Indoor Radon and Annual Effective Dose in Dwellings in Tiruchirappalli City, Tamilnadu, India

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Introduction

The natural back ground radiation comes from the primordial radionuclides present on earth, forms the terrestrial component and radiation from cosmic rays are the extra-terrestrial ones that prevails everywhere [1]. More than 3.5 billion years ago,the natural background radiation was three times greater than the present level [2]. The natural material such as sand, soil, cement, bricks etc., are used for the construction purposes that have different amount of radioactive isotopes [3]. Long and short exposure of radiation causes health issues in human beings. Of these radiations, alpha particles are considered to be more carcinogen than gamma radiations [4]. ^{222}Rn, a daughter product of ^{226} Ra which is also a daughter product of ^{238} Uranium, a long lived alpha emitter contributenearly 50 % of radiation to the living organisms [5]. The daughter products of radon (^{222} Ra) a short lived gas (3.825 days) decays to ^{214}Po, ^{214}Pb, ^{214}Bi and^{218} Po causes respiratory problem through inhalation [6, 7]. Radon as an inert gas in the environment is naturally present in the atmosphere, soil and dissolved forms in water [8]. The assessment of population exposure to the radon gas present naturally in the building materials provides us the information of the radionuclides present in the environment. The source of indoor radon is mainly due to the soil construction material, its topography, characteristics of the soil and climatic conditions [9]. The concentration of radon gas depends on the rate of diffusion in soil and air and may vary with time both diurnally and seasonally [10]. Radon gas enters the dwelling by convection via utility access points, cracks and openings. The amount of radon is due to the presence of radionuclides in the surrounding environment such as ventilation, topography of the buildings, sanitary fittings etc., there would be a considerable amount of radiation in low ventilation areas [11,12].

A numerous work had been done for the estimation of radon gas from buildings materials like sand, soil, bricks, cement etc. Rocks are the poor emitters of radon gas except granite that has an emanation factor of greater than 10% of other materials but very low for tiles and clay bricks baked under high temperature [13]. The lung cancer is caused mainly due to the indoor radon gas next to smoking [WHO, 2003] and the national reference level of radiation was 200 Bq m^{-3}[14]. Since the exposure of radon to the public in residential buildings provides evidence that the lung cancer can be commonly found at even at low radon levels and hence the reference level was reduced to 100 Bq m^{-3} [WHO, 2009]. Radon and its progenies deposit on the bronchio-pulmonary tree as solids causing cancer [15]. Based on the health effects of

radon and its progenies an environmental monitoring is done in the city of Tiruchirappalli, Tamil Nadu, India using LR-115, Type II, Dosirad films.

Materials and methods

SSNTD (Solid State Nuclear Track Detector) is an effective tool to measure the aerosols by track density. LR- 115, a non-strippable film of 12 μm red cellulose nitrate is (high energy alpha particle between 2-4 MeV causes tracks in the film) pasted on to a 100μm clear inert polyster base is used in the experiment. The Dosirad, type II, LR-115 fims were cut to a size of 1x1 cm^2. These films were attached to a cardboard to be exposed to the environmental radiation and was made to hang at a distance of 1m from the walls and ceiling so as to avoid the direct exposure of radiation from the construction materials. They were hung for a period of three months and left undisturbed. The alpha particle in the air causes a localized damage to the molecular structure of cellulose nitrate. The films were then etched with 2.5 N of NaOH solution maintained at a temperature of 60˚ C for about 90 minutes. They were washed with distilled water to remove the colloids struck on the sheets. Under careful observation the film is separated from polymer sheet and the subjected to a spark counter (PSI-SCI). The counts in the spark counter gave the number of tracks formed by the alpha particle.

Study area

Tiruchirappalli city being the fourth largest municipal corporation in Tamil Nadu has a population of 847,387 (2011, census). The measurement of radiogenic gases were done by using SSNTD films in the dwellings of the city. All the samples were hung in the first floor of the buildings in living rooms. The buildings were of concrete flooring and some of the roofing were of concrete and asbestos sheets. The raw materials used for the construction of the dwellings were obtained from the surroundings and the sand from the Cauvery river beds. The houses had a normal ventilation condition. The film was hung at 21 different dwellings in the city and was left undisturbed for a period of three months.

Results and discussion

The study of radon and its progenies that is present naturally in the environment and its distribution makes us to predict the amount of radiation exists in the surroundings. The buildings materials in the dwellings too contribute to the radon gas inside the room. The poaching of aerosols in air is an important factor as it causes mutations in DNA of living organisms. Table 1 shows the concentration of radon and annual effective dose rate of radon and its progeny in the dwellings of Tiruchirappalli city, Tamilnadu, India. 21 places have been selected in the city and SSNTD films were hung for a period of three months and the films are etched and counted using spark counter.

