ANNUAL EFFECTIVE DOSE OF RADON TO RESIDENTS OF BABABUDAN SCHIST BELTS, SOUTH KARNATAKA, INDIA

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Abstract

The present study was carried out to measure the risk of ambient gamma radiation to the general public by measuring indoor radon and thoron activity concentrations in dwellings around Bababudan schist belts of South Karnataka, India. The study area is surrounded by old granites, younger granites, metabasic, schist and genesis type of rocks. The measured radon and thoron concentrations in dwellings ranged from 44.44 to 85.62 Bq m^{-3} and 17.78 to 46.67 Bq m^{-3} with geometric mean values of 63.51 and 29.33 Bq m^{-3} respectively. The estimated total annual effective dose from radon and thoron ranges from 1.55 to 3.33 mSv y^{-1} with an geometrical mean value of 2.43 mSv y^{-1}. The current study shows that the annual effective dose that residents of the study region receive is less than 3-10 mSv y^{-1}, the level of radiation exposure that the International Commission of Radiological Protection recommends and that they are safe from exposure to radon, thoron, and their progenies.

Keywords: SSNTD, Dwellings, Radon, Thoron, Annual Effective Dose

1. Introduction

Long-term exposure to concentrated radon radiation causes lung and skin cancer, the biggest contributor to lung cancer is radon inhalation (National Research Council 1999). Significant attention has been given to radon in recent years, particularly the issues related with exposure to radon and its progeny in buildings and dwellings. Worldwide, continuous measurements of radon activity in indoor dwelling air are made (Kaur R et al, 2019, Chege M et al, 2019, Serge Didier T S et al, 2019, Salupeto-Dembo J et al, 2020, Adelikhah M et al, 2021, Kamalakar D V et al, 2022). Around 1.0 mSv.y^{-1} of the 2.4 mSv.y^{-1} average yearly effective dose from ionizing radiation from natural sources worldwide is due to radon exposure (UNSCEAR 1993).

Humans are exposed to radiation by breathing because of the ^{222}Rn and ^{220}Rn short-lived decay products. Higher radon levels in dwellings and the environment also contribute to this. The radioactive elements ^{218}Po, ^{214}Po, ^{214}Pb, and ^{214}Bi that are produced, when radon emits alpha particles are known as radon progenies (Harrison J D et al, 2020). The radon progeny spends a long period in the atmosphere, enters the lungs through inhalation, and by generating high-energy alpha particles, the progeny is transformed into another radioactive element until it becomes a stable element (Shikha D et al, 2021).

The interaction of the released alpha particles with lung cells leads to cell damage and lung cancer. The long-lived progeny of ^{222}Rn are ^{210}Pb, ^{210}Bi, and ^{210}Po. The two most significant long-lived offspring of ^{222}Rn are ^{210}Po and ^{214}Bi. Radon migrate via fissures and air-filled pores in soil and rocks to permeate the indoor environment (Sorimachi A et al, 2019). Compared to radon, indoor thoron concentrations are typically modest. But its concentrations are high in some uncommon circumstances. The dose from indoor inhalation is increased by the radon and thoron content in the interior environment. Regional geology and meteorology variations in radon, thoron, and their progeny concentrations are caused by factors including parameters, building kinds, building materials, ventilation conditions, minerals, type of soil, and rocks (Nugraha E D et al, 2019). Particularly when concentrated in some enclosures such underground mines, caverns, cellars, or inadequately ventilated and poorly constructed homes, radon and its decay products may pose serious health risks(Tokonami S et al, 2022). Since we spend the majority of our time indoors, it is crucial to measure and restrict the radon content in buildings (Mishra R et al, 1999). The potential for radon gas to build up to harmful levels is a worry for property owners. Similar to other environmental contaminants, there is significant ambiguity regarding the severity of the health concerns posed by radon. According to the USEPA, radon may be to blame for up to 22,000 lung cancer fatalities in the US each year (USEPA 2013). The negative impact on human health is the fundamental reason for the interest in radon research. The proposed study uses SSNTD-based pin-hole dosimeters to assess the concentration of ^{222}Rn, ^{220}Rn, and its daughter products in the study area of the Bababudan schist belts, while keeping in mind the radiation dangers of radon for the general population.

