Residential radon exposure in some areas of Bangalore city, India

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ABSTRACT

Background: Two isotopes, 222Rn and 220Rn of the natural radioactive gas radon are generally of radiological importance. About half of the total radiation effective dose to the general public is due to the irradiation of the lungs by alpha particles following the inhalation of radon decay products. In view of this, 222Rn and 220Rn measurements were carried out for a period of 1 year in about 50 dwellings belonging to different residential areas of Bangalore city. The results obtained were systematically analysed and discussed. Materials and Methods: 222Rn and 220Rn measurements were carried using Solid State Nuclear Track Detectors. The gamma exposure rate measurements were also carried out in all the dwellings using a G M tube based Environmental Radiation Dosimeter. Results: The concentration of 222Rn and 220Rn was found to be highest in the dwellings having mud flooring (Bare) and lowest in the dwellings having mosaic flooring. The geometric mean values of the concentrations of 222Rn and 220Rn were found to be 24.1 ± 8.3 and 24.5 ± 10.8 Bq m⁻³ respectively. The annual mean value of the gamma absorbed dose rate is found to be 175.8 nGy y⁻¹. Conclusion: The mean value of radon concentration is well within the indian average (42 Bq m⁻³) and world average (40 Bq m⁻³) values. The mean effective dose was found to be 1.19 mSv y⁻¹ and is well within the action level as prescribed by ICRP-65.

INTRODUCTION

222Rn is a ubiquitous radioactive inert gas and is an alpha emitting radionuclide having a half-life of 3.82 days. Exposure to natural airborne radon in indoors has been identified as the primary mode of radiation exposure. Its importance rests on radio-hygienic point of view because exposure to radon is one of the most relevant cause of cancer diseases related to respiratory tract and lungs among non-smokers. It has been established that, the dose due to inhaled radon and its progeny accounts for more than 50% of the total radiation dose that the world population receive from the natural sources of radiation.⁵ It has also been found that the radon and its progeny are responsible for 5-20% of all lung cancer deaths in USA and hence about 21,000 lung cancer deaths occur annually from radon-induced lung cancer in the USA.²³

Numerous measurements at various parts of the world including India along with epidemiological studies regarding the indoor radon and risk of lung cancer have been published in recent years. In spite of the several attempts made to understand the production, transport, and variations of radon and its progeny in indoors with respect to various parameters, more detailed studies are needed with respect to different meteorological and geological conditions for their clear understanding. Though Bangalore (12°15′ and 13°13′ N latitude and 77°3′ and 77°56′ E longitude) is one of the major cities of India with a population of about 8 million, only a few radon measurements were reported till date. Geologically, the Bangalore district is composed largely of younger granites, older granites, and peninsular gneiss. As a result of ever increasing demand for living places, closely packed high-rise residential buildings and
apartments are found everywhere and seem to prevent the normal dispersion of radon due to poor ventilation. Measurement of indoor radon concentration helps to quantify the dose to the inhabitants and improves our understanding about the processes which drive such an entry, which in turn helps to establish the procedures for the development of mitigation techniques.

In view of the above, indoor radon and thoron measurements were carried out using solid state nuclear track detectors (SSNTD) in about 50 dwellings belonging to different residential areas of Bangalore city. The results obtained were systematically analyzed and discussed.

MATERIALS AND METHODS

The SSNTDs used (LR-115 TYPE II [Kodak Pathe, France]) in this study were of 12 µm thick. The twin cup dosimeter used in this study is designed and developed by Environmental Assessment Division, Bhabha Atomic Research Centre, Mumbai. It consists of two identical chambers of cylindrical shape each having a length of 4.5 cm and a diameter of 6.2 cm. One of the chambers is covered with a semi-permeable membrane (e.g., latex) that allows entry of only radon gas into the cup and the second chamber is covered with a glass fiber filter that allows both radon and thoron to diffuse into it from the ambient atmosphere. The semi-permeable membranes have permeability constants in the range of $10^{-8}$ to $10^{-7}$ and allow more than 95% of the radon gas to diffuse and suppress thoron gas to less than 1%. These dosimeters were suspended at the center of a room at a height of 2 m from the ground level. At the end of the stipulated period of exposure (90 days), the dosimeters are retrieved and both the SSNTDs were etched with 10% NaOH solution in a bath at a temperature of 60°C for 60 min. The etched films were peeled off from the base and the tracks developed were counted using a spark counter. The measured tracks were converted into radon concentration using the calibration factors for the etching procedures utilized.

