Committed Effective Dose from Thoron Daughters Inhalation

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INTRODUCTION

Mankind has been constantly exposed to radiation by natural radioactivity, nuclear tests, medical applications and nuclear energy activities. The natural radioactivity is the main component to human exposure and it is recognized that the most important contributors to the committed effective dose received by population due to natural sources are the short-lived decay products of radon (^{222}Rn) and thoron (^{220}Rn).

The Earth crust contains trace quantities of ^{238}U and ^{232}Th which decay to ^{222}Rn and ^{220}Rn, respectively. In most human radon exposure studies, the contribution of thoron is usually neglected. The reason for this are: the ^{220}Rn concentration is generally much lower than ^{222}Rn and ^{220}Rn has a relatively short half-life (55.3 s) than ^{222}Rn (3.83 d).

For a long time, it is well known that residents of high background areas like Brazil, China and India, where the predominant geological material is decomposed granite which has a relatively high content of ^{232}Th (1), receive elevated doses, so it is incorrect to neglected ^{220}Rn in radon exposure studies.

However, recent studies shown that besides the residents of those high background areas, workers in the mineral sand processing industries receive elevated doses up to 180 mSv/y. In addition, recent surveys indicate that for members of general public living in certain Japanese wooden and mud houses the contribution from thoron daughters can represent a significant fraction of the total lung exposure (2).

The thoron direct determination is very difficult, due to its very short half-life (55.3 s). So, to obtain the thoron concentration in the air, we use the concept of equilibrium equivalent concentration (EEC), defined as the thoron concentration, in equilibrium with its short-lived daughters, that has the same potential alpha energy concentration per unit volume as exists in a sample mixture. The equilibrium equivalent concentration is calculated through the ^{212}Pb and ^{212}Bi concentrations (3).

The committed effective dose from exposure to thoron progeny was obtained from the thoron equilibrium equivalent concentration and dosimetric models for inhalation and distribution of airbone radioactivity by human body. These models incorporate the data on respiratory tract deposition and clearance of particles, as well as the behaviour of inhaled radionuclide in the body.

The primary pathway for health detrinent associated with ^{220}Rn arise from inhalation of the short-lived decay products (^{212}Pb e ^{212}Bi) and the resultant alpha particle exposure to the respiratory tract, but, due to the relatively long half-life of ^{212}Pb (10.6 h), a considerable fraction of the energy deposited in the lungs is transferred to other organs. For this reason, the committed effective dose from thoron daughters inhalation was calculated considering the activity incorporated as being only the activity of ^{212}Pb.

At the Instituto de Pesquisas Energéticas e Nucleares (IPEN) there is a thorium purification plant where materials containing thorium among others elements are manipulated and a nuclear materials storage site where safeguarded materials are stored; consequently, thorium exists in high concentration and the thoron contribution can not be neglected. In this study, we assess the committed effective dose from thoron for workers of those two places.

SAMPLING AND MEASUMENT TECHNIQUES

The ^{212}Pb and ^{212}Bi activities were obtained by the active detection method, when the air pumped by an air sampler is collected on glass fiber filters, subsequently analyzed.

The air sampling was realized with a Staplex air sampler model TFRC-41B at the nuclear materials storage site and with a Staplex air sampler model LVC-50 at the thorium purification plant. The air samplers were calibrated with the Staplex calibrator models CK-140 and CK-8C, respectively. The sampling flux was daily corrected for pressure and temperature at the sampling place through the pressure and temperature correction factors, according to air sampler manual (4).

A total of 21 glass fiber filter samples with diameter of 47 mm (12 samples collected at the nuclear materials storage site and 9 samples collected at thorium purification plant), were arranged in aluminum planchets with diameter of 50 mm and measured by passive high resolution gamma-ray spectrometry in order to obtain the ^{212}Pb and ^{212}Bi activities.

The gamma ray spectrometry system is a high resolution 15 cm^3 EG&G Ortec HPGe detector, with conventional electronics, coupled to a 4K-channels memory EG&G Ortec 918-A ADCAM multichannel buffer and 476-8 multiplexer and a 586-133 MHz computer. The energy resolution for the 1.33 MeV ^{60}Co is 1.9 keV.

The background distribution was obtained by measuring a blank glass fiber filter in the same sample

geometry.

All spectra were analyzed with the MicroSAMPO (5) software for personal computer analysis of gamma-ray spectra from HPGe detectors. The self-absorption correction of the samples was achieved using a pre-determined standard efficiency curve (6).

THORON EQUILIBRIUM EQUIVALENT CONCENTRATION RESULTS

The equilibrium equivalent concentration (EEC) of thoron was obtained considering to the following equation (3):

$$EEC = 0.91\ (A) + 0.09\ (B) \qquad [1]$$

where:
A – concentration of ^{212}Pb in Bq/m^3
B – concentration of ^{212}Bi in Bq/m^3

The ^{212}Pb concentration was determined through the gamma transitions of 238 keV and 300 keV as the mean value of those two gamma transitions. The ^{212}Bi concentration was determined through the gamma transitions of 727 keV and 1620 keV as a mean value of those two gamma transitions.

