STUDIES ON RADON AT MYSORE CITY, INDIA

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Abstract

Humans are continuously exposed to ionizing radiation from natural sources. The main contributors to natural radiation are high-energy cosmic radiation and radioactive nuclides that originate in the earth's crust. ^{222}Rn, a decay product of ^{226}Ra, originates from the naturally occurring ^{238}U decay series. ^{222}Rn, the only gas in the ^{238}U decay series, is chemically inert, but is radioactive and exposure to it and its decay products constitutes about half the radiation dose received by general population. The quantity of radon that escapes from the earth depends mainly on the concentration of radium in the soil along with other factors, like the type of the soil cover, porosity, etc.

With this in mind, a systematic study of radionuclide in samples of soil, rocks and water and also in ambient air was measured at about 500 locations in Mysore City, India. Radon, thoron and its progeny concentration in the atmosphere were determined using solid state nuclear track detectors (SSNTD), LR-115 type II which were placed inside the dosimeters and were suspended at a height of 2.5 m above the ground. The Gamma ray spectrometry method was employed to estimate the activity of ^{226}Ra, ^{232}Th and ^{40}K in the soil and rock samples. Radon in the soil gas and radon exhalation rates from soil and building materials were also measured using SSNTDs. A gamma ray scintillometer was used to measure the gamma absorbed dose levels. Uranium analysis in water samples was performed using a laser flurometer. Radium and Radon concentration in water samples was measured using radon bubblers and scintillation cells.

Analysis of the samples found that the concentration of ^{222}Rn, ^{220}Rn and their daughters in the atmosphere occurred higher during winter and lower during summer. The geometric median activity of ^{226}Ra, ^{232}Th and ^{40}K in soil samples is found to be 20.3, 64.0 and 396.7 Bq kg^{-1}; and rock samples was found to be 46.4, 68.7 and 634.9 Bq kg^{-1} respectively. The average gamma absorbed dose rate in dwellings varies from 46.2 to 286.5 nGy h^{-1}. Radon exhalation rates varied from 8.3 to 196.3 mBq m^{-2} h^{-1} in different types of soil and rock samples. The ^{222}Rn and Uranium concentrations in water samples were found to vary from 280 to 794,170 Bq L^{-1} . and from 0.3 to 635.4 μg L^{-1} respectively.

Introduction

Great interest has been expressed worldwide for the study of naturally occurring radiation and environmental radioactivity. This interest has led to the performance of extensive surveys in many countries (UNSCEAR, 2000). The primary reason for these studies is the simple fact that natural radiation background is the primary source of human radiological exposure. A significant component of this background radiation exposure comes from natural radionuclides in soil. The high geochemical mobility of certain radionuclides in the environment allows them to migrate and under certain conditions, concentrate at levels where exposure to them may cause a human radiological hazard. Naturally occurring radionuclides in the earth's crust are strongly influenced by the local geological and geographical conditions. Soil is a complex mixture of different organic and inorganic compounds and solid

rock. In nature, soil is an important source of exposure to natural radiation because of the presence of gamma emitting radionuclides (primarily ^{226}Ra, ^{232}Th and ^{40}K). Knowledge of the distribution and concentrations of these radionuclides in soil and rocks is of great importance for radiation protection and measurements (Beretka et al., 1985).

When ground water moves through radium/radon bearing soil and rocks, radon, which is soluble in water, is dissolved and transported with the water. Hence, the higher the radium and uranium concentrations in the soil and rocks the greater the potential for radon absorption. With respect to human health risk from radon in water, the risk from inhalation (from desorption into air) far exceeds those associated with direct ingestion.

Mysore, Karnataka State, India lies between 12^{0}N latitude and 76^{0}E longitude, 770 m above sea level forming a part of the catchment zone of the Cauvery and Kabini rivers. Mysore city has an area of about 89 sq.km (Figure 1). For the study, this geographical footprint was divided into 8 zones separated by an angle of 45^0 with each area less than 2.5 km from the center considered as central zone. As for orientation, a large water reservoir namely Krishnaraja sagar (KRS) is situated towards north west of Mysore city. Chamundi hill (1048m) is situated towards south east of Mysore.

