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Assessment of Annual Effective Dose from the Indoor Radon in Bathinda District of Punjab in India

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ABSTRACT

Carrying out of indoor radon studies have been done in the 50 dwellings of Bathinda district (Punjab), India using LR-115 type II cellulose nitrate films in the bare mode. The films were exposed into four consecutive trimesters, i.e. from March 2010 to February 2011. The work has been undertaken for health risk assessment. The calibration constant of 1 track $cm^{-2}day^{-1}$ equal to 50 Bqm^{-3} (Becquerel/m^3) was used. In the present study average radon values vary from 83.15 (BTD-7) to 124.35 (BTD-8) Bqm^{-3} in different villages, which are higher than the word average value of 40 Bqm^{-3}. The inhabitants of the area of study receive average annual radiation dose varying from 1.41 (BTD-7) - 2.12 (BTD-8) mSv (millisievert). The effective dose is found to be less than lower limit of the recommended action level (3-10 mSv). The value of radon for the first floor portion of the same dwelling is lower in comparison to the ground floor. The values in the cemented floors are lower than in the dwellings with the un-cemented floors. The indoor radon values are more in very poorly ventilated dwellings in comparison to the very well-ventilated dwellings.

INTRODUCTION

UNSCEAR (1994) has revealed that a radioactive inert gas Radon (^{222}Rn) is a decay product of radium occurring naturally in the uranium series and almost half of the radiation dose received by common residents is from Radon (^{222}Rn). Kitto et al. (2009) found that 15,000-20,000 lung cancer deaths per year are related to Radon. As of 2005 in USA 90139 men and 69078 women died of lung cancer. The studies have been conducted in U.S.A., Canada, Australia, china and Europe, which have consistently shown an increase in lung cancer with exposure to radon decay products. Radon is a noble radioactive, invisible, odourless, tasteless and natural occurring gas which cannot be detected with the human senses. In 1923, the International Committee for Chemical Elements and International Union of Pure and Applied Chemistry (IUPAC) choose its name to be radon. Archer et al. (2004) has found that being single atom gas, it can penetrate many materials like paper, low density plastic, gypsum and concrete. When radon is condensed, it starts glowing because of the intense radiations it produces. Auxier et al. (1973) revealed that the concentration of radium (^{226}Ra) in alum shale varies from 125-43000 $Bq.kg^{-1}$, from 1-60 $Bqkg^{-1}$ in sand stone, and from 5-40 $Bqkg^{-1}$ in lime stone, which decays into radon by emitting α-particle. The natural concentration of radon in ambient outdoor air is about 10 Bqm^{-3}. Radon gets dissolved into groundwater and can be released into the air when the water is used. Radon is present in almost all the air. Every one of us breathes radon everyday but its concentration varies. Radon is significant contaminant, which affects indoor air quality worldwide. Radon gas levels vary with one location to another and with the composition of the underlying soil and rocks. Lide (1963) found that radon entry rate from subjacent earth and outdoor air is 56%and 20% respectively. Transport of radon is carried out by molecular diffusion or by forced transport. Henshaw et al. (1990) claimed that indoor radon exposure is associated with the risk of leukaemia and certain other cancers, such as cancers and melanoma of the prostate and kidney. Large temporal and local fluctuations are shown by the concentration of radon and its decay products in the indoor atmosphere due to variation in nature of building materials pressure, temperature, wind speed and ventilation conditions, etc.

Indoor Radon Sources

Radon is a problem in all types of dwellings, i.e. cold, new, draftee, insulated, etc. In outdoors radon is diluted to low concentration in the air, hence, it possesses less risk than indoors. The two major factors which can help in magnifying the radon concentration indoor are building materials and underlying soil. Few important sources (Fig. 1) are shown in the house as per following:

- Cracks in solid floors
- Construction joints
- Drainage hole
- Water supply
- Cavities inside walls
- Fractures in walls
- Gaps around service pipes