The concentrations of radon and thoron were calculated using the following relations:

$$C_R (\text{Bq m}^{-3}) = \frac{T_m}{dS_m}$$  \hspace{1cm} (1)

$$C_T (\text{Bq m}^{-3}) = \frac{T_t}{dS_u}$$  \hspace{1cm} (2)

where $T_m$ is the track density of the film in membrane compartment (tracks/cm²), $d$ is the period of exposure (days), $S_m$ is the sensitivity factor of membrane compartment (tracks/cm² per Bq days/m³), $T_t$ is the track density of the film in filter compartment, $S_u$ is the sensitivity of radon in filter compartment, and $C_R$ and $C_T$ are the radon and thoron concentrations, respectively.

The inhalation dose (mSv/y) to the inhabitants due to the inhalation of $^{222}$Rn, $^{220}$Rn, and their progeny was estimated using the following relation:

$$D = 10^{-3} \left[(0.17 + 9F_R)C_R + (0.11 + 32F_T)C_T\right]$$  \hspace{1cm} (3)

Where $F_R$ and $F_T$ are the equilibrium factors for radon (0.4) and thoron (0.1), respectively.

The external gamma dose rate in air was measured at a height of 1 m above the ground using a portable GM tube-based Environmental Radiation Dosimeter (Model ER709, Nucleonix Systems Pvt. Ltd., Hyderabad, India) in all the dwellings where the radon concentration was measured. The dosimeter was factory calibrated using gamma survey instruments calibrator (model 773 abbreviation itself (AEA) Technology, USA). The instrument is capable of measuring gamma dose rates in the range of 0-10 mR/h. The accuracy and the sensitivity of the dosimeter are ± 15% and 1 µR/h, respectively. About 10-15 readings were noted at each location and the geometric mean of the readings was taken. The gamma exposure rate in µR/h was converted into absorbed dose rate nGy/h using the conversion factor of $1 \mu R/h = 8.7 \text{nGy/h}$, which stems from the definition of Roentgen.

RESULTS AND DISCUSSIONS

The radon and thoron concentrations were measured in about 50 dwellings for a period of 1 year at different residential areas of the Bangalore city. The dwellings which are constructed with the construction materials (such as cement, soil, sand, and bricks or cement bricks) made up of local soil were selected for this study. The mean values of the concentrations of $^{222}$Rn, $^{220}$Rn, and gamma exposure rates measured in the dwellings are presented in Table 1. It can be seen from the table that $^{222}$Rn concentration varies from 9.8 Bq/m³ to 43.6 Bq/m³ with a mean value of 24.1 ± 8.3 Bq/m³ and that of $^{220}$Rn varies from 11.1 to 47.1 Bq/m³ with a mean value of 24.5 ± 10.8 Bq/m³. The observed mean values are well within the worldwide, population-averaged radon concentration of 40 Bq/m³ for indoors and the Indian average of 42 Bq/m³. Again, even though there is a small difference in the maximum value of $^{222}$Rn and $^{220}$Rn, this can be considered insignificant as it is less than the standard deviation. The frequency distributions of $^{222}$Rn and $^{220}$Rn concentrations are presented in Figures 1 and 2, respectively. It is found that the $^{222}$Rn concentration in maximum number of dwellings lies between 20 Bq/m³ and 30 Bq/m³ and it agrees well with the mean value of 24.1 Bq/m³, whereas about
70% of the dwellings show the $^{220}\text{Rn}$ concentration in the range of 15-30 Bq/m$^3$. In order to understand the observed range of concentration of these radionuclides, the concentration of the natural radionuclides viz., $^{226}\text{Ra}$, $^{232}\text{Th}$, and $^{40}\text{K}$ which were measured in the soil samples of the Bangalore environment was considered.

The reported mean values of natural radioactivity contents of $^{226}\text{Ra}$, $^{232}\text{Th}$, and $^{40}\text{K}$ for Bangalore soil are 26.2, 53.1, and 635.1 Bq/kg, respectively.$^9$ The bricks, local soil, sand, and cement are the materials used in large quantities for the construction. Major quantities of bricks used for the construction of the buildings are brought from places in the city outskirts namely Nelamangala and Magadi. The average activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$, and $^{40}\text{K}$ in the soils of Nelamangala and Magadi are reported as $31.3 \pm 0.6$ Bq/kg, $52.6 \pm 0.9$ Bq/kg, and $303.1 \pm 6.1$ Bq/kg and $16.9 \pm 0.6$ Bq/kg, $57.5 \pm 1.1$ Bq/kg, and $1073.0 \pm 15.6$ Bq/kg, respectively.$^{10}$ Hence, the lower concentrations of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ observed in majority of the dwellings may be attributed to the observed lower concentration of $^{226}\text{Ra}$ in the soil and building materials and also the good ventilation conditions of the dwellings.