The archean rocks of south India are best developed in Mysore and are made up of schists, gneisses and granites. The rocks known as the Peninsular Gneisses are widely distributed in Mysore. They consist mainly of gneisses, granites and granodiorites of varying composition, texture and structure. The emplacement of alkaline dykes has domed up the area southeast of Mysore. It is predominantly pink granite with a minor component of grey granite. Pegmatitic intrusions into the Precambrian gneisses and schists have also been found near Krishna Raja Sagar. Red sandy loams are mainly found in the entire Mysore district.

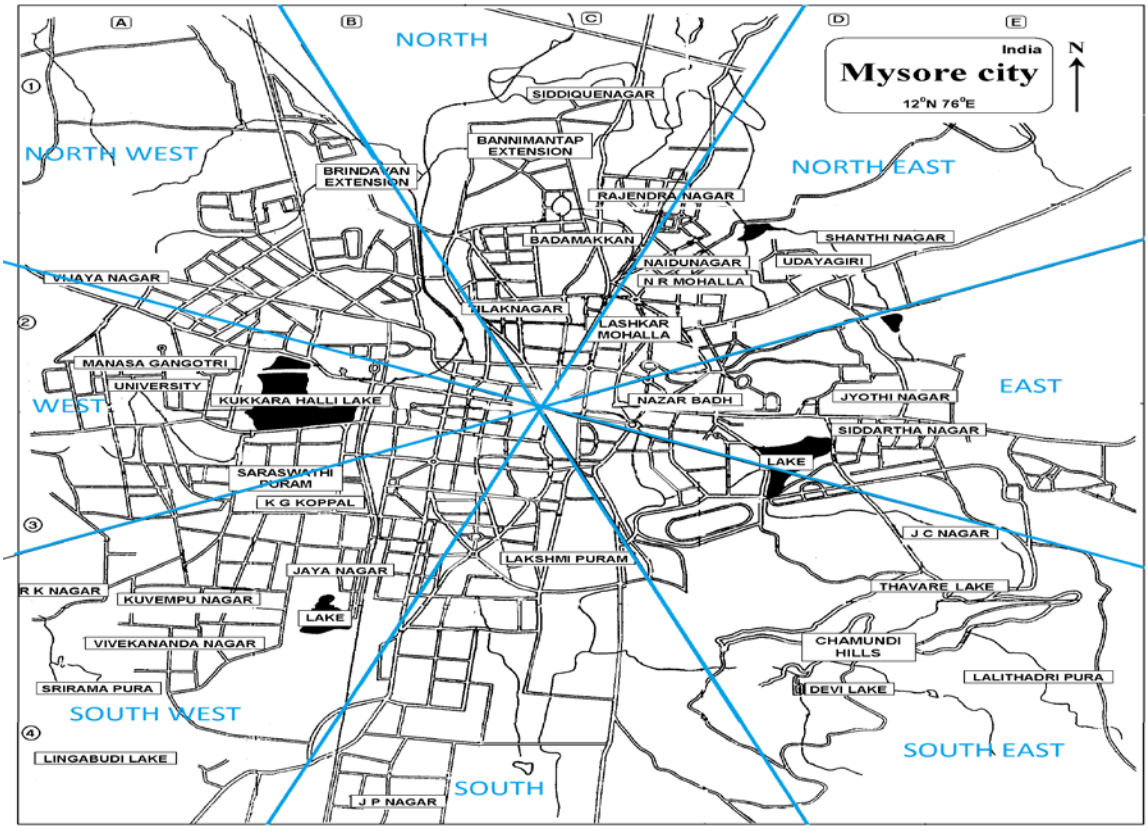

Figure 1. The Study area, Mysore City, Karnataka State, India.

