AN INNOVATIVE METHOD FOR MITIGATION OF INDOOR RADON

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Abstract. Radon (Rn) mitigation techniques and radioactivity control in house are well-established. Majority of these techniques apply to detached and semi-detached houses, where the earth beneath the structures serves as the primary source of Rn. For the place of Bangalore city, indoor Rn and Tn (thoron) concentrations have been measured using solid state nuclear track detector-based dosimeters. Observations were recorded with and without formica laminated material (a composite material) on the room walls. After a month, the measured concentrations of Rn (^{222}Rn) and Tn (^{220}Rn) were 43.5 and 28.6 Bq m^{-3} without any coatings and 12.9 and 9.7 Bq m^{-3} with a thin sheet of formica laminated material. For the same measurements the dose rates of Rn and Tn were 0.5 and 0.2 mSv y^{-1}, respectively. According to the preliminary study, formica laminated material on the walls caused a concentration drop more than 50 %.

Key words: Exhalation, Radon, Thoron, concentrations, reduction, dose rate. de rând, de 2 ori

INTRODUCTION

The radium isotopes ^{226}Ra and ^{224}Ra, produce the short-lived decay products Rn (3.82 d) and Tn (55 s), respectively. Exposure to the radiation emitted by these two elements is unavoidable because they are primordial radioactive elements naturally occurring in the environment. Numerous studies have demonstrated that prolonged exposure to Rn is hazardous to human health increasing the risk of lung cancer [26]. It is estimated that exposure to Rn and its decay products causes annual average effective dose as 1.3 mSv y^{-1}, whereas the annual effective dose from worldwide natural radiation sources is 2.4 mSv y^{-1} [26].

The effective dose from breathing Rn and its decay products is even higher, according to some researchers [18]. The main sources of indoor Rn, according to WHO [27], are ventilation, building materials, and soil gas infiltration. Cracks in concrete floors and walls, drainage pipes, connecting parts of buildings, heating,

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ventilation, and air conditioning ducts are the possible routes through which Rn can enter into indoor environments [25]. Although the ground is the primary route for Rn to enter a home, Shahrokhi *et al*. [22] report that the concentration of Rn is lower in well-ventilated homes compared to those that are inadequately ventilated. The findings of this study are in line with other studies [5, 9, 16]. Dey *et al*. [5] found that indoor Rn concentrations in well-ventilated homes are lower than those in poorly ventilated ones due to the fact that the indoor Rn concentration depends on the level of indoor ventilation and that Rn can easily escape from well-ventilated homes and does not accumulate inside. Therefore, concentrations of Rn and also of Tn are inversely correlated with ventilation rates. Hence, it is considered that, ventilation can be used to reduce indoor Rn concentrations in homes [5]. Therefore, doubling the initial ventilation is needed to reduce the concentrations by 50 %. One considers that, it would take 10 times better ventilation to reduce the concentration by 90 % [11, 17]. Massive changes in ventilation rates are necessary to alter the of Rn and Tn concentrations, because whole-building ventilation needs to be changed significantly which contributes to the annual consumption of dose rate [23].

According to the currently available literature [20], the concentrations of Rn and Tn in the study area ranged from 17.2 ± 1.2 to 85.8 ± 2.3 Bq m^{-3} and 8.3 ± 1.2 to 38.3 ± 5.4 Bq m^{-3}, respectively, with a mean of 32.2 ± 1.6 and 21.4 ± 1.0 Bq m^{-3}.

The previous studies reported the activity concentrations of ^{226}Ra and ^{232}Th were found to vary from 8 to 110 Bq kg^{-1} with a mean of 26 Bq kg^{-1}, and from 17 to 100 Bq kg^{-1} with a mean of 53 Bq kg^{-1}, respectively. The global average activity concentrations of ^{226}Ra and ^{232}Th are 32 and 40 Bq kg^{-1}, but, the activity concentrations of ^{226}Ra and ^{232}Th in the soil for the Bangalore region were found to be 26 Bq kg^{-1} and 53 Bq kg^{-1} and ^{232}Th are higher than the global average values [23].

The research area's groundwater contains Rn concentrations ranging from 55.9 Bq L^{-1} to 1,189.3 Bq L^{-1} [8]. Additionally, it has been reported that there are locations where the Rn concentration is up to 100 times [8] the allowed limit of 11.8 Bq L^{-1} [8]. In view of this, by applying the formica laminated layer to the walls and fitting the mosaic on the flooring, it has observed a reduction in Rn concentrations.

