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INDOOR RADON LEVELS AND INHALATION DOSES IN DWELLINGS NEAR THE SOME SITES OF HIMACHAL PRADESH, INDIA

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ABSTRACT : In view of the fact that radon and its daughters are a major source of natural radiation exposure, the measurement of radon concentration levels in dwellings has assumed ever-increasing importance. Keeping this in view, the indoor radon level measurements were carried out in the dwellings of different villages known to be located in the vicinity of uranium-mineralized pockets of Hamirpur district, Himachal Pradesh. Track-etch technique, a passive method using the Solid State Nuclear Track Detectors (SSNTDs), LR-115 type II, was utilized for these measurements. An attempt has been made to assess the levels of the indoor radon in the dwellings and inhalation dose rates of the population living in these villages. The radon concentrations were found to be varying with seasonal changes, building materials and mode of construction of houses. The radon concentrations were found to be higher in houses made from local sandstone and with mud floor in comparison to the houses having cemented brick floors. The annual indoor radon concentration and thus annual effective dose in most of the dwellings of these villages is certainly quite higher and even in some of the dwellings it even exceeds the upper limit of the proposed action level of ICRP, 1993. The inhalation dose rates in dwellings of these villages located in the vicinity of uranium mineralized pockets of Hamirpur district, Himachal Pradesh have been found to be quite higher than dose rate in the dwellings in the Amritsar city, Punjab, which is located in a completely uranium free zone.

The radon survey in the dwellings of these villages has also been carried out using the Alpha-Guard technique, which is based on the pulse ionization chamber. The indoor radon concentration levels measured using the active technique of Alpha Guard have been found to be quite different from those measured in these dwellings by the passive technique of SSNTDs; indicating the importance of the SSNTDs in the long-term integrated measurement of the radon levels in the dwellings.

Keywords: *radon, exposure, SSNTD, alpha-guard.*

1. INTRODUCTION

Radon and its progeny (^{218}Po, ^{214}Pb and ^{214}Bi) are present in trace amounts almost everywhere on earth but they become a health risk to general public when present in significant concentrations in the human environment. The measurement of radon and its progeny in the human environment has gained popularity after the realization of the fact that prolonged inhalation of radon and its progeny may lead to pathological effects like respiratory functional changes and the occurrence of lung cancer in many cases (Sevc et al., 1976, Edling et al., 1986, Jacobi, 1991). The radon progeny can attach to the surface of airborne particles and get deposited in the lungs and irradiate the tissues when inhaled. UNSCEAR (1986); NRC (1988) and ICRP (1986, 1991) reports provide the epidemiological evidence for the induction of lung cancer following inhalation of radon from several case studies of underground miners. Sevc et al. (1988, 1993) reported the quantitative risk analysis based on the data of uranium miners cohorts from Bohemia.

Indoor radon surveys have been carried out all over the globe during the last two decades to assess the health hazard risk to general population. Solid state nuclear track detection technique has been used by Jonsson (1988) for indoor radon measurements in Sweden; by Humar et al. (1992) for indoor and outdoor radon surveys in Slovenia, and Toth et al. (1997) in a Hungarian village. Ramola et al. (1988), Singh et al. (1989), Virk et al. (1999), Khan et al. (1997) and Ramachandran et al. (1988) have used this technique for indoor radon measurements in India. Stranden et al. (1984) and Ramola et al. (1988) have reported the seasonal variations of the indoor radon levels in dwellings in Sweden and India, respectively. The equilibrium factor F, an important parameter which relates radon daughter concentration to radon gas levels, is calculated by Swedjemark (1983) and its variation studied by Ramachandran and Subba Ramu (1994). Narayanan et al. (1991) found that the total background radiation dose received by the Indian population is due to inhalation of indoor radon progeny. Virk et al. (1999) reported high radon levels and inhalation dose rates inside dwellings near the some sites in Himachal Pradesh.

