

Chapter VI

SUMMARY AND CONCLUSIONS

In case of radiation protection two distinct objectives are identified; exposure assessment for individual worker to ensure compliance with exposure limit and area monitoring to maintain a safe working place and prevent high exposure. By deciding a monitoring program which takes these differences into account cost effectiveness can be increased and manpower requirement reduced. The main objective of this dissertation is to characterize radon, thoron and their progeny and estimate dose to the public since these are the most significant sources of natural radiation. In order to accurately estimate dose due to radon and thoron; not only the radon and thoron concentration is essential but also requires the activity median aerodynamic diameter (AMAD) derived from the activity-weighted size distribution of attached radon and thoron progeny on the particulate matters. In the case of both occupational and domestic exposure to thoron progeny are less well know but aerosol AMAD is probably larger than for radon progeny. Cascade impactor is well known as a tool to study airborne particles, because it provides means for direct determination of the distribution of aerodynamic diameter.

6.1 Conclusions and discussion

This study presents the successful development of the portable and economical technique for measuring the activity size distribution of attached radon and thoron progeny for dose assessment. In development of technique, performance test, effect of some parameters on sensitivity, validation and field test for dose assessment were studied. Results suggest about future improvements and to use successfully in field survey. It could be concluded as per following:

6.1.1 The 4-stages portable impactor has been designed and constructed according to the basic principles. Laboratory tests have been carried out in a standard laboratory of NIRS, Japan where radon and thoron chambers are calibrated with other international laboratories. Developed technique results are comparable with successfully with standard ones. Impactor could separate particles in the diameter ranges: <0.5, 0.5-1, 1-2.5, 2.5-10 and >10 μm , at an operation flow-rate of 4 L min^{-1}

by a battery-operated mini-pump. The collection efficiency as a function of particle size for the 0.5 and 1 μm cut-point stages were determined using monodisperse carnauba wax aerosols using glass fiber filter and aluminum-vaporized Mylar film disk as the substrate on impactor plate. Both substrates have the same 50 % collection efficiency cut-point (within experimental uncertainty of 95% confidence interval) at stage 3rd (1 μm) and stage 4th (0.5 μm), approximately at 0.95 ± 0.04 to 1.00 ± 0.03 μm and 0.50 ± 0.17 to 0.53 ± 0.06 μm , respectively. Thus, they are very close to the cut-point diameters those suggested by Rader et al [74]. The square root of the Stokes number at a 50% collection efficiency was found to 0.54 and this was comparable with reported value [63, 74]. The advantages of developed impactor are :

- It is suitable for using in the field where direct electric power supply is not available.

- It has a reasonable price (130,000 baht) in comparison with commercial items (870,000-3,000,000 baht).

The disadvantage is only a small amount of particle would be collected due to the limitation of 4 liter/min flow rate of DC pump that present available in the market. However, it is not much a significant factor.

6.1.2 Simultaneous measurement of radon and thoron progeny technique was developed using the combination of CR-39 detector and aluminum-vaporized Mylar film for the activity size distribution. The following findings were obtained from the experiment studies;

6.1.2.1 The proper aluminum-vaporized Mylar film density for cutoff alpha energy about 4.2, 6.1 and 7.7 MeV of uranium-thorium, ^{214}Po and ^{214}Pb , respectively was confirmed by track density on CR-39 detector at 2 geometries; a) the collection media side and b) the opposite side of backup filter.

6.1.2.2 The counting efficiencies of radon and thoron progeny alpha particles on CR-39 were estimated to be about 12 % and 10% at 2 geometries; a) the collection media side and b) the opposite side of backup filter, respectively. The detected efficiency of CR-39 detector found to be lower than a traditional ZnS (Ag) scintillation detector ($\approx 30\%$). This might be due to factors such as, background effects, losses due to the backward movement of the alpha particles, personnel error etc.

However, the obtained efficiency of the CR-39 is considered to be reasonable within the acceptable range. Nevertheless, CR-39 has other advantages comparing to a ZnS(Ag) detector, for instant: CR-39 has no mechanically affected by humidity and temperature, and it has lower price (144 chips \approx 10,000 Baht) than ZnS (Ag) scintillation detector (60,000 Baht).

6.1.3 Influence of sensitive parameters such as relative humidity (30-90%), temperature (5-30 °C), unattached progeny, changing of air sampling flow-rate (\approx 12-75%), were investigated. It was found that high- unattached radon progeny (at radon concentration \approx 10 kBq m⁻³) enhanced deposition effect on impactor stage 1st (10 μ m) and stage 2nd (2.5 μ m) about 4 and 3 times, respectively in comparison to normal condition. In addition, the changing of activity median diameter (AMAD) could not be observed at different relative humidity, temperature and changing of air flow-rate at about 20-40%.

