Chapter Three Experimental Techniques

3.1 Introduction

This chapter is devoted to the presentation of the experimental procedure for radiation measurements. A twin radon-thoron dosimeter cup method which is a passive sampling method was used. Indoor radiation concentrations are measured in every floor level to address for radiation as a function of multi floor levels in a building. Various selected units at each floor level are measured to obtain a good sampling of the results and for subsequent averaging and comparison. Households are surveyed on the patterns of their occupancy habits and post-occupancy modification in order to assess for any likely influence of renovation on indoor radiation concentration and the effective dose exposure. Results are presented for the building as a function of floor level as well as individual units per floor level.

3.2 Scope of Measurements

Indoor studies of environmental radiation, namely the total alpha radiation energy concentrations, equilibrium radon concentrations, and equilibrium thoron concentrations, were measured in a multi storey residential building in urban Kuala Lumpur.

The different structures, sizes, localities, and layout of the various buildings, were adding to the diversity and complexity of studying indoor radon concentration patterns in a multi-storey building.

Subsequently when the Apartment Abdullah Hukum Kuala Lumpur (Figure 3.1) was identified, its sheer structural size was befitting a multi storey building indoor radon study. The reasons are as follows:

Firstly, some scientific conveniences arise out of the standardised layout of the units in Apartment Abdullah Hukum, in such that, while housing 600 units of compact sized three-bedroom apartments, all units have been built in the same layout design. The structure is labeled G, 1, 2, to 14, meaning fifteen floor levels in height variations. Subsequent alterations are cosmetic in nature and are merely arising out of the individual renovation works to add to comfort and hygiene of living (Figure 3.2). It was done so by adding new built materials, new furniture and fittings, to the existing barren conditioned apartment units. Such features of the apartment had helped to formulate concise objectives and hypotheses of this study as stated in **Chapter One**.

Secondly, Apartment Abdullah Hukum Kuala Lumpur is located in the Klang Valley, a zone within the City of Kuala Lumpur. This study focuses on the indoor radon concentrations from lower floor level to higher floor level apartment units. Assisting in this end it is a naturally ventilated residential building.

3.3 Passive Sampling Method

Passive measuring method was adopted as opposed to active measuring method as many apartment units and households are involved. With passive measuring method, the solid state nuclear track detectors (SSNTDs) are light-weight and readily prepared in multiple units for immediate employment at the apartments (Figure 3.3).

Environmental radiation is occurring twenty four hours at any time any day. The

Figure 3.1: Apartment Abdullah Hukum, Bangsar, Kuala Lumpur (external outlook).

Figure 3.2: Example of Apartment Abdullah Hukum, Bangsar, Kuala Lumpur (internal furnished spacing).

SSNTDs installed at apartment units would measure continuously over the period of time. The set number of days for retrieval is 30 days and above.

Figure 3.3: SSNTDs applied inside a canister dosimeter, the
'twin radon-thoron cup dosimeter'

3.4 Sampling Priorities

Apartment units for sampling were selected based on residential occupancy criterion, not warehousing or business office, which did not occur in this building evidently.

Priorities were attempted at sampling in the four different orientations of the building, namely, north, south, east, west. Sticker labels were prepared by including information on floor level and building orientation. There were conversations with persons of knowhow on building architecture in which they mentioned changes in building pressure which would be due to temperature differences, while vertical lifts travel may transport pollutants from ground source to the higher floor levels. The staff at management office had facilitated permission for entry into the building. It was respected however that the research and investigation could not ask for direct communication information on the households. As no full list disclosure of households contact details were provided, individual permission had to be inquired.

At the field of study, sampling priorities develop into a focus to sampling at least four units per floor level at the apartment. That gives ten percent of household sampled (60/600), or twelve percent (60/500), as 100 other units were still vacant at time of measurement.

3.4.1 Selection Criteria of Location

Various building related developments have occurred in Kuala Lumpur. Construction and development which entail works in soil excavation and pilling, concrete and cement pouring, which may contribute to radon and its daughter products emanation. Work on indoor environmental radon has not been done before, similar studies of indoor radon dispersion in high-rise building has not been reported in Malaysia.

The apartment selected was completed and resident move-in occurred at about the time the study was initiated in 2007. The apartment is facing a road and a river, with flyover roads right in front of its location. The apartment is L shape in layout. It is an open-air building with natural ventilation attributes.