Thus keeping in view the health hazardous effects of radon, a survey had been carried out for indoor radon measurements in the dwellings of some villages situated particularly in the radioactive sites of Hamirpur district, Himachal Pradesh, which is known for the radioactive anomalies (Kaul et al., 1993; Sharma et al., 2000). These sites have already been exploited by the Department of Atomic Energy Government of India for the uranium prospection. In this survey both the old and new set of pelliculable & non-pelliculable plastic track detectors (LR-115) have been utilized in different villages for the indoor radon measurements and then the exposure and annual effective dose has been calculated using the ICRP,1993 recommendations.

Geology of the area

Hamirpur district of Himachal Pradesh is situated between 76° 18' to 76° 44' East longitude and 31° 52' 30" North latitude (Balokhra, 1997). The tract is hilly covered by the Siwalik range with elevation varying from 400 to 1100 m. The middle and upper Siwalik and the comparatively recent deposits constitute the main geological formations. The Siwalik comprises of conglomerates, sandstones, siltstones, claystones, granites, quartzite and pebbles. The siwalik represents 6000 m of layered sequence of sandy rocks deposited in the floor plain of the area now occupied by the Himalayan foothills. The sediments were bought down 2 – 25 million years ago by numerous fast flowing rivers.

2. EXPERIMENTAL

Experimental methods for the radon detection and measurement are based on detection of radioactive emissions from the decay of radon and its progeny. Most of the methods are based on detection of alpha particles and a review of experimental techniques is given by Durrani and Ilic (1997). Real time measurements are carried out by electronic counters, commonly known as alpha -loggers, while plastic detectors based on track-etch technique are used for long-term integrated measurements of radon and its progeny levels in dwellings.

2.1 Track Etch technique

The plastic track detector (LR-115 Type II) is a cellulose nitrate film of 12mm thickness manufactured by Kodak Pathe, France. These pelliculable & non-pelliculable plastic track detectors of size 2cm x 2cm were fixed on glass slides and then these slides were mounted on the walls of different dwellings at a height of about 2 m from the ground with their sensitive surface facing the air, taking due care that there was nothing to obstruct the detectors. After an exposure time of four months, detector films were removed and etched in 2.5 N NaOH solution at 60° C for 80 minutes in a constant temperature bath. After etching, the detector were thoroughly washed, dried and scanned manually for track density measurements using a Carl Zeiss binocular microscope. The track density so obtained was converted into the units of Bq/m^3 using the calibration factor given by Eappen et al., 2001 for the bare mode of detectors, which satisfies the conditions prevailing in the Indian dwellings. This calibration factor has been used only for the new set of pelliculable type of detectors used in the dwellings of Ramera and Galot villages, whereas for all other villages since the old set of non-pelliculable type of detectors has been used, so the track density has been converted to radon concentration in dwellings using a calibration factor of Subba Ramu et al., 1988. ICRP (1993) conversion factors have been used to calculate the exposure (an exposure of an individual to radon progeny of 1WLM is equivalent to 3.54 mJh m^{-3}) and the annual effective dose (1WLM=3.88 mSv).

2.2 Alpha-Guard technique

Alpha-Guard supplied by Genitron Instrument Co., Germany, can be used for the short-term radon measurements in soil-gas and even in the indoor air of dwellings. It is based on the principle of pulse ionization chamber and can be operated in the diffusion and flow modes. A specially designed soil-gas unit measured radon concentration in soil by connecting the Alpha-Guard, Alpha-pump and soil gas probe. To measure the indoor radon concentration in the dwellings, the Alpha-Guard has been operated in the diffusion mode.

