ESTIMATION OF ANNUAL EFFECTIVE RADON DOSES AND RISK OF LUNG CANCER IN THE RESIDENTS OF DISTRICT BHIMBER, AZAD KASHMIR, PAKISTAN

by

Muhammad RAFIQUE [1*], ***Said RAHMAN*** [2], ***Saeed U. RAHMAN*** [3], ***Mumtaz H. RATHORE*** [3], ***Muhammad I. SHAHZAD*** [4], ***Shujaht BUKHARI*** [1], ***Zulfiqar ALI*** [1], ***Muhammad WASEEM*** [1], ***Muhammad U. RAJPUT*** [5], ***and Matiullah*** [5]

[1] Department of Physics, University of Azad Jammu & Kashmir Muzaffarbad, Azad Kashmir, Pakistan
[2] SPAS DTE, SUPARCO HQs, Karachi, Pakistan
[3] Department of Medical Physics, Nuclear Medicine, Oncology and Radiotherapy Institute, Islamabad, Pakistan
[4] High Energy Physics Group, Physics Division, Directorate of Science PINSTECH, Nilore, Islamabad, Pakistan
[5] Physics Division, PINSTECH, Nilore, Islamabad, Pakistan

Scientific paper
UDC: 546.296:616.24-006
DOI: 10.2298/NTRP1103218R

Results of indoor radon survey in the dwellings of district Bhimber are presented. Current study is continuation of our preceding studies aiming to setup baseline indoor radon data for the state of Azad Jammu & Kashmir, Pakistan. In this context, 60 representative houses were carefully selected and CN-85 based box type radon detectors were installed in bedrooms and living rooms of each house. The detectors were exposed to indoor radon for 90 days. After etching CN-85 detectors in 6M NaOH at 70 °C for 3 hours, the observed track densities were related to the indoor radon concentration using calibration factor of 0.0092 tracks cm²/h per Bq/m³. The measured indoor radon concentration ranged from 29 11 to 58 8 Bq/m³, 40 9 to 60 7 Bq/m³, and 29 12 to 66 7 Bq/m³ in the regions of Bhimber, Samani, and Barnala, respectively. Excess relative risk factors were calculated using measured indoor radon concentrations, by using the risk model reported in the Biological Effects of Ionizing Radiation (BEIR VI, 1999) report. Excess relative risk was calculated for age groups of 35 and 55 years. Using local occupancy factor, average excess lung cancer risk for the population group of 35 and 55 years of age was found to be 0.42 0.09 and 0.34 0.08. The mean annual effective dose for Bhimber, Samani, and Barnala regions were found to be 1.05 0.17 mSv, 1.09 0.17 mSv, and 1.16 0.17 mSv, respectively. These values are within in the safe limits recommended by the international organizations.

Key words: CN-85 detector, indoor radon concentration, biological effects of radiations, lung cancer, mean annual effective dose

INTRODUCTION

Radon contributes one half of the total annual dose from radiations of all kinds [1, 2]. It is colorless, odorless, and inert monatomic gas; the heaviest of six noble gases. There are three naturally occurring radioactive isotopes of radon, (1) ^{222}Rn (will be called radon in rest of text), (2) ^{220}Rn (thoron), and (3) ^{219}Rn (actinon). Radon which has half life of 3.82 days is a part of ^{238}U series; on the other hand ^{220}Rn and ^{219}Rn (with half lives of 56 seconds and 4 seconds, respectively) are generated from ^{232}Th and ^{235}U series, respectively. Radon is the most important of all three isotopes, because of its higher concentration in indoor environment and health threats associated with its decay products [3].

^{220}Rn can contribute to indoor radiation exposure (due to large reserves of ^{232}Th), but its concentration is low due to its short half-life. ^{219}Rn does not significantly contribute to indoor radiation exposure due to low natural abundance of its precursor ^{235}U and extremely short half life, so only radon isotope remained the matter of discussion. Radon decays into a series of short-lived progenies, including ^{218}Po and ^{214}Po, which are alpha emitters. The lung cancer risk associated with indoor radon exposure is due to α-particles emitted by radon progeny. When an alpha particle is emitted in the lung, it deposits all of its energy on the lining of the airways of lung within the small thickness. The epithelium may be damaged due to irradiation of energy emitted by α-particles on their passage through the cells.

Since uranium and thorium are present as trace amounts in soil, rocks, and building materials, so these

* Corresponding author; e-mail: mrafique@ajku.edu.pk

are the major sources of indoor radon exposure. Natural gas and water from deep wells may contain substantial amount of radon [4].

Due to the importance of issue, numerous studies have been conducted at national and international levels [5-26]. The main aim of these studies remained monitoring of radon and investigating the areas with elevated levels. In order to assess radon health threats (if any present) systematic studies have been initiated in Azad Kashmir. These studies are continuation of our efforts to set up base line data for Azad Kashmir at radon Atlas. This paper presents results of indoor radon concentration along with estimation of lung cancer risk for the residents of district Bhimber of Azad Kashmir.

