MEASUREMENT OF RADON, THORON AND THEIR PROGENY CONCENTRATIONS IN MIZORAM WITH SPECIAL REFERENCE TO AIZAWL, CHAMPHAI AND KOLASIB DISTRICTS

(Synopsis of the proposed research for the Ph.D. degree under Mizoram University)

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INTRODUCTION

In view of the fact that radon, thoron and their progeny concentrations contribute the most to the natural radiation dose to general populations, large scale and long-term measurement of radon, thoron and their progeny concentrations has been receiving considerable attention (Mayya et al., 1998). Radon and thoron present in outdoor and indoor air as they exhaled from soil and building materials. It is critically important that inhalation of radon and their progeny concentrations has been shown experimentally to cause lung cancer in rats and observed to cause lung cancer in men exposed to large amounts in the air of mines. Even though measurement of radon, thoron and their progeny concentrations was done over the past 50 years in many countries, with the improvement of experimental apparatus and technical formulation, the same is going on till today. With these improvements, monitoring of radon, thoron and their progeny concentrations are well correlated with the prediction of earthquakes (Ramachandran et al., 2004). Fault region also plays vital role in the out gassing process of radon and thoron from soil. The measurement of radon, thoron and their progeny concentrations also leads to the knowledge of the presence of radioactive elements, which are the sources of these elements. Since Uranium-238 is the parent nuclei of Radon and Thorium-232 that of Thoron, hence with the concentrations of these gases in air, one can predict the presence of high or low concentrations of the source radioactive elements.
In India, measurements of these concentrations have been done for the past many years which were undertaken by Environment Assessment Division (EAD), Bhabha Atomic Research Center (BARC), Mumbai (Ramachandran et al., 2003). With these results conditions of some places, mines, etc. can be studied well. In North-East India, in spite of its geological and seismic characteristics the radon data remained almost unrepresented (Dwivedi and Ghosh, 1991).

Radon is a natural radioactive gas that occurs ubiquitously throughout the world. Radon having an atomic number of 86, is a colourless, odourless, tasteless and radioactive noble gas that generally lacks activity towards other chemical agents. It is the heaviest member of the rare gas group (∼100 times heavier than hydrogen and ∼7.5 times heavier than air) and has a half life of 3.82 days. It is denoted by $^{222}\text{Rn}$. Thoron is an isotope of radon, it has atomic number 86, mass number 220 and half life of 55.3 seconds (Pillai and Paul, 1999). It is denoted by $^{220}\text{Rn}$. The main characteristic of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ among other natural radioactive elements is the fact that their behaviour is not affected by chemical processes (Nazarof, 1988). In addition, their concentration levels depend strongly on geological and geophysical conditions, as well as on atmospheric influences such as barometric pressure and rainfall. Formed as a result of the natural radioactive series in the earth’s crust they are free to move through soil pores and rock fractures; then to escape into the atmosphere. $^{222}\text{Rn}$ and/or $^{220}\text{Rn}$ exhaled from the earth’s surface into the free atmosphere is rapidly dispersed and diluted by natural convection and turbulence. When a dwelling is present, they may migrate into this structure and accumulate indoors in sufficient quantities to pose a health hazard.

Radon and thoron decay with the emission of alpha particles and produce daughter nuclei – polonium, lead and bismuth. These daughter nuclei emit alpha or beta particles.
Among these daughter nuclei, $^{218}$Po and $^{214}$Po from $^{222}$Rn and $^{216}$Po and $^{212}$Po from $^{220}$Rn have short half life, and these are the progenies which are under consideration.

The present work tries to explore the concentration of radon, thoron and their progeny in Mizoram with special reference to Aizawl, Champhai and Kolasib Districts which will supplement the mapping of concentration of these gases in Mizoram. In this experimental work, indoor concentrations are measured using solid state nuclear track detector (SSNTD). The activities of the source radioactive elements viz., uranium and thorium for the considered gases in soil are measured using NaI(Tl) detector in which soil samples are collected and analyzed. This will be used to understand the deposition of the mentioned radioactive elements in Mizoram and can be well correlated with the concentrations of radon and that of thoron in dwellings. Measurement of radon and thoron concentrations will be carried out using twin cup dosimeters inside which a detector, LR-115 films are mounted. In these films nuclear tracks will be formed due to alpha particles decay from the measured radioactive gases which will then be analyzed. The progeny concentrations of these gases will be measured using direct progeny sensor (DPS) mounted along with the twin cup dosimeters.