Material and Methods

Ambient gamma level

Indoor and outdoor ambient gamma radiation levels in Mysore city were measured using a scintillometer. Indoor measurements were performed using dosimeters in all locations. All measurements were made one meter above the ground level. The arithmetic mean of the readings were taken as representative figure for each location. The conversion coefficient of 0.7 per Gray and occupation factor 0.2 for outdoor and 0.8 for indoor was used to convert the absorbed dose in air to effective equivalent dose for an adult (UNSCEAR, 2000).

Estimation of ^{226}Ra, ^{232}Th and ^{40}K in soil samples

The concentration of ^{226}Ra and ^{232}Th in soil samples were measured using HPGe gamma ray spectrometer (IAEA/RCA, 1989; Chandrashekara et al., 2011). The total absorbed dose rate (nGy h^{-1}) in air due to the activity concentrations of ^{226}Ra and ^{232}Th at 1m above the ground surface was calculated using the formula (UNSCEAR, 2000),

$$D\ (nGy\ h^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_{K,}$$

Where, A_{Ra} is the activity of ^{226}Ra, A_{Th} is the activity of ^{232}Th and A_K is the activity of ^{40}K.

Estimation of ^{222}Rn in water

Water samples were collected from the selected locations around Mysore City from manually operated bore wells, open wells, lakes and running water. Radon and radium concentrations in water was determined by emanometry using water samples (60 ml glass bottles) from different locations. To estimate ^{226}Ra activity, 20 liters of water was collected and pre-concentrated by chemical methods. The pre-concentrated sample of about 60 ml was then transferred to and evacuated radon bubbler. An evacuated scintillation cell was then connected to the bubbler and radon in the water was transferred to the cell. The cell was coupled to an alpha counter for analysis. The radon and radium concentration in water was determined by measuring the net alpha counts using a standard procedure (Raghavayya, 1990; Chandrashekara et at., 2011). Dose due to ingestion of radon from drinking water was calculated by the equation (UNSCEAR, 2000),

$$\text{Ingestion dose (mSv)} = {}^{222}\text{Rn (k Bq l}^{-1}) \times 60\ \text{l.y}^{-1} \times 10^{-3}\ \text{m}^3\ \text{l}^{-1} \times 3.5\ \text{nSv Bq}^{-1}$$

Solid State Nuclear Track Detector (SSNTD)

The concentrations of radon, thoron and their progeny were measured in dwellings of Mysore city using Solid State Nuclear Track Detectors (SSNTD). For each measurement, three SSNTD films fixed in twin cup dosimeters were used (Mayya et al., 1998; Eappen and Mayya, 2004; Sannappa et al., 2003). These dosimeters are suspended from the mid-point of the house at a height of 2 meters from ground level. To measure outdoor concentrations, the detector was mounted inside an inverted 1-liter plastic cylinder protected against direct sunlight. A nylon stocking was then placed over the entire assembly to protect the dosimeter from dust and insects. Radon exhalation rate from soil samples was measured using the Can Technique employing SSNTD (Abu-Jard, 1988; Khan et al., 1992).

The inhalation dose due to radon and thoron, was calculated by using a conversion coefficient of 9 nSv (Bq h m^{-3})$^{-1}$ and 32 nSv (Bq h m^{-3})$^{-1}$ and equilibrium factors 0.4 and 0.1 for radon and thoron respectively. The dose coefficient for radon and thoron dissolved in blood are calculated using conversion coefficient 0.17 nSv for radon and 0.11 nSv for thoron respectively. The inhalation dose in mSv.y^{-1} may then be provided using the formula (UNSCEAR, 2000),

Dose 1 (mSv) = Indoors Radon (Bq m^{-3}) × 0.4 × 7,000 h × 9 nSv (Bq h m^{-3})$^{-1}$

Dose 2 (mSv) = Outdoors Radon (Bq m^{-3}) × 0.6 × 1,760 h × 9 nSv (Bq h m^{-3})$^{-1}$