STUDY AREA

Bhimber is located 54 km in the north of Gujrat city and 80 km in the north-east of Mirpur. Geographically it is located at 32°45' to 33°15' latitude and 74°0' to 74°15' longitude. From Islamabad, Bhimber is located in the south east at a distance of 150 km by road.

The investigated area is underlain by sedimentary rocks of Siwalik group of non-marine origin, ranging in age from late Miocene to Pleistocene (see fig. 1). It is postulated that the sediments of the group were deposited in a slowly sinking basin under fresh water conditions. The total thickness of the sequence is about 5000 meters and constitutes a major portion of the whole Siwalik group. The geological rock formations present in the area include (1) Soan formation, (2) Chinji formation, (3) Nagri formation, and (4) Dhok Pathan formation.

Climate

The climate is variable, the average maximum and minimum temperatures are 28.9 °C and 15.8 °C. June and July are the hottest months of the year with 40 °C and 45 °C average temperatures, respectively. The highest temperature recorded during June and July is 48 °C. December and January are the coldest months of the year with 6.3 °C and 5.2 °C average temperatures, respectively. The total average rainfall is about 1233 mm per year. High rainfall is recorded in the months of July and August which is 264.94 mm and 255.26 mm, respectively, and low in October and November which is 31.68 mm and 16.82 mm, respectively. Humidity remains high in rainy season. The highest value of humidity is 83.4%, recorded in August in the morning, the lowest value of humidity is 29% recorded in the month of May in the evening.

MATERIAL AND METHODS

Measurements of indoor radon concentration were carried out in the dwellings of district Bhimber. Since district Bhimber is administratively divided into three parts, results are presented in accordance with these parts (Bhimber city, Samani, Barnala).

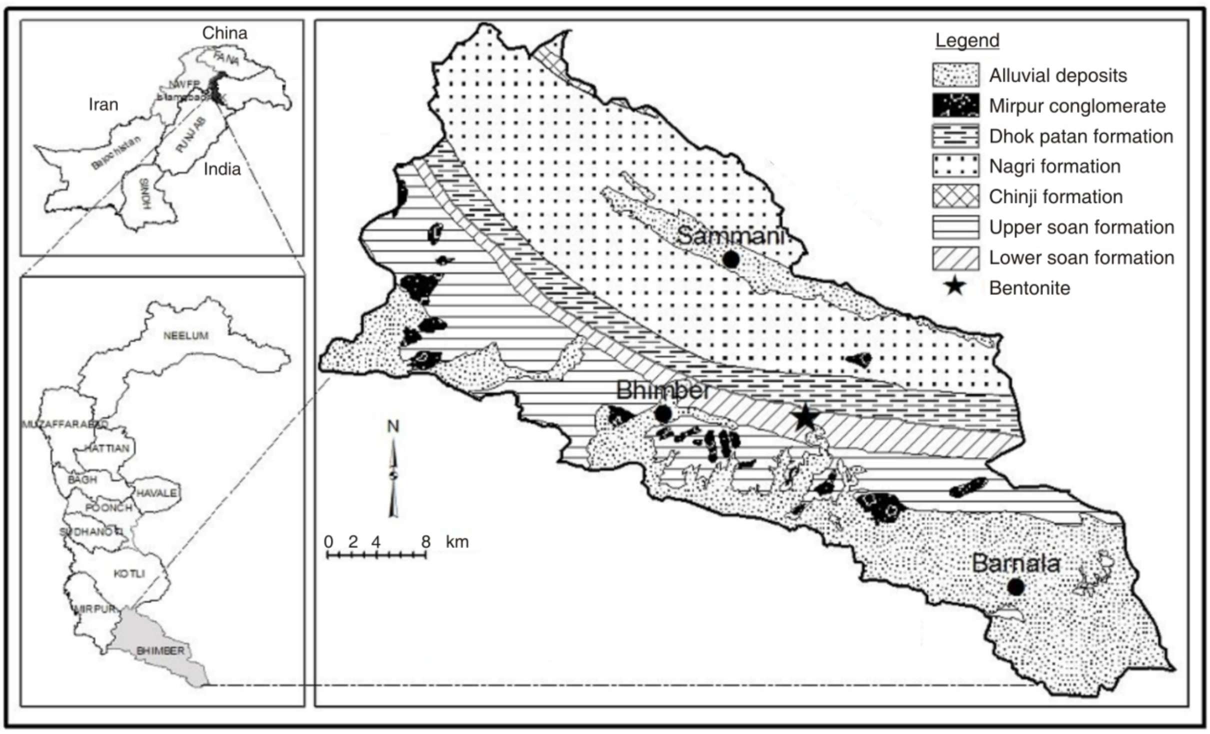

Figure 1. Geological map of district Bhimber; area under investigation

Selection of houses was based upon their geological spread, locality and design of the houses as well as willingness and co-operation of the house occupants. Cellulose nitrate (CN-85) track detectors were chosen because of their high sensitivity to alpha particles in the energy range of 0.1-6 MeV. CN-85 detectors based radon dosimeter were installed in bedrooms and living rooms. Sheets of CN-85 detectors were cut into small strips (having dimensions 3 cm 3 cm) and placed in a box-type dosimeters with dimensions 3 cm 3 cm 1.14 cm (see, fig. 2). Sixty geographically spreaded population based houses were selected to measure indoor radon levels. The detectors were placed at a height of about 1.5 m from the ground in the bedroom and drawing room of each house (all at the ground floor) and were allowed to expose to radon for 90 days. After exposure, the detectors were retrieved from the houses and etched in a 6N NaOH solution at 70 °C for 3 hours. After the background correction, track densities were determined

