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Study of ^{220}Rn and its Progeny Circulation in a Test Room

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Abstract

Data for ^{220}Rn in indoor and industrial environments are limited since it is widely accepted that its concentrations are meager on account of its diminutive half life, so its participation to respiration dose is disregarded on account of the incidence of considerable sources of ambient radiation. An effective dose from indoor ^{222}Rn and its half springs accounts for almost half to the sources of natural radiation. However, indoor studies carried out in Asian continent imply the dose intake from ^{222}Rn and its progeny may not be much lower than, or possibly more than, that from ^{220}Rn. In light of this, an effort has been made to track Bangalore, India's ^{220}Rn level distribution. Dosimeters were positioned throughout the room at fixed intervals from the wall, ceiling, and floor. To analyze the variances with respect to distance, all windows and doors were shut for 90 days. Additionally, dosimeters were placed in an upper and lower parabolic configuration. Cellulose Nitrate based Nuclear Track Detector (SSNTD) was used to examine the ^{220}Rn coupled with ^{222}Rn in test room. Higher concentrations were seen when the detector was moved away from the walls, ceiling, and floors of the room. This study covers the technical aspects of measuring the ^{220}Rn distribution in a room. The findings are contrasted with figures provided in the literature for residences and regions with high background radiation levels.

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Introduction

Since the focus on the health effects of radiation exposure has switched from acute high levels to chronic low levels, both scientists and the general public is becoming more concerned about background radiation.[1] Due to higher average concentrations of early radionuclides in soil and the by products of their decay, such as ^{222}Rn (radon) and ^{220}Rn (thoron), in the surroundings, many places on Earth have higher natural background radiation levels.[1] The background radiation has recently increased due to the technological advancement of naturally existing radioactive material. It's estimated that inhaling ^{222}Rn, ^{220}Rn, and their temporary offspring contributes over 54 percent of the radiation dose from the ambient environment that the general

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public encounters,[2,3] So, the external component also needed to include an inhaling component. No country has an accurate national estimate for this component as of yet.[3] The ^{220}Rn issue will also cause issues for businesses who use thorium nitrate.[3] Thoriated petrol mantle lamps are still used in countries like India for both indoor and outdoor environment, as well as by street vendors in both rural and urban areas.[3] These businesses handle a lot of thorium nitrate, which means that the amount of ^{220}Rn gas they emit and the offspring they create may both have a considerable impact on the breathing dose of their staff.[3] It is untrue that large concentrations of ^{220}Rn may be present in living and working environments throughout a wide range of countries, and it is increasingly clear that information on ^{220}Rn in the environment may be required to fully understand inhalation dose[4] and the new dose conversion coefficients are available in the literature for the half springs.[5] As a result, compared to ^{222}Rn,[6] even small quantity of ^{220}Rn progenies result in a larger radiation dose. As a result, the health sciences community is becoming more interested in ^{220}Rn exposure. Numerous ^{220}Rn surveys were recently conducted in various cities and states reported by several researchers.[7–11] Additionally, numerous papers[12] have argued for the adoption of trustworthy ^{220}Rn measurement methodologies. This paper summarizes the existing situation of ^{220}Rn levels in indoor settings, workplaces, and other substantial amounts of ^{220}Rn. A description of measurement methods and levels reported in the literature is also provided.

Materials and Methods

According to reports, the inhalation pathway is the main source of the radiation dosage that humans receive from natural sources.[13] Radon and its progeny nuclides are the principal contributors to this route dosage. Thus, measuring the amount of radon in the internal air becomes crucial for assessing the exposure of ambient atmosphere. Because atmospheric radon gases change throughout the day and throughout the seasons, it is crucial to conduct long-term integrated measurements to accurately estimate the gas concentration. For long term measurements cellulose nitrate based dosimeters are used.[14,15] The detailed explanations are available in the literature.[16,17] The activity fractions in relation to the parent gas are recovered through ventilation rate.[18] Working level concentrations and equilibrium factor are estimated through the formulas provided by UNSCEAR.[5] The calibration facilities, dosimeter standardization, and dosimetry methodology are all covered in depth elsewhere.[19]

Result and Discussion

On the basis of the material we have read and the data we have collected, we project the findings below. We display the ^{220}Rn readings obtained in a test chamber during a three-year period. All measurements were made on the ground floor. Dosimeters were positioned in lower and upper parabolic arrangements, 60 cm to 450 cm apart from one another, and at equal heights from the floor and the ceiling in the 31 m^3 test room.