Dose 3 (mSv) = Indoors Thoron EEC (Bq m^{-3}) 7,000 h × 32 nSv (Bq h m^{-3})$^{-1}$

Dose 4 (mSv) = Indoors Thoron EEC (Bq m^{-3}) 1,760 h × 32 nSv (Bq h m^{-3})$^{-1}$

Results and Discussion

Radon/thoron and their progeny levels

As was mentioned in the Introduction, for this inhalation dose study a geographical footprint was divided into 8 zones separated by an angle of 45^0 with each area less than 2.5 km from the center considered as central zone. The results are shown in Table 1 and Table 2. Examination of the data shows a small variation in the concentration of radon and its daughter products in Mysore city as a function of geographical location. For example, the data shows concentrations higher in the north east, east and south east regions with no significant variation in the other parts of the city. These measurements are consistent with the observation of higher concentrations of radon and thoron (^{226}Ra and ^{232}Th) in these locations as well as significant levels of radon measured in the water samples collected from the borewells. However, lower concentrations outdoors was observed in all locations. Inhalation dose due to radon and its progeny concentration was calculated to be 1.51 mSv.y^{-1} and 0.58 mSv.y^{-1} for indoor and outdoor environment respectively.

Table 1. Annual average indoor radon/thoron and their progeny concentrations

Area	Concentration Bq m^{-3}		Progeny concentrations mWL		Dose mSv.y^{-1}		
	Rn	Tn	Rn	Tn	Rn	Tn	Total
North	19.03	38.09	1.13	1.78	0.50	0.88	1.39
North East	47.18	42.61	0.90	2.57	1.24	0.99	2.23
East	51.89	35.09	0.87	2.27	1.37	0.81	2.18
South East	39.91	26.99	1.05	0.91	1.05	0.63	1.68
South	28.73	22.70	0.33	0.34	0.76	0.53	1.29
South west	21.51	15.40	0.24	0.14	0.57	0.36	0.93
West	26.21	20.27	0.30	0.21	0.69	0.47	1.16
North west	27.89	25.27	0.40	0.34	0.74	0.59	1.32
Central	31.51	26.27	0.39	0.24	0.83	0.61	1.44
Average	32.65	28.08	0.62	0.98	0.86	0.65	1.51

Table 2. Annual average outdoor radon/thoron and their progeny concentrations

Area	Concentration Bq m^{-3}		Progeny concentrations mWL		Dose $mSv.y^{-1}$		
	Rn	Tn	Rn	Tn	Rn	Tn	Total
North	9.00	10.39	0.22	0.13	0.09	0.06	0.12
North East	17.56	14.22	0.22	0.16	0.17	0.08	0.20
East	27.79	26.15	0.86	2.27	0.27	0.15	0.34
South East	23.49	31.10	0.46	0.70	0.23	0.18	0.34
South	11.65	8.98	0.21	0.22	0.11	0.05	0.13
South west	10.62	8.42	0.14	0.09	0.10	0.05	0.12
West	8.98	7.89	0.29	0.21	0.09	0.05	0.11
North west	11.65	10.62	0.39	0.34	0.11	0.06	0.14
Central	9.86	7.65	0.18	0.14	0.10	0.04	0.11
Average	14.51	13.94	0.33	0.47	0.14	0.08	0.18

The average seasonal variation of indoor radon concentration as a function of zone is shown in figure 2. The concentration is at its maximum during the winter periods of Nov-Feb with lower concentrations observed during the summer. The lower summer levels are due primarily to increased natural ventilation because of open windows and possible vertical mixing and dispersion caused by increased ceiling fan usage.

