Chapter V

MEASUREMENT OF ATTACHED RADON AND THORON PROGENY SIZE DISTRIBUTION AND ESTIMATION OF DOSE ASSESSMENT IN THE MINERAL TREATMENT INDUSTRY

In this chapter, the main focus has been given to the temporal and spatial variation of attached radon and thoron progeny activity size distribution by developed technique and estimation of effective dose. The particle size distribution characterized by activity median aerodynamic diameter (AMAD) is a dominant parameter for dose assessment. At the very onset of the study, a field survey was conducted to speculate the spatial variations of attached radon and thoron progeny activity size distributions at a workplace in Phuket, Thailand. Final goal of this study was to estimate dose for worker.

5.1 Study location

Mineral treatment industry is located at Tambon Vichit, Amphur Muang Phuket, Thailand. The attached radon and thoron progeny activity size distributions were measured by developed technique at three areas such as health and safety office (HSE), ore sampling area and production storage area. The studies took place from 16th to 18th February, 2010. Figure 5-1 shows the location of measurement points.

5.2 Method and measurement set up

5.2.1 Determination of attached radon and thoron progeny activity size distribution

Measurements for the attached radon and thoron progeny activity size distribution have been performed using our modification portable cascade impactor consisting of four stages with a backup filter holder. The air flow rate through the impactor is 4 L min^{-1} by a mini-pump (Sibata, MP-Σ500, Japan). The 50% efficiency aerodynamic cut-off diameters for the stages are 10, 2.5, 1, and 0.5 μm. Attached radon and thoron progeny aerosol particles were collected and measured. The unattached particles were separated at the entrance of impactor using a 400-mesh wire

screen. The aerosol collection time was 6 h and the cooling time was 4 d. The cooling time was set long enough to decay out ^{212}Pb (Thoron progeny) that has a half life of 10.64 h. After that, all the exposed CR-39 chips were chemically etched for 24 h in 6.25 N NaOH solution at 60 °C. The track densities were counted using an optical microscope.
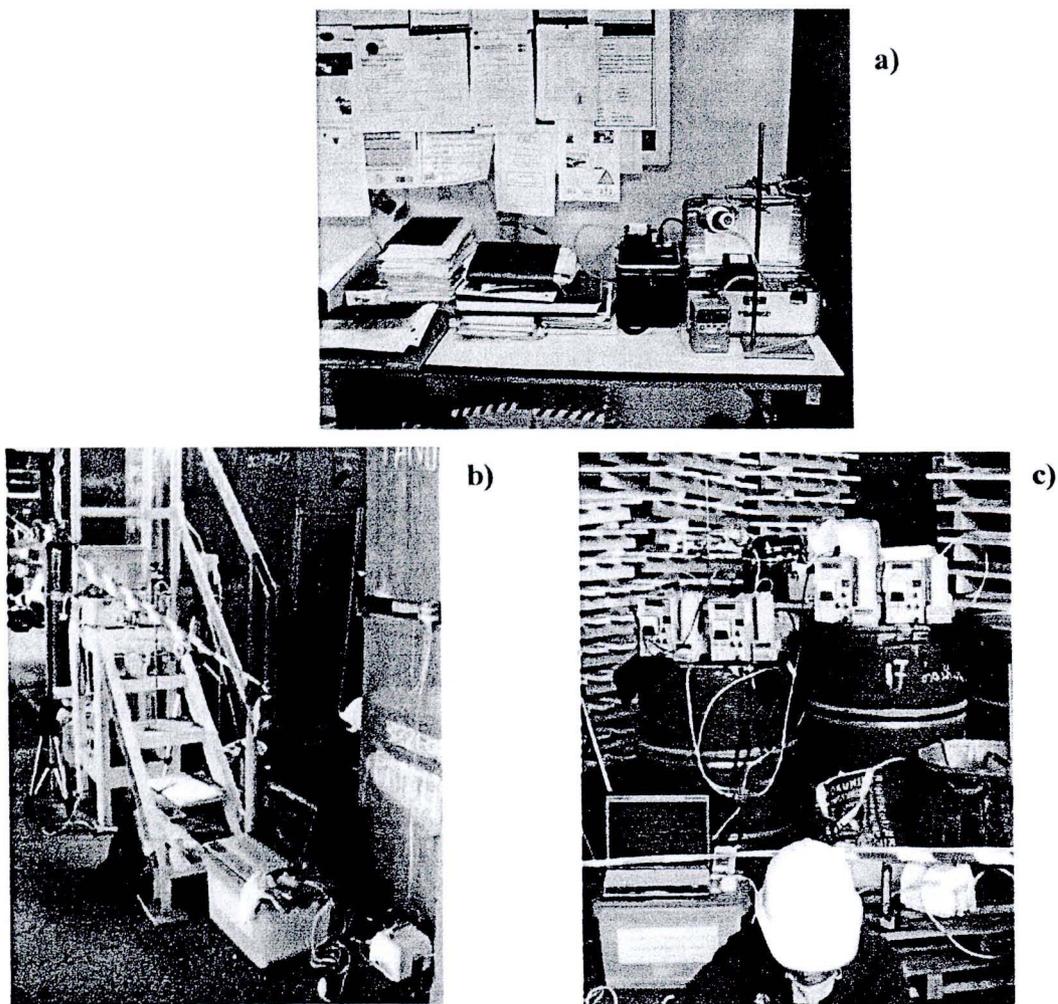

