Measurement of Indoor Radon and Thoron using Single entry Pin-Hole Dosimeters in the dwellings of Bathinda District of Punjab, India

Kirandeep kaur, Mannmohan Singh Heer, Rohit Mehra, H. S. Sahota

Abstract— An indoor radon and thoron study has been carried out in 24 dwellings of 8 villages situated in Bathinda district of Punjab, using LR-115 type II nuclear track detectors installed for three months in four seasons covering a period of one year. Indoor radon values varied from 7.20 to 47.39 Bqm$^{-3}$ in rainy, 38.24 to 59.80 Bq m$^{-3}$ in winter, 9.64 to 63.07 Bq m$^{-3}$ in spring and 2.61 to 79.08 Bqm$^{-3}$ in summer time with an average values of 30.70, 49.44, 30.97 and 21.80 Bq m$^{-3}$ respectively. Indoor thoron concentrations varied from 31.11 to 150.51Bq m$^{-3}$ in rainy, 76.67 to 177.22Bq m$^{-3}$ in winter, 7.22 to 197.78 Bq m$^{-3}$ in spring and 34.44 to 217.78 Bq m$^{-3}$ in summer time with an average values were found to be 78.73, 120, 101.85 and 86.49 Bq m$^{-3}$ in the corresponding seasons. The average annual effective dose to the residents in dwellings for radon and thoron is 0.96 and 2.44 mSv y$^{-1}$ respectively.

Index Terms — Annual Effective dose, Nuclear track detectors, Radon, seasonal variations, Thoron.

INTRODUCTION

Radon possess three naturally occurring radioactive isotopes namely $^{220}$Rn (Thoron), with half-life of 55.6s, $^{222}$Rn (Actinon) with half-life of 3.96s and $^{226}$Rn with half-life of 3.8 days [1]. As short lived $^{219}$Rn has low activity in the environs, only $^{222}$Rn and $^{226}$Rn shows their presence in indoors. The World Health Organization [2] recognized radon exposure as the second major cause for lung cancer, after smoking. Radon and thoron originates from uranium ($^{238}$U) and thorium ($^{232}$Th) respectively, which is present in the earth’s crust in variable concentrations [3]. The estimated world average of annual effective dose to the human beings by natural radiation is 2.4 mSv y$^{-1}$ and about 50% of which is due to internal exposure of radon and thoron progenies [4]. This grasps the essence of extensive radon measuring campaigns and epidemiological studies made in the previous decades [5]. Radon ooze out from the earth’s surface through its production point, where it resides in the environs including our homes, offices and other workplaces especially in the buildings having uncovered floors (mud floorings). Along with radon, thoron also plays a vital role in the risk evaluation [6]. As radon is a gas, its decay products form a very fine dust, which is toxic and radioactive in nature. It may potentially stick to the sensitive lung tissues by inhalation and do heavy damage than radon itself [7]. Various studies revealed that occupationally radon exposed miners and direct observation from the individuals exposed to indoor radon in their houses provide a firm scientific foundation which proves that radon is a major environmental carcinogen [8][9][10][11]. Previous studies done all over the world shows that systematic and well planned measurements of indoor radon and thoron concentration are necessary to calculate the actual levels and effective dose due to exposure of indoor radon and thoron. In the last years the interest to thoron ($^{220}$Rn) is also increasing [12] [13]. The present study is aimed to measure the radon and...
thoron concentration and annual effective dose in
the selected dwellings of 8 villages of District
thoron levels with different building construction
materials and ventilation conditions of the rooms of
all dwellings.

GEOGRAPHY OF STUDY AREA
The selected area Bathinda is a district of Punjab
state which is situated in the northwestern
region of India. The exact co-ordinates of Bathinda are
30.20°N 74.95°E with an average elevation of 201
meters from the sea level. Its climate corresponds
to high variation between summer and winter
temperatures.

BUILDING CHARACTERISTICS
For radon and thoron measurements, one room in
each of the 24 dwellings was randomly selected
from the type of living room, kitchen, bedroom etc.
All the selected dwellings were constructed using
cement, concrete, marble and bricks. Most of the
dwellings were partially ventilated and had single
storey. During summer ceiling fans were used in
most of the rooms and only few used air
conditioners and air coolers.

MATERIALS AND METHODS
Single entry pin-hole based detector was used to
measure the concentration of radon and thoron in
the indoor environment. The detector has two
identical cylindrical chambers each having length
of 4.1 cm and radius 3.1 cm and are separated by a
pinhole based $^{222}$Rn/$^{220}$Rn discriminating plate.
Radon and thoron enter the first chamber, called
“radon + thoron” chamber, through a filter paper
which filters out the decay products of radon and
thoron. However, only radon diffuses into the

Bathinda, Punjab. An attempt has been made to
find possible relationships of indoor radon and
second chamber, called “radon” chamber, through
four pin-holes of discriminating plate which cut off
thoron due to its short half-life. Therefore, the LR-
115 film kept in the ‘radon + thoron’ chamber
registers the alpha tracks due to both radon and
thoron and their progeny, while the LR-115 film in
the ‘radon’ chamber registers the alpha tracks only
due to $^{222}$Rn and its progeny. The use of multiple
pin-holes of reasonably small radius minimizes the
effect of turbulence on $^{222}$Rn/$^{220}$Rn transmission
factors so that the calibration factor remains
independent of indoor turbulence [14].