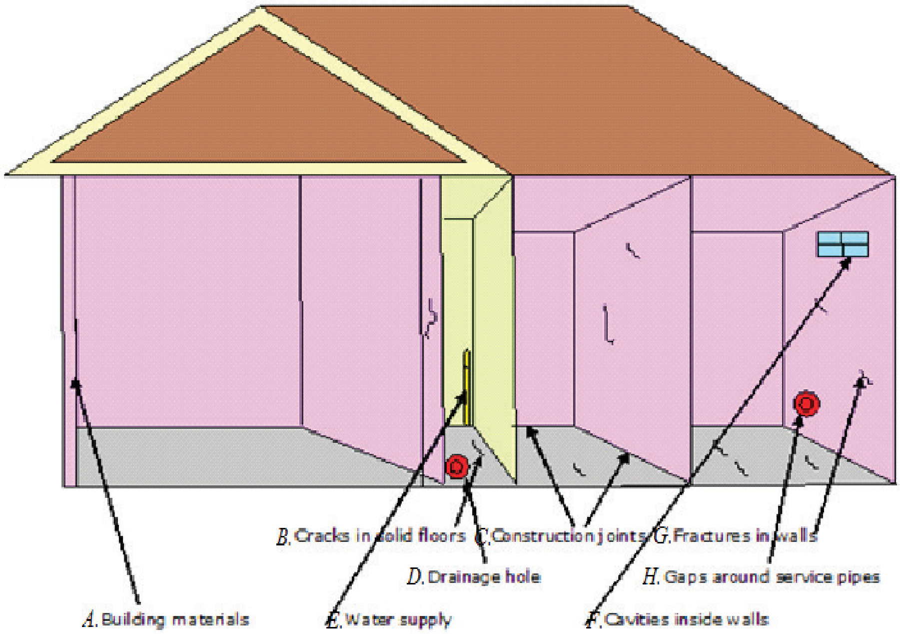

Fig. 1: Sources of radon in a house.

Radon and Lung Carcinoma

In 1597, the high incidence of lung disease was first noted by Agricola. There is association between indoor radon exposure and lung carcinoma as claimed. The mechanism of lung cancer due to radon exposure is explained below:

An unusual high mortality from lung disease was observed among the miners in Schneeberg Region of Germany in early 16th century. The occurrence of this lung disease increased manifolds in 17th and 18th century when mining was increased and later on this disease was identified as lung cancer by Harting & Hesse in 1879. About 15 years later, Ludewig and Lorenzer purposed that high lung cancer occurred among the Schneeberg miners because of high radon concentration of the order of 1000 Bqm^{-3} or higher Porstendorfer et al. (1994) . Bale et al. (1956) the real cause for the lung cancer is not the inhalation of Radon (^{222}Rn) the short lived daughters like ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po).

Types of Lung Cancer

Of all lung cancers, small cell (oat cell carcinoma) accounts for 10-15% and non-small cell accounts for 85-90% of are lung cancer type's small cell carcinoma. This is divided further as follows:

- Adeno carcinoma - 40%
- Squamous cell carcinoma - 25-30%
- Large cell carcinoma - 10-15%

Sun et al. (2007) revealed that the most common type of lung cancer is Adeno carcinoma in never smokers.

Mechanism of Lung Cancer Due to Radon Exposure and its Progeny

As per the American Cancer Society (2008) Radon-222 (^{222}Rn) is carcinogenic to human beings. Radon is claimed to be second leading cause of lung cancer. Evidence shows that generally cancers are of monoclonal origin, i.e. their origination from damage to a single cell. Cytoplasm and nuclei of the secretary cells and basal cells in the bronchioles are presumed to be regarded as sensitive targets, both of whose location is in the epithelial lining of the bronchial tree. For tumour growth, minimum estimated time is 5 years from initial cells transformation to clinical detection. A multiplicative interaction is there from exposure to radon progeny and cigarette smoking. Before the age of 40 years lung cancer is rare. Occurrence of radon related deaths have not been there if the victims would have not smoked. After inhalation, some of the radon progeny are deposited and attached to bronchiolar epithelium; this deposited progeny will irradiate the cells with alpha particles, the basal cells in the bronchiolar epithelium are attacked and some of the deposited activity is spread by the body fluids to other organs. Unattached progeny is filtered by the nose. The ionization radiation emitted by radon can cause genetic mutation which depends upon:

- Type of radiation
- Dose rate
- Part of the body exposed
- Age and health of the person exposed