The geopositioning of apartment is at latitude: 3° 6' 57.5" N, longitude: 101° 40' 46.6" Of the forty units per floor, four apartment units each floor were sampled to cover for all fifteen levels from G to 14th floor. Each unit is identical and has a built up area of 720 square feet. A total of sixty units were sampled between January to May, 2011. Some units were resampled if the returned device were found in a hindered condition.

The sampling was done in three phases in these months from the ground up in gradual. This is due to limited manpower, exposure time required, and the need to recycle the number of equipments also.

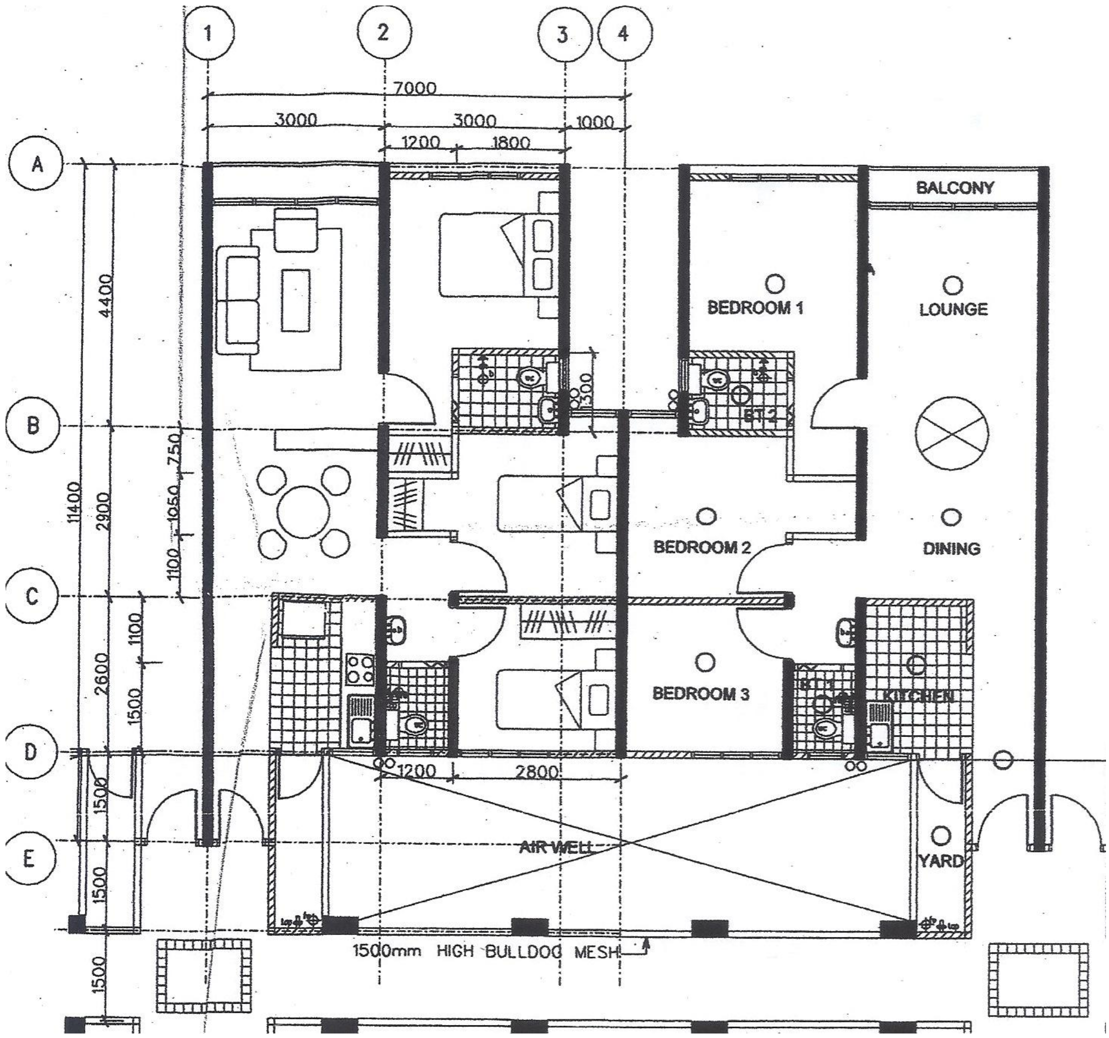

Figure 3.4 Internal layout plan of two neighbouring units
("BEDROOM 2" and "BEDROOM 3" sharing a common apartment building wall)

The main bedrooms (BEDROOM 1 in Figure 3.4) are identified as the biggest, most spacious personal indoor space. They are also where people spend the most time occupying. As is recommended by the EPA, one of the measurements should be made in a bedroom, because most people spend more time in their bedrooms than in any other room in the house (Chapin 1974, Moschandreas 1981, and Szalai 1972). They are also known colloquially as “the master bedroom”, and they are selected for the purpose of sampling throughout the building.