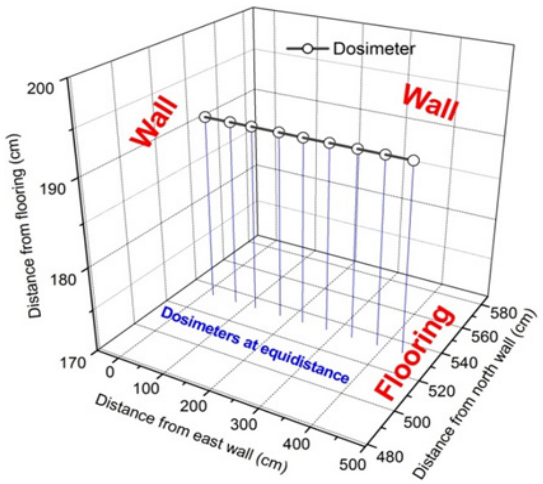

Fig 1: Dosimeters spaced equally apart

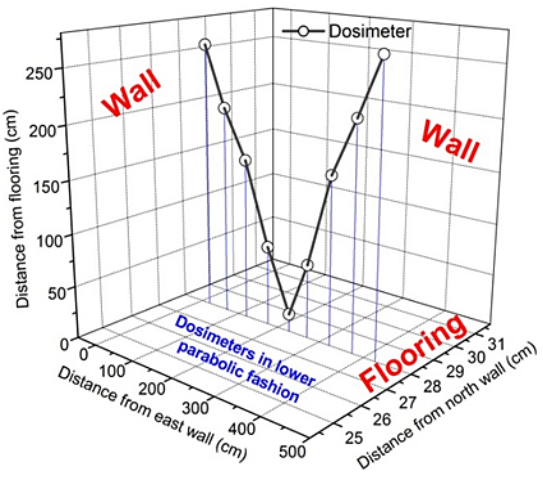

Fig 2: Dosimeters in a parabolic decline

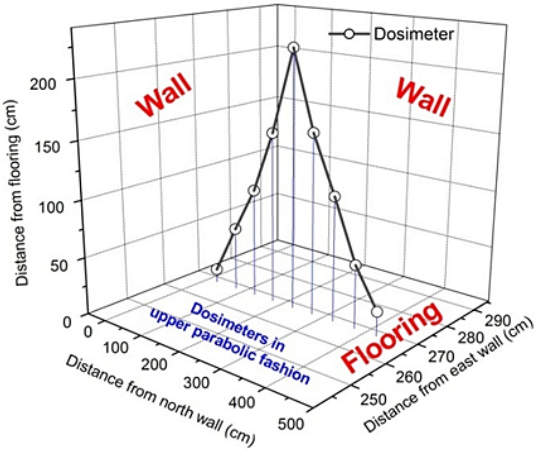

Fig 3: Dosimeters in parabolic growth

parabolic form, respectively. Figure 4 displays the results of the ^{220}Rn concentration measurement with equally spaced wall spacing. In the southern part of India, these measurements are the first of their kind.