Lung cancer epidemiological studies on underground miners have shown that inhalation of radon progeny is related with risk of lung cancer. Rerichal et al. (2006) and Smith et al. (2007) found that there is sufficient evidence available that lung tumours in miners exposed to radon progeny have a characteristic mutation pattern in the p-53 tumour suppressor, but these kinds of data further need conformation. Even the human foetuses are affected by radiations. Radon is an inert gas because of which, it has low solubility in body fluid. The majority of lung cancers are caused by the isotopes ^{214}Po and ^{218}Po. Research has revealed in experiments on animals that lung cancer may be induced by exposure to radon progeny as low as 20 WLM (working level month) corresponding to a life time 70-year exposure of about 60 Bqm^{-3}. Radon decay products ^{218}Po and ^{214}Po get attached to aerosols or dust particles; if inhaled then they get trapped in the lungs where mucous membranes cells, bronchi and other pulmonary tissues are affected. The ionising radiation energy affecting the bronchial epithelial cells actually is believed to start off the process of carcinoma genesis. The fat content of organ is the determining factor of concentration of Radon as of because compared to blood radon is 16 times more soluble in fat. Miles et al. (1992) study has shown a yearly dose of 16 μSv to soft tissue consisting of 1% fat arise from exposure at 20 Bqm^{-3} in dwellings. Risk of leukaemia induction is present due to high fat content in bone marrow, from indoor radon exposure. 40% fats are contained by the red bone marrow, applying the speculations that the fat is dissolved constantly in bone marrow, and the yearly dose rising from exposure at 20 Bqm^{-3} can be calculated as 96 μSv (Richardson et al. 1991), but distribution of fat is not uniform, therefore, the sensitive cells are delivered with the maximum delivery dose in the bone marrow Miles et al. (1992), so the value of 96 μSv is likely to overestimate the annual dose. The action level of 200-600 μSv suggested by ICRP (1993) is likely not to increase further from 0.1-0.3 mSv for irradiation of red bone marrow, hence from radon exposure rise in lung cancer is the major health risk. Electrically charged daughter products get attached to minute dust particles, water, oxygen present in indoor air, vapours inhalation and solid surfaces of these aerosols into the lungs make it get attached to the epithelial lining of the lungs which may irradiate the tissue. These daughter products are decayed by emitting alpha particles, beta particles and gamma radiations, but out of them beta particles and gamma radiations have lower biological effects, so the doses from these are negligible. Alpha radiation may mutate the DNA of lung cells, which may initiate few events leading to cancer. Health hazard from radon is smaller than from its progeny due to their long half-life. Alpha radiations can damage DNA and induce mutation which may defect once genes, this may result in neoplasm formation. When inhaled these radioactive particles can damage cells that line the lungs which lead to lung cancer. Since, penetration of alpha particles is not more than a fraction of a millimetre into the tissues, hence the damages confined to the lung tissue in the immediate area. There is no well-known organisation at present that recommends screening for early detection of lung cancer (Collins et al. 2007), but Henschke et al. (2008) in their study in a new England General of medicine particle, have revealed that lung cancer can be detected in 85% of patients in their early stage by the use of annual low dose CT screening.

Cancer Other Than Lung Due to Radon Exposure

A study claimed that indoor exposure is associated with the risk of leukaemia and cancers of kidney and prostate. There have been studies showing correlations between domestic radon levels and cancer of specific sites, cancer of stomach and liver are found to have co-relation with radon exposure. There is relationship between radon and leukaemia as supported by studies. The radon progeny can attach itself to the smoke of cigarette, which is lodged with in the lungs. Radon is considered to be a known human carcinogen (classified by IARC as Group 1).

Geography of Bathinda Area

Bhatinda is located in the southern part of Punjab State, the heart of Malwa region. Faridkot Revenue Commissioner's Division, a newly created division is also consisted by this district and is located between north latitude (29^{o}33' & 30^{o}36') and east longitude (74^{o}38' & 75^{o}46'). The region is enclosed with places of Haryana State like Sirsa and Fatehabad in south, Sangrur in east and Mansa district from north-east Moga and Muktsar and Faridkot in the north-west. Bathinda is regarded as cotton fabricating belt of Punjab.