**SCOPE OF THE PRESENT STUDY**

The measurement of radon/thoron concentrations has covered some of the states in India and work has been in progress in studying radon and thoron in soil gas, ground water and in correlation to earthquake. The status of some part of India has been not only determined but continuous monitoring is also in progress. While in Mizoram, even though some previous studies had been done including only 17 houses, this is far less than the required data to show the exact status of the state. The work regarding measurement of the concentration of these gases is still in the initial stage. There exist no data available for the
study of inhalation doses of these gases contained in the inhaled air in the dwellings and for the study of deposition in the soil.

The present work will help in understanding the status of indoor and outdoor radon, thoron and their progeny concentrations and status of the exhalation of these gases from soil. This will extensively help in finding out the contribution of the building materials (Rohmingliana et al., 2009) used for dwellings to the radon, thoron and their progeny concentrations besides the atmospheric air and will also further enable the determination of the activity and type of radioactive elements in and around the dwellings. This will help in contributing the status of Mizoram in the mapping of radon in India.

**REVIEW OF LITERATURE**

A perusal of the available literature on the various studies of radon, thoron and their progeny concentrations reveals some features. Although there exist is a wide range of study for this kind of work in global level with different approach to various conditions, very little has been done in Mizoram. Measurement in various countries yields a vast body of data. Studies have been done with the approach of correlation to lung cancer (epidemiological studies), earthquake prediction, deposition of radioactive elements in soil and also to the upgradation of instruments and formulation for the same.

The first major studies of the health concern occurred in the context of uranium mining, first in the Joachimstal region of Bohema and then in the Southwestern United States during the early Cold War. Because radon is a product of uranium, uranium mines may have high concentrations of radon and its highly radioactive daughter products. Many uranium miners in the Four Corners region contracted lung cancer and other pathologies as a result of high levels of exposure to radon in the mid-1950s. The danger of radon exposure in
dwellings was discovered in 1984 with the case of Stanley Watras, an employee at the Limerick nuclear power plant in Pennsylvania (Nazarof, 1988).

Building materials’ radon exhalation rate has been studied by The Nuclear Engineering Section of the National Technical University of Athens (Petropoulos et al., 2001), Investigation of the influences of atmospheric condition on the variability of radon and progeny in buildings has been done in Northampton, UK (Marley, 2001) and Particle deposition onto surfaces of building materials has also been studied (Lai, 2004). In Japan, work has been in progress for the study of thoron chamber and interference of thoron on radon measurements (Tokonami, 2008). The concentrations of radon, thoron and progeny deviate from place to place and depend on the building material in case of indoor concentration. In India, Ranu et al. (1990) had initiated indoor radon measurements in some dwellings of 15 towns which were specially selected on the basis of high uranium content in the soil. Radon Monitoring has been done in Haryana by Kant and Chakravarti (2004) and found indoor radon levels in dwelling of Harayana to be 40 – 134 Bq/m$^3$ in Cemented House. Studies of radon and thoron levels in Mysore City have also been done and radon concentrations were found within 33 Bq/m$^3$ in more than 50% of the dwellings studied (Chandrashekara and Paramesh, 2008). In Mizoram, measurement of radon, thoron and their progeny concentrations were done only in 17 dwellings (Ramachandran et al., 2003).

As for the correlation with earthquakes, by continuous monitoring of radon concentration in a specific area, there has been a high deviation on the concentration of radon before or after the earthquake. Radon anomalies were observed prior to earthquakes in California in 1979, in Japan at Kobe in 1995, in China at Tangshan in 1976, etc (Ramachandran et al., 2004). In India, Guru Nanak Dev University, Amritsar and Palampur Station, Himachal Pradesh which has continuously monitored radon concentrations reported
that their data recorded shows 25 anomalies correlated to earthquakes in the region (Virk, 1994). Both Chamobi and Bhuj earthquake that occurred in March 29, 1999 and January 26, 2001 respectively were postdicted by correlation of radon anomalies recorded at Palampur in the soil-gas and ground water (Ramchandran et al., 2004).

Several techniques are in use to measure the radon/thoron levels in air. This includes their collection on a filter paper and subsequent alpha counting. Several personnel dosimeters employing tracks detectors have also been developed. These techniques have been increasingly used for the measurement of radon or thoron in soil gas, uranium exploration, earthquake predictions and geological studies. The nuclear track detector technique is the most reliable method for the integrated and long-term measurement of indoor radon activity (Ramu et al., 1992).

Frank and Benton (1977) studied the improvement of two-detector devices, where one detector is placed open, and the other is placed inside the chamber closed with an inlet filter. By this method they propose the possibility to determine the equilibrium factor. Twin cup dosimeter was developed, in which membrane is use to filter the inlet of radon chamber.