Table 1 shows the thoron equilibrium equivalent concentration at the nuclear materials storage site between October 1996 and June 1997 and table 2 shows the thoron equilibrium equivalent concentration at the thorium purification plant between June 1997 and December 1998.

Table 1: Thoron equilibrium equivalent concentration (EEC) at the nuclear materials storage site, between October 1996 and June 1997.

Date	EEC (Bq/m^3)
10/21/96	2.70 ± 0.19
10/22/96	0.30 ± 0.03
11/01/96	6.83 ± 0.38
12/11/96	3.75 ± 0.20
12/17/96	2.18 ± 0.12
02/05/97	5.09 ± 0.25
03/03/97	2.25 ± 0.02
03/13/97	3.33 ± 0.10
04/23/97	4.29 ± 0.67
05/06/97	1.76 ± 0.13
05/13/97	1.11 ± 0.05
06/17/97	2.54 ± 0.07

Table 2: Thoron equilibrium equivalent concentration (EEC) at thorium purification plant, between June 1997 and December 1998.

Date	EEC (Bq/m^3)
06/30/97	50.2 ± 4.1
08/25/97	110.8 ± 7.4
08/26/97	78.4 ± 1.8
09/12/97	9.9 ± 0.8
09/09/97	99.8 ± 2.0
11/26/98	192.8 ± 3.6
12/03/98	249.8 ± 14.8
12/08/98	128.2 ± 8.4
12/10/98	74.4 ± 2.8

COMMITTED EFFECTIVE DOSE RESULTS

The inhalation is the main pathway of thoron daughters intake and the ^{212}Pb is the main contributor for radiation dose, so we use the ICRP 66 lung compartment model (7) and the ICRP 67 lead metabolic model (8) to describe the radionuclide distribution in the body and to calculate the committed effective dose.

For purposes of modeling, the respiratory tract is represented by four regions. The extrathoracic region comprises the anterior and posterior nasal passages and the oral passages, including the mouth, pharynx and larynx with associated lymphatic tissues. The thoracic regions are bronchial consisting of the trachea and bronchi, bronchiolar consisting of the bronchioles and terminal bronchioles and alveolar interstitial consisting of the respiratory bronchioles, the alveolar ducts and sacs with their alveoli, also with associated lymphatic tissues.

The model evaluates fractional deposition of an aerosol in each dosimetric region considering the aerosol size, inhalability and nose and mouth breathing and give reference values of regional deposition for reference workers.

Materials deposited in the respiratory tract are cleared by three main routes: into blood by absorption, to the gastrointestinal tract via the pharynx and to regional lymph nodes via lymphatic channels.

The functions describing uptake and retention in a body tissue following particle intake are quite complex and therefore, it is convenient to describe the transfer of radionuclide from air to body by simple models which facilitate calculation and yet still allow sufficiently accurate dose estimates.

According to the metabolic model described in the ICRP 67, lead leaving the transfer compartment is distributed to blood, liver, kidneys and skeleton. More than 99% of the activity in blood is associated with red blood cells. Skeleton behaviour of lead appears to be similar to that of the heavier alkaline earth elements, if account is taken of the slower deposition of lead in the skeleton due to competition with other tissues and fluids, particularly red blood cells.

Using informations about the ICRP 66 lung compartment model, the ICRP 67 lead metabolic model and the lead annual intake (obtained through the thoron equilibrium equivalent concentration, breathing rate and the exposure period), we calculated the committed effective dose due to thoron daughters inhalation using the AnaComp code (9). The workers were exposed during 2000 hours per year at the nuclear materials storage site and 500 hours per year at the thorium purification plant and we considered a breathing rate of 1.2 m^3/h.

The AnaComp code uses the MIRD (Medical Internal Radiation Dose) formalism to calculate the radiation doses through compartment model.

The figure 1 shows the values of committed effective dose at the nuclear materials storage site between October 1996 and June 1997.

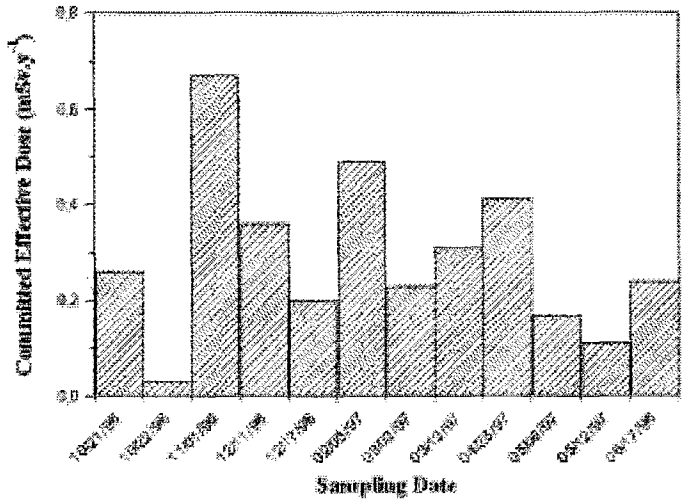

Figure 1. Committed effective dose at nuclear materials storage site between October 1996 and June 1997.