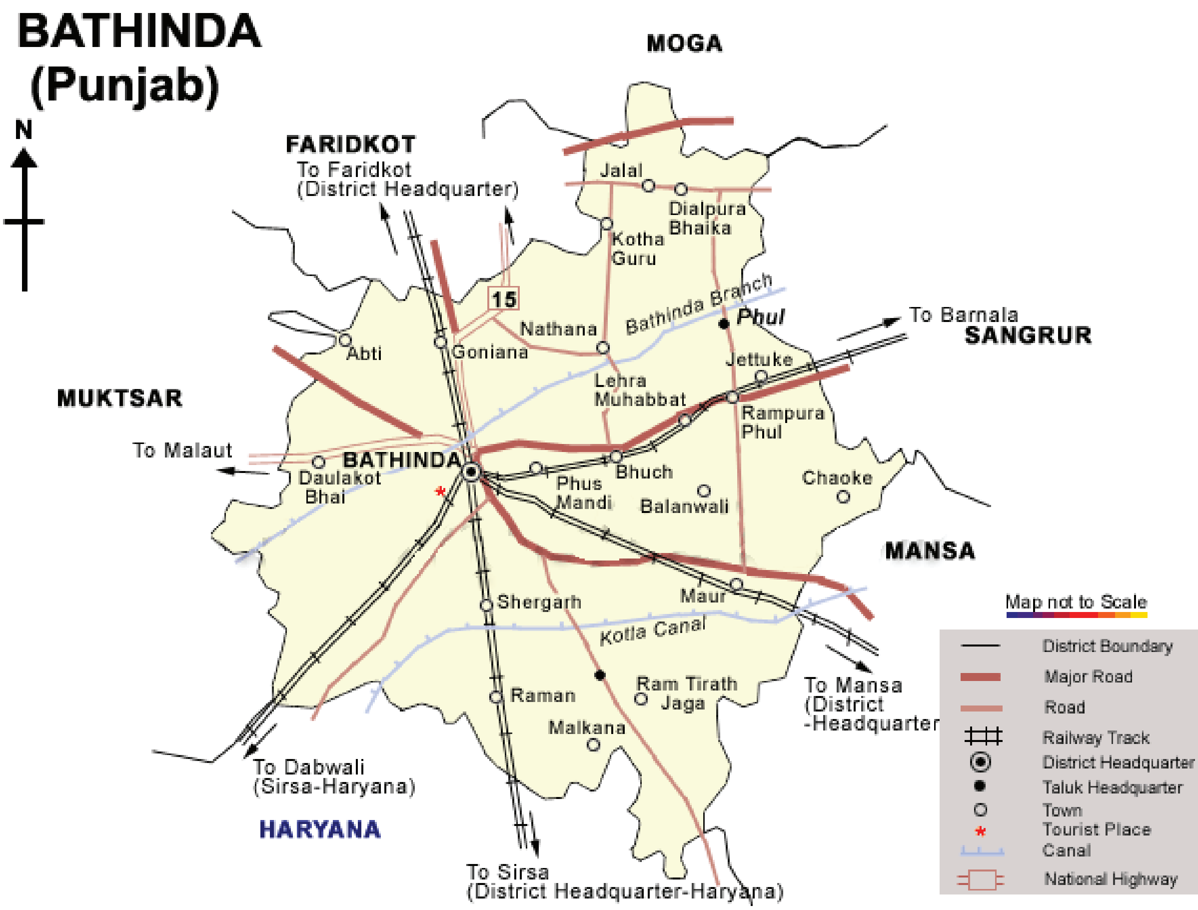

Fig. 2: Location of the study area.

The district encompass an area of 3,344 square kilometres as shown in the map. The location and the geography of the study area is shown in Fig. 2.

MATERIALS AND METHODS

LR-115 Type 2 (pelliculable) plastic track detectors of size approximately 1.3 cm × 1.5 cm were fixed on micro glass slides that were suspended at the centre of room in the bare mode for the annual duration, i.e. March 2010 to February 2011 in order to estimate the indoor concentration levels of radon by breaking it into four successive trimesters. To avoid any disturbance in the reactors due to the resident's movements, the detectors were suspended in the rooms at a height of more than 2 meter above from the ground level and 1 meter below the ceilings of the room so that direct α-particle from the building materials of the ceiling does not reach the detectors. LR-115 type-II has a property that it can register alpha particles with energy ranging between 1.7 MeV and 4.8 MeV (Mega electron volt). The radon daughter products ranging from ^{218}PO to ^{214}PO will not be registered on LR-115 because their alpha particle energies are 6.0 and 7.68 MeV respectively, which is more than its upper threshold energy, which can be tracked by LR-115. The detection efficiency as determined by Nakhara et al. (1980), Deamkjare (1986) and Ramola et al. (1987) is about 50% of energies between 1.5 MeV and 4.8 MeV at a normal incidence. The films of LR-115 in the electromagnetic resonance are not affected by radiations or by electrons. The LR-115 type II detectors (1.3 cm × 1.5 cm) are washed in triple distilled water and deionised water in succession. We can use IR lamp and hot air blowers also for quick drying of detectors. Afterwards, the detectors are stored carefully for future use. Etching recovers the path of particle, which is being travelled during the exposure. Etching is carried under controlled temperature approximately 70°C for 90 minutes. The detectors were etched using 2.5N NaOH solution. The tracks can be enlarged by chemical etching, hence they become visible under the optical microscope. The etching of samples was conducted in a constant temperature bath.