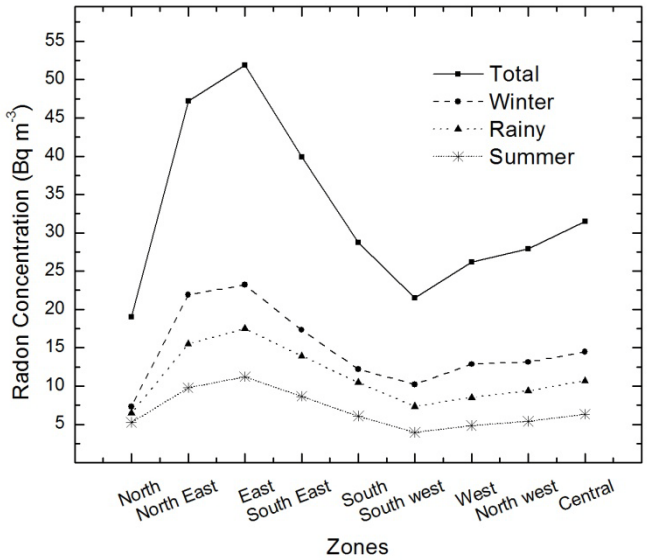

Figure 2. Seasonal variation of radon concentration.

3.2 ^{226}Ra, ^{232}Th and ^{40}K concentration in soil samples

The variation of ^{226}Ra, ^{232}Th and ^{40}K concentration in soil samples collected from the different zones and ^{222}Rn exhalation rates from soil samples are shown in Table 3. The

exhalation rate of radon is highest from samples collected in the east and south-east regions and lowest samples collected in the north and north-east samples. High levels of ^{226}Ra, ^{232}Th and ^{40}K concentrations were also found in samples collected in the east and south regions. Equivalent effective dose estimated from ^{226}Ra,^{232}Th and ^{40}K in soil varies from 0.22 to 1.05 mSv.y^{-1} with an average value of 0.44 mSv.y^{-1}. The average measured equivalent effective dose in outdoor and indoor is 0.51 and 0.09 mSv.y^{-1} respectively.

Table 3. Variation of exhalation rate of radon, ^{226}Ra, ^{232}Th and ^{40}K concentration in soil samples and equivalent effective dose.

Area	Exhalation of Radon	Concentration (Bq kg^{-1})			Equivalent Effective Dose mSv y-1			
	Bq kg^{-1}s^{-1} x10^{-5}	^{226}Ra	^{232}Th	^{40}K	Estimated	Indoor	Outdoor	Total
North	0.63	14.30	25.63	343.5	0.22	0.38	0.09	0.47
North East	0.86	9.65	98.39	492.4	0.52	0.65	0.10	0.75
East	3.57	95.20	115.60	986.2	0.95	0.83	0.14	0.97
South East	3.25	70.30	156.24	1074.5	1.05	1.41	0.16	1.57
South	1.02	13.85	125.70	51.1	0.52	0.38	0.09	0.47
South west	2.25	15.12	29.30	768.3	0.35	0.23	0.07	0.30
West	2.81	14.60	47.92	401.2	0.32	0.27	0.08	0.35
North west	1.28	12.20	68.70	246.80	0.35	0.26	0.05	0.31
Central	1.41	16.98	32.60	349.60	0.26	0.31	0.06	0.37
Geometric Mean	2.12	20.30	64.00	396.75	0.44	0.43	0.09	0.53

