

# Assessment of lung cancer risk due to indoor radon exposure in inhabitants of the state of Azad Kashmir; Pakistan

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**Background:** Several epidemiological studies conducted on underground miner's show that exposure to elevated levels of radioactive radon gas is expected to increase the risk of lung cancer. Relative risk of lung cancer is almost linear with radon exposure. Elevated concentrations of radon are not only reported within mines but also for closed indoor environment of general public houses. Measurements of radon play a serious role in scrutinizing public health and safety in homes.

**Materials and Methods:** Indoor radon measurements were taken over a period of year, using CR-39 detectors. Measured indoor radon concentrations, was converted in to excess relative risk (ERR) factors by using the risk model reported in the Biological Effects of Ionizing Radiation (BEIR VI) report. ERR was calculated for age groups of 35 and 55 years. A careful selection of occupancy factor based on interviews with house occupants has been made.

**Results:** Using this local occupancy factor, average excess lung cancer risk for the age group of 35 and 54 y peoples was found to  $0.51 \pm 0.03$  and  $0.42 \pm 0.03$ . Similarly average values of ERR for local occupancy factor with ages 35 and 55 years was found as  $0.59 \pm 0.03$  and  $0.45 \pm 0.03$ . **Conclusion:** The overall average excess lung cancer risk for the studied area was  $0.46 \pm 0.03$ . The study suggested that United State Environmental Protection Agency (US EPA) occupancy factor gave a higher excess lung cancer risk as compared with the local occupancy factor used for studied areas. The ERR due to indoor radon is within the standard limits and does not pose any serious threat to the occupants of the houses under investigation. *Iran. J. Radiat. Res., 2012; 10(1): 19-29*

**Keywords:** Indoor radon concentration, CR-39 radon detectors, lung cancer, ionizing radiations.

cause of lung cancer after cigarette smoking. Studies concerning occupationally radon-exposed miners and direct observation from the individuals exposed to radon in their homes prove that radon is a major environmental carcinogen<sup>(1,2-8)</sup>. In the Book VI (Meteorology and Geology) written by Lucretius reported that malignant breath is exhaled by gold mines. How it acts upon men's features and complexions? Vapors given off by the earth and blown out into the open, into the unconfined spaces of the air" (Lucretius, 55 BC). According to Steinhäusler<sup>(9)</sup> (1988), the medical observations of Paracelsus (1493-1541) and Agricola in the sixteenth century "when it was noted that the mining population in parts of Germany (Schneeberg) and Bohemia (St Joachimsthalin Czechoslovakia) were suffering from a widespread fatal lung disease known as 'male metallorum' [metal sickness] or 'Schneeberger Krankheit' [Schneeberg Illness]. It was not until the nineteenth century that lung cancer was identified as the primary cause of death for about 75% of all miners in the Schneeberg region. As mentioned in the BEIR VI report that there is evidence that a single alpha particle can cause major genomic changes in a cell, including

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## INTRODUCTION

Radon exposure is the second leading

mutation and transformation which may cause lung cancer as most cancers are of monoclonal origin <sup>(10)</sup>. The excess risk of lung cancer due to radon is about 16% per 100 Bq.m<sup>-3</sup> throughout a wide range of exposure levels, then radon in homes currently accounts for about 9% of the deaths from lung cancer and hence 2% of all cancer deaths in Europe<sup>(11)</sup>. Eighteen case-control studies of residential radon and lung cancer have been published; some of these studies reported a positive or weakly positive association between lung cancer risk and residential radon concentration, while others have reported results consistent with no association <sup>(12)</sup>.

Combined analysis of 11 cohorts of over 60,000 underground miners conducted by Lubin<sup>(15)</sup> *et al.* and updated by the U.S. National Research Council which provides a comprehensive assessment of the lung

cancer risks associated with radon. The BEIR VI committee modeled the excess relative risk (ERR) as a linear function of past exposure to radon. This model allows the effect of exposure to vary flexibly with the length of time that has passed since the exposure, with the exposure rate, and with the attained age. The mathematical form of the model for ERR <sup>(1)</sup>. The BEIR VI suggested two alternative preferred models namely the “exposure-age-concentration model” and the “exposure-age-duration model”. In the present research work “exposure-age-concentration model” has been used in order to calculate the excess lung cancer from the measured indoor radon concentration. Excess relative risk (ERR) was calculated in the Azad Kashmir (figure 1) using the US EPA and local occupancy factors, using time since exposure model of the BEIR VI.