2. Geology of the study area

Bababudan schist belts are in south Karnataka, India**.** with latitudes ranging from 12° 48' 31" to 13° 35' 12" N and longitudes ranging from 75° 09' 09" to 76° 37' 59" E. A Bababudan schist belts are encircled by old granites, younger granites, metabasic, schist and genesis type of rocks as shown in Figure 1. The Western Ghats Kudremukh-Gangamula sequence and the arc-shaped Bababudan mountain range serve as the type area for the Bababudan group (Geology and Mineral Resources of the states of India, 2006, Boraiaha C K, 2022). One of the earliest instances of rocks deposited in a stable cratonic environment is the Bababudan group, the lower succession of the Dharwar sequence composed of basaltic flows and clastic quartzites (Geology and Mineral Resources of the states of India, 2006, Boraiaha C K, 2022). The dwelling chosen in this area is of varies flooring and roof and also with different ventilation condition. The different types of dwelling considered are vitrified tiles floor and Cement roof, cement floor and clay tiles, Granite floor and concrete roof. Walls of all dwellings are constructed with mud bricks and concrete plastering.

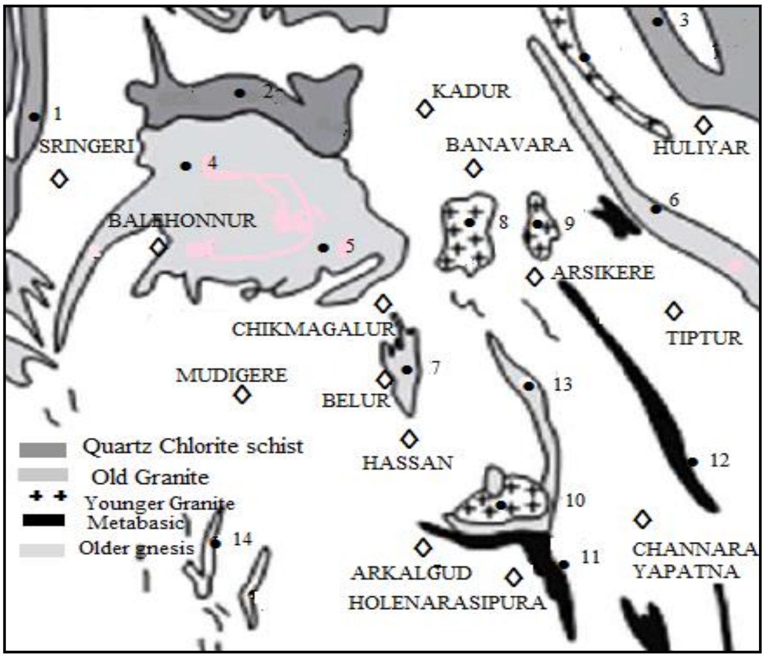

Figure 1. Babadudan Schist belts, South Karnataka, India (Geology and Mineral Resources of the states of India, 2006)

3. Material and Methods

Using a pin-hole dosimeter with LR-115 type II films, the amounts of radon and thoron are measured in 14 locations. Figures 2, 3, and 4 show the schematic diagrams for pin-hole dosimeters, direct thoron progeny sensors, and direct radon progeny sensors, respectively. Based on their availability in 14 locations, the different type's dwellings are chosen. After inserting the LR-115, pin hole dosimeters are hanged from the middle of the dwellings at a height of 2 meters above ground level. Pinhole dosimeters and LR-115 films are collected after 90 days of exposure at the same site, and further etching has been done using sodium hydroxide solution with a concentration of 2.5N for duration of 60 min at a steady heat of 60 °C. The film and cellulose acetate base are separated, and spark counters are used to count the density of alphas (Ramola R C et al, 2016).