3.3 ^{238}U, ^{226}Ra and ^{222}Rn concentration in water samples

The ^{226}Ra and ^{222}Rn activity concentration in ground water (bore well, open well, running water and lakes) samples collected from different locations around Mysore city were determined by an emanometry method. The ^{226}Rn activity concentration in ground water samples varied from 0.52 to 456.56mBq L^{-1} with a geometric mean of 16.97 mBq L^{-1}. The geometric mean (GM) values of ^{226}Ra concentration in water samples of each sector are shown in Table (4). The highest ^{226}Ra activity concentration in ground water sample was found in south-east region with GM of 189.10 mBq L^{-1} whereas the lowest ^{226}Ra activity concentration was found in western region with a GM of 4.62 mBq L^{-1}. As for ^{222}Rn concentration in ground water, activity was found to vary from 2.80 to 794,170 Bq L^{-1} with a GM of 38.6 Bq L^{-1}. As for the GM of the ^{222}Rn concentrations in ground water, the highest was found in the south-east region (434.60 Bq L^{-1}) with the lowest in the northern region (12.50 Bq L^{-1}). The geometric mean of ingestion dose for ^{222}Rn is estimated to be 7.10 µSv y−1. The Uranium concentration in the water samples was measured using a Laser Flurimeter. The GM values of concentration (ppb) in each zone are also shown in Table 4. The highest uranium concentration is observed in south-west region with a GM of 16.50 ppb and lowest is observed in north-east region with a GM of 2.24 ppb.

Table 4. ^{238}U, ^{226}Ra and ^{222}Rn in ground water and dose due to ingestion of ^{222}Rn.

Area	Uranium (PPB)	^{226}Ra ($mBqL^{-1}$)	^{222}Rn (BqL^{-1})	Ingestion Dose ($\mu Sv\ y^{-1}$)
North	6.30	12.68	12.50	2.63
North East	2.24	9.21	15.17	3.19
East	5.55	40.00	56.00	11.76
South East	14.60	189.10	434.60	91.27
South	12.30	17.16	17.75	3.73
South west	16.50	14.15	19.00	3.99
West	3.60	4.62	37.18	7.81
North west	4.50	18.06	48.44	10.17
Central	5.50	16.98	20.50	4.31
Geometric Mean	6.50	18.87	33.79	7.10

For completeness, a dose summary to the population from other natural sources is summarized in Table 5. In summary, the annual average inhalation dose due to radon and thorn was calculated to be 1.00 $mSv.y^{-1}$ and 0.73 $mSv.y^{-1}$ respectively whereas the ingestion dose from drinking radon in water was found only to be 0.02 $mSv\ y^{-1}$. Combined, the total dose due to radon and thoron from airborne inhalation and ingestion was calculated to be 1.75 $mSv\ y^{-1}$. With respect to other terrestrial natural radiation sources, the equivalent effective dose was estimated to be 0.60 $mSv\ y^{-1}$. For dose due to cosmic rays, the Indian annual effective dose of 0.32 $mSv.y^{-1}$ was used for Mysore. All total, the total dose from natural radiation sources in the Mysore region was found to be 2.67 $mSv\ y^{-1}$ which is slightly higher than the world average (2.4 $mSv\ y^{-1}$) (UNSCEAR, 2000).

Table 5. Annual average dose due to natural radiation sources

Components of source	Dose rate ($mSv\ y^{-1}$)
Cosmic ray	0.32
Terrestrial radiation	0.60
Inhalation (Radon)	1.00
Inhalation (Thoron)	0.73
Ingestion dose from radon in drinking water	0.02
Total	2.67

Conclusion

The concentration of ^{222}Rn, ^{220}Rn and their daughters in the indoor and outdoor atmosphere were studied at Mysore city, India. Higher concentrations were observed in East and South East zone where the geometric median activity in soil of ^{226}Ra, ^{232}Th and ^{40}K was found to be 20.3, 64.0 and 396.7 Bq kg^{-1} respectively. Based upon these measurements, the annual average inhalation dose due to radon was calculated to be 1.00 $mSv.y^{-1}$ and thoron 0.73 $mSv.y^{-1}$. Analysis of the collected water samples estimated that the ingestion radon dose from drinking water to be only 0.02 mSv y^{-1}. Combining the radon (inhalation and ingestion) and thoron doses, a dose of 1.75 mSv y^{-1} was estimated which was found to be significantly higher than the estimated equivalent effective dose due to terrestrial radiation (0.60 mSv y^{-1}). All combined the total dose from natural radiation sources in the Mysore region was found to be 2.67 mSv y^{-1}which is slightly higher than the world average dose of 2.4 mSv y^{-1}.

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