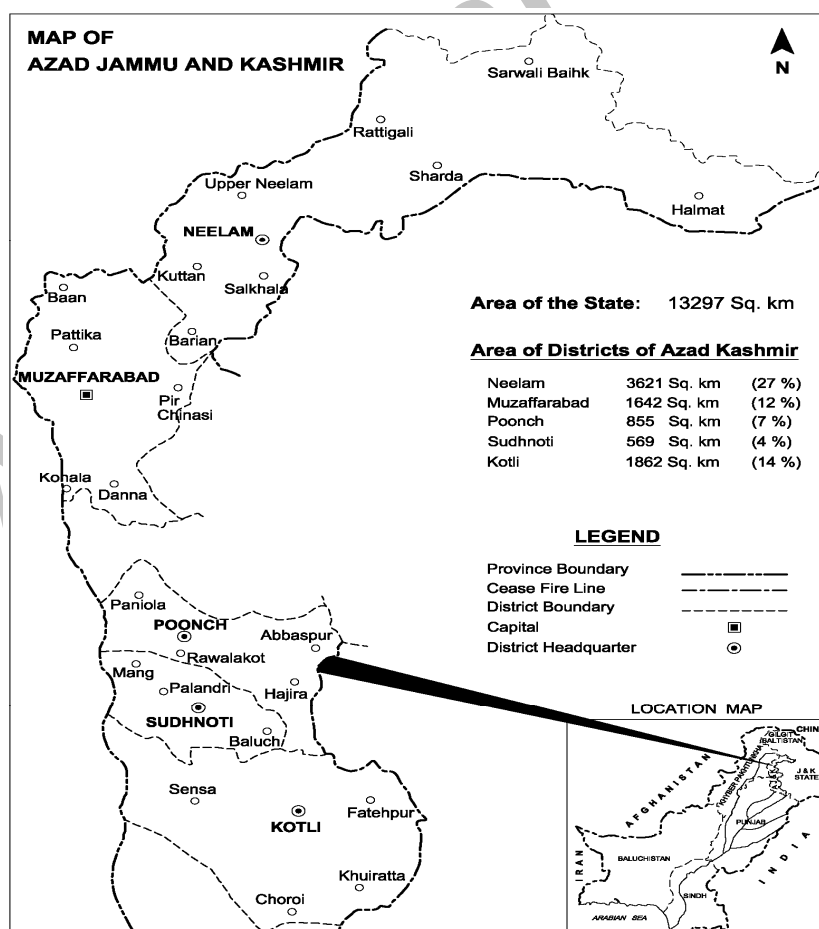


Figure 1. Map showing studied area of Azad Kashmir, Pakistan.

## MATERIALS AND METHODS

Radon concentrations were measured by using CR-39 based radon detectors in the dwellings of the Azad Kashmir. CR-39 detectors were cut into small strips (having dimensions 3 cm × 3 cm) and then fixed in a box type dosimeters with dimensions 3 × 3 × 1.14 cm<sup>3</sup> (figure 2). Two detector strips were placed at two opposite walls of the holder. The design of this type of radon detector ensures that all the aerosols and radon decay products are kept outside and only radon diffuses into the sensitive volume of the chamber. The detectors were placed at a height of five feet from the ground in the bedrooms and living rooms of each house (all in the ground floor storey). Study spans over the years taking. Since in Pakistan there are four seasons (summer, autumn, winter and spring) each spanning over three months. Therefore detectors were installed four times in a year to measure indoor

radon concentration for each season (i.e. for 90 days). After exposing the detectors for indoor radon, CR-39 detectors were etched in a 6M NaOH solution at 70°C for 9 h and tracks were counted under an optical microscope. After the background correction, track densities were related to the indoor radon concentrations (Bq m<sup>-3</sup>).

Studies have been carried out to measure the indoor radon levels in five districts of the State of Azad Kashmir namely Muzaffarabad, Neelum, Hattian, Poonch, Kotli in different seasons round the year and has been published elsewhere<sup>(16-18)</sup>. In order to avoid the effect from seasonal variation, a measurement period of 12 months is preferred to monitor indoor radon levels<sup>(19)</sup>.

The weighted average <sup>222</sup>Rn concentrations (WARn) were calculated using the following formula:

$$\text{WARn} = 0.40 \times \text{living rooms} + 0.60 \times \text{bedrooms}$$

Following mathematical models as proposed by BEIR IV, 1999 were used for calculating relative lung cancer risk.