3.1 Measurement of Radon and thoron concentration

Concentrations of radon C_R and thoron C_T has been calculated with the equations given bellow (Sahoo B K et al, 2013).

$$C_R(Bqm^{-3}) = \frac{T_1 - B}{txK_r} \qquad (1)$$

$$C_T(Bqm^{-3}) = \frac{T_2 - T_1}{txK_t} \qquad (2)$$

T_1 is the track density (tracks cm^{-2}) of LLR-115 film in the radon chamber, T_2 is the track density of LLR-115 film in the radon + thoron chamber, B is the background track density in LR-115 film before exposure (measured as 6 tracks cm^{-2}), t is the exposure period, and K_r is the calibration factor of the radon chamber and K_t is the calibration factor in the radon + thoron chamber (Sahoo B K et al, 2013).

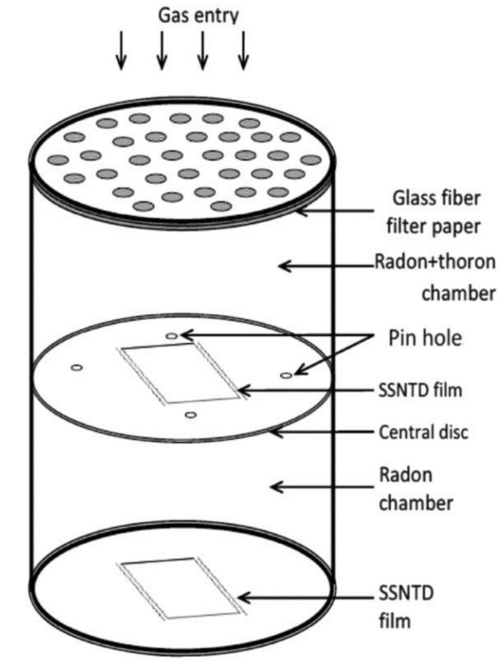

Figure 2: Schematic diagram of Pin-hole dosimeter

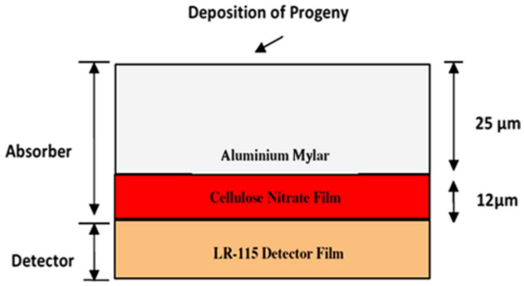

Figure 3: Schematic diagram of DTPS

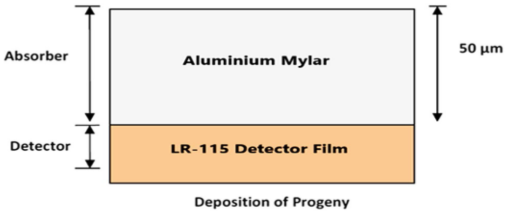

Figure 4: Schematic diagram of DRPS

3.2 Equilibrium equivalent radon and thoron progeny concentrations

Equilibrium equivalent thoron progeny concentrations (EETC) has been estimated using the following equation

$$EETC(Bqm^{-3}) = \frac{T_T - B}{txS_T} \qquad (3)$$

Where S_T is the thoron progeny sensitivity factor (0.94 0.027 tracks cm^{-2} d^{-1} Bq^{-1} m^{-3}), T_T is the number of tracks cm^{-2} in the Direct Thoron Progeny Sensor (DTPS), B is the background tracks cm^{-2} before exposure of LR-115 film, which is measured at 6 tracks cm^{-2}, *t* is the number of exposure days. The DTPS track density is used to calculate the EETC. This has a

25 m thick absorber and is unaffected by radon progenies. The number of tracks received from DTPS is deducted from the number of tracks from DRPS as provided in equation below in order to determine the precise track density from radon progeny from the Direct Radon Progeny Sensor (DRPS) (Mishra R et al, 2008).

$$T_{Rn} = T_{DRPS} - \left[\frac{\eta_{RT}}{\eta_{TT}}\right] T_{DTPS} \qquad (4)$$

Where, T_{Rn} are tracks obtained only from the radon progeny, T_{DRPS} is the total number of tracks in DRPS, T_{DTPS} is the total number of tracks obtained from DTPS, η_{RT} is 0.01 ± 0.0004 in DRPS and η_{TT} is 0.083 ± 0.004 for in DTPS (Mishra R et al, 2008).