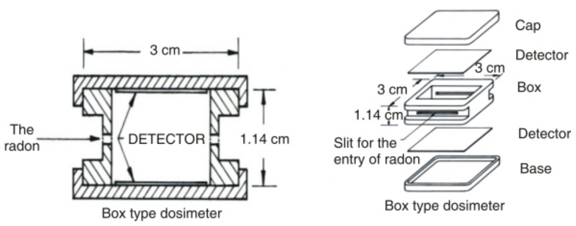

Figure 2. Schematic representation of the CN-85 detector based box-type radon dosimeter

and converted into radon concentrations (Bq/m^3) using the calibration factor (CF) of 0.0092 tracks per cm^2 per hour = 1 Bq/m^3 of ^{222}Rn. CF of the system was determined at PINSTECH Laboratory, Islamabad. Khan *et al*. [27] methodology was adopted for determination of numerical value of CF. The arrangement consists of rich uranium ore (source) along with an exposure box (dosimeter).

RESULTS AND DISCUSSION

To conduct current radon survey, 60 representative houses were selected and 120 dosimeters were installed. Out of 120 dosimeters only 90 were collected back from 45 dwellings. The remaining dosimeters were lost. Once the indoor radon concentrations for living rooms and bedrooms were calculated, then these values were used to find weighted averages of radon. Based on interviews with dwellers it was concluded that occupants spent ~60% of their indoor time in their bedrooms and 40% time in living rooms. Weighted average indoor radon concentration for each house was calculated using the following formula.

$$WARn \quad 0.40\,^{222}Rn(LR) \quad ^{222}Rn(BR) \qquad (1)$$

where WARn is the weighted average ^{222}Rn concentration, ^{222}Rn(LR) – the radon concentration in living room, and ^{222}Rn(BR) – the radon concentration in bedroom.

Results are shown in figs. 3-5. Figure 3 shows results of the indoor radon concentrations in Bhimber

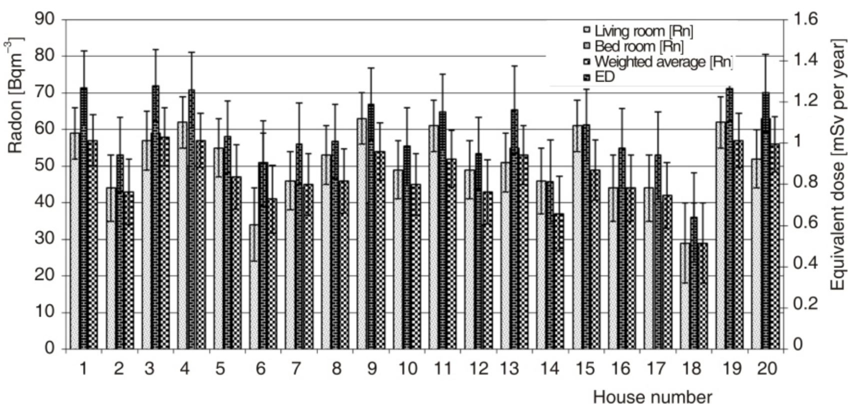

Figure 3. Indoor radon concentration and resulting doses in the houses of Bhimber city