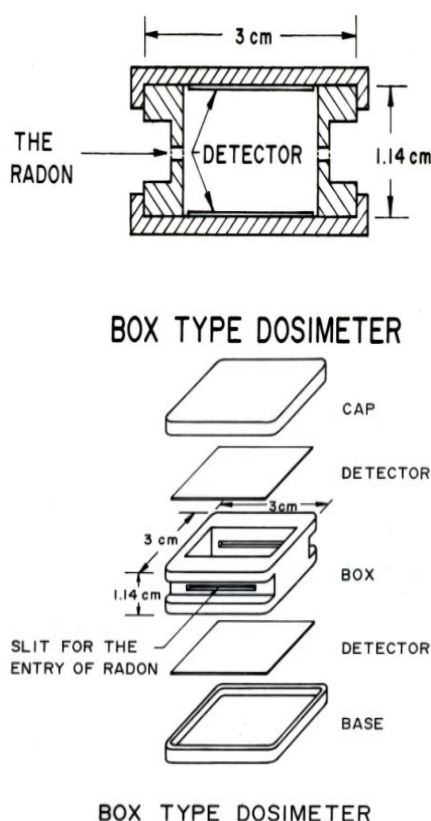
$$\text{RR} = 1 + \beta\omega, \quad (1)$$

Where  $\beta\omega$  estimates the excess relative risk (ERR),  $\omega$  is the exposure and  $\beta$  estimates the increment in ERR for unit change in the exposure  $\omega$ <sup>(20)</sup>.

A modified mathematical form of the model for ERR<sup>(1)</sup> is given as:

$$\text{ERR} = \beta (w_{5-14} + \theta_{15-24} w_{15-24} + \theta_{25+} w_{25+}) \times \phi_{ageyz} \quad (2)$$

The parameter  $\beta$  represents the slope of the exposure-risk relationship for the assumed reference categories of the modifying factors. 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,  $\theta_{5-14}$  (set equal to unity),  $\theta_{15-24}$ , and  $\theta_{25+}$ , respectively.



**Figure 2.** Schematic representation of the box type radon detector used for the measurement of indoor radon in current study.

## RESULTS

Weighted average radon concentrations were measured for five districts of Azad Kashmir for one year. From the measured weighted average indoor radon concentrations, excess relative risk (ERR) was calculated using the US EPA <sup>(21)</sup> and local occupancy factors for the area under study. The results obtained are shown in Tables 1-5. In Table 6 mean values of ERR are mentioned for local and US EPA occupancy factors.

For district Muzaffarabad, the variations in the values of ERR are mentioned in table 1, for the local occupancy factor with 35 and 55 year ages, ERR varies from  $0.19 \pm 0.06$  to  $0.97 \pm 0.02$  and  $0.20 \pm 0.05$  to  $0.85 \pm 0.02$ , respectively. Whereas for US EPA occupancy factor with 35 and 55 year ages ERR values ranges from  $0.20 \pm 0.05$  to  $0.96 \pm 0.02$  and  $0.22 \pm 0.05$  to  $0.89 \pm 0.03$ , respectively. Average (A.M  $\pm$  S.D) values of ERR for local occupancy factor in surveyed houses (for ages 35 and 55 years) are  $0.57 \pm 0.02$  and  $0.45 \pm 0.02$ . Similarly for US EPA occupancy factor mean values of ERR for 35 and 55 year ages are found as  $0.64 \pm 0.02$  and  $0.51 \pm 0.03$ , respectively.

Table 2 shows ERR variations in district Kotli of Azad Kashmir. While using the local occupancy factor with 35 and 55 year ages, ERR varies from  $0.23 \pm 0.06$  to  $0.99 \pm 0.02$  and  $0.26 \pm 0.05$  to  $0.89 \pm 0.02$ . On the other hand for US EPA occupancy factor with 35 and 55 year ages ERR values ranges from  $0.27 \pm 0.05$  to  $0.98 \pm 0.02$  and  $0.29 \pm 0.05$  to  $0.91 \pm 0.03$ . Average (A.M  $\pm$  S.D) values of ERR for local occupancy factor in surveyed houses (for ages 35 and 55 years) are  $0.65 \pm 0.03$  and  $0.54 \pm 0.02$ . Similarly for US EPA occupancy factor mean values of ERR for 35 and 55 year ages are found as  $0.72 \pm 0.03$  and  $0.59 \pm 0.03$  respectively.