The yard area in every apartment is designed to face an internal air well. The air well runs from the ground floor to the top of the building. A corridor runs through the building, connecting the front entry of all forty apartment units per level on opposite facing.

3.5 Collection of Samples

For measuring low and varying radiation levels, well-calibrated standard dosimeters are available in the passive method. The passive method is simple, reliable and relatively inexpensive equipments. Among the time integrated passive devices, use of SSNTDs are well-accepted and widely used for radon dosimetry. Active methods usually involve digital measurement which can give instantaneous assessment of radiation levels set at per unit of time. Consequently, a data recalculation is necessary to derive representative figure overtime to produce meaningful charts.

Calculation is also made on the inhalation dose absorbed by a human organ provided with the amount of activity retained in the organ and the radionuclide deposited in the internal organ. The dose absorbed, or absorbed dose, is the amount of energy that ionizing radiation deposits in a unit mass of matter (IAEA, 2004). Using the dose conversion models and conversion factors, we estimate the effective dose equivalent to the lung tissues.

3.6 Detail Description of Dosimeter

A canister dosimeter, the ‘twin radon-thoron cup dosimeter’ is used in the present study. It is capable of measuring indoor radon (discriminating against thoron), thoron, and their progeny products. It can also give the measure of potential alpha activity in terms of a special unit called the ‘working level’, from a compartment designed in the outer centre of the canister dosimeter device. The system is a cylindrical plastic chamber divided into two equal compartments, in a canister shaped hand held device, each having an inner volume of 135 cm^3 and height of 4.5 cm. By design, each canister can maximally fix up to three detector films. The detector films, LR-115 Type II pelliculable films are capable of recording tracks of alpha particles resulting from the decay of the isotopes of interest.

The concentrations of radon, thoron and their progeny levels inside the apartments were measured using the twin radon-thoron cup discriminating dosimeter is developed by Bhabha Atomic Research Centre (BARC) in Mumbai, India (Mayya et al. 1998). In brief, one compartment with membrane filter paper diffuses radon, the other compartment of the canister, having a glass fibre filter paper, allows both radon and thoron gases to diffuse, but not their progenies. In this project, each canister is prepared with three pelliculable LR-115 Type II, cellulose nitrate SSNTD film of area size approximately 2 cm x 1.5 cm, for registering alpha tracks. The three strips of SSNTD films are therefore exposed in ‘Bare’, ‘Filter’ and ‘Membrane’ modes. Figure 3.5 shows the twin radon-thoron cup dosimeter system.

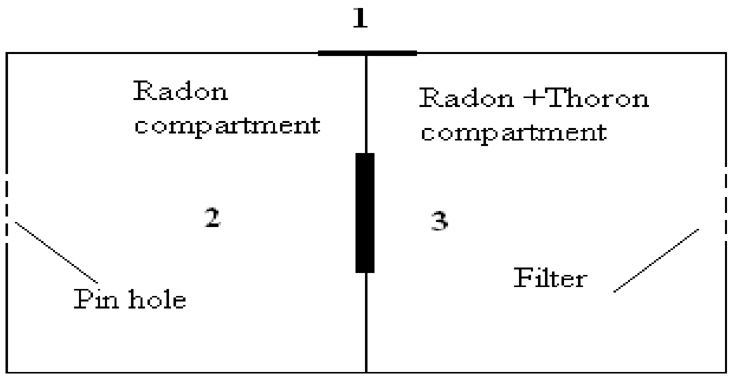

Figure 3.5 Twin radon-thoron dosimeter system

(1) Bare mode SSNTD film, (2) Radon mode SSNTD film, (3) Radon + Thoron mode film.