Eappen (2005) comes out with the improvement of twin cup dosimeter, where membrane filter was replaced by a pinhole cap of the radon chamber. In this, one pinhole is used to block the entry of radioactive nuclides other than radon. In 2009, this pinhole cap was again improved by replacing it with 4 holes.

For the correct choice of the design of a radon and thoron measuring device using track detectors, it is necessary to have information about the response of the detector to radon and its progeny. The mathematical basis for calculation of these dependencies was first developed by Fleischer and Mogro Campero (1978). Several theoretical papers, based
on various calculation techniques to obtain the response of detectors and elements of design, have been reported.

A detailed exploration of the relevant literature will be presented in the final thesis.

**OBJECTIVES**

1. To find out the seasonal concentrations of indoor as well as outdoor radon, thoron and their progeny in Mizoram.

2. To determine the soil radioactivity around the dwellings as well as in available building materials.

3. To correlate the concentrations of the mentioned gases in indoor air with the type of buildings and soil radioactivity. Further, the concentrations of the measured gases will be correlated with the geological location of that particular place.

**METHODOLOGY**

**Theory**

Radon and thoron atoms decay producing isotopes of polonium, lead, and bismuth. These elements are heavy metals chemically very active, which may exist briefly as ions and/or free atoms before forming molecules in condensed phase or attached to airborne dust particles, typically to those with a sub-micron range of sizes, forming radioactive aerosols. This fraction may be inhaled and deposited in the respiratory tract, in which they release all their α-emissions. These emitted alpha particles are used to calculate the actual concentration of the parent atom. The alpha particles can be registered using a special detector called LR-115 film in which tracks are produced. The track density is then used to calculate the concentration of that particular gas producing the α-emissions using the following formulae.
The Formula used for calculating radon concentration is given as (Mayya et al., 1998)

\[
C_R (Bq/m^3) = \frac{T_P}{\text{Calibration factor} \times \text{Exposure period (days)}}
\]  

(1)

where \(C_R\) is the radon concentration in \(Bq/m^3\) and \(T_P\) is the track density of films (Tracks/cm\(^2\)) in pinhole compartment. Calibration factor is the quantity, which is used for converting the observed track density rates to the activity concentrations of the species of interest.

For calculating Thoron concentration the following formula was used.

\[
C_T (Bq/m^3) = \frac{T_F - T_P}{\text{Calibration factor} \times \text{Exposure period (days)}}
\]  

(2)

where \(C_T\) is the thoron concentration, \(T_F\) is the track density of films in filter compartment and \(T_P\) is that for pinhole compartment.

The content of source radioactive elements especially uranium and thorium in the soil and building material can be determined using Gamma Spectrometer.

**Experimental Methodology**

In the present experimental work, for indoor measurement a special detector film, particularly suitable for the spark counter, manufactured by Kodak under the trade name LR-115 is used. This detector consists of thin films of cellulose nitrate \(\{(C_8H_{10}O_5)_n\}\) coloured deep red and coated on a 100\(\mu\)m thick polyester backing. These detectors are kept inside a twin cup dosimeter, a cylindrical plastic chamber divided into two equal compartments (Nambi et al., 1994), each having an inner volume of 135cm\(^3\) and height 4.5cm. The two equal compartments on both sides are filter and pinhole compartments. There is one small compartment at the external middle attached to it which is used for bare mode exposure. Films are then inserted at the three compartments by which tracks are
recorded. In the filter cup, filter paper is used to cover the entry point of the compartment blocking the entry of the progeny while it allows both radon and thoron gas to pass through (Eappen, 2005). In the pinhole side, we have a pinhole in which radon gas only pass through. One filter paper is used to cover the entry point to block the progenies. In bare mode, as is clear from its name, the film is being exposed barely to the environment and tracks on it are due to radon gas, thoron gas and their progenies. Dosimeters are hanged overhead on the ceiling at the height of minimum 1.5m from the floor and at least 10 cm away from any surface for a minimum of 90 days. The exposed dosimeters are taken for analysis and replaced with new ones for the next deployment. To have seasonal variations in concentrations of these gases particularly during rainy, winter and summer seasons in a year, these dosimeters will be exposed in each season for about four months. During deployment and retrieving of these dosimeters, background gamma radiation at ground level and 1m height inside and outside the house are measured using survey meter (Vanchhawng et al., 2009). The variation of background gamma radiation will also help in tracing the origin of these radiations viz. whether it is cosmic of terrestrial. The room size, distance of the dosimeter from roof, wall and floor, and size of the ventilations present at that specific room are measured. The number of windows, ventilations and doors are also counted. This contributes to the ventilation rate of air inside the specific room.