The equilibrium equivalent radon progeny concentrations (EERC) has been estimated using equation given below (Mishra R et al, 2008).

$$EERC(Bqm^{-3}) = \frac{T_{Rn} - B}{txS_R} \qquad (5)$$

Where, S_R is the radon progeny (0.09 ± 0.0036 tracks cm^{-2} d^{-1} Bq^{-1} m^{-3}) sensitivity factor.

3.3 Annual effective dose

The annual effective doses from radon (AEDR) and from thoron (AEDT) are used to calculate the combined effect of radon and its progenies. The equations are shown below for both radon and thoron (UNSCEAR, 1993).

$$AEDR = [(CRX0.17) + (EERCX9)]X8760hX0.8X10^{-6} \quad (6)$$

$$AEDT = [(CTX0.11) + (EETCX40)]X8760hX0.8X10^{-6} \quad (7)$$

Where C_R is the radon concentration, C_T is the thoron concentration. The total annual effective dose is determined by adding AEDR and AEDT (UNSCEAR, 1993).

Table 1 C_R, C_T, EERC and EETC measured in Bababudan schist belts.

Locations	Type of Dwellings	C_R Bq m^{-3}	C_T Bq m^{-3}	EERC Bq m^{-3}	EETC Bq m^{-3}
Koppa	G (F) - Cn (R)	71.24	38.89	26.71	5.07
	V T (F)- Cn (R)	60.13	31.11	27.26	3.71
	Ce (F) - CT (R)	48.37	23.33	19.48	2.41
Sirugalale	Gn (F) - Cn (R)	70.59	42.22	23.39	5.48
	VT (F)- Cn (R)	60.13	28.89	14.92	3.76
	Ce (F) - CT (R)	52.29	22.22	18.06	2.42
Kanchipura	VT (F)- Cn (R)	58.82	31.11	31.33	3.69
	Ce (F) - CT (R)	52.29	24.44	35.60	2.47
Bidare	Gn (F) - Cn (R)	67.97	40.00	24.81	5.45
	VT (F)- Cn (R)	62.75	26.67	26.82	3.68
	Ce (F) - CT (R)	52.94	23.33	17.31	2.35
Chikkolale	VT (F)- Cn (R)	62.75	28.89	26.27	3.74
	Ce (F) - CT (R)	59.48	26.67	16.60	2.54
Banjarahatti	VT (F)- Cn (R)	58.82	30.00	24.92	3.78
	Ce (F) - CT (R)	60.13	25.56	16.02	2.41
Hosahalli	Gn (F) - Cn (R)	75.16	41.11	24.28	5.58

	VT (F)- Cn (R)	62.75	28.89	25.05	3.81
	Ce (F) - CT (R)	51.63	27.78	15.66	2.46
Mavuthanahalli	Gn (F) - Cn (R)	84.31	43.33	23.58	5.47
	VT (F)- Cn (R)	77.12	32.22	24.18	3.74
	Ce (F) - CT (R)	74.51	31.11	13.57	2.48
Harathanahalli	Gn (F) - Cn (R)	85.62	46.67	25.64	5.60
	VT (F)- Cn (R)	78.43	31.11	27.87	4.01
	Ce (F) - CT (R)	73.20	27.78	18.17	2.67
Kyathanahalli	Gn (F) - Cn (R)	84.97	43.33	25.07	5.54
	VT (F)- Cn (R)	74.51	28.89	27.99	3.69
	Ce (F) - CT (R)	71.24	31.11	17.12	2.66
Tirumalapura	Gn (F) - Cn (R)	67.97	32.22	42.61	1.64
	VT (F)- Cn (R)	62.75	26.67	19.79	3.72
Thavarekere	VT (F)- Cn (R)	66.67	25.56	19.42	3.72
	Ce (F) - CT (R)	58.17	22.22	16.54	2.51
Gandasi	VT (F)- Cn (R)	58.82	27.78	19.60	3.71
	Ce (F) - CT (R)	44.44	17.78	12.99	2.35
Jadigadde	VT (F)- Cn (R)	57.52	24.44	20.27	3.63
	Ce (F) - CT (R)	45.75	20.00	13.68	2.41
Minimum		**44.44**	**17.78**	**12.99**	**1.64**
Maximum		**85.62**	**46.67**	**42.61**	**5.60**
Geometrical mean		**63.51**	**29.33**	**21.51**	**3.38**