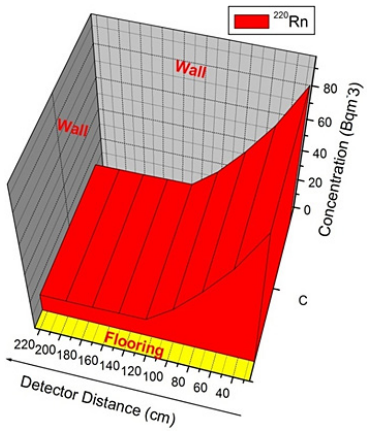

Fig 4: Parallel dispensation of ^{220}Rn

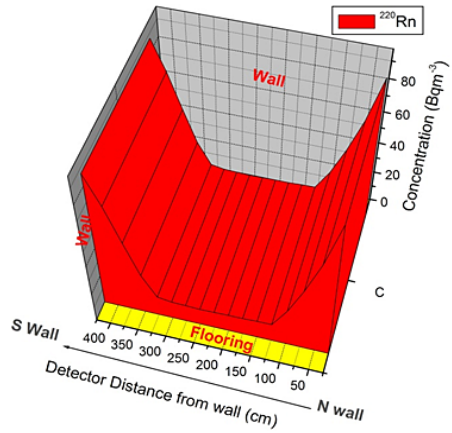

Fig 5: Dispensation of ^{220}Rn from the wall

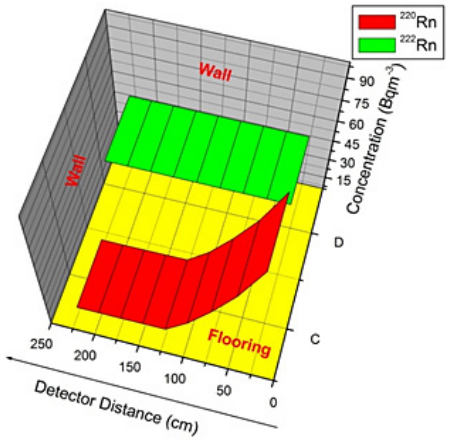

Fig 6: Distribution of ^{220}Rn and ^{222}Rn

The short half-life of this substance may be the reason for the exponential concentration[20,21] drops with distance shown in Figure 4. This suggests that when measuring indoor ^{220}Rn, it's crucial to maintain a safe distance from the wall of the house. As seen in Fig. 5, the effect of distance on concentrations changes when dosimeter is moved away from one point of the wall, like one point of the north wall, and placed closer towards another point of the wall, like one point of the south wall. In order to monitor the simultaneous dispersion of ^{222}Rn and ^{220}Rn concentrations at various distances from walls, ceilings, and floors, twin cup dosimeter measurements were also made. The distribution of ^{220}Rn and ^{222}Rn concentrations within a home is shown in Figure 6. Locally produced bricks were used to build the walls and floors, and it is assumed that the ^{222}Rn and ^{220}Rn in the bricks came from local soil resources. Due to the small time of ^{220}Rn, length of moment needed to transit, as seen in Fig. 6, the concentration is waning towards the centre point of the test room. However, due to longer period of time of ^{222}Rn, the level is constant throughout the entire house. Figure 7 illustrates that the concentration of ^{220}Rn is significantly higher than that of ^{222}Rn near the walls. More wall distance results in more similar concentrations. The ^{220}Rn levels fall below the ^{222}Rn concentration at a distance greater than 20 cm from the wall, but it stands constant. Our findings concur with other researchers' findings.[22]