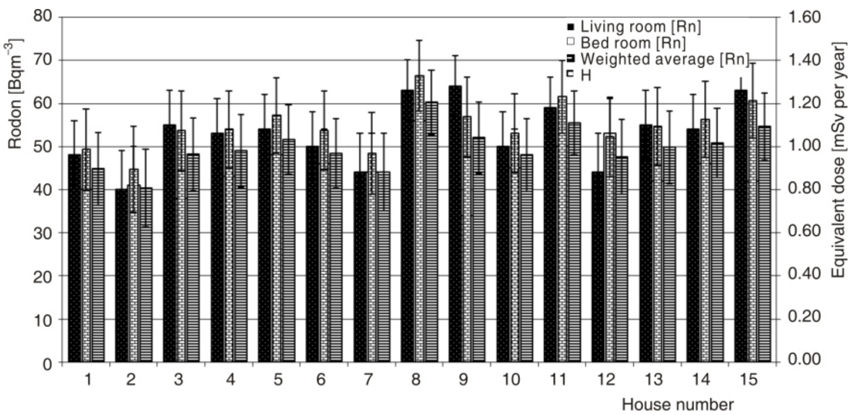

Figure 4. Indoor radon concentration and resulting doses in the houses of Samani

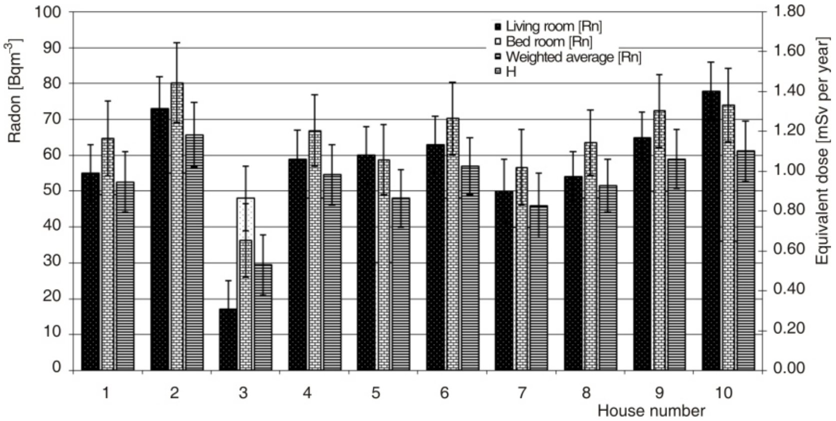

Figure 5. Indoor radon concentration and resulting doses in the houses of Barnala

City. In Bhimber city, radon concentration varies from 29 11 to 63 q m^3 in bedrooms and 24 12 to 63 7 Bq/m^3 in living rooms, respectively. Mean values of radon concentrations in bedrooms and living rooms are 51 8 and 43 9 Bq/m^3, respectively.

Figures 4 and 5 shows results of the indoor radon concentrations in Samani and Barnala. In Samani, radon concentration varies from 40 9 to 64 7 Bq/m^3 in bedrooms and 34 10 to 56 8 Bq/m^3 in living rooms, respectively. Mean values of radon concentrations in bedrooms and living rooms are 53 8 and 45 9 Bq/m^3 respectively. In Barnala, radon concentration varies from 17 14 to 78 6 Bq/m^3 in bedrooms and 30 11 to 55 8 Bq/m^3 in living rooms. Mean values of radon concentrations in bedrooms and living rooms are 57 7 and 45 8 Bq/m^3, respectively. Overall weighted average indoor radon concentration for district Bhimber was found to be 48 8 Bq/m^3.

To get a clearer picture of the variation observed in the indoor radon levels, a frequency distribution graph is plotted in fig. 6. Figure 6, shows that 2.2% of the houses have radon concentrations below 20 Bq/m^3 and 6.7% between 21 and 40 Bq/m^3. Majority of the houses surveyed (64.4%) have radon concentrations between 41 to 60 Bq/m^3 while 26.7% of the houses have radon concentrations between 61 and 80 Bq/m^3.

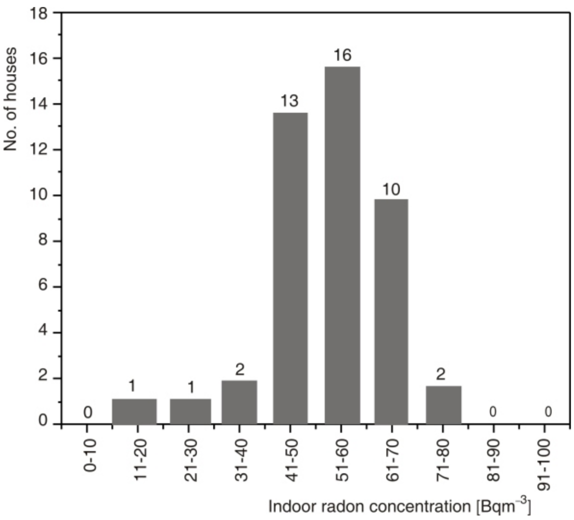

Figure 6. Frequency distribution of indoor radon concentration in district Bhimber

Determination of effective dose from radon exposure

Information of aerosol concentrations and their size distribution, depositions rate of radon progeny, unattached fraction, breathing rate, fractional deposition in the airways and location of the target cells in the airways, helps in estimating absorbed dose to the critical cells of the respiratory tract per unit radon exposure to the general population. Such type of estimates for absorbed dose strongly depend upon the model on which assumptions are based upon and carries uncertainties associated with the input data of the model. To avoid these confusions and misunderstandings we have used UNSCEAR 2000 conversion conventions in our current study.

Annual effective radon doses (*ED*) were calculated by using model, given in UNSCEAR 2000 report [2]

$$\text{ED[mSv per year]} \quad C(^{222}\text{Rn}) \quad E_{\text{f}} \quad O_{\text{f}} \quad D_{\text{cf}} \qquad (2)$$

where, $C(^{222}\text{Rn})$ is weighted average radon concentration, E_{f} – the equilibrium equivalent radon factor (0.4 taken for indoors), O_{f} – the indoor occupancy factor (0.8, reported in UNSCEAR 2000 report), and D_{cf} – a dose conversion factor (9 nSv per year per Bq/m^3). Based upon epidemiological studies and physical dosimetry, range of dose conversion factor D_{cf} for radon, varies from 6 to 15 nSv per year per Bq/m^3. No such values were defined for the domestic epidemiological radon studies up till now. Therefore in current study we have used conversion factor of 9 nSv per year per Bq/m^3 which is still considered appropriate for average effective dose calculations [2].