3. RESULTS AND DISCUSSION

The results of our investigation of indoor radon activity and inhalation doses in the dwelling of Ramera and Galot villages of Himachal Pradesh, where radon concentration has been recorded using the pelliculable detectors for the whole year during Aug. 1997 to Sep. 1998 are summarized in Tables 1&2. During autumn season (Aug.- Dec. 1997), the radon concentration varied from 122.0 ±10.9 Bq/m^3 to 297.0 ±13.9 Bq/m^3 for Ramera dwellings and from 140.5± 9.0 Bq/m^3 to 180.0±11.7 Bq/m^3 for Galot dwelling (Table1). During the winter season (Dec. 1997-April 1998), the radon concentration inside dwellings showed a steep rise, with maximum radon concentration of 741.5±18.1 Bq/m^3 in one of the dwelling of Ramera village. During summer and rainy season (April–Sep.1998), the radon concentration decreased and recovered its original level corresponding to the autumn season of 1997. It is evident from Table 1, that the radon concentration inside the dwellings is almost doubled during the winter season as compared to its value during the autumn, summer and rainy seasons. This can be attributed to increased exhalation and reduced ventilation in winter season. The large-scale variation of radon concentration between different dwellings of both the villages may be explained due to different ventilation rates and the nature of the soil underneath. It has been established that the radon activity in soil-gas is highly variable changing as much as by an order of magnitude over a domain of 10m (Toth et al., 1997).

For the comparison purposes, the indoor radon levels particularly in the winter interval were also recorded using the pelliculable detectors in the Dashmesh Nagar locality of the Amritsar city, Punjab (Table 3), which can be considered as non-radioactive area as no uranium-mineralization had ever been reported throughout the Punjab. The radon concentration in the dwellings of Dashmesh Nagar locality has been found to be varying from 41.5 ± 9.0 Bq/m³ to 97.5± 5.0 Bq/m³ only. In all these dwellings of this location, the building material used is generally the sand, brick and cement and it is well known that these materials have considerably low value of radium content as compared to the sandstones which have been extensively utilized in the villages of Ramera & Galot Villages in Himachal Pradesh, giving higher values of radon activity in the dwellings of these villages. The indoor radon levels for comparison purpose were again recorded in another locality Adarsh Nagar of Amritsar city for an exposure period from Oct.2000 to June.2001 (Table 4), where the radon concentration were found to be varying from 30.6± 5.8 Bq/m³ to 56.3 ± 5.8 Bq/m³. The comparison of these results (Tables 2, 3 & 4) clearly shows that the quite higher radon concentration levels are observed in the dwellings of particularly the Ramera and Galot villages located in uranium-mineralized pockets of Himachal Pradesh State as compared to radon levels in the dwellings of Amritsar City, Punjab recorded during the two different winter seasons. Thus clearly indicating that the higher concentration of radon activity in the Ramera and Galot villages of Himachal Pradesh is mainly due to its higher amount of radioactive radon gas emanating from uranium bearing rocks and soils of these areas.

The average radon concentration values for dwellings of Ramera and Galot villages are estimated for the whole year, Aug.1997-Sept.1998 and then the exposure and the yearly inhalation dose values were calculated for the inhabitants of these villages using the ICRP, 1993 (Table 2). The radon exposure varied from a minimum of 1.8±0.2 mJh/m³ for a dwelling of Galot to a maximum of 7.1±0.2 mJh/m³ for a Ramera dwelling and the corresponding inhalation dose for these dwelling varied from 2.0±0.2mSv/y to 7.8±0.2 mSv/y, whereas even the highest value of dose delivered to the inhabitants in dwellings of Dashmesh Nagar and even Adarsh Nagar localities of Amritsar City, Punjab has not been found to be more than 1.7 mSv/y and 1.0 mSv/y respectively. Therefore, for most of the dwellings in the Ramera and Gallot villages of the Hamirpur district, the annual effective dose received by the residents lies in the range of action level (3-10 mSv/y) recommended by ICRP (1993) for remedial action against radon health hazard to general public.