Figure 5-1 Location of measurement points at Mineral treatment industry, Phuket, Thailand: a) HSE office, b) Ore sampling area, and c) Production storage area.

5.2.2 Determination of radon, thoron and their progeny concentration

RAD-7 (Durridge Co, Let., USA) was employed to monitor radon and thoron concentration. In this study, RAD-7 was employed for a minimum of 12 h to a maximum of 24 h to measure the activity concentration of radon and thoron at every 5 min interval by sniffer mode. During this period, setup of impactor and air sampling operates for a period of 6 h. The WLx portable working level radiation monitor (Pylon Electronics Inc., Model 147, and Canada) was operated for the same period of RAD-7 with a continuous sampling mode. This monitor uses 0.8 µm pore size and 25 mm diameter mixed cellulose-ester membrane filter (Millipor, USA) to estimate the activity concentration of radon and its progeny. After sampling, the total alpha activity on the membrane filter was measured by solid state detector and the working level (WL) concentration was calculated and recorded automatically.

Thoron progeny concentration was employed using CR-39 technique. The method used for this purpose is sampling air through an open-faced high efficiency filter paper (Whatman, $\varnothing$ 25 mm, USA) at flow rate of 0.5 Lmin^{-1} for 24 h. In order to determine thoron progeny concentration, the registration on thoron progeny has to be distinguished from that of radon progeny. After air sampling is over, the filter is left for more than 6 h to allow radon progeny to completely decay. An aluminum foil with a thickness of 15 µm (4.0 mg.cm^{-2}) is then placed on the filter to reduce alpha particle energy emitted from ^{212}Po and to increase the detector effectiveness. Afterward, CR-39 detector is placed directly on the aluminum foil and left for about 2 d to allow registration of alpha tracks on the detector. All the detectors exposed were chemically etched for 24 hr in 6.25 N NaOH solution at 60°C and track density was counted by an optical microscope. From these data, EETC can be obtained with a proper calculation procedure [70].

The equilibrium factor "F" was determined from the ratio of the obtained equivalent equilibrium concentration of radon and thoron progeny to the concentration of radon and thoron.

5.3 Results of field survey

5.3.1 Attached radon and thoron progeny activity size distribution

The activity median aerodynamic diameter (AMAD) and geometric standard deviations (σ_g) of attached radon and thoron progeny in all experimental areas for Thaisarco is presented in Table 5-1 and the illustration of the particle size distribution is depicted in Figure 5-2.

Table 5-1 Size information of AMAD and σ_g of attached radon and thoron progeny at different places in Mineral treatment industry.