### Table 1: $^{222}\text{Rn}$, $^{220}\text{Rn}$ and gamma exposure rates in the dwellings

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<th>Place</th>
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<th>SD</th>
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G. mean: Geometric mean, SD: Standard deviation

### Figure 1: Frequency distribution of $^{222}\text{Rn}$ concentrations in dwellings

### Figure 2: Frequency distribution of $^{220}\text{Rn}$ concentrations in dwellings

Variation of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ concentrations with different floorings

The dwellings selected for the study are of different
types of flooring materials and the mean concentrations are found to vary significantly with the type of flooring materials. The variation of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ concentrations with different flooring types is presented in Figure 3. From the figure, it can be seen that, the concentration of $^{222}\text{Rn}$ is highest in the dwellings of mud flooring (34.7 Bq/m$^3$) and lowest in those with mosaic flooring (14.0 Bq/m$^3$). The concentration is found to be slightly higher in those houses with granite flooring because of higher concentrations of $^{226}\text{Ra}$ in granite.$^{[11]}$ The houses with mud flooring have very poor ventilation compared to the houses with granite and other floorings. Also, the mud flooring leads to the easy escape of radon from the soil underneath. Hence, due to the combined effect of enhanced release of radon from the mud and poor ventilation, mud houses are having relatively higher radon concentration than houses with granite flooring.

**Inhalation dose due to radon and thoron**

The inhalation doses and the gamma absorbed dose rates to the residents of different regions are presented in Table 2. The mean value ($\pm$SD) of annual inhalation dose due to $^{222}\text{Rn}$, $^{220}\text{Rn}$, and their progeny for indoor exposure was found to be 1.19 $\pm$ 0.46 mSv/y. The inhalation dose is found to vary from 0.67 mSv/y to 2.10 mSv/y. The highest dose of 2.10 mSv/y is delivered to the residents of Mudala Palya region, where the buildings are densely packed and having poor ventilation. The doses received by the residents living in all the areas of the study are well within the action level of 200 Bq/m$^3$ as proposed by International Commission on Radiological Protection.$^{[12]}$ Hence, it is not necessary to undertake any kind of action to mitigate radon in any of the dwellings.

Several researchers have studied the probability of lung cancer risk in relation to the exposure to indoor radon.$^{[13-14]}$ Using the risk factor for lung cancer induction as $18 \times 10^{-6}/(\text{mSv}),^{[15]}$ lung cancer risk per $10^6$ persons has been calculated. The radon-induced lung cancer risk for the residents of this region is found be 21.4 per $10^6$ persons. This study shows that the residents of this region are being exposed to relatively lower levels of indoor radon which thus implies a low-risk factor for radon-induced lung cancer.

In the indoor environment, since the external exposure is another way through which the residents receive the radiation dose, the gamma exposure rate was measured in each dwelling and from which the gamma absorbed dose rate was estimated. The observed gamma absorbed dose rate in the dwellings varies from 139.2 nGy/h to 208.8 nGy/h with a mean value of 175.8 $\pm$ 30.6 nGy/h. The result [Table 2] shows that, the gamma absorbed dose rate varies from one dwelling to other. Again, an attempt was also made to understand the dependence of $^{222}\text{Rn}/^{220}\text{Rn}$ concentration on the gamma exposure level which in turn depends on the concentration of radium which is one of the natural radioactive nuclides present in the construction materials used. The result shows that, the dependence of concentration of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ on gamma exposure level is less. The latter will be strongly influenced by the presence of natural radionuclide $^{40}\text{K}$ in soil and building materials.

**CONCLUSION**

The measured indoor $^{222}\text{Rn}$ and $^{220}\text{Rn}$ levels are well within the action level recommended by the ICRP. Majority of the dwellings showed the $^{222}\text{Rn}$ and $^{220}\text{Rn}$ concentrations are in the range of 20-30 Bq/m$^3$. The dwellings with
bare flooring were found to have higher radon levels when compared to the other type of floorings. The mean effective dose to the residents was found to be 1.19 mSv/y and is well within the action level as prescribed by ICRP-65. Hence, it is not necessary to undertake any kind of action to mitigate the radon in these dwellings.

REFERENCES


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