In the current survey the same values as suggested in UNSCEAR 2000 report were adopted for parameters E_{f} and D_{cf} where as an indoor occupancy factor of 0.7 instead of 0.8 mentioned in UNSCEAR 2000 report was adopted for O_{f}. The value of occupancy factor is based upon interview with dwellers. On average these persons spent approximately 17 hours per day within the buildings. Here it is expected a calculation like 17 hours per day   7 days per week / 168 hours per week = 0.70 occupancy fraction. In the Bhimber city, doses due to indoor radon exposure are found to vary from 0.64   0.22 to 1.28   0.17 mSv per year. Minimum value of the dose has been observed in house No. 18, whilst maximum value has been found in house No. 3. Mean value of radon dose for Bhimber city is reported as 1.05   0.17 mSv per year. In the Samani and Barnala doses due to the indoor radon exposure range from 0.90   0.20 to 1.32   0.16 mSv per year, and 0.65   0.26 to 1.45   0.16 mSv per year respectively. Minimum values for the doses have been observed in houses No. 2 and 3, whilst maximum values have been found in houses No. 8 and 2, respectively. Mean value of radon doses for Samani and Barnala are 1.1   0.18 mSv per year and 1.16   0.17 mSv per year.

Assessment of lung cancer risk

Mathematical model as proposed by BEIR IV, 1999 [28] for calculating relative lung cancer risk has been used.

$$\text{ERR} \quad \beta(\theta_{5\ 14} w_{5\ 14} \quad \theta_{15\ 24} w_{15\ 24} \quad \theta_{25} \ w_{25}\ )\varphi_{\text{age}}\gamma_{\text{z}} \tag{3}$$

where ERR represents excessive relative risk.

The parameter β in eq. (3) represents the slope of the exposure-risk relationship for the assumed reference categories of the modifying factors, θ represents relative level of effect, γ_z represents rate of radon exposure, and φ_{age} declining ERR with increasing age.

Exposure at any particular age has 4 components: exposure in the last 5 years – excluded as not biologically relevant to the cancer risk – and exposures in 3 windows of past time, namely 5-14, 15-24, and 25 or more years previously. Those exposures are labeled as w_{5-14}, w_{15-24} and w_{25+}, respectively, and each is allowed to have its own relative level of effect, θ_{5-14} (set equal to unity), θ_{15-24}, and θ_{25+}, respectively.

Results obtained for the current survey are listed in tabs. 1-3. For Bhimber city, using local occupancy factor, average excess lung cancer risk for the groups of individuals aged 35 and 55 years was found to vary from 0.25 ± 0.09 to 0.49   0.07, and 0.20   0.08 to 0.40   0.05. For Samani average excess lung cancer risk for the population group of 35 and 55 years of age was found to vary from 0.34   0.08 to 0.51   and   0.06 to 0.42   0.05. Similarly for Barnal, average excess lung cancer risk for the population group of 35 and 55 years of age was found to vary from 0.56   0.06 to 0.25   0.10 and 0.20   0.08 to 0.46   0.05. As may be seen from tabs. 1-3 that US EPA (2003) [29] occupancy factor gave a higher excess lung cancer risk compared with the local occupancy factor used for studied areas. The ERR due to indoor radon is within

Table 1. Excess relative risk of lung cancer due to the weighted indoor radon using local and US EPA occupancy factors in the Bhimber district

House No.	WARn	ERR for 35 years age (Local OF*)	ERR for 35 years age (EPA OF)	ERR for 55 years age (Local OF)	ERR for 55 years age (EPA OF)
1	57 7	0.48 0.06	0.55 0.07	0.40 0.05	0.45 0.06
2	43 9	0.36 0.08	0.42 0.09	0.30 0.06	0.34 0.07
3	58 8	0.49 0.07	0.56 0.08	0.40 0.06	0.46 0.06
4	57 7	0.48 0.06	0.55 0.07	0.40 0.05	0.45 0.06
5	47 9	0.40 0.08	0.45 0.09	0.33 0.06	0.37 0.07
6	41 9	0.35 0.08	0.40 0.09	0.29 0.06	0.33 0.07
7	45 8	0.38 0.07	0.44 0.08	0.31 0.06	0.36 0.06
8	46 9	0.39 0.08	0.45 0.09	0.32 0.06	0.37 0.07
9	54 8	0.46 0.07	0.52 0.08	0.38 0.06	0.43 0.06
10	45 8	0.38 0.07	0.44 0.08	0.31 0.06	0.36 0.06
11	52 8	0.44 0.07	0.50 0.08	0.36 0.06	0.41 0.06
12	43 9	0.36 0.08	0.42 0.09	0.30 0.06	0.34 0.07
13	53 8	0.45 0.07	0.51 0.08	0.37 0.06	0.42 0.06
14	37 10	0.31 0.08	0.36 0.10	0.26 0.07	0.30 0.08
15	49 8	0.42 0.07	0.47 0.08	0.34 0.06	0.39 0.06
16	44 9	0.37 0.08	0.43 0.08	0.31 0.06	0.35 0.07
17	42 9	0.36 0.08	0.41 0.09	0.29 0.06	0.33 0.07
18	29 11	0.25 0.09	0.28 0.11	0.20 0.08	0.23 0.09
19	57 7	0.48 0.06	0.55 0.07	0.40 0.05	0.45 0.06
20	56 8	0.47 0.07	0.54 0.08	0.39 0.06	0.45 0.06