MATERIALS AND METHODS

Exhalation measurements for Rn concentrations were made using Can technique methods [1, 2]. Fifteen samples of soil and granite, used in building construction, were collected. Each sample was taken in known quantities (0.01 kg) and placed in plastic cans after being oven dried and filtered using a 150 µm sieve. Each Can's bottom lid was fastened with solid state nuclear track detector-based films (LR-115 Type II). The Cans were sealed and tightly closed from the top. After the exposure for the periods of 30 to 50 days, the films were retrieved and chemically etched in 2.5 NaOH solutions at 60 °C. The detectors were cleaned, dried, and their alpha levels were measured using a spark counter. According to other researchers [3, 6, 21], the calibration factor for the LR-115 Type II detector is 0.021 track cm^{-2} d^{-1} = 1 Bq m^{-3}, which was used to translate the recorded track density (track cm^{-2} d^{-1}) into Rn concentration in Bq m^{-3}. The following equation has been used to compute the effective radium content (C_{Ra}) [14, 15]:

$$C_{\mathrm{Ra}} = \frac{\rho h A}{K T_{\mathrm{e}} M} \tag{1}$$

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where, ρ is background corrected track density due to Rn (track cm^{-2}), h is the distance between the detector and top of the sample (m), A is surface area of sample (m^2), K is sensitivity factor (track cm^{-2} d^{-1} per Bq m^{-3}), M is mass of sample (kg) and T_{e} is effective time of exposure (days) given by:

$$T_{\mathrm{e}} = \left[T_{1/2}\lambda^{-1}\left(1 - e^{-\lambda T_{1/2}}\right)\right] \tag{2}$$

where λ is the decay constant for Rn given by $\lambda = \frac{0.693}{T_{1/2}}$. Here, $T_{1/2}$ is half-life of Rn which is 3.82 d.

Mass exhalation rates, $M_{\mathrm{E_x}}$ and surface exhalation rates, $S_{\mathrm{E_x}}$ were calculated using the following equations [4, 10]:

$$M_{\mathrm{E_x}} = \frac{CV\lambda/M}{T + 1/\lambda\left(e^{-\lambda t} - 1\right)}\ (\mathrm{Bq\ kg^{-1} h^{-1}}) \tag{3}$$

$$S_{\mathrm{E_x}} = \frac{CV\lambda/A}{T + 1/\lambda\left(e^{-\lambda t} - 1\right)}\ (\mathrm{Bq\ m^{-1} h^{-1}}) \tag{4}$$

where, C is the integrated Rn exposure (Bq m^{-3}h^{-1}), V is the volume of air in the Can (m^3), T is the time of exposure (h), λ is the decay constant for Rn (h^{-1}), M is mass of sample (kg) and A is surface area of the sample (m^2).

Seven spots on the flooring and four distinct points on the individual walls were selected randomly. The Cans placed on the walls and floorings of the study room is depicted in Fig. 1. For the purpose of measuring the concentrations of Rn and Tn, a circular surface with a diameter of 15 cm is randomly selected on each wall and on flooring. Can with a depth of 40 cm and a detector installed inside were placed on measurement spot. Figures 2 to 5 show the actual images of Cans installed on the walls and floorings before and after renovations. Rn and Tn were measured using solid state nuclear track detector based twin cup dosimeters, which is a method for examining long-term observations [7]. The literature presents a thorough discussion of experimental technique and calibration procedures [19]. Figures 6 and 7 show the dosimeters installed in a room center before and after renovations.

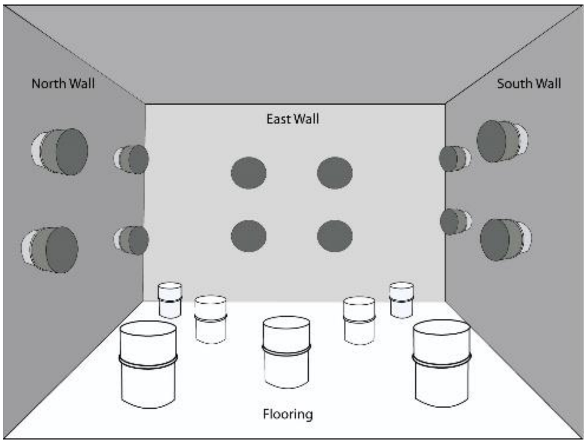

Fig. 1. Cans placed on walls and flooring of room.

Fig. 2. Can on bare walls.

Fig. 3. Can on bare flooring.

Fig. 4. Can on formica laminated wall.

Fig. 5. Can on mosaic flooring.

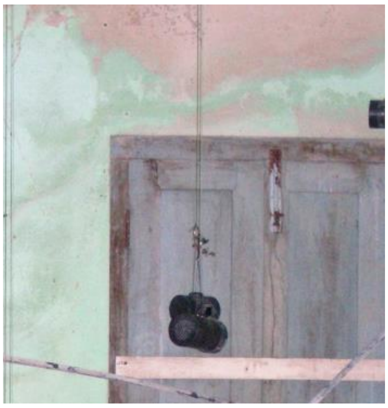

Fig. 6. SSNTD in old room.