In district Poonch (table 3) for 35 and 55 year ages, ERR varies from  $0.20 \pm 0.06$  to  $0.93 \pm 0.02$  and  $0.22 \pm 0.05$  to  $0.80 \pm 0.02$  for local occupancy factor. For US EPA occupancy factor with 35 and 55 year ages

ERR values ranges from  $0.23 \pm 0.05$  to  $0.92 \pm 0.02$  and  $0.24 \pm 0.05$  to  $0.84 \pm 0.03$ . Mean (A.M  $\pm$  S.D) values of ERR for local occupancy factor (with ages 35 and 55 years) are  $0.41 \pm 0.04$  and  $0.36 \pm 0.03$ . For US EPA occupancy factor mean values of ERR for 35 and 55 year ages are found as  $0.45 \pm 0.04$  and  $0.38 \pm 0.04$  respectively.

Table 4 shows ERR variations in district Neelum of Azad Kashmir. While using the local occupancy factor with 35 and 55 year ages, ERR varies from  $0.24 \pm 0.06$  to  $0.72 \pm 0.02$  and  $0.26 \pm 0.05$  to  $0.57 \pm 0.02$ . On the other hand for US EPA occupancy factor with 35 and 55 year ages ERR values ranges from  $0.28 \pm 0.05$  to  $0.80 \pm 0.03$  and  $0.25 \pm 0.04$  to  $0.64 \pm 0.04$ . Average (A.M  $\pm$  S.D) values of ERR for local occupancy factor in surveyed houses (for ages 35 and 55 years) are  $0.47 \pm 0.03$  and  $0.39 \pm 0.02$ . Similarly for US EPA occupancy factor mean values of ERR for 35 and 55 year ages are found as  $0.53 \pm 0.03$  and  $0.42 \pm 0.03$  respectively.

For district Palandri (table 5) ERR varies with ages of 35 and 55 years for local occupancy factor from  $0.20 \pm 0.06$  to  $0.98 \pm 0.02$  and  $0.22 \pm 0.05$  to  $0.86 \pm 0.02$ . On the other hand for US EPA occupancy factor with 35 and 55 year ages ERR values ranges from  $0.23 \pm 0.05$  to  $0.97 \pm 0.02$  and  $0.25 \pm 0.05$  to  $0.90 \pm 0.03$ . Average (A.M  $\pm$  S.D) values of ERR for local occupancy factor in surveyed houses (for ages 35 and 55 years) are  $0.51 \pm 0.03$  and  $0.40 \pm 0.02$ . Similarly for US EPA occupancy factor mean values of ERR for 35 and 55 year ages are found as  $0.57 \pm 0.03$  and  $0.45 \pm 0.03$  respectively.

## DISCUSSION

As discussed in results section that highest value of weighted average radon concentration was measured for district Kotli ( $107 \pm 7$  Bq.  $m^{-3}$ ) and lowest value ( $66 \pm 5$  Bq.  $m^{-3}$ ) for district Poonch (table 6). High radon concentration values for district Kotli may be attributed due to poor ventilation and construction material used in buildings. For current radon survey large number of

houses with mud as construction material was used in floor and walls. These numbers of houses in district Kotli were large in frequency as compared to other districts. On

the other hand newly built houses with better ventilation system and concrete floors with tile covering have lower values of radon concentration.

