

ii. $$\text{DAC} = \frac{\text{ALI}}{2{,}400\ m^3} = \frac{0.02}{2{,}400}\ \text{joule}\ m^{-3}\ \text{(For radiation worker)}$$

DAC = 8.3 microjoules per cubic meter but 1 WL = 2.10 x 10^{-5} joules m^{-3}
Therefore:

$$\text{DAC} = \frac{8.3\ \text{microjoules}\ m^{-3}}{10 \times 10^{-5}\ \text{joules}\ m^{-3}}$$

DAC = 0.4 WL

iii. Annual Exposure Limit is the concept of the annual limit on exposure, meaning the exposure to airborne radionuclide, specified as time integral of the concentration which may cause a reference man to inhale the annual limit on intake (ALI) for that particular radionuclide.

Annual Exposure Limit (ALE) = 0.017 J.j.m^{-3} (5 WLM)

(f) For Thoron Daughters
By the same manner the following values for thoron and its daughters can be derived:

i. ALI for thoron daughters = 0.06 joules
ii. DAC = 25 microjoules per cubic meter
iii. DAC = 1.2 WL
iv. ALE = 0.05 J.j.m^{-3} (15 WLM)

(g) Limit for members of the public

Annual limits for members of the public against radon, thoron and their daughters are 1150 of the annual limit for radiation workers.

5. Measurement of Radon, Thoron and Their Daughters

Radon gas, thoron gas and their daughters can be detected and measured by using special equipment and using specific measurement procedures. Equipment which can be used, inter-alia:

i. RDA-200; and
ii. ALPHA PRISM.

Figure I. Radon Daughters (Immediate decay products)

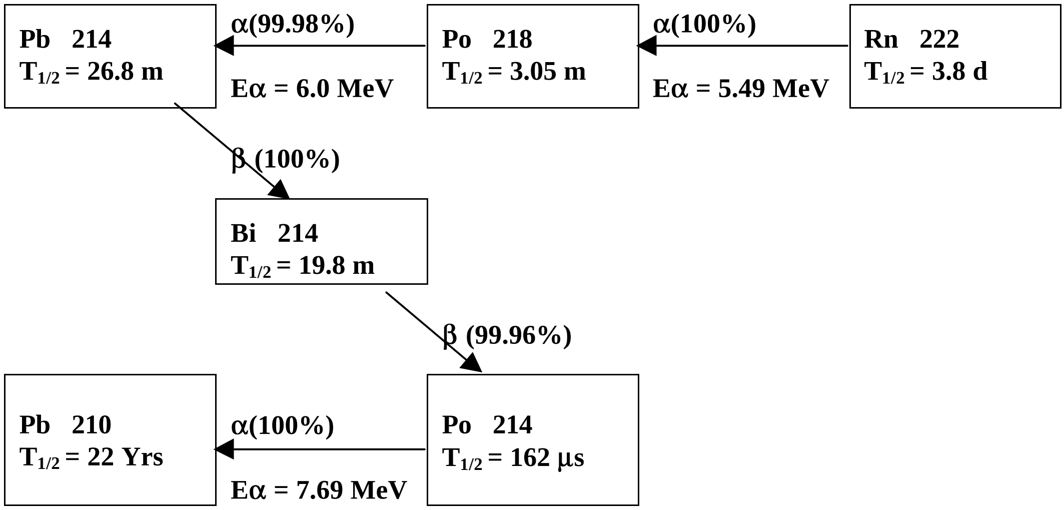

Figure 2: Thoron daughters (decay Products)