In the twin cup dosimeter, SSNTD films can be exposed in three modes simultaneously so that levels of radon, thoron and their progeny can be assessed simultaneously. The modes are called (1) Bare mode SSNTD film; (2) Radon mode SSNTD film; (3) Radon + Thoron mode film.

(1) Bare mode SSNTD film

The third detector film exposed to the open is in the bare mode and registers alpha tracks contributed by the concentrations of both gases and their alpha emitting progeny (Prasad et al., 2010).

(2) Radon + Thoron mode film/ the glass fibre filter paper compartment

The exposure of the SSNTD film inside the compartment is termed as the compartment mode. One of the compartments has its entry covered with a glass fibre filter paper which permeates both radon and thoron gases into the compartment and is called the glass fibre filter compartment (Prasad et al., 2010).

(3) Radon mode SSNTD film / the membrane filter paper compartment

The other compartment is covered with a semi-permeable membrane filter paper. This membrane has permeability constant in the range of 10^{-8} to 10^{-7} cm^2/s and allows more than 95% of the radon gas to diffuse while it suppresses the entry of thoron gas almost completely. Thus, the detector film inside the membrane compartment registers tracks contributed by radon only, while that in the filter cup records both radon and thoron.

A shirt hook was glued against a flat surface either on the wall, or wardrobe cabinet. The canister is then mounted on the hook. In some master bedrooms owing to surface availability, it was possible to place the canister on top of the dresser cabinet with bare mode facing upwards.

The canister as such became exposed to the indoor air. In order to prevent surface contamination and overestimation of indoor radon and thoron pollutant, the canister was mounted 10 cm away from nearby wall surfaces.

Both side covers of the radon-thoron twin dosimeter cups were washed and dried with tissue paper. These involved only a simple exercise to warrant dryness and cleanliness of the measuring canisters before usage.

2cm x 1.5 cm pelliculable films were trimmed to size and the cellulose nitrate side of the films each is then applied onto the edges of the radon measuring side of the compartment. In this side of the compartment, glass fibre filter is subsequently applied on the brim of the cover, before the plastic compartment cover is then placed back by means of twisting. A SSNTD film is also applied onto the thoron measuring compartment with membrane filter applied. The centre protruding square of the canister captures physical alpha radiation of radon. It is unscrewed and one SSNTD film is pieced on before the seal is screwed back on to contain its attachment. All canisters are preserved in plastic bags to prevent infiltration and exposure to the air before they are delivered to the field site.

Four canisters were distributed per floor at the apartment. In total, 60 were deployed and fixed in bedrooms.

3.7 Processing of SSNTD Film Samples

The equipments used at the radiation lab involved a spark counter, double wall beakers and concentrated NaOH solution.

Canisters were exposed in the bedrooms from 30 to 50 days. Retrievals of the canisters were done on the thirtieth day onwards. During retrievals, some accidents observed were canisters had fallen off together with the adhesive wall hook. Some canisters were retrieved with missing fibre or membrane filter paper, likely due to tamper by unknowing members of the household. They were sent back to the households for sampling again with new SSNTD films applied.

Etching is a process of analyzing the registered tracks by treating the exposed SSNTD films with an alkali solution. The alkali solution used is 2.5N of NaOH. The prepared alkali solution is poured into a double wall beaker. The double wall beakers are used for the thermostatisation of liquids. When the temperature of the NaOH bath solution has reached 60^{o}C, the SSNTD films arranged in a casket are inserted in place for etching. The temperature of the alkali solution is set at 60^{o} C and the etching process is 60 minute under mild stirring of the alkali solution. These processes were performed in the environment of the Research Lab of Advanced Physics, Fatima Mata National College, Kerala, India.

After etching, the exposed films are removed from the alkali solution and put into a beaker containing flowing distilled water for washing. After a few rounds of washing the films are dried using a tissue paper and the films are removed from its base using tongs. The etched films are then counted for the tracks registered using a spark counter after studying its performance characteristics.

The SSNTDs suitable for spark counting consist of Kodak LR-115 Type I and Type II films. They are respectively 6 µm and 12 µm in thickness. The film-like LR-115 SSNTDs are produced of cellulose nitrate, coloured deep red, and coated onto 100 µm thick polyester backing. In this project, Type II film is used for its pelliculable traits.