Study Areas	Radon progeny		Thoron progeny	
	AMAD (μm)	σ_g	AMAD (μm)	σ_g
1.HSE Office	0.469	2.19	0.451	2.20
2.Sampling area	0.527	2.39	ND	ND
3.Production storage area	0.722	2.47	0.420	2.27

ND: non-detectable (Lower than the detection limit: 0.13 Bq m^{-3} for radon progeny and 0.02 Bq m^{-3} for thoron progeny)

It could be observed from Table 5-1 that, AMAD at three areas' indoor environment in Mineral treatment industry for attached radon progeny varies from 0.469~0.722 μm with σ_g of 2.19~2.47 whereas for attached thoron progeny less variation from (0.420~0.451 μm) with σ_g of 2.20~2.27. It can be noticed in Table 5-1 that AMAD of attached radon progeny varied with location. On the other hand, similar size values are obtained in the case of attached thoron progeny. The different size of attached radon and thoron progeny may affect due to different aerosol sources and environment conditions: in the case of HSE office used air conditioner during the sampling period.
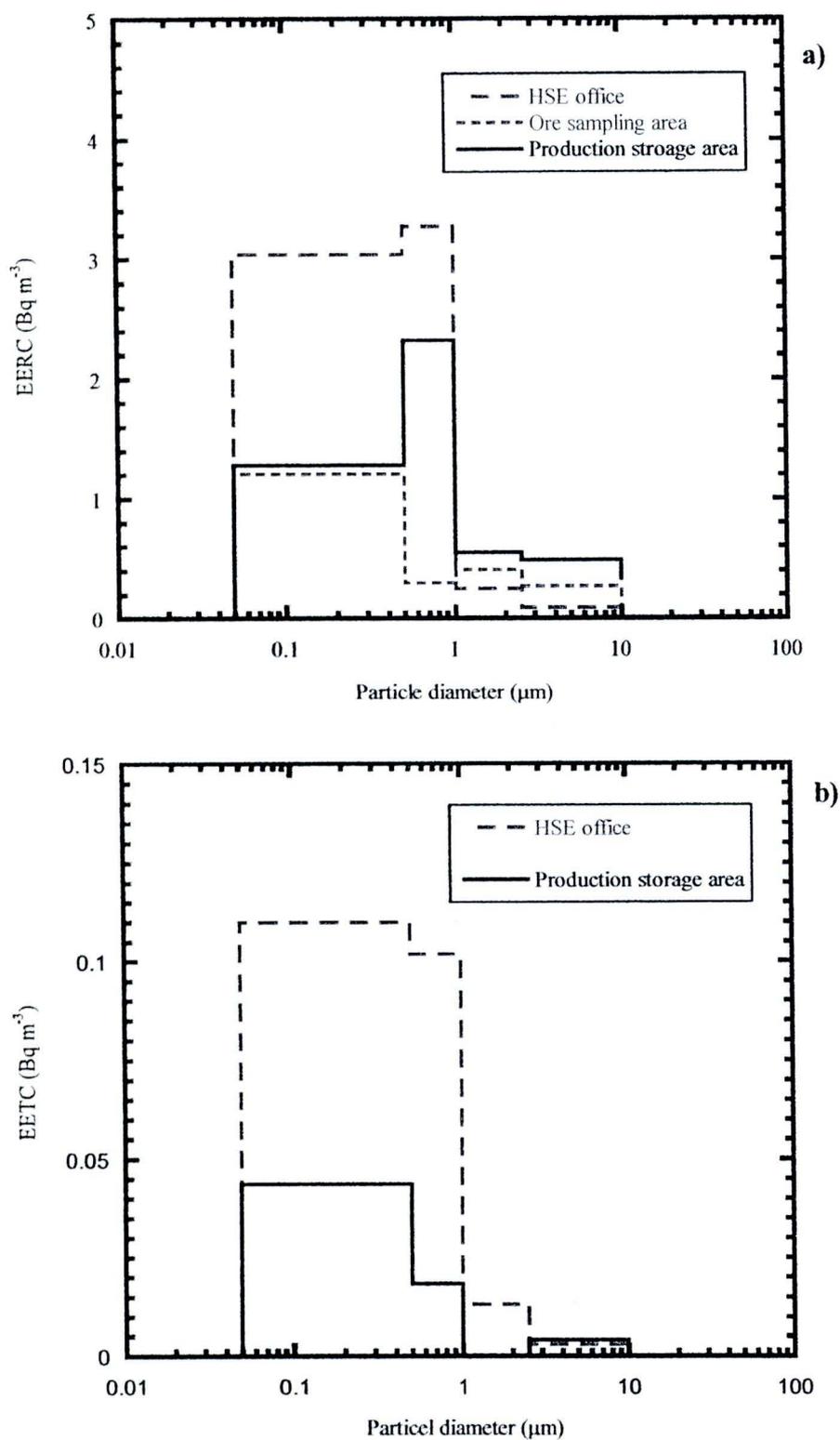
Figure 5-2 Illustration of the particle size distribution: a) attached radon progeny size distribution b) attached thoron progeny size distribution.