The indoor radon concentrations have also been measured in the dwellings of Chakmoh, Baddu, Khiah, Asthota and Baturli villages, where the old set of non-pelliculable type of LR-115 detectors have been used. These villages are also located in the same uranium mineralized zone of Hamirpur district of Himachal Pradesh. As can be observed from the Tables 5, the annual indoor radon concentration and thus annual effective dose in almost all the dwellings of these villages is certainly quite higher and even in some of these dwellings it even exceeds the upper limit of the proposed action level of ICRP, 1993. The higher indoor radon concentration values in these villages may again be due to the uranium enriched building materials (local rocks and soil etc.) being used in the construction of these dwellings and even can also be explained due to the presence of uranium mineralization in the area (Kaul et al., 1993). In general in all these dwellings the radon concentrations were found to be higher in dwellings made from local sandstone and with mud floor especially as in case of the dwellings situated in the radioactive zones of Himachal Pradesh, in comparison to the houses having cemented brick floors in Punjab state.

The indoor radon levels have also been measured through the active technique using Alpha-Guard in some dwellings of these villages situated in this uranium-mineralized zone during different seasons, showing comparatively quite low values of indoor radon levels (Table 6a & 6b), as compared to the levels observed earlier through long-term integrated measurements using the SSNTDs. This may be due the reason that these measurements using active technique were on the spot observations taken for quite short intervals of ten minutes or twenty four hours, as compared to the long-term passive measurements and does not take into account the contributions by the thoron and radon progenies, thus indicating the importance of the long-term integrated measurements for the indoor radon study as far as radon epidemiology is concerned. Thus as compared to the alpha-guard the long-term integrated measurements can provide better results for radon epidemiology study, but the alpha-guard technique can be better utilized for measuring the water and soil gas radon concentrations in discrete and continuous modes.

Table 1. Radon concentration for inhabitants of Ramera and Galot villages of Himachal Pradesh using the passive technique (SSNTD)

Location	Radon Conc. (Bq/m^3) (Aug.1997-Dec.1997)	Radon Conc. (Bq/m^3) (Dec.1997-Apr.1998)	Radon Conc. (Bq/m^3) (Apr.1998-Sept.1998)
Ramera	122.0 ±10.9	353.5 ±11.3	187.0 ± 9.3
	114.5 ± 8.8	170.5 ± 8.0	110.0 ± 7.0
	297.0 ±13.9	741.5 ±18.1	328.5 ±11.7
	131.5 ± 7.8	445.0 ±17.4	194.5 ±10.8
Galot	140.5 ± 9.0	320.0 ±11.7	145.5 ± 7.9
	180.0 ± 11.7	216.5 ±11.3	198.0 ±11.1
	170.5 ± 10.4	372.5 ±10.8	109.0 ±13.0
	117.5 ± 10.3	-----	-----

Table 2. Average radon concentration exposure and effective doses for inhabitants of Ramera and Galot villages using the passive technique

Location	Year Avg. Radon Conc. (Bq/m^3)	Year Avg. Exposure (WLM)	(m Jh/m^3)	Effective (mSv/y)
Ramera	220.8± 9.7	1	3.4 ± 0.2	3.8 ± 0.2
	131.7± 7.4	0.6	2.1 ± 0.1	2.3 ± 0.1
	455.7 ±13.2	2	7.1 ± 0.2	7.8 ± 0.2
	257.0± 11.1	1.1	4.0 ± 0.2	4.4 ± 0.2
Galot	202.0 ± 8.7	0.9	3.2 ± 0.1	3.5 ± 0.2
	198.2 ± 10.8	0.9	3.1 ± 0.2	3.4 ± 0.2
	217.2 ± 11.3	1	3.4 ± 0.2	3.7 ± 0.2
	117.5 ± 9.8	0.5	1.8 ± 0.2	2.0 ± 0.2

Table 3. Radon concentration exposure and effective dose for inhabitants of Dashmesh Nagar locality, Amritsar using the passive method