*OF = Occupancy factor

Table 2. Excess relative risk of lung cancer due to the weighted indoor radon using local and US EPA occupancy factors in the region Samani of district Bhimber

House No.	WARn	ERR for 35 years age (Local OF*)	ERR for 35 years age (EPA OF)	ERR for 55 years age (Local OF)	ERR for 55 years age (EPA OF)
1	45 8	0.38 0.07	0.44 0.08	0.31 0.06	0.36 0.06
2	40 9	0.34 0.08	0.39 0.09	0.28 0.06	0.32 0.07
3	48 8	0.41 0.07	0.46 0.08	0.33 0.06	0.38 0.06
4	49 8	0.42 0.07	0.47 0.08	0.34 0.06	0.39 0.06
5	52 8	0.44 0.07	0.50 0.08	0.36 0.06	0.41 0.06
6	48 8	0.41 0.07	0.46 0.08	0.33 0.06	0.38 0.06
7	44 9	0.37 0.08	0.43 0.09	0.31 0.06	0.35 0.07
8	60 7	0.51 0.06	0.58 0.07	0.42 0.05	0.48 0.06
9	52 8	0.44 0.07	0.50 0.08	0.36 0.06	0.41 0.06
10	48 8	0.41 0.07	0.46 0.08	0.33 0.06	0.38 0.06
11	55 7	0.47 0.06	0.53 0.07	0.38 0.05	0.44 0.06
12	48 9	0.41 0.08	0.46 0.09	0.33 0.06	0.38 0.07
13	50 8	0.42 0.07	0.46 0.08	0.35 0.06	0.40 0.06
14	51 8	0.43 0.07	0.49 0.08	0.36 0.06	0.41 0.06
15	55 8	0.47 0.07	0.53 0.08	0.38 0.06	0.44 0.06

*OF = Occupancy factor

Table 3. Excess relative risk of lung cancer due to the weighted indoor radon using local and US EPA occupancy factors in the region Barnala of district Bhimber

House No.	WARn	ERR for 35 y age (Local OF*)	ERR for 35 y age (EPA OF)	ERR for 35 y age (Local OF)	ERR for 55 y age (EPA OF)
1	53 8	0.45 0.07	0.51 0.08	0.37 0.06	0.42 0.06
2	66 7	0.56 0.06	0.64 0.07	0.46 0.05	0.53 0.06
3	29 12	0.25 0.10	0.28 0.12	0.20 0.08	0.23 0.10
4	55 7	0.47 0.06	0.53 0.07	0.38 0.05	0.44 0.06
5	48 9	0.41 0.08	0.46 0.09	0.33 0.06	0.38 0.07
6	57 7	0.48 0.06	0.55 0.07	0.40 0.05	0.45 0.06
7	46 8	0.39 0.07	0.45 0.08	0.32 0.06	0.37 0.06
8	52 8	0.44 0.07	0.50 0.08	0.36 0.06	0.41 0.06
9	59 7	0.50 0.06	0.57 0.07	0.41 0.05	0.47 0.06
10	61 8	0.52 0.07	0.59 0.08	0.43 0.06	0.49 0.06

*OF = Occupancy factor

Table 4. The comparison of mean radon concentrations in indoor air samples with different countries

Sr. No.	Location	Weighted average radon concentratin [Bqm^{-3}]			References
		Drawing room		Bedroom	
1	Muzaffarabad, Pakistan		87		[17]
2	Balakot, Pakistan		67		[21]
3	Rawala kot, AJK	67		76 30	[19]
4	Hajira, AJK	71		83 33	[19]
5	Abbaspur, AJK	118		128	[19]
6	Islamabad and Rawalpindi	53		36	[8]
7	Islamabad		70.67 11.44		[30]
8	Lahore	74		52	[31]
9	N.W.F.P		65		[14, 15]
10	Sweden		140-400		[32]
11	Demark		53		[5]
12	Saudi Arabia		16		[12]
13	UK		20		[7]
14	USA		46		[10]
15	Brazil		82		[11]
16	Bhimber Pakistan		48 8		Present study

limits and does not pose any serious threat to the occupants of the houses under investigation. A comparison of weighted average radon concentrations of studied area with national and international data is given in tab. 4. Values from the present survey are lower than those reported in many other studies conducted at national and international levels and greater than average concentration in some other ones.

Lower values for indoor radon concentrations (as compared to other studies at national level) are reported in current study. There may be a number of reasons.

(1) houses were well separated and room's dimensions were considerably greater in district Bhimber as compared to houses in other parts of Azad Kashmir (*e. g*., like in Muzaffarabad, Bagh, *etc*.),
(2) in many of houses ventilation system was remarkably good, and
(3) there was proper drainage system in investigated area.