F-floor, R-Roof, Vetrified Tiles =VT, Concrete=Cn,
Granite=Gn, Cement= Ce and Clay Tiles=CT

Table 1 Annual effective dose due to radon and thoron measured in Bababhdan schist belts.

Locations	Type of Dwellings	AEDR mSv y^{-1}	AEDT mSv y^{-1}	Total annual effective dose mSv y^{-1}
Koppa	G (F) - Cn (R)	1.77	1.45	3.22
	V T (F)- Cn (R)	1.79	1.06	2.86
	Ce (F) - CT (R)	1.29	0.69	1.98
Sirugalale	Gn (F) - Cn (R)	1.56	1.57	3.13
	VT (F)- Cn (R)	1.01	1.08	2.09
	Ce (F) - CT (R)	1.20	0.70	1.90
Kanchipura	VT (F)- Cn (R)	2.05	1.06	3.10
	Ce (F) - CT (R)	2.31	0.71	3.02
Bidare	Gn (F) - Cn (R)	1.65	1.56	3.20
	VT (F)- Cn (R)	1.77	1.05	2.82
	Ce (F) - CT (R)	1.15	0.68	1.83
Chikkolale	VT (F)- Cn (R)	1.73	1.07	2.80
	Ce (F) - CT (R)	1.12	0.73	1.85
Banjarahatti	VT (F)- Cn (R)	1.64	1.08	2.73

	Ce (F) - CT (R)	1.08	0.70	1.78
Hosahalli	Gn (F) - Cn (R)	1.62	1.60	3.22
	VT (F)- Cn (R)	1.65	1.09	2.74
	Ce (F) - CT (R)	1.05	0.71	1.76
Mavuthanahalli	Gn (F) - Cn (R)	1.59	1.57	3.16
	VT (F)- Cn (R)	1.62	1.07	2.69
	Ce (F) - CT (R)	0.94	0.72	1.66
Harathanahalli	Gn (F) - Cn (R)	1.72	1.61	3.33
	VT (F)- Cn (R)	1.85	1.15	3.00
	Ce (F) - CT (R)	1.23	0.77	2.00
Kyathanahalli	Gn (F) - Cn (R)	1.68	1.59	3.27
	VT (F)- Cn (R)	1.85	1.06	2.91
	Ce (F) - CT (R)	1.16	0.77	1.93
Tirumalapura	Gn (F) - Cn (R)	2.77	0.49	3.25
	VT (F)- Cn (R)	1.32	1.06	2.39
Thavarekere	VT (F)- Cn (R)	1.30	1.06	2.37
	Ce (F) - CT (R)	1.11	0.72	1.83
Gandasi	VT (F)- Cn (R)	1.31	1.06	2.37
	Ce (F) - CT (R)	0.87	0.67	1.55
Jadigadde	VT (F)- Cn (R)	1.35	1.04	2.38
	Ce (F) - CT (R)	0.92	0.69	1.61
Minimum		**0.87**	**0.49**	**1.55**
Maximum		**2.77**	**1.61**	**3.33**
Average		**1.43**	**0.97**	**2.43**

F-floor, R-Roof, Vetrified Tiles =VT, Concrete=Cn,
Granite=Gn, Cement= Ce and Clay Tiles=CT