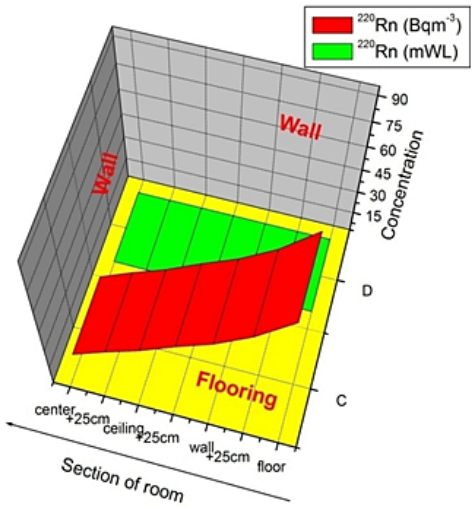

Fig 7: Vertical distributions of ^{220}Rn and its progeny

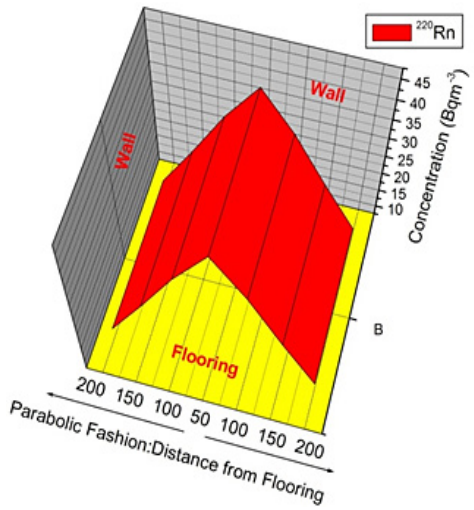

Fig 8: ^{220}Rn level when dosimeter is parabolic decline

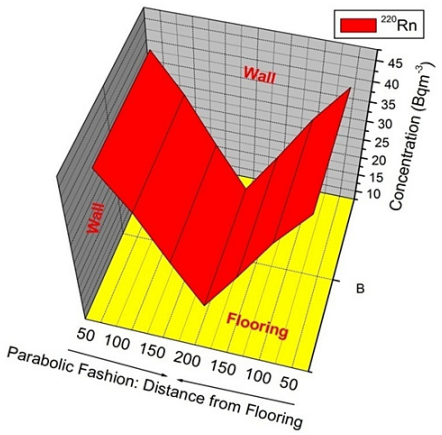

Fig 9: Waning of ^{220}Rn concentration

Similar findings were also made in a number of homes in the Gansu region, according to Shang *et al,*[23] which indicates that ^{222}Rn indoor concentration is generally present. The dramatic increase in concentration close to the wall is shown in Figures 5, 6, and 7. The turbulence flowing from the wall towards the middle of the space diminishes the comparative part of ^{220}Rn levels towards the wall. Only ventilation rates greater than the exhalation saturation of the entire activity are important for occupant dose assessment.[24] Interior ^{220}Rn concentrations increase as a result of ^{220}Rn-emitting building materials. There is a concentration gradient in the room as a result of the short half-life, with concentrations being greater on the walls, ceiling, and floor.

Figure 7 shows the progeny concentration and vertical distributions of ^{220}Rn. The concentration of ^{220}Rn decreases rapidly as one gets farther away from the ground. Still, the distance to the wall had little effect on the progeny concentration. Model estimates revealed a potential link between the homogeneity of ^{220}Rn progeny concentrations throughout a residence and their lengthy half-life (10.64 h).[20] The modifications are shown in Figs. 8 and 9. The dosimeters were also arranged in parabolic decline and growth configurations to acquire the measurements. Observing the concentrations in relation to the locations of the dosimeters in reverse order is pretty interesting. This might be as a result of the short half-life of ^{220}Rn, which causes the concentrations to reverse as moving the detector away from the floor of the room. The dosimeters were also put in 300 residences over 10 distinct Bangalore neighborhoods over a period of more than ten years. With a mean value of 22.8 Bqm^{-3} (GM: 18.9) and 0.33 mWL, the observed concentrations of ^{220}Rn and its progeny ranged from 8.4±0.2 to 69.4±3.5 Bqm^{-3}, 0.01 to 6.2 mWL. Smaller houses and houses with granite flooring had higher concentrations, which may be connected to the neighborhood's higher ^{232}Th activity levels.[25] The authors[25] found that ^{232}Th concentrations in 67% of the samples were greater than the 40 Bqkg^{-1} global norms. The readings for both India as a whole and the rest of the world were comparable to the average concentration of ^{232}Th (53.1 Bqkg^{-1}).