Fig. 7. SSNTD in fomica laminated room.

RESULTS

Four different points on individual walls and seven points on floorings were randomly chosen. A circular surface of 15 cm in diameter is spotted on each wall and on the floorings to place the Can of depth 40 cm, in which the solid-state nuclear track detector is fixed inside, for the measurement of Rn and Tn concentrations. Figs 8 and 9 displays the measured concentrations of Rn and Tn in a room on bare wall and formica laminated material wall.

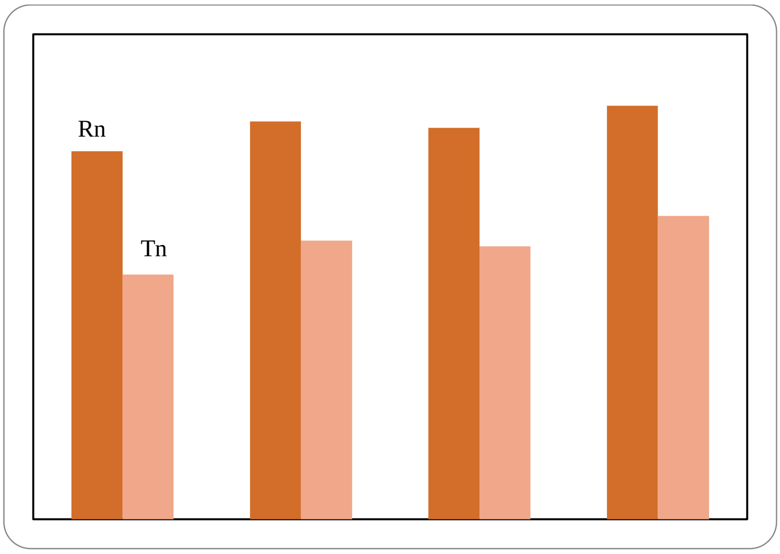

Fig. 8. Rn and Tn concentration (bare wall).

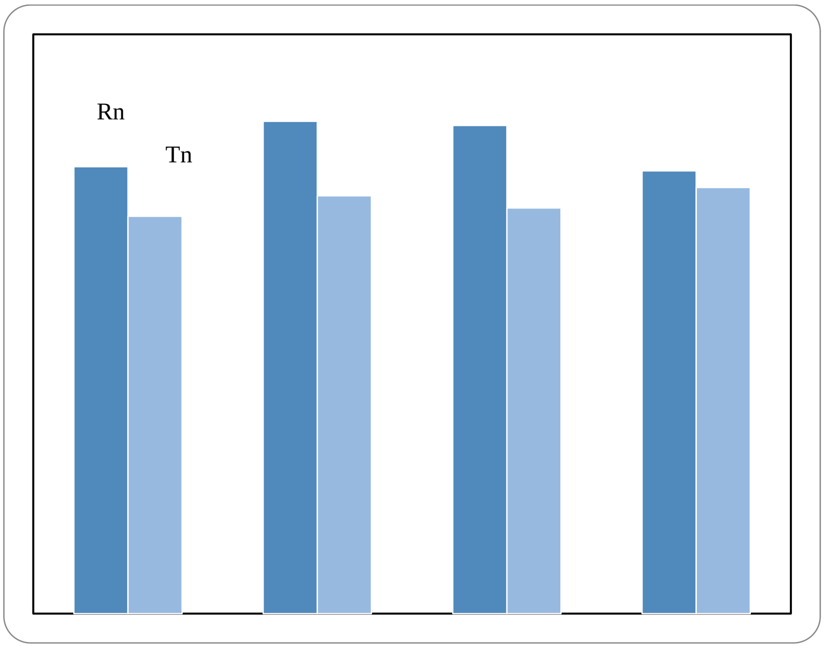

Fig. 9. Rn and Tn concentration (formica laminate).

Figures 10 and 11 displays the measured concentrations of Rn and Tn in a room on bare flooring and mosaic flooring.