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

House No.	WARn	ERR for 35y age (Local)	ERR for 35y age (EPA)	ERR 55y age (Local)	ERR for 55y age (EPA)
1	60±4	0.41±0.03	0.45±0.03	0.32±0.02	0.36±0.02
2	53±4	0.33±0.03	0.39±0.04	0.27±0.02	0.29±0.03
3	153±3	0.90±0.02	0.96±0.02	0.76±0.02	0.81±0.03
4	54±4	0.34±0.03	0.39±0.04	0.29±0.02	0.30±0.03
5	149±3	0.89±0.02	0.94±0.02	0.74±0.02	0.80±0.03
6	90±3	0.60±0.03	0.68±0.03	0.48±0.02	0.54±0.03
7	94±3	0.64±0.02	0.71±0.03	0.51±0.02	0.57±0.02
8	51±4	0.32±0.03	0.37±0.04	0.25±0.02	0.28±0.03
9	67±4	0.44±0.03	0.50±0.03	0.35±0.02	0.40±0.03
10	153±3	0.89±0.02	0.96±0.02	0.75±0.02	0.80±0.03
11	55±4	0.36±0.03	0.41±0.04	0.29±0.02	0.32±0.03
12	82±3	0.55±0.03	0.62±0.03	0.44±0.02	0.49±0.03
13	35±8	0.21±0.06	0.24±0.05	0.23±0.05	0.26±0.05
14	218±3	0.97±0.02	0.96±0.02	0.85±0.02	0.89±0.03
15	124±3	0.82±0.02	0.89±0.02	0.66±0.02	0.76±0.03
16	59±4	0.40±0.03	0.45±0.04	0.32±0.02	0.36±0.03
17	64±4	0.43±0.03	0.48±0.03	0.34±0.02	0.38±0.03
18	22±9	0.19±0.06	0.20±0.05	0.20±0.05	0.22±0.05
19	29±8	0.20±0.06	0.22±0.05	0.21±0.05	0.24±0.05
20	69±4	0.46±0.03	0.52±0.03	0.37±0.02	0.41±0.03
21	50±6	0.31±0.03	0.36±0.04	0.25±0.02	0.27±0.03
22	212±3	0.95±0.02	0.94±0.02	0.82±0.02	0.86±0.03
23	56±5	0.37±0.03	0.42±0.04	0.30±0.02	0.33±0.03
24	132±3	0.85±0.02	0.90±0.02	0.67±0.02	0.77±0.03
25	73±4	0.49±0.03	0.55±0.03	0.39±0.02	0.44±0.03
26	90±4	0.60±0.03	0.68±0.03	0.48±0.02	0.54±0.03
27	63±4	0.42±0.03	0.48±0.03	0.34±0.02	0.38±0.03
28	52±5	0.33±0.03	0.38±0.04	0.26±0.02	0.29±0.03
29	60±4	0.41±0.03	0.45±0.03	0.32±0.02	0.36±0.02
30	47±5	0.31±0.03	0.36±0.04	0.24±0.02	0.29±0.03
31	121±3	0.81±0.02	0.89±0.02	0.65±0.02	0.75±0.03
32	50±5	0.35±0.03	0.36±0.04	0.30±0.02	0.32±0.03
33	127±3	0.83±0.02	0.90±0.02	0.66±0.02	0.77±0.03



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

House No.	WARn	ERR for 35y age (Local)	ERR for 35y age (EPA)	ERR 55y age (Local)	ERR for 55y age (EPA)
1	92±6	0.62 ±0.04	0.71±0.03	0.51±0.04	0.58±0.04
2	58±8	0.39±0.04	0.44±0.03	0.32±0.04	0.35±0.04
3	103±6	0.69±0.02	0.78±0.03	0.57±0.02	0.63±0.02
4	237±4	0.99±0.02	0.98±0.02	0.89±0.02	0.91±0.03
5	95±7	0.65±0.04	0.75±0.03	0.54±0.02	0.59±0.02
6	93±7	0.64±0.04	0.73±0.03	0.52±0.02	0.58±0.02
7	92±7	0.62±0.02	0.71±0.03	0.51±0.02	0.57±0.02
8	59±9	0.40±0.04	0.45±0.03	0.33±0.04	0.36±0.04
9	180±6	0.92±0.02	0.97±0.02	0.80±0.02	0.83±0.03
10	104±6	0.70±0.02	0.79±0.03	0.58±0.02	0.64±0.02
11	117±7	0.79±0.02	0.88±0.02	0.63±0.02	0.70±0.03
12	40±9	0.23±0.06	0.27±0.05	0.26±0.05	0.29±0.05
13	218±5	0.97±0.02	0.96±0.02	0.85±0.02	0.89±0.03
14	170±5	0.90±0.02	0.94±0.02	0.79±0.02	0.83±0.03
15	84±8	0.56±0.03	0.63±0.03	0.45±0.02	0.50±0.02
16	91±7	0.61±0.03	0.69±0.03	0.49±0.02	0.55±0.03
17	125±6	0.84±0.02	0.92±0.02	0.69±0.02	0.75±0.03
18	109±6	0.73±0.03	0.82±0.03	0.58±0.02	0.65±0.02
19	57±8	0.38±0.04	0.43±0.03	0.30±0.04	0.33±0.04
20	85±7	0.57±0.02	0.64±0.02	0.45±0.02	0.51±0.03
21	182±10	0.93±0.02	0.95±0.02	0.81±0.02	0.85±0.03
22	59±9	0.40±0.04	0.45±0.03	0.33±0.04	0.36±0.04
23	152±5	0.89±0.02	0.96±0.02	0.75±0.02	0.80±0.03
24	53±9	0.34±0.04	0.40±0.03	0.28±0.04	0.30±0.04
25	108±7	0.73±0.02	0.81±0.03	0.58±0.02	0.65±0.04
26	86±7	0.58±0.03	0.64±0.03	0.46±0.02	0.51±0.04
27	80±7	0.54±0.03	0.60±0.03	0.43±0.02	0.48±0.05
28	122±6	0.82±0.02	0.90±0.02	0.67±0.02	0.73±0.03
29	101±7	0.68±0.02	0.77±0.02	0.55±0.02	0.61±0.03
30	72±7	0.49±0.03	0.54±0.03	0.39±0.02	0.43±0.03
31	143±5	0.88±0.02	0.94±0.02	0.73±0.02	0.79±0.03
32	61±8	0.42±0.03	0.47±0.04	0.34±0.02	0.38±0.03
33	101±6	0.68±0.02	0.77±0.02	0.56±0.02	0.61±0.03