The tracks are counted manually through an optical microscope at a magnification of 400X. Calibration factor used is 0.02 tracks $Cm^{-2}day^{-1} = 1.Bqm^{-3}$. In the current study, the calibration factor adopted from the study of Eappen et al. (2001) for LR-115 type-II was taken after the inter-laboratory comparison exercise carried out at the national level by the Environmental Assessment Division of Bhabha Atomic Research Centre (BARC), Mumbai and is also being used by other researchers.

RESULTS AND DISCUSSION

The effect of dose received by residents annually and their life time fatality risks were estimated as per the guidelines laid down by ICRP (1993). In the present study, annual average radon values vary from 83.15 (BTD-7) to 124.35 (BTD-8) Bqm^{-3} in different villages, which are higher than the global average value of 40 Bqm^{-3} (UNSCEAR 2000). These values are less than the lower limit of action level (200 to 300 Bqm^{-3}) recommended by ICRP (1993) safeguarding work and home from radon radiations. Different works have also been reported to calculate average radon values by different workers. The inhabitants of the area of study receive an average annual dose received ranging from 1.41 (BTD-7)-2.12 (BTD-8) mSv (Table 1). The effective dose is found to be less than lower limit of the recommended action level (3-10 mSv). The annual average of radon concentration for 10 villages comes out to be 100.43 Bqm^{-3} for the present study of dwellings of Bathinda District of Punjab, for the period March 2010-February 2011 with different floor and ventilation conditions. The lifetime casualty hazard of the inhabitants of the area of study varies from 1.09×10^{-4} (BTD-7) to 1.64×10^{-4} (BTD-8) (Table1) with an average value of 1.32×10^{-4} which is 0.01% and comparatively a smaller segment as compared to 4% of the life time hazard of lung cancer due to chewing of tobacco and smoking of cigarette (Evans et al. 1981). Un-cemented floor and poor ventilated dwellings have high radon concentration levels as compared to dwellings with cemented floor with well ventilation. The reason for the former is due to the high contribution of radon from soil which enters in the room along with the less dispersion of radon and the reason for the later is due to the prevention of radon from the underlying soil to enter in the room. Also, radon concentration values for limited number of dwellings having ground floor as well as first floor have been presented. The frequency distribution of annual average radon concentration (Bqm^{-3}) in different dwellings is given in Fig. 3. The radon concentration in the above dwellings is well below the recommended level. The Fig. 4 shows the distribution of life time fatality risk and annual average dose because of radon concentration in (Bqm-3) in the dwellings of different villages Bathinda district of Punjab from March 2010-February 2011. The Fig. 5 shows the frequency distribution of annual average radon concentration (Bqm^{-3}) for 50 dwellings of different villages of Bathinda District of Punjab for the period of March 2010 to February 2011. Fig. 6 shows