The exposed films are then etched in an etching bath using 2.5N NaOH solution at 60°C for 90mins during which 4µm thickness is etched away. Etching of the film is necessary because the tracks produced on the films are visible for counting only after etching. The tracks recorded in this SSNTD films are then counted using a spark counter, which is an electronic counter operating on high voltage. Direct progeny sensors viz., direct
radon progeny sensor (DRPS) and direct thoron progeny sensor (DTPS) are used to monitor the progeny concentrations and are used to find the equilibrium factor.

For measuring the source radioactivity element content of soil, samples are taken from around the dwellings where dosimeters are hanged. These samples are then powdered into a small particle sizes and packed in a sealed container which are kept for at least 30 days in such a way to obtain secular equilibrium between radon and thoron with their parent nuclides before counting. The samples are placed inside the NaI(Tl) detector which is previously calibrated using standard radioactive sources. 1K MCA is used to monitor the content of uranium, thorium, potassium, etc. Monitoring of each sample is carried out as long as a minimum of 30,000 seconds. Spectrum obtained in the 1K MCA is used to obtain the net peak area for each nuclide. From this net peak area, the activity can be calculated using the following formula.

\[
\text{Activity} = \frac{\text{Net Peak Area}}{\text{Counting Time} \times \eta} \ (Bq/g)
\]

where \( \eta \) is efficiency obtained using standard source, counting time is in second.

The same procedure is used for measuring the radioactivity of different building materials.

**Classification for measurements**

As there are many factors influencing the concentration of radon, thoron and their progeny, the following factors are taken under consideration for the present work.

1. **Geographical Conditions**

   Locations are selected carefully taken into consideration the geographical conditions of the place/area which are then sub-divided as follows:
a) **Fault Region**

These are the region where faults are observed. These places are located using the available geological mapping of the state. Since outgassing of the interested gasses increase in the area where there is fault hence, the study of concentration of these gases in these areas will be important.

b) **Fossils area**

The other selected geographical condition is the areas where there are fossils. For example, in Aizawl District, fossils are found in Hiimen Quarry.

c) **Dwellings**

The third selected areas are places where no geological distinctiveness like fault or fossils regions are indicated and they may be treated as having normal soil. These areas covered mostly the habitats/dwellings in Mizoram.

2. **Types of Houses**

Another important factor that influences especially the concentration of indoor radon, thoron and their progeny is the types of houses. As the building material contributes the indoor radon and thoron concentration, hence the material used for roof, wall and floor and elevation of the building from the ground are considered for selection of houses. The types of houses selected are categorized as follows:

a) **Reinforced Cement Concrete (R.C.C.)**

The building material used for this type is cement concrete reinforced using iron rod. Hence, roof and floors are all made up of the same, while wall material is usually of bricks. However, the construction of this type of building may not be fully concrete at all. In such cases, the type of material will be indicated clearly whether the roof, wall or floor material is made of different materials.
b) **Assam Type**

In this type of house, roofs are G.I.Sheets, walls are mostly made up of asbestos (tile) while some are wooden and bamboo. Floors are mostly concrete while some are wooden.

c) **Thatched**

In this type of house, roofs are thatched with sungrass, walls are made of bamboo and floors are mostly bare using the ground itself while some are bamboo.

While the first two house types are very common in the studied areas, the third type of house construction is almost nil except in remote rural places due to the modernization of construction of houses.

**ORGANISATION OF THE THESIS**

The tentative arrangement of the thesis in the form of chapters will be as follows:

**Chapter 1:** This chapter will contain the complete introduction of the present studies. It will also include the review of literature related to the present research work.

**Chapter 2:** This chapter will contain the theoretical formulae used in the research work. A complete methodology will also be given in this chapter.

**Chapter 3:** This chapter will contain the experimental calibration and determination of operating points of the instruments used which will be followed by the details of results obtained from the experiments carried out in the present study.

**Chapter 4:** This chapter will include the possible and even critical discussion on the results obtained in the present investigation.

**Chapter 5:** This chapter will present the conclusion that could be drawn out of the present research work.

This will be followed by references, appendices, etc.
REFERENCES


Concentrations in Correlation to Geographical Location and Construction types of Buildings in Mizoram (with special reference to Aizawl, Champhai and Kolasib Districts). *Proc. VI*\(^{th}\) *Conference of Physics Academy of North East*, Tripura University, April 3-4.