These detectors, keeping LR-115 Type-II films
of size 3×3 cm, were suspended in the selected
rooms at a height >200 cm above the ground level
(so that the detectors remain undisturbed by the
random movement of the residents) and about 50-
60 cm below the ceiling of the room. The detectors
were mounted along the corner of the room about
80 cm away from the two adjacent walls. After the
completion of exposure period of 90 days, films
were removed from the both chambers and etched
using 2.5 N NaOH solution at 60°C for 90 minutes.
After this chemical treatment, the etched films
were thoroughly washed and dried. The registered
tracks were counted using spark counter. Average
concentrations of radon and thoron were calculated
by using the following equations [14]
\[ K_{R,1} = \frac{T_{R,1} - B}{tC_R} \]  
\[ K_{T,1} = \frac{T_{T,1} - B}{tC_T} \]

Here \( K_{R,1} \), \( K_{T,1} \) are the calibration factors, \( K_{R,1} = 0.017 \text{ tr. cm}^{-2} (\text{Bq m}^{-3} \text{ d})^{-1} \) in ‘radon’ chamber, \( K_{T,1} = 0.01 \text{ tr. cm}^{-2} (\text{Bq m}^{-3} \text{ d})^{-1} \) in ‘radon + thoron’ chamber, \( T_{R,1} \) is total track density (tr. cm\(^{-2}\)) in detectors for radon in ‘radon’ chamber, \( T_{T,1} \) is track density (tr. cm\(^{-2}\)) of thoron in ‘radon + thoron’ chamber, \( B \) is the background track density for unexposed LR-115 films (about 4 ± 2 tr. cm\(^{-2}\)). \( C_R \) and \( C_T \) is the entry face concentration (Bqm\(^{-3}\)) of radon and thoron and \( t \) is exposure period [14].

The annual effective dose due to the exposure to radon, thoron and their progeny in the dwellings of study area were calculated using the following relations [4]:

Annual effective dose from radon and its progeny  
= \( C_R \) (Bq m\(^{-3}\)) × 0.46× 7000h × 9 n Sv (Bq h m\(^{-3}\))\(^{-1}\)

Annual effective dose from thoron and its progeny  
= \( C_T \) (Bq m\(^{-3}\)) × 0.09× 7000h × 40 n Sv (Bq h m\(^{-3}\))\(^{-1}\)

**RESULTS AND DISCUSSION**

The seasonal variations of radon and thoron concentrations for 24 dwellings of 8 villages (Three in each village) are summarized in Table 1. The radon concentration varied from 7.20 to 47.39 Bqm\(^{-3}\) in rainy, 38.24 to 59.80 Bq m\(^{-3}\) in winter, 9.64 to 63.07 Bq m\(^{-3}\) in spring and 2.61 to 79.08 Bqm\(^{-3}\) in summer. The average values over all the 8 villages (24 dwellings) for the corresponding seasons were found to be 30.70, 49.44, 30.97 and 21.80 Bq m\(^{-3}\) respectively. Thoron concentration varied from 31.11 to 150.51 Bq m\(^{-3}\) in rainy, 76.67 to 177.22 Bq m\(^{-3}\) in winter, 7.22 to 197.78 Bq m\(^{-3}\) in spring and 34.44 to 217.78 Bq m\(^{-3}\) in summer time and the average values were found to be 78.73, 120, 101.85 and 86.49 Bq m\(^{-3}\) respectively. It can be seen that radon and thoron concentrations for most of the dwellings are higher in winter than in summer. This is because of escape of radon and thoron due to high ventilation conditions (opened doors and windows) in dwellings and use of electrical appliances like fan, cooler and air conditioner in summer. In winter, the ventilation conditions were poor, as doors and windows remained closed and electrical appliances were turned off for all the time. The average annual concentration of radon over all the seasons and all the 8 villages is obtained as 33.23 Bqm\(^{-3}\), which is less than the lower limit of the action level (200-300 Bq m\(^{-3}\)) recommended by International Commission on Radiological Protection [15]. It is also lower than that of the world average value of 40 Bqm\(^{-3}\)[4] and the action level (100 Bqm\(^{-3}\)) recommended by World Health Organization [16]. The average annual effective dose of radon and thoron is found to be 0.96 and 2.44 mSv respectively. In all the villages, the annual effective dose received by the occupants is less than the lower limit of the recommended action level 3-10 mSv y\(^{-1}\) (ICRP, 1993) [17].
Table 1: Seasonal variation of concentration of radon and thoron and corresponding average annual effective dose.

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Notes:
- $C_R$ and $C_T$ represent the concentration of radon and thoron, respectively.
- The values are given in Bq m$^{-3}$ for radon and Bqm$^{-3}$ for thoron.
- The annual effective dose is calculated based on the seasonal concentration values.
Table 2 The Building construction materials, ventilation conditions in 48 dwellings of 12 villages.

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V.C : ventilation condition  
I: poorly ventilated,  
II: partially ventilated,  
III: well ventilated

H1: (Floor: Brick, Roof: Brick)  
H2: (Floor: concrete, Roof: bricks & white wash)  
H3: (Floor: concrete, Roof: concrete)  
H4: (Floor: marble, Roof: Brick & POP)  
H5: (Floor: Tile, Roof: bricks)
Table 2 shows the building construction materials and the ventilation conditions for all the 24 dwellings. The radon and thoron concentration levels in well-ventilated dwellings are lower as compared to poorly ventilated dwellings. This is because radon and thoron can easily escape out of the well-ventilated dwellings. Here a dwelling with one door and no window is considered as poorly ventilated, with one door and one window is partially ventilated and with more than one door and window as well ventilated.

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