5.3.2 Determination of Equilibrium factor

The estimated activity concentrations of radon, thoron and their progeny corresponding to equilibrium factor "F" are represented in Table 5-2.

Table 5-2 Activity concentration of radon, thoron, their progeny concentration

Study area	Radon concentration (Bqm^{-3})	Radon progeny Concentration (Bqm^{-3})	F_{Rn}	Thoron concentration (Bqm^{-3})	Thoron progeny Concentration (Bqm^{-3})	F_{Tn}
1.HSE Office	12.73±1.79	6.66±0.27	0.52	12.01±4.76	0.43 ± 0.02	0.04
2.Ore Sampling area	4.74±2.25	4.24±0.74	0.89	20.65±4.49	0.14 ± 0.01	0.01
3.Production storage area	3.47±1.39	2.76±0.17	0.79	14.09±7.18	0.07 ± 0.01	0.01

F_{Rn}: Equilibrium factor of radon
F_{Tn}: Equilibrium factor of thoron

The activity concentration of radon, thoron and their progeny in workplace environment largely exhibits the indoor air quality. We have observed the average activity concentration of radon and thoron is almost equal at HSE office. On the other hand, thoron concentration was higher than radon concentration at ore sampling area as well as production storage area. That can be attributed to higher thorium than uranium concentration in ore and products [71]. In case of progeny concentrations, it is noticed that average radon progeny concentration is higher than average thoron progeny concentration at all study areas. Since uranium concentration is much higher than natural environmental samples, may be the reason why radon progeny is predominant over thoron progeny though thorium concentration is also high.

5.4 Dose assessment

For dose calculation of inhaled radon and thoron progeny, UNSCEAR [72] has come up with a very simple expression for calculating effective dose, E as follows:

$$E = C \times F \times T \times DCF \tag{5-1}$$

where, C = Rn/Tn concentration (Bq m^{-3})

F = Equilibrium factor of Rn/Tn

T = Occupancy factor (2000 h y^{-1} for workplace and 7000 h y^{-1} for home)

DCF = Dose conversion factor of Rn/Tn progeny (mSv (Bq m^{-3} h)$^{-1}$)

In this study, dose conversion factor of attached radon and thoron progeny were assessed using a computer program name LUDEP (Lung Dose Evaluation Program, distributed by NRPB) based on the ICRP 66 model. The input values for major parameters used for the calculation are listed in Table 2-1. It is considered that AMAD as one of the most important input parameter. Dose Conversion Factor (DCFs) of attached radon and thoron progeny from LUDEP program are shown in Table 5-3.

Table 5-3 Dose Conversion Factor (DCFs) of attached radon and thoron progeny by LUDEP.

Study areas	Dose Conversion Factor (DCFs) $nSv (Bq\ h\ m^{-3})^{-1}$	
	Radon progeny	Thoron progeny
1.HSE Office	11.23	56.36
2.Sampling area	12.25	-
3.Production storage area	15.20	58.57
Average	12.89±2.06	57.47±1.56

Initially the radon and thoron progeny are formed as the unattached particles. Most of these unattached nuclei attach themselves to aerosol particles immediately after formation to produce attached radon and thoron progeny. Table 5-3 shows the particle size distribution of aerosol attached progeny influences the dose in the airways as particles of different size deposit.