From the track density, the concentration of radon was calculated using the sensitivity factor of radon and it was determined from controlled experiments

and found to be 0.020 Tr cm^{-2} d^{-1} $(Bqm^{-3})^{-1}$. The concentration of radon and its progeny is calculated from the equation 1.

$$C_r\ (Bqm^{-3}) = T_m / (d \times S_m) \quad (1)$$

where C_r is the concentration of radon, T_m be the track density in the cellulose nitrate film, d is the exposure time of the films in the environment and S_m be sensitivity or calibration factor of the membrane. The concentration of radon gas and its progenies ranges from 10.50 Bqm^{-3} to 32.70 $Bqm^{-3}$with an average of 23.39 Bqm^{-3}. The concentration of aerosols is high at the location site S19 which is due to poor ventilation. The variation of values in the city at the spots are given in Table 1.

Table 1. Indoor radon levels and annual effective dose rate in Tiruchirappalli city dwellings

S. No.	Indoor Concentration (C_r) (Bq/m^3)	Annual Effective dose (mSv)	EEC_{Rn} (Bq/m^3)	PAEC (mWL)
S1	19.44	0.48	7.77	0.62
S2	21.66	0.54	8.66	0.69
S3	28.33	0.71	11.33	0.9
S4	15.00	0.37	6.0	0.48
S5	13.88	0.34	5.55	0.44
S6	32.70	0.82	13.08	1.04
S7	17.70	0.40	7.08	0.56
S8	21.66	0.54	8.66	0.69
S9	10.50	0.26	4.20	0.33
S10	19.44	0.48	7.77	0.62
S11	22.73	0.57	9.09	0.72
S12	32.38	0.81	12.95	1.03
S13	27.52	0.69	11.0	0.88
S14	21.94	0.55	8.77	0.71
S15	26.73	0.67	10.69	0.85
S16	18.27	0.46	7.30	0.58
S17	32.65	0.82	13.06	1.04
S18	27.54	0.69	11.01	0.88
S19	33.71	0.84	13.48	1.06
S20	17.62	0.44	7.04	0.56
S21	29.80	0.75	11.63	0.96
Maximum	32.70	0.82	13.08	1.06
Minimum	10.50	0.26	4.2	0.33
Average	23.39	0.58	9.35	0.74

The range of distribution varies due to the type of flooring and the ceiling of the dwellings and also the place where it was hung. The annual effective dose (AED) due to radon and its progeny in the houses of study area was calculated

from the radon concentration to assess the variability of expected radon exposure to the public. The amount of aerosols depends on the temperature and the climatic conditions. AED is calculated from the Equation 2.

Annual Effective Dose =

$$C_r \text{ (Bq m}^{-3}) \times 0.09 \times 7000 \text{ h} \times 40 \text{ nSv (Bq h m}^{-3})^{-1} \quad (2)$$

where Cr is the average concentration of radon in the study area and 0.46 be the equilibrium factor for radon and its progenies for Indian dwellings. The annual effective dose rate varies from 0.26 mSv to 0.82 mSv. The average annual effective dose is 0.58 mSv which is low compared to the standards. An effective dose rate of 3-10 mSv has been proposed by ICRP and a range from 200 to 600 Bqm^{-3} for the action level of radon activity [17]. The present study had been compared with the indoor levels of radiation from the states Haryana, Kerala, Uttar Pradesh, Rajasthan, Punjab, Uttaranchal and Arunachal Pradesh in India and the values obtained from the present work lie below the range [11,16,19]. Potential alpha energy concentration is the sum of the potential energy of all the daughter atoms present in a unit volume of air. The inhalation exposure to individuals is expressed by potential alpha energy exposure and is given by the equation

$$\text{Cp (WL)} = T_m / \text{KT (mWL) milli Working Levels} \quad (3)$$

where Cp is the potential alpha energy exposure, T_m be the track density, K is the calibration factor and was taken as 625 Tr Cm^2 d^{-1} per WL. The values lies between 1.06 mWL and 0.33 mWL with an average of 0.77 mWL

Equilibrium equivalent radon concentratrion (EEC_{Rn})

It depends on the activity concentration of radon (A_{Rn}) and short lived radon daughter products. EEC_{Rn} is the concentration of radon for which the daughter products are in equilibrium and might also have the same potential alpha energy as the actual radionuclides in the atmosphere and is given by the relation [17]

$$EEC_{Rn} = F. A_{Rn} \quad (4)$$

where F is the equilibrium constant and for indoor air the range is assumed to be 0.3-0.6, the mid value of 0.4 is taken in the reported values [18]. The values obtained for different locations in the city is given in table 1.

Conclusion

The radon concentration was measured in dwellings in Tiruchirappalli city, Tamilnadu, India. The concentration of radon and the annual effective dose are in safe limits and ventilation in the dwellings play a major role in the radon concentration. Apart from this, other factors like flooring, roofing and man-made materials present in it too contribute to the radon concentration. The observed doses are below the recommended limits and hence the radiation doesnot pose any significant causeto the livings beings. Hence the values obtained are of safe from health hazard from the radium point of view and the values can be used as a baseline data in the study area.

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