Location	Radon Conc. (Bq/m^3)	Year Avg. Exposure WLM	(mJh/m^3)	Effective Dose (mSv/y)
Dasmesh Nagar, Amritsar	55.0 ± 8.5	0.2	0.9 ± 0.1	0.9 ± 0.1
	89.5 ± 14.4	0.4	1.4 ± 0.2	1.5 ± 0.2
	97.5 ± 15.0	0.4	1.5 ± 0.2	1.7 ± 0.2
	89.5 ± 12.3	0.4	1.4 ± 0.2	
	89.5 ± 12.3	0.4	1.4 ± 0.2	1.5 ± 0.2
	41.5 ± 9.0	0.2	0.6 ± 0.1	0.7 ± 0.1
	67.0 ± 15.6	0.3	1.0 ± 0.2	1.1 ± 0.3

Table 4. Radon concentration exposure and effective doses for inhabitants of Adarsh Nagar locality, Amritsar, using the passive method.

Location	Radon Conc. (Bq/m^3)	Year Avg. Exposure WLM	(mJh/m^3)	Effective Dose (mSv/y)
Adarsh Nagar, Amritsar	56.3 ± 5.8	0.3	0.9± 0.1	1.0 ± 0.1
	37.7 ± 4.8	0.2	0.6 ± 0.1	0.7 ± 0.1
	55.3 ± 6.0	0.2	0.9 ± 0.1	0.9 ± 0.1
	30.6 ± 5.8	0.1	0.5 ± 0.1	0.5 ± 0.1
	44.0 ± 4.3	0.2	0.7 ± 0.1	0.7 ± 0.1

Table5. Average annual exposure for inhabitants of Chakmoh, Baddu, Khiah, Asthota and Batrali villages of Himachal Pradesh.

Sr No.	Location (Village)	Average radon Concentration (Bq/m^3)	Annual Exposure WLM	mJh/m^3	Annual effective dose (mSv/y)
1	Chakmoh	519.7	2.3	8.1	8.9
2.	Baddu	670.0	3.0	10.4	11.4
3.	Khiah	803.0	3.7	11.7	12.7
4.	Asthota	434.4	1.9	6.7	7.4
5.	Batarli	342.0	1.5	5.3	5.8

Table 6 a. Radon concentration in the living rooms of Ramera and Galot villages on 10th April, 1998 using the active technique of Alpha-Guard.

Village	*Radon Conc.* (Bq/m^3)	*Temperature* ($^{\circ}C$)	*Rel. Humidity* (%)	*Pressure* (mbars)
Ramera	133 ± 53*	19	74	922
	69 ± 40*	25	53	919
	45 ± 38*	27	40	918
Galot	157 ± 54	25	53	935
	179 ± 58	25	58	936
	136 ± 53	25	60	936
	146 ± 53	26	58	934
Mehre	128 ± 52	21	63	922

on 29th Sept., 1998, using the active technique of Alpha-Guard :

Village	Radon Conc. (Bq/m^3)	Temperature (^oC)	Rel. Humidity (%)	Pressure (mbars)
Ramera	44 ± 5*	25	93	919
	149 ± 10*	24	84	920
	95 ± 6*	25	89	917
Mehre	29 ± 4*	27	77	924
	43 ± 5*	25	77	923

observations recorded in the diffusion-mode for 10 minutes duration

* *observations have been recorded for full night.*

Table 6 b. Alpha-Guard radon concentration (active technique) in the living rooms of different villages on 7th October, 2000.

Village	Radon Conc. (Bq/m^3)	Temperature (^oC)	Rel. Humidity (%)	Pressure (mbars)
Ramera	46 ± 36	26	57	919
	69 ± 40	26	58	919
	45 ± 38	26	64	919
Galot	52 ± 38	28	63	931
	40 ± 39	29	62	933
	44 ± 38	29	59	932
	23 ± 34	33	44	930
Nukhel	42 ± 36	23	63	924
	41 ± 37	26	69	931
	39 ± 36	26	69	931
Samurkhurd	81 ± 38	34	52	961
Samurkalan	31 ± 35	34	53	966
Ropa	50 ± 37	29	50	921
Changer	45 ± 37	32	50	924

observations recorded in the diffusion-mode for 10 minutes duration

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