The Nucleus, 46 (1-2) 2009 : 15-20

The Nucleus
A Quarterly Scientific Journal of Pakistan Atomic Energy Commission
NCLEAM, ISSN 0029-5698

MEASUREMENT OF RADON (^{222}Rn) CONCENTRATION AT HIGH ALTITUDES IN THE NORTHERN AREAS OF PAKISTAN

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(Received September 09, 2008 and accepted in revised form March 27, 2009)

Radon (^{222}Rn) concentration has been measured using CN-85 solid-state nuclear track detectors in the dwellings of Northern Areas of Pakistan at different altitudes. The CN-85 detectors, installed in box type radon dosimeters, were exposed for a period of one year. The average radon concentration level has been found at altitudes 3020 m, 3540 m, 3665 m and 4265 m above sea level and the ^{222}Rn concentrations were found to be (16.4±2.5) Bq m^{-3}, (21.7±4.8) Bq m^{-3}, (13.8±3.2) Bq m^{-3} and (19.3±3.4) Bq m^{-3}, respectively. It has been observed that there are no significant differences in the radon concentrations with different altitudes. However, differences in concentrations were observed with types of rooms attributed to better ventilation, atmospheric parameters and source of radon present in the soil. These results have been compared with radon concentration measurement found in literature. The ^{222}Rn concentration measured in the area under study is found below the permissible level recommended by the International Commission on Radiological Protection (ICRP) for public exposure.

Keywords: Radon, Box type dosimeter, CN-85, Alpha tracks

1. Introduction

The origin of radon (^{222}Rn) in the earth's crust stems directly from the uranium, thorium and their decay products distributed in minute quantities in the earth's surface [1, 2]. In the natural environment, radon is present almost in all locations (in soil, rocks etc.), in trace amount throughout the earth surface with different concentrations. An odourless, tasteless, invisible gas that mixes with air, chemically and essentially non-reactive heaviest noble gas with highest melting and boiling point, highly soluble in non-polar solvent moderately soluble in cold water, able to diffuse through rock and soil, decays by alpha particle emission. Unlike radon its progeny are not gaseous, but rather particle in nature. These progeny attach themselves to dust paticle or other particulates that are suspended in the air. The radon being chemically inert can move through earth or structural material, with a half-life of 3.824 days to reach the outdoor or indoor air. The rocks like granite, shales, fluorspars and sandstones may contain substantial amount of uranium concentration although they are not considered to be ores. The major sources of radon in buildings include construction material such as gypsum board, granite gravels for heat storage, granite building stones and uranium rich concrete, soil gas which enter the basements of buildings by diffusion through foundation or cracks and radon rich water drawn from soil. This radon rich water outgas in houses when used for washing and bathing purposes. Variation in airborne radon in houses may occur by several orders of magnitude. This is because of radium concentration in bedrocks and its varying emanation rate etc. The level of radon in buildings thus particularly depends upon the underground geological pattern of the radon source in soil and rocks. Radon atoms generated in the earth's crust enter the pore spaces and are then transported by diffusion and advection into the atmosphere.

Exposure to radon and its radioactive progeny contributes the major dose received by human beings from natural sources. The continuous damage produced by alpha particles emitted from radon and its progeny in lungs may cause cancer [3]. There is continuous emanation from the ground water sources such as wells, springs, bore holes, etc.; which may also contain high concentrations of radon dissolved in water that get released to the atmosphere. In the studies made in multi-storey buildings, measurements have shown that the radon levels are more in the basements and first

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floor rooms [4, 5]. Concentration drops off substantially as floor level increases. Underground cavities have a greater potential for radon buildup than the above ground structures due to poor ventilation in underground cavities. Without ventilation, it can be assumed that radon level in caverns would come into approximate equilibrium with soil gas levels. In recent years, substantial attention has been paid to radon and its progeny in buildings and dwellings. Many countries such as Australia [6], Luxembourg [7], Russia [8], Mexico [9], Latin American countries [10], Bangladesh [11], India [12-14], Hong Kong [15], Pakistan [4, 5, 16-19] have carried out surveys to determine the level of radon and its progeny in buildings and dwellings. The International Commission on Radiological Protection (ICRP) has recommended an “action level” between 200 Bq m^{-3} and 600 Bq m^{-3} [20]. The National Radiological Protection Board UK [21] has also recommended an “action level” of 200 Bqm^{-3} for radon in houses [22, 23].

Different laboratories for the monitoring of radon and its progenies have developed a number of passive and active techniques [24, 25]. The choice of a particular method depends on the objective of the study. Active methods are usually used for the short-term measurement of radon progenies and for other parametric studies. The passive methods are suitable for the assessment of radon exposures on long time scale. These are based on integrating devices and therefore, the data obtained represent averages over temporal variations. One of the important methods for long-term passive measurement of radon and its progenies is based on the use of solid state nuclear track detectors [26-28]. The principle of this off-line method is very simple. Radon and its progeny emit alpha particles, which are registered in solid state nuclear track detector (e.g. CR-39, CN-85, LR-115 etc.) in the form of latent damaged trails. After chemical etching of the detectors, the latent damaged trails are sufficiently enlarged to become optically visible. The number of tracks per unit area of the detector is counted either manually with the help of an ordinary optical microscope or by using suitable automatic track measuring system. This measured track density is directly related to the cumulative exposure and hence the average concentration during the period of monitoring. In the present study, CN-85 plastic track detectors have been employed, which are extensively used in the radon surveys carried out worldwide [29-32]. Present survey has been performed at different altitudes of Northern Areas of Pakistan as shown in Fig. 1. This part of the area consists of limestone of Devonian age and phyllites, slates, quartizites, marbles, schists and sandstones. The detectors placed in radon dosimeters were exposed for a period of one year.