Upon etching, the SSNTDs are transferred to the spark counter workstation to calculate the track density (number of tracks per cm^2) using the spark counter. The calibration factor then allows us to convert track density into Bq/m^3 for, radon, and thoron concentration, and m/WL for PAEC. Using the gas concentration and equilibrium factor, occupancy factor, effective dose equivalent is calculated with a focus on the inhalation dose.

The spark counter utilizes a spark counting technique and it is automatically scanning and counting solid state nuclear tracts. The SSNTD is placed on a thick conductive electrode, and covered in contact with aluminized plastic foil. Through the tract holes, electrical discharge on spark takes place throughout when a high voltage is applied across the capacitor C. The voltage pulse produced across a load resistor can easily be counted electronically by the spark counter. A second spark does not occur in a same tract hole, due to the evaporation of the aluminium in the electrode. The spark randomly jumps until all tract holes are counted. Furthermore, the aluminium replica can be counted under a microfiche reader or an optical microscope. The voltage applied is 400 to 600 V. A higher voltage is necessary for punching out tracts that are not completely etched through.

3.8 Formula Derivations of Radon, Thoron Gas Concentrations, Inhalation Doses, and PAEC

The concentrations of radon and thoron gases were estimated using sensitivity factors as obtained from past calibration experiments[3,4] (Mayya et.al., 1998, Jojo et al., 1995). The dose conversion factors reported by UNSCEAR (2008) have been used to estimate the annual indoor inhalation doses. Annual effective dose equivalents (mSv/ y) for radon EDE_R and that for thoron EDE_T were calculated using the formula (Mayya, Y.S. et al. 1998):

$$EDE_R = EEC_R \,.\, DCF_R \,.\, OF \quad \text{-----} \ (1)$$

$$EDE_T = EEC_T \,.\, DCF_T \,.\, OF \quad \text{-----} \ (2)$$

where EEC_R and EEC_T are the equilibrium equivalent radon and thoron concentrations (Bq/m^3).

The radon and thoron dose conversion factors are:

$$DCF_R = 9 \text{ nSv/h Bq/m}^3 \text{ and}$$

$$DCF_T = 40 \text{ nSv/h Bq}^/\text{m}^3$$

OF = 7000 h is the occupancy factor, i.e., hours of indoor air exposure per year. For calculation of the equilibrium dose equivalent, the equilibrium factors of 0.1 for radon and 0.4 for thoron were used. The sums of both EDE equations (1) and (2) henceforth add up to the total EDE.

Separately, the Potential Alpha Energy Concentration, C_p, in units of mWL was calculated using the equations (Ramola et al., 1996, and Eappen and Mayya, 2004);

$$C_p = \rho/Kt \qquad \text{------- (3)}$$

where ρ is the track concentration in cm^{-2}, K is the calibration factor taken to be 0.25 tracks cm^{-2}/WL, a value normally adopted for the detector used, and t is exposure time.

The radiological concentrations of radon and thoron were calculated using the the following equations (Sonkawade et.al., 2005, Sannappa et.al., 2003, and Mayya et.al. 1998);

$$C_R(Bqm^{-3}) = \frac{T_m}{d \times S_m} \qquad \text{-----------(4)}$$

and

$$C_T(Bqm^{-3}) = \frac{(T_f - d \times C_R \times S_{rf})}{d \times S_{tf}} \qquad \text{-----------(5)}$$

Where C_R is radon concentration while C_T is thoron concentration. T_m is track density in membrane compartment, and T_f is track density in filter compartment and d being exposure time.

At the lab, three scans of the films were carried out using a spark chamber. In the case of some exposed SSNTD films, consistent data reading was obtained, 20, 20, 20, and so indeed averaging out to be 20. On the other hand, minimal erratic reading was also observed, 44, 46, 49, thus averaging out to be 46.3. Lastly, there was no occasion of extreme deviation, which would otherwise then be misleading. The proper action would be to disregard the deviant reading and scan a fourth time, before averaging for final output on that film.

3.9 Survey Administration

A brief questionnaire to collect data on housing characteristics was also included with each detector. This questionnaire obtained data on the condition of ventilation of the bedroom on which measurement was made, and construction materials used on the wall and floor. Some practices may stir up more radon exhalation and radon activity.

END.

Built material samples on soil, sand, bricks, marble and cement measured for their radon exhalation may be varying but do not pose health hazards and are safe alternatives of construction materials with their exhale of radon occurred at low level (Faheem and Matiullah, 2008).