The figure 2 shows the values of committed effective dose at the thorium purification plant between June 1996 and December 1998.

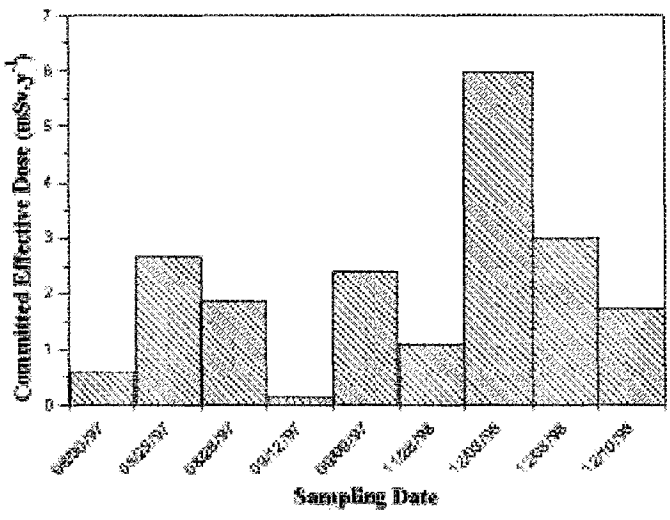

Figure 2: Committed effective dose at thorium purification plant between June 1997 and December 1998.

CONCLUSION

As it can be seen from tables 1 and 2, at the thorium purification plant, the levels of thoron daughters in the air are greater than at the nuclear materials storage site, which is expected, as at the thorium purification plant materials containing thorium exists in greater quantities than at the nuclear materials storage site.

The variation of the equilibrium equivalent concentration values at the nuclear materials storage site can be explained by a considerable exchange air rate, because the entrance and renewal of air were inevitable every time when the storage site door was opened.

At the thorium purification plant, the variation in the thoron equilibrium equivalent concentration are justified by the different thorium activities of the manufactured materials. If we compare the values obtained with indoor values of 17.9 Bq/m^3 and 19.2 Bq/m^3 obtained in Korea (10) and Italy (11), respectively, and with the thoron daughters derived air concentration (DAC) of 330Bq/m^3 (12), it can be observed the high radioactivity level present at thorium purification plant.

The effective committed dose received by the workers at both places is below 20 $mSv.y^{-1}$ (12), suggested as an annual effective dose limit for occupational exposure by ICRP 60, considering a working time of 2000 hours per year. Nevertheless, it must be pointed that, at the thorium purification plant, the Radiological Health Service established an working time of only 500 hours per year. So, the local work routine is correct, as if for an working time of 2000 hours per year, the annual dose limit would be exceeded..

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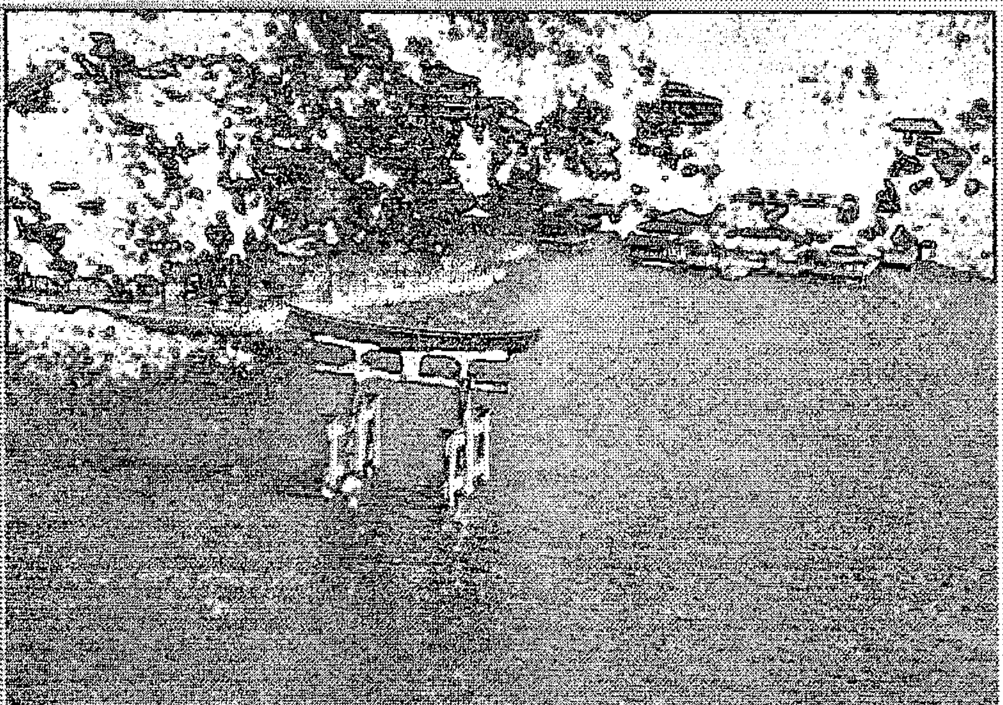

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