In this study, measurement on unattached fraction of radon and thoron progeny size distribution has not been carried out. Dose conversion factor for unattached radon and thoron progeny by LUDEP has been suggested that AMAD and σ_g of a typical particle size distribution for the unattached are 1 nm and 1.3, respectively [45]. Therefore, DCFs of unattached radon and thoron progeny was calculated to be 8.66 and 21.91 nSv (Bq h m^{-3})$^{-1}$, respectively. Thus, the dose conversion factor of radon and thoron progeny for mineral treatment industry were calculated to be 21.55 and 79.38 nSv (Bq h m^{-3})$^{-1}$, respectively. It shows that dose conversion factor of thoron progeny is about 3.5 times higher than dose conversion factor of radon progeny. In addition, dose conversion factors from this study are consistent with earlier studies [43] on the radon (ranging from 9-22 nSv (Bq h m^{-3})$^{-1}$)

and thoron progeny (ranging from $51 - 114$ nSv $(Bq\,h\,m^{-3})^{-1}$) dose conversion factors using the ICRP-66 human respiratory tract model [32].

It is a general practice in radon and thoron dosimetry to measure radon and thoron concentration and then translate their concentrations into individual radon and thoron progeny concentrations using equilibrium factor "F". The factor "F" for this study were experimentally determined by measuring radon and thoron concentration using RAD-7, WLx portable working level radiation monitor and CR-39 technique to obtain the values of potential alpha energy concentration of radon and thoron progeny, respectively. The experimentally obtained equilibrium factors have already been presented in Table 5-2. Consequently, the rough dose assessment for study areas at mineral treatment industry were calculated from equation 5-1 with relates parameters. The effective dose for radon, thoron and their progeny is presented in Table 5-4.

Table 5-4 Annual effective doses at Mineral treatment industry due to exposure of radon, thoron and their progeny

Study areas	Annual effective dose (mSv y^{-1})		
	E_{Rn}	E_{Tn}	total
1.HSE Office	0.29	0.08	0.37
2.Sampling area	0.18	0.03	0.21
3.Production storage area	0.12	0.02	0.14

E_{Rn} and E_{Tn} is annual effective dose from radon, thoron and their progeny, respectively.

It is observed from Table 5-4 that effective dose for the three areas of mineral treatment industry, varies from 0.14 mSvy^{-1} to 0.37 mSvy^{-1}, which is in the acceptable range resulting in equivalent dose to a single public member (lower than 1 mSvy^{-1}). In addition, most of effective dose for workers at mineral treatment industry are due to the inhalation of radon and thoron.

5.5 Conclusions

The field survey on attached radon and thoron progeny size distribution assess dose in working environment. The experimental sites were selected at the Mineral treatment industry. The following conclusion can be made from the experimental findings:

The mean radon and thoron concentration at three usual experimental sites ranges from 3.47±1.39 to 12.73±1.79 Bq m^{-3} and 12.01±4.76 to 20.65±4.49 Bq m^{-3},

respectively. It was found that thoron concentration was higher than radon concentration.

The AMAD of attached radon size distribution varied in between 0.469 μm~0.722 μm at three locations. On the other hand, AMAD of attached thoron size distribution are 0.420 μm and 0.451 μm at HSE office and production storage area, respectively.

The ICRP 66 dosimetric approach through the use of LUDEP to estimate the effective dose of radon and thoron in three sites of Mineral treatment industry and was found to be 4-6 times higher radon dose than thoron. The implementation of particle size distribution, exposure time, breathing rate, equilibrium factor and the activity concentration of radon, thoron and their progeny altogether in LUDEP are required to make a significant dose assessment procedure. Such information will reflect about the actual situation and could be considered more compatible with the ambient environment to assess the effective dose due to inhalation of radon thoron and their progeny. These studies have impact on human health. Thus, a comparison has been made to visualize the workplace environment of Mineral treatment industry.