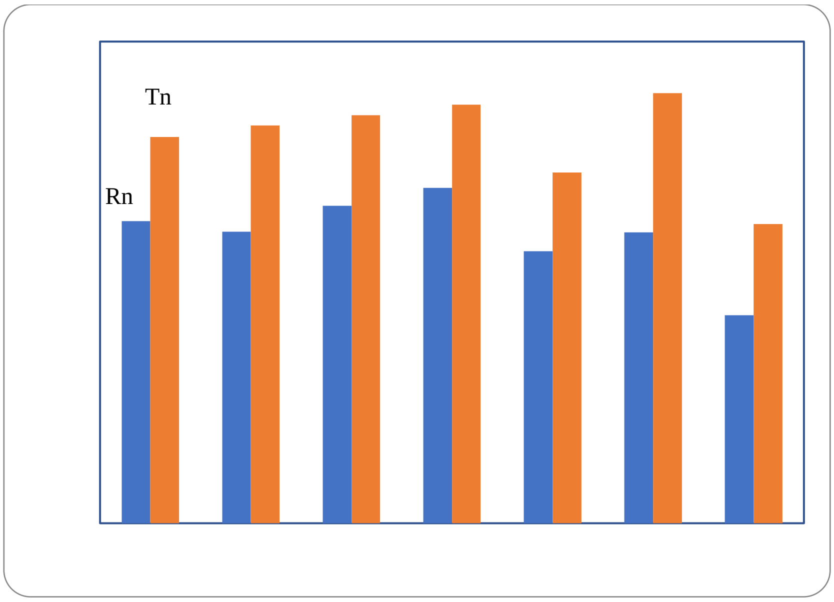

Fig. 10. Rn and Tn concentration (bare flooring).

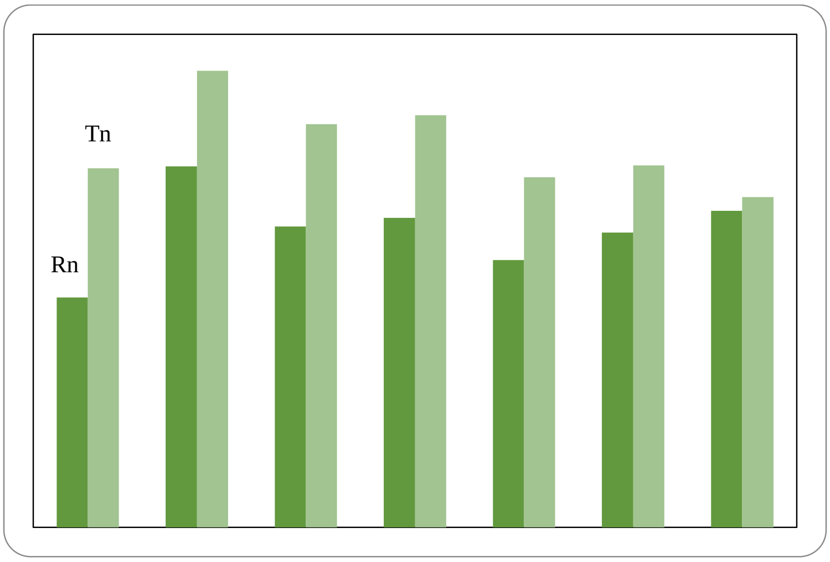

Fig. 11. Rn and Tn concentration (mosaic flooring).

The concentrations showed a wide range of variations. According to the findings, the decrease in Rn and Tn concentrations in the room, after the installation of wooden paneling ranged from 17.9 to 20.8 % with a median of 20.5 % and 23.5 to 27.1 % with a median of 24.9 %, respectively. The reduction in concentrations for mosaic flooring, ranged from 37.1 to 60.4 % with a median of 47.0 % and from 41.0 to 56.0 with a median of 48.1 %, respectively. Before and after renovations, the concentrations of Rn and Tn in the room centre were 43.5 and 28.6 Bq m^{-3} and 12.9 and 9.7 Bq m^{-3}, respectively, and these values indicate the reduction as 29.6 and 33.9 % for Rn and Tn, respectively. Before and after renovations, the mass exhalation of Rn and Tn on the walls and flooring were 24.9 ± 1.1 and 14.5 ± ± 1.0 mBq m^{-2} h^{-1} and 4.1 ± 0.3 and 4.5 ± 1.6 mBq m^{-2} h^{-1}, respectively, and the reduction in concentrations was 16.4 and 42.0 %. This could be due to the laminate layer on the walls and to the mosaic fittings on the flooring that prevent the Rn emanating from any part of the house. Further, it was also observed that the concentrations varied from one point of the flooring to another. The variation could be due to the haphazard use of radioactive rock species in the building construction materials of houses [13]. The correlations between ^{226}Ra/Rn and ^{232}Th/Tn out of this present study were 0.97 and 0.68 respectively. This could be the main cause for the increase in Rn and Tn levels in this study spot. The results showed laminated paneling on the walls and mosaic fitting on the flooring significantly reduces the concentrations of Rn. The Rn exhalation measured by solid-state nuclear track detector method and Can method show a strong correlation coefficient of 0.94.

CONCLUSIONS

The main sources of indoor Rn and Tn are the activity concentrations of ^{226}Ra and ^{232}Th in granite and soil samples that were ignorantly used for building constructions.

The ventilation of houses is very important to reduce the concentrations. After the renovation work of houses there is a better reduction of indoor concentrations of Rn and Tn.

Feasibility of using formica laminated material on walls and mosaic on flooring, with regard to cost efficiency, are under progress and shall be published in near future.

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