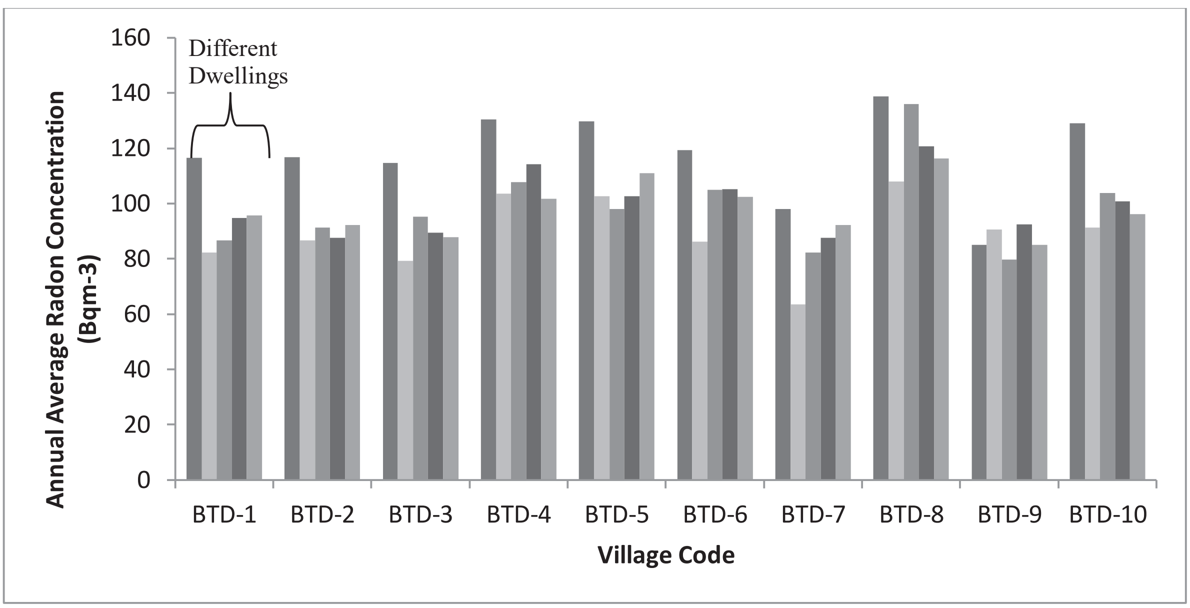

Fig. 3: Annual Average Distribution of Radon Concentration (Bqm^{-3}) level in the dwellings of different villages of Bathinda district of Punjab from March 2010-February 2011.

Table 1: Annual Average Indoor radon levels in the dwelling of Bathinda District of Punjab, corresponding Annual Average Dose and their Life Time Fatality Risk estimates for the period from March 2010 to February 2011.

Sr. No.	Village code	Villages studied	No. of dwellings studied	Radon concentration (Bqm^{-3}) from March 2010-February 2011			Geometric Mean (GM)	Geometric standard deviation (GSD)	Annual average concentraion ($Bq\ m^{-3}$)	Exposure in Working level month	Exposure ($mJ\ h\ m^{-3}$)	Life time fatality risk × 10^{-4}	Annual average dose (mSv)
				Max.	Min.	Average value with ± (SD)							
1	BTD-1	Bhucho Mandi	5	163	55	95.2 ± 12.69	94.51	1.62	95.2	.418	1.47	1.25	1.62
2	BTD-2	Guniana	5	163	53	93.7 ±14.6	94.3	1.62	93.7	.412	1.45	1.23	1.59
3	BTD-3	Lehra Mohabat	5	142	59	93.3 ±12.8	92.58	1.64	93.3	.410	1.45	1.23	1.59
4	BTD-4	Rampura Phull	5	160	81	11.5 ±10.35	111.06	1.59	111.5	.490	1.73	1.47	1.90
5	BTD-5	Thermal Plant	5	182	77	108.85 ±14.79	108.30	1.62	108.85	.478	1.69	1.43	1.85
6	BTD-6	Bhagta	5	191	53	103.65 ±12.07	103.1	1.6	103.65	.456	1.61	1.36	1.76
7	BTD-7	Kotshmir	5	117	50	83.15 ±12.77	83.79`	1.63	83.15	.365	1.29	1.09	1.41
8	BTD-8	Bajakhan	5	196	78	124.35 ±14.1	123.39	1.63	124.35	.547	1.93	1.64	2.12
9	BTD-9	Pithu	5	141	43	86.35 ±10.89	86.43	1.35	86.35	.379	1.34	1.13	1.47
10	BTD-10	Nathana	5	158	73	104.2 ±14.87	103.44	1.67	104.2	.458	1.62	1.37	1.77