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

House No.	WARn	ERR for 35y age (Local)	ERR for 35y age (EPA)	ERR 55y age (Local)	ERR for 55y age (EPA)
1	70±5	0.47±0.03	0.53±0.04	0.38±0.03	0.42±0.03
2	147±4	0.86±0.02	0.92±0.02	0.71±0.02	0.76±0.03
3	42±6	0.24±0.06	0.28±0.05	0.26±0.05	0.29±0.05
4	45±6	0.27±0.06	0.30±0.05	0.29±0.05	0.32±0.05
5	59±5	0.40±0.03	0.45±0.04	0.32±0.02	0.36±0.03
6	34±7	0.20±0.06	0.23±0.05	0.22±0.05	0.25±0.05
7	53±5	0.33±0.03	0.39±0.04	0.27±0.02	0.29±0.03
8	129±4	0.83±0.02	0.88±0.02	0.66±0.02	0.75±0.03
9	45±6	0.27±0.06	0.30±0.05	0.29±0.05	0.32±0.05
10	52±5	0.33±0.03	0.38±0.04	0.26±0.02	0.29±0.03
11	59±5	0.40±0.03	0.45±0.04	0.32±0.02	0.36±0.03
12	56±5	0.37±0.03	0.42±0.04	0.30±0.02	0.33±0.03
13	39±6	0.21±0.06	0.23±0.05	0.22±0.05	0.24±0.05
14	209±3	0.93±0.02	0.92±0.02	0.80±0.02	0.84±0.03
15	58±5	0.39±0.04	0.44±0.03	0.32±0.04	0.35±0.04
16	44±6	0.30±0.04	0.36±0.03	0.31±0.04	0.25±0.04
17	49±6	0.30±0.03	0.35±0.04	0.23±0.02	0.26±0.03
18	82±4	0.75±0.03	0.84±0.03	0.59±0.02	0.67±0.02
19	44±6	0.30±0.04	0.36±0.03	0.31±0.04	0.25±0.04
20	41±6	0.23±0.06	0.25±0.05	0.25±0.05	0.27±0.05
21	62±5	0.41±0.03	0.46±0.03	0.32±0.02	0.36±0.03
22	39±6	0.22±0.06	0.23±0.05	0.23±0.05	0.25±0.05
23	59±5	0.40±0.03	0.45±0.04	0.32±0.02	0.36±0.03

**Table 4.** Excess relative risk of lung cancer due to the weighted indoor radon using local and US EPA occupancy factors in the Neelum district.

House No.	WARn	ERR for 35y age (Local)	ERR for 35y age (EPA)	ERR 55y age (Local)	ERR for 55y age (EPA)
1	107±4	0.72±0.02	0.80±0.03	0.57±0.02	0.64±0.04
2	69±5	0.46±0.03	0.52±0.03	0.37±0.02	0.41±0.03
3	60±5	0.41±0.03	0.45±0.03	0.32±0.02	0.36±0.02
4	90±4	0.60±0.03	0.68±0.03	0.48±0.02	0.54±0.03
5	88±4	0.59±0.03	0.67±0.03	0.47±0.02	0.53±0.02
6	42±6	0.24±0.06	0.28±0.05	0.26±0.05	0.29±0.05
7	81±5	0.54±0.03	0.61±0.03	0.43±0.02	0.48±0.02
8	68±5	0.45±0.03	0.51±0.03	0.36±0.02	0.41±0.03
9	79±4	0.53±0.03	0.60±0.03	0.42±0.02	0.48±0.02
10	80±4	0.54±0.03	0.60±0.03	0.43±0.02	0.48±0.04
11	54±6	0.35±0.04	0.41±0.03	0.29±0.04	0.31±0.04
12	44±6	0.30±0.04	0.36±0.03	0.31±0.04	0.25±0.04
13	77±4	0.52±0.03	0.58±0.03	0.41±0.02	0.46±0.03
14	64±4	0.43±0.03	0.48±0.03	0.35±0.02	0.39±0.03
15	59±5	0.40±0.03	0.45±0.04	0.32±0.02	0.36±0.03

**Table 5.** Excess relative risk of lung cancer due to the weighted indoor radon using local and US EPA occupancy factors in the Pal-andri district.