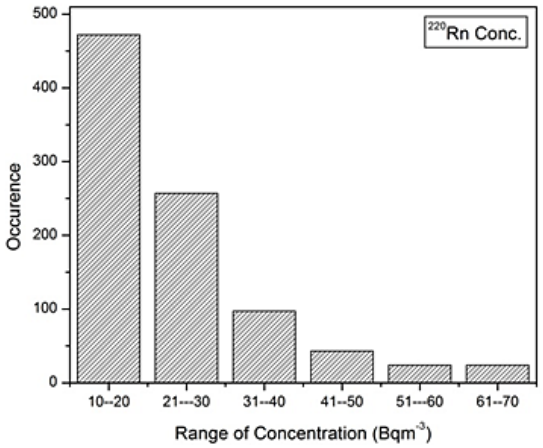

Fig 10: Frequency distribution of ^{220}Rn

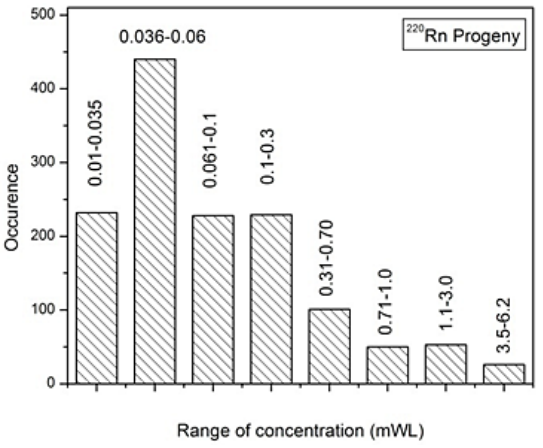

Fig 11: Frequency distribution of ^{220}Rn progeny

The data also showed a definite seasonal fluctuation with a summer minimum and a winter high. The impact of interior ventilation may have an impact on this trend.[26] Numerous factors, such as the ^{226}Ra and ^{224}Ra present in building materials, the exhalation from walls, and ventilation conditions, have been shown to have an impact on indoor ^{222}Rn and ^{220}Rn concentrations.[26] The short half life of ^{220}Rn may make exhalation the most important component. Since dirt walls tend to be more porous than other types of building materials, ^{220}Rn diffusion is made simpler.[26] This might be the reason for the elevated ^{220}Rn content found in brick and earth-walled homes.[26] For houses based on space, room, season, and wall considerations, the link between ^{220}Rn and its progeny was found to be 0.84, 0.74,

0.85, and 0.75, respectively. A stronger connection of 0.85 was seen in data that were dependent on the season. This can be due to the variable ventilation conditions. Similar findings were observed by Guo *et al.*[26] who also reported a correlation coefficient of 0.79 between the levels of ^{220}Rn and its offspring. The frequency distribution of the ^{220}Rn and ^{220}Rn progeny is shown in Figs. 10 and 11, respectively. 90% of ^{220}Rn concentrations fell between 10 and 40 Bqm^{-3}, with 10% of ^{220}Rn concentrations reaching a maximum of 70 Bqm^{-3}. Around 66% of ^{220}Rn progeny concentrations had a minimum of 0.01 mWL, 28% were in the 0.11 to 3 mWL range, and the final 6% were in the 3.1 to 6.2 mWL range.

The average concentrations of ^{220}Rn and its progeny at the observed sites were found to be 22.8 Bqm^{-3} and 0.33 mWL, respectively. Zhuo *et al*[27] measured the concentrations of ^{220}Rn and its offspring in both indoor and outdoor contexts using the grab sampling approach. 48.1± 20.0 and 22.1±10.7 Bqm^{-3} were the results, respectively. The average equilibrium-equivalent concentrations for the same environment were 1.13±0.80 and 0.50±0.29 Bqm-^{3}, respectively. For all types of wall construction, homes with soil/ mud walls had the greatest ^{220}Rn concentration; the reported average value for this kind of home was 104 Bqm^{-3}. The ratio of exposure to ^{222}Rn, ^{220}Rn, and their offspring to that from ^{220}Rn and its offspring was reported[25] to be 30.5% in Guangdong province. Martinez *et al*[28] conducted extensive research on the levels of indoor ^{220}Rn in residences in Mexico City, and the findings revealed a broad log-normal distribution of integrated concentration with annual geometric and arithmetic averages of 82 and 55 Bqm^{-3}, respectively. It deviates by 8 to 234 Bqm^{-3} from the global average of 3 Bqm^{-3}. The observations made in Bangalore's surroundings have been recorded, and they align with those made elsewhere.[27–29]

Conclusion

^{220}Rn levels were highest on the walls, ceiling, and floors of the test room and rapidly fell away from them. The concentration of ^{220}Rn offspring indoors is unaffected by the separation between walls. It is essential to analyze public exposure to natural radiation more carefully across the nation, with a focus on ^{220}Rn and its offspring.

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Conflict of interest

Author(s) do not have any conflict of interest.

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