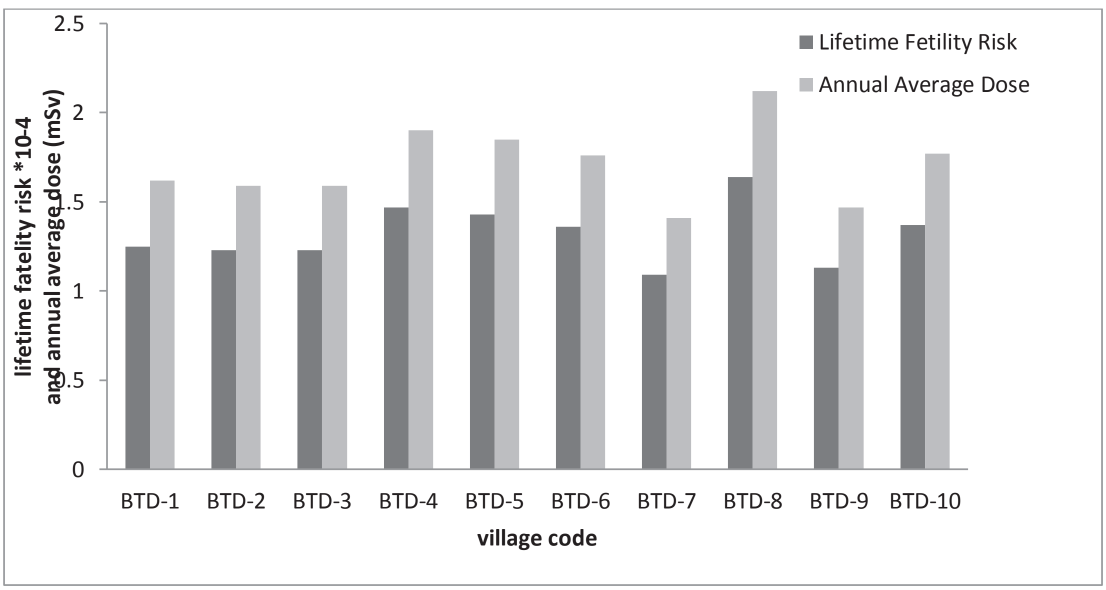

Fig. 4: Distribution of Life Time Fatality Risk and Annual Average Dose because of radon concentration (Bqm^{-3}) in the dwellings of different villages of Bathinda district of Punjab from March 2010-February 2011.

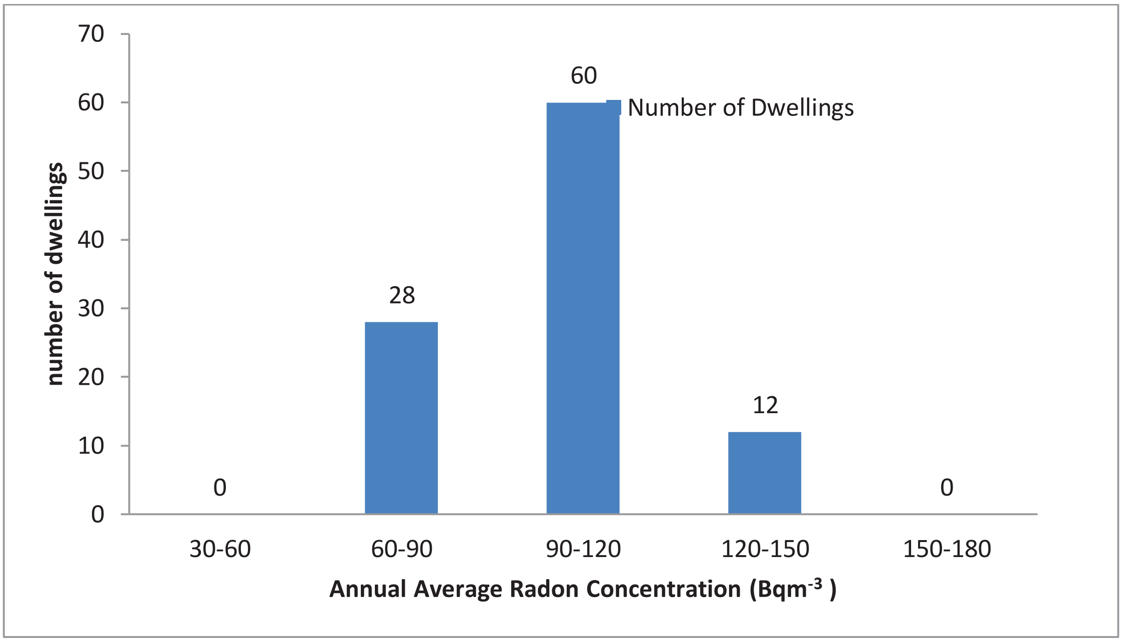

Fig. 5: Frequency distribution of Annual Average Radon Concentration (Bqm^{-3}) for 50 dwellings of different villages of Bathinda district of Punjab for the period of March 2010 to February 2011.