House No.	WARn	ERR for 35y age (Local)	ERR for 35y age (EPA)	ERR 55y age (Local)	ERR for 55y age (EPA)
1	34±7	0.20±0.06	0.23±0.05	0.22±0.05	0.25±0.05
2	66±5	0.45±0.03	0.50±0.03	0.36±0.02	0.40±0.02
3	67±5	0.46±0.03	0.51±0.03	0.36±0.02	0.41±0.03
4	44±7	0.26±0.06	0.29±0.05	0.28±0.05	0.30±0.05
5	62±6	0.42±0.03	0.47±0.04	0.33±0.03	0.38±0.03
6	42±7	0.24±0.06	0.26±0.05	0.26±0.05	0.28±0.05
7	65±5	0.43±0.03	0.49±0.03	0.35±0.02	0.39±0.03
8	68±5	0.45±0.03	0.51±0.03	0.36±0.02	0.41±0.03
9	221±3	0.98±0.02	0.97±0.02	0.86±0.02	0.90±0.03
10	57±6	0.38±0.04	0.43±0.03	0.30±0.04	0.33±0.04
11	153±5	0.90±0.02	0.96±0.02	0.76±0.02	0.81±0.03
12	29±8	0.28±0.05	0.32±0.05	0.31±0.02	0.34±0.03
13	81±4	0.74±0.03	0.83±0.03	0.59±0.02	0.66±0.02
14	78±4	0.52±0.03	0.59±0.03	0.42±0.02	0.47±0.02
15	66±5	0.44±0.03	0.50±0.04	0.35±0.03	0.40±0.03
16	69±5	0.46±0.03	0.52±0.03	0.37±0.02	0.41±0.03

**Table 6.** Mean values of excess relative risk of lung cancer due to the weighted indoor radon using local and US EPA occupancy factors in the five district of Azad Kashmir.

House No.	WARn	ERR for 35y age (Local)	ERR for 35y age (EPA)	ERR 55y age (Local)	ERR for 55y age (EPA)
Muzaffarabad	85±5	0.57±0.02	0.64±0.02	0.45±0.02	0.51±0.03
Kotli	107±7	0.65±0.03	0.72±0.03	0.54±0.02	0.59±0.03
Poonch	66±5	0.41±0.04	0.45±0.04	0.36±0.03	0.38±0.04
Neelum	71±5	0.47±0.03	0.53±0.03	0.39±0.02	0.42±0.03
Palandri	75±5	0.51±0.03	0.57±0.03	0.40±0.02	0.45±0.03

Figure 3 gives more clearer picture for variation observed in ERR estimation. Variations in ERR values can be seen for local and EPA adopted occupancy factors.

Reported ERR values for local occupancy factor are smaller than US EPA occupancy factor. ERR values for both occupancy factors are higher for 35 years age as compared to 55 year age group.

A comparison of present study results with the data available for excessive relative lung cancer risk at national and at international level have been carried out. For Pakistan, Faheem <sup>(22)</sup> *et al.*, reported average excess lung cancer risk for the 35-54 y age group residents to be 0.66, 0.52,

0.37, 0.49, 0.57 and 0.59 for districts of Gujranwala, Gujrat, Hafizabad, Sialkot, Mandibahauddin and Narowal. Similarly, for 55-64 year age group her reported values are 0.5, 0.40, 0.47, 0.39, 0.46 and 0.46 for the residents in the Gujranwala, Gujrat, Hafizabad, Sialkot, Mandibahauddin and Narowal districts, respectively. The overall average excess lung cancer risk for all above discussed districts was found to be 0.53. For the current study ERR values reported for 35-54 y and 55-64 year age group are close to those found by Faheem <sup>(22)</sup> *et al.* Overall average excess lung cancer risk for five districts of Azad Kashmir is found as 0.46, which is smaller than the value reported by



Faheem <sup>(22)</sup> *et al.*, at the national level.

Several epidemiological studies have been performed at international level in different parts of world to assess relative risk of cancer due to radon exposure. e.g., Goran <sup>(23)</sup> *et al.*, carried out a study in Sweden and reported the relative risk of lung cancer risk as 1.3 (95 percent confidence interval, 1.1 to 1.6) for average radon concentrations of 3.8 to 10.8 pCi per liter (140 to 400 Bq/m<sup>3</sup>), and it 1.8 (95 percent confidence interval, 1.1 to 2.9) at concentrations exceeding 10.8 pCi per liter.