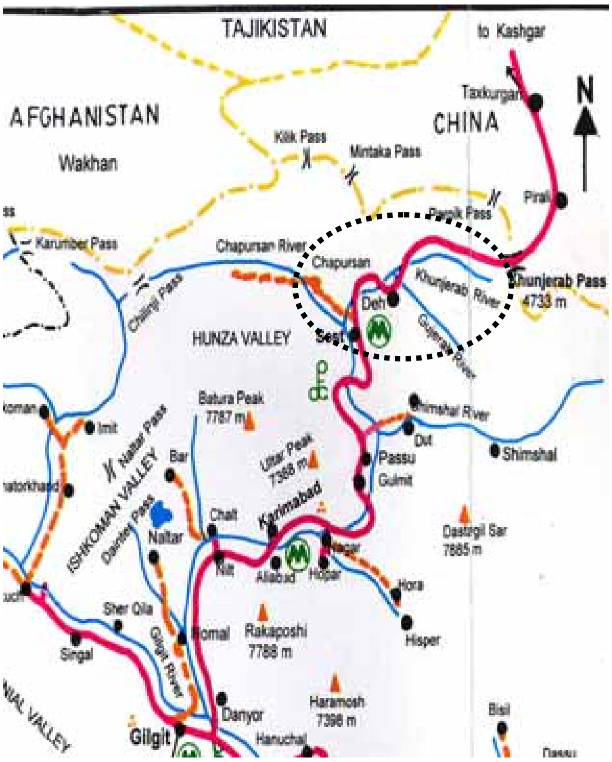

Figure 1. The map of a portion of Northern Areas of Pakistan in the Himalyan range. The present studies has been carried out in four locations at different altitudes in the dotted encircled part.

2. Experimental Details

The radon concentration measurement was done using the CN-85 nuclear track detectors as a passive radon dosimeter because the CN-85 detectors have low background as compared to other solid state nuclear track detectors.

The detectable range of these detectors for alpha particles varies from 5.0 MeV and 7.7 MeV energy. The CN-85 detectors (3×3) cm^2 were fixed in box type dosimeters which have dimensions of (3 cm × 3 cm × 1.14 cm) as shown in Fig. 2. The design of the dosimeter ensures that all particulates including the radon decay products are cut off by the slit window and only radon gas diffuses through it to the sensitive volume of the chamber. Proper cataloging was made on the dosimeters pertaining to the location of their installation in the building at a height of 2-3 m above the ground level. After an exposure of one year the dosimeters were retrieved and the nuclear track detectors were chemically etched in 6N NaOH at 50°C for 70 minutes for the development of the latent tracks. The counting of tracks was done manually under an optical microscope at a magnification of 400X. The exposed area of each detector was scanned thoroughly and average track density was measured. The track densities obtained were converted into radon concentration (Bq/m^3) using calibration factor. We used calibration factor of 0.092 tracks cm^{-2}.hr^{-1} per Bq m^{-3} followed by Tufail et al. [5].

The mean values of radon concentration in the rooms, baths and stores of the building is shown in the Fig. 3.

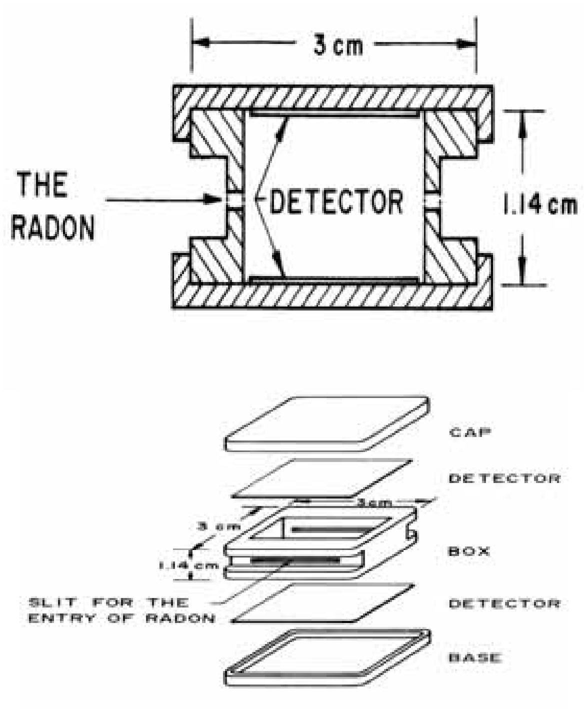

Figure 2. Schematic diagram of the dosimeter, (a) dosimeter ready for use and (b) exploded views of the dosimeter.

It can be seen that frequency distribution of the radon concentration looks normal or below normal like as in the case of most of the national surveys [17, 30, 31].

3. Results and Discussions

The minimum, maximum and average values of radon concentrations at different altitudes have been measured using CN-85 nuclear track detectors. The total number of radon dosimeters used in this study was 360 containing CN-85 nuclear track detectors which were installed at different locations of