CONCLUSIONS

Indoor radon concentration and excess relative risk of cancer was estimated for the residents of district Bhimber, Azad Kashmir, Pakistan. The measured indoor radon concentrations and resulting doses are found to be within acceptable ranges. Average excess lung cancer risk for the population group of 35 and 55 years of age was found to be 0.42 ± 0.09 and 0.34   0.08. To conclude, according to the recommendations made by the Health Protection Agency, UK (200 Bq/m^3) and US EPA (148 Bq/m^3), all the houses surveyed are within the safe limits from radon exposure.

ACKNOWLEDGEMENTS

The authors are grateful to the University of Azad Jammu & Kashmir for providing funds to complete current project. We are indebted to the Department of AKMIDC Muzaffarabad, Azad Kashmir, regarding their help for providing geological map and technical assistance in completion of this study.

REFERENCES

[1] Durrani, S. A., Ilić, R., eds., Radon Measurements by Etched Track Detectors Singapore, World Scientific Public Co., Singapore, 1997
[2] ***, UNSCEAR (2000) Sources and Effects of Ionizing Radiation. United Nations, New York, 2000
[3] ***, United Nations Environment Programme: Radiation: Doses, Effects, Risks; Nairobi, Kenya, 1985
[4] Zakrzewski, S. F., Environmental Toxicology, 3rd ed., Oxford University Press, 2002, p. 170, 272
[5] Ulbak, K., *et al*., Results from the Danish Indoor Radiation Survey, *Radiat Prot Dosimetry, 24* (1988), 1-4, pp. 401-405
[6] Tufail, M., *et al*., Preliminary Radon Concentration Survey in Some Houses of Islamabad, *Nucl. Tracks Radiat. Meas., 15* (1988), 1-4, pp. 659-662
[7] Wrixon, A., *et al*., Natural Radiation Exposure in UK Dwellings, NRPB-R190, 1988
[8] Tufail, M., *et al*., Measurement of Radon Concentration in Some Cities of Pakistan, *Radiat. Prot. Dosim., 40* (1992), 1, pp. 39-44
[9] Tufail, M., *et al*., Estimation of Internal and External Dose Equivalent Rates for the Dwellers of Dera Ismail Khan Pakistan, *Nucl. Tracks and Radiat. Meas., 22* (1992), 1-4, pp. 479-482
[10] Marcinowski, F., Nationwide Survey of Residential Radon Levels in the US, *Radiat. Prot. Dosim., 45* (1992), 1-4, pp. 419-424
[11] Canoba, A., *et al*., Indoor Radon Measurements and Methodologies in Latin American Countries, *Radiat. Meas., 34* (2001), 1-6, pp. 483-486
[12] Al-Jarallah, M. I., Indoor Radon Measurement in Dwellings of Four Saudi Arabian Cities, *Radiat. Meas., 36* (2003), 1-6, pp. 445-448
[13] Kam, E., Bozkurt, A., Environmental Radioactivity Measurements in the Kastamonu Region of Northern Turkey, *Appl. Radiat. Isot., 65* (2006), 4, pp. 440-444
[14] Rahman, S., *et al*., Measurement of Indoor Radon Levels in North West Frontier Province and Federally Administered Tribal Areas – Pakistan during Summer, *Radiat. Meas., 42* (2007a), 2, pp. 304-310
[15] Rahman, S., *et al*., Seasonal Indoor Radon Concentration in the North West Frontier Province and Federally Administered Tribal Areas – Pakistan, *Radiat. Meas., 42* (2007), 10, pp. 1715-1722
[16] Rafique, M., Shahida, J., Ikram, M. S., General Public's and Physicians' Perception of Health Risk Associated with Radon Exposure in the State of Azad Jammu and Kashmir, *Public Health Nursing, 25* (2008), 4, pp. 327-335
[17] Rafique, M., *et al*., Measurement and Comparison of Indoor Radon Levels in New and Old Buildings in the City of Muzaffarabad (Azad Kashmir), Pakistan: A Pilot Study, *Radioisotopes, 58* (2009), 11, pp. 749-760
[18] Rafique, M., *et al*., Indoor Radon Concentration Measurement in the Dwellings of District Poonch (Azad Kashmir), Pakistan, *Radiat. Protect. Dosim., 138* (2010), 2, pp. 158-165
[19] Rafique, M., *et al*., Assessment of Indoor Radon Doses Received by the Students in the Azad Kashmir Schools, Pakistan, *Radiat. Protect. Dosi., 142* (2010), 2-4, pp. 339–346
[20] Rafique, M., *et al*., Radiation Doses Due to Indoor Radon Exposure, before and after the 2005 Earthquake, in the Dwellings of Muzaffarabad and the Jhelum Valley, Azad Kashmir, Pakistan, *Indoor and Built Environment, 20* (2010), 2, pp. 259-264
[21] Rafique, M., Assessment of Indoor Radon Doses Received by Dwellers of Balakot – NWFP Pakistan: A Pilot Study, *Carpathian Journal of Earth and Environmental Sciences, 6* (2011), 1, pp. 133-140
[22] Rahman, S. U., *et al*., Indoor Radon Concentrations and Assessment of Doses in Four Districts of the Punjab Province – Pakistan, *J. Radiat. Res., 50* (2009), 6, pp. 529-535
[23] Rahman, S. U., *et al*., Radon Measurement Studies in Workplace Buildings of the Rawalpindi Region and Islamabad Capital Area, Pakistan, *Building and Environment, 45* (2010), 2, pp. 421-426