Lung cancer risk reported by Tomotaka <sup>(24)</sup> *et al.*, associated with indoor radon levels of 25-49, 50-99 and 100 or more Bq/m<sup>3</sup>, were found to be 1.13 (95% confidence interval: 0.29-4.40), 1.23 (0.16-9.39) and 0.25 (0.03-2.33), respectively.

Pershagen <sup>(25)</sup> *et al.* reported relative risk results for the study carried out in Stockholm on population sample of 210 female lung cancer patients and 400 controls. A RR of 1.7 (95% Confidence Interval, 1.0–2.9) was linked with a time-weighted average radon exposure exceeding the value of 150 Bq/m<sup>3</sup> as compared to an exposure of up to 75 Bq/m<sup>3</sup>.

Ruosteenoja <sup>(26)</sup> E., conducted a survey on men from a rural area in Finland, for population sample of 238 lung cancer patients and 434 controls. The RR for highest radon exposure ( $\geq 265$  Bq/m<sup>3</sup>) was 1.23 (95% Confidence Interval, 0.71– 2.13) compared to the lowest radon level ( $<109$  Bq/m<sup>3</sup>).

Létourneau <sup>(27)</sup> *et al.* carried out a case control-study in relation with exposure to radon in Winnipeg, Manitoba, Canada including 738 lung cancer patients and 738 controls (55). RRs of 0.97 (95% CI, 0.81– 1.15) and 0.93 (0.71–1.11) per unit of cumulative radon exposure were observed for bedroom (3750 Bq/m<sup>3</sup>·years) and basement (5000 Bq/m<sup>3</sup>·years) respectively.

On comparison of current survey result for five districts of Azad Kashmir with ERR values for radon exposure at national and international level, we conclude that current survey estimated ERR values are lower than reported for other parts of world.

## CONCLUSION

Weighted average radon concentrations for one complete year have been measured

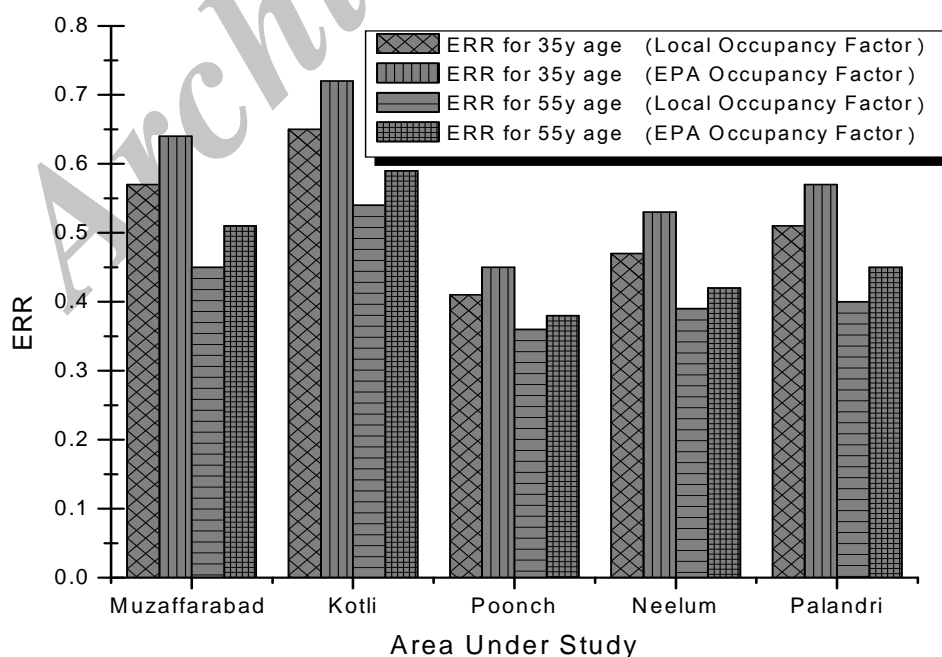


Figure 3. ERR values for local and EPA adopted occupancy factors.

in five districts of Azad Kashmir. From the measured indoor radon concentrations, excess lung cancer risk was calculated using local and US EPA occupancy factors. Average values of ERR for local occupancy factor with ages 35 and 55 years was found as  $0.51 \pm 0.03$  and  $0.42 \pm 0.03$ . Similarly average values of ERR for local occupancy factor with ages 35 and 55 years was found as  $0.59 \pm 0.03$  and  $0.45 \pm 0.03$ . The overall average excess lung cancer risk for the studied area was  $0.46 \pm 0.03$ . The ERR due to indoor radon is within the limits and does not pose any serious threat to the occupants.

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