6.1.4 Validation of developed technique with the commercial devices was performed at aerosol sizes 0.3, 0.5 and 1 μ m and radon concentration of 5,000 Bq m⁻³. ELPI and MOUDI instruments were used as references of particle sizes and ZnS(Ag) scintillation counters was used as alpha detectors. It is found that AMAD measured by the developed technique can be compared with commercial devices in the range of 0.5 to 1 μ m. However, developed technique shows smaller AMAD of 43% at 0.3 μ m than the commercial devices. When the dose conversion factor was considered, it seemed to increase by 6 %. This technique can demonstrate as an alternative to commercial devices from the viewpoint of dosimeter. Thus, the developed technique could be employed in determining size distribution characteristics of attached radon and thoron progeny aerosols for dose assessment study.

6.1.5 The developed technique was tested in field for dose assessment. The experimental results in dose calculations by LUDEP showed that AMAD play a significant role on the particle size distribution of attached radon and thoron progeny. The dose conversion factor from short term measurement due to exposure from inhalation of radon and its progeny shows high dose conversion factor of thoron 4 times than dose conversion factor from radon and its progeny. This study can be

compared with previous reports published elsewhere [43] and effective dose for the workers exposed to radon is about 4-6 times higher than thoron.

Thus, it concludes that this new finding technique and device is suitable for measuring of attached radon and thoron progeny size distribution in the viewpoint of the dosimeter because

- 1) It is a passive device that is easily to handle and operate with DC power,
- 2) It has low cost consumption,
- 3) It is simple to carry for a field measurement,
- 4) It has efficiency good enough to detect radon and thoron progeny alpha particles.

6.2 Suggestions and future studies

Suggestions and future studies are as follow;

6.2.1 There are some experiments that could not be completed during this investigation due to limitation of laboratory facilities such as collection efficiency of impactor stage 1st (10 μm) and stage 2nd (2.5 μm).

6.2.2 The effect of relative humidity, temperature on the measuring sensitivity should be studied in laboratory with hygroscopic aerosols in the future. These factors might play an important role in activity size distribution of attached radon and thoron progeny as well as the mass size distribution studies [73].

6.2.3 In case of using this developing technique to measure attached radon and thoron progeny at different aerosol size conditions smaller than 0.2 μm , the impactor system should have the lowest cutpoint diameter smaller than 0.5 μm to be more effective on AMAD.

6.2.4 The radon and thoron related radiation dose varies considerably. The factors that influence the variability are manifold and not well understood. Among them are radioactive source, particle characteristics, its transport, and behavior patterns on movement. Further studies should be focused to assess the temporal and spatial variation of activity size distribution on seasonal basis of attached radon and

thoron progeny. The particle size distribution characterized by AMAD is a dominant parameter for dose assessment.

6.2.5 For proper dose assessment by LUDEP, the actual parameters, such as unattached fraction, equilibrium factor, AMAD of attached and unattached radon and thoron progeny should be measured at in-situ.

6.2.6 The objective of measurement and monitoring must be to achieve and maintain safe working conditions for occupationally exposed groups and safe environmental conditions for members of the general public. Monitoring must also demonstrate compliance with national dose standards. It should enable the effectiveness of environmental control measures to be evaluated and also provide estimates of exposure suitable for future analysis of epidemiological data. Considering these objectives, monitoring for occupational exposure should combine operational monitoring for control of the workplace with individual monitoring of high risk workers. For non-occupational exposure it is first necessary to identify areas or types of housing with enhanced levels of radon and thoron progeny exposure, for which individual measurements in selected dwellings are required. Subsequent monitoring must then be concerned with achieving or demonstrating compliance with national standards.

Regulation of NORM has not been implemented yet in Thailand. Such type of studies is important to support while preparing guideline of NORM and radiological impact assessment by NORM to industry workers and the public.

6.3 List of publications

6.3.1 Kranrod, C., Tokonami, S., Ishikawa, T., Sorimachi, A., Janik, M., Shingaki, R., Furukawa, M., Chanyotha, S., Chankow, N. "Mitigation of the effective dose of radon decay products through the use of an air cleaner in a dwelling in Okinawa, Japan" *Applied Radiation and Isotopes*, Volume 67, Issue 6, June 2009, Pages 1127-1132.

6.3.2 Kranrod, C., Chanyotha, S., Chankow, N., Tokonami, S., Ishikawa, T., Sahoo, S.K. "Simple Technique for Determining the Equilibrium Equivalent Thoron Concentration Using a CR-39 Detector: Application in Mineral Treatment Industry" *Radioprotection*, Volume 44, Number 5, June 2009, Pages 301-304.

6.3.3 Kranrod, C., Ishikawa, T., Tokonami, S., Sorimachi, A., Chanyotha, S., Chankow, N. “Comparative dosimetry of radon and thoron” Radiation Protection Dosimetry 141 (2010) : 424-427.

6.3.4 Kranrod, C., S., Sorimachi, A., Tokonami, S., Ishikawa, T., Chanyotha, S., Chankow, N., Pattarasumunt A., “A Simple Technique for Measuring the Activity Size Distribution of Attached Radon and Thoron Progeny” The 5th International Symposium on Radiation Safety and Detection Technology (ISORD-5), 15-17 July 2009. Kitakyushu International Conference Center, Kitakyushu, Japan.