[24] Rahman, S. U., Indoor Radon Survey in 120 Schools Situated in Four Districts of the Punjab Province – Pakistan, *Indoor and Built Environment*, *19* (2010), 2, pp. 214-220

[25] Rafique, M., *et al*., Assessment of Seasonal Variation of Indoor Radon Level in Dwellings of Some Districts of Azad Kashmir, Pakistan, *Indoor and Built Environment, 20* (2011), 3, pp. 354-361

[26] Rafique, M., *et al*., Radon Exhalation Rate from Soil, Sand, Bricks and Sedimentary Samples Collected from Azad Kashmir, *Pakistan Russian Geology and Geophysics, 52* (2011), 4, pp. 451-458

[27] Khan, E. U., *et al*., Environmental Radioactivity in D. I. Khan and Its Adjacent Areas – Pakistan, *Nucl. Tracks Radiat. Meas., 19* (1991), 1-4, pp. 761-764

[28] ***, BEIR-VI Committee on Health Risks of Exposure to Radon (BEIR VI): Health Effects of Exposure to Radon Board on Radiation Effects Research, Commission on Life Sciences, National Academy Press, Washington, DC, USA, 1999

[29] ***, US EPA, EPA Assessment of Risks from Radon in Homes: Air and Radiation: EPA, 402-R-03-003, Washington DC, USA, 2003

[30] Ali, N., Estimation of Mean Annual Effective Dose through Radon Concentration in the Water and Indoor Air of Islamabad and Murree, *Radiat. Prot. Dosimetry, 141* (2010), 2, pp. 183-191

[31] Khan, S. A., Radon Concentration Levels in Fatima Jinnah Women University Pakistan, *Radioprotection 40* (2005), 1, pp. 11-27

[32] Mjones, L., Measurement Protocols for Radon in Dwellings in Sweden, Thirteen Years of Experience, in: Annual Meeting of American Association of Radon Scientists and Technologists, Denver, Col., USA, (Swedish Radiation Protection Institute, Stockholm, 1993)

Received on April 13, 2011
Accepted on October 5, 2011

Мухамад РАФИК, Саид РАХМАН, Сајед У. РАХМАН, Мумтаз Х. РАТОРЕ, Мухамад И. ШАХЗАД, Шуџат БУКАРИ, Зулфкар АЛИ, Мухамад ВАСИМ, Мухамад У. РАЏПУТ, Матиулах

ПРОЦЕНА ГОДИШЊИХ ЕФЕКТИВНИХ ДОЗА РАДОНА И РИЗИКА КАНЦЕРА ПЛУЋА СТАНОВНИКА ОКРУГА БИМБЕР У ЗАПАДНОМ КАШМИРУ, ПАКИСТАН

Приказани су резултати мерења концентрације радона у зградама округа Бимбер. Ова студија је наставак претходних истраживања, са циљем да се установе основни подаци о концентрацији радона у зградама државе Западни Џаму и Кашмир, Пакистан. С том намером, 60 репрезентативних кућа пажљиво је изабрано и у дневне и спаваће собе сваке од њих постављени су CN-85 детектори радона. Детектори су били изложени радону у периоду од 90 дана. По развијању CN-85 детектора у 6 M NaOH при 70 °C током три часа, уочене густине трагова повезани су са концентрацијом радона коришћењем калибрационог фактора за трагове од 0.0092 cm^2/h по Bq/m^3. Измерена концентрација била је за Бимбер од 29 Bq/m^3 до 58 8 Bq/m^3; за Самани од 40 Bq/m^3 до 60 7 Bq/m^3; и за Барналу од 29 12 Bq/m^3 до 66 7 Bq/m^3. Додатни релативан радијациони ризик израчунат је коришћењем измерене концентрације радона према моделу ризика приказаном у извештају Биолошки ефекти јонизујућег зрачења (BEIR VI, 1999) и одређен је за старосне групе од 35 и 55 година. Користећи податке о боравку становника на појединим локацијама, за старосне групе од 35 и 55 година такође је израчунат додатни релативни радијациони ризик за рак плућа од 0.42 0.09 и 0.34 0.08, респективно. Средња годишња ефективна доза за округе Бимбер, Самани и Барналу износила је 1.05 0.17 mSv, 1.09 0.17 mSv и 1.16 0.17 mSv, респективно. Ове вредности су у границама безбедних вредности препоручених од стране међународних организација.

Кључне речи: CN-85 дешекшор, конценшрација радона у зашвореном иросшору, биолошки ефекши зрачења, рак илућа, средња годишња ефекшивна доза