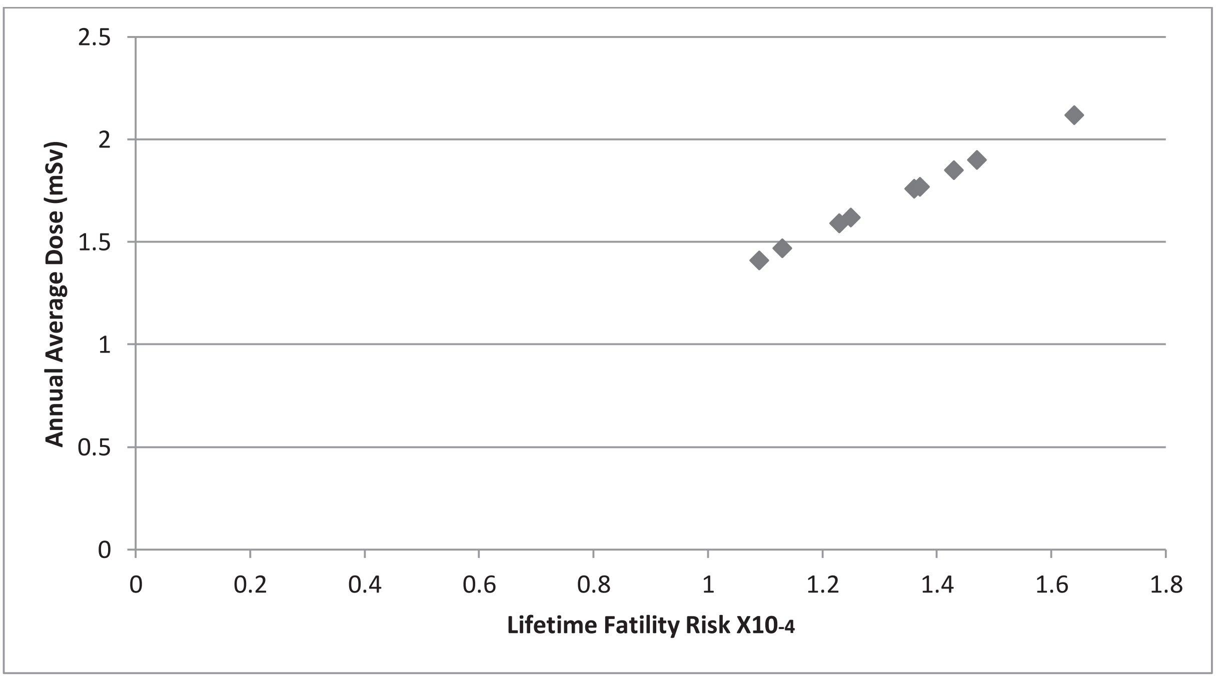

Fig. 6: Lifetime Fatality Risk vs Annual Average Dose for dwellings of Bathinda district of Punjab for the period of March 2010 to February 2011.

the life time fatality risk vs annual average dose for dwellings of Bathinda District of Punjab for the period of March 2010 to February 2011. The present work deviates from Singh et al. (2005) in Malwa region of Punjab and the minimum value reported in present work is more by 6.9 Bqm^{-3} and maximum value in the present study is less by 21.15 Bqm^{-3} than their work. The recent study deviates from the study of Mehra et al. (2009) in Hisar District of Haryana and the minimum value in the present study is more by amount of 19.55 Bqm^{-3} and maximum value in recent study is more by an amount of 3.95 Bqm^{-3} than their work. The recent calculated value deviating from the high content of the radon can be explained because of the uranium mineralization in the concerned area.

CONCLUSIONS

The value of radon for the first floor portion of the same dwelling is lower in comparison to the ground floor because of its more distance from the underlying soil.

The values in the cemented floors are lower than in the dwellings with the un-cemented floors because of the fact that the cement provides the shielding for the underlying soil. The indoor radon values are more in very poorly ventilated dwellings in comparison to the very well ventilated dwellings because radon and its progeny get accumulated in very poorly ventilated dwellings.

The area under the study is safe as per as health hazard affects due to radon on human beings are concerned for the above-said period. The desired outcome of this study was a recommendation to the residents of the survey area to alter the ventilation conditions, to reduce the cracks in the floor and wherever feasible to make the cemented floor, in order to reduce the indoor radon concentration in the dwellings which were studied.

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