4. Results and Discussion

The measured concentrations of indoor radon and thoron, along with their progenies, have been
tabulated in Table 1, for three different types of dwellings in the study area, including those with cement floors and clay tiles, granite floors with concrete roofs, and vitrified floors with concrete roofs. The study area's indoor radon concentration ranges from 44.44 to 85.62 Bq m^{-3}, with an estimated geometrical mean value of 63.51 Bq m^{-3}. In the research region, the indoor thoron concentration ranges from 17.78 to 46.67 Bq m^{-3}, with a geometrical mean value of 29.33 Bq m^{-3}. The main causes of variations in radon and thoron concentrations include radionuclide concentrations in the soil, water, and air, the kind of dwelling and its varying ventilation requirements, and the materials used in its construction (Ningappa C et al, 2008, Kamalakar D V et al, 2022). Both the measured radon and thoron concentrations fall under the ICRP recommended limit (ICRP 1993).

The annual effective dose in all 14 locations as mentioned in Table 2. The AED caused by radon and its progenies ranges from 0.87 to 2.77 mSv y^{-1} with a geometrical mean value of radon concentration 1.43 mSv y^{-1}. The AED caused by thoron and its progenies ranges from

0.49 to 1.62 mSv y^{-1} with an average thoron concentration of 0.907mSv y^{-1}. The total AED caused by radon, thoron, and its progeny concentrations ranges from 1.55 to 3.33 mSv y^{-1} with a geometrical mean value of 2.54 mSv y^{-1}. In a dwellings with granite floors and a concrete roof, the annual effective dose was higher because granite rocks had higher radionuclide activity (Ningappa C, 2008). Therefore, increased annual effective dose has also been noted in dwellings with granite floors. A lower annual effective dosage was absorbed in the dwellings with the cement floor and clay tiles. Radon gas rapidly diffuses in clay tiles and does not concentrate inside clay tiles type of buildings. In Harathanahalli, dwellings with concrete roofs and floors made of granite have higher annual effective dose values, Granodiorite, Tonalite, and Migmatite-type rocks, which have increased radioactive activity, are found everywhere around this region (Geology and Mineral Resources of the states of India, 2006, Boraiaha C K, 2022) . Low annual effective dose is found in Gandasi cement floor and clay tiles roofs. This area is attributed with older genesis rocks have less radionuclides than other types of rocks, therefore they have low concentrations of radon and thoron (Geology and Mineral Resources of the states of India, 2006, Boraiaha C K, 2022, Ningappa C et al, 2008, Rani S et al, 2023). Radon concentration is high in dwellings of younger granite regions and less in the regions having older genesis type of rocks. The granite flooring dwellings contains the highest concentration of radon because granite has a high concentration of radionuclides. The clay tiles roof dwellings have high porosity will allow the radon to pass through it easily, so the concentration of radon in clay tiles roof type of dwelling has less concentration compared to all other two types of dwellings. The minimum value of annual effective dose is absorbed in the concrete floor and clay tiles roofing. The highest annual effective dose is absorbed at the location Harathanahalli granite flooring and concrete roof dwellings, due to accumulation of radon gas inside the residences and the surrounding area is with younger granite having higher concentration of radionuclides (Narsha L et al, 2023).

5. Conclusions

Radon concentrations are higher than thoron levels in Bababudan schist belt dwellings. The main factor influencing radon and thoron levels is the kind of dwellings, granite flooring with concrete roofs dwellings has high radon and thoron concentrations, dwellings with concrete floors and clay tile roofs have low radon and thoron concentrations. AED is higher in Harathanahalli, this location is surrounded by younger granite type of rocks with stronger radioactive activity. Annual effective dose in Gandasi is lowest, older genesis type of rocks with lower radioactive concentrations surround this location. The estimated total annual effective dosage in the Bababudan schist belts from the concentrations of radon and thoron in various types of flooring and roof dwellings is less than the recommended limit of 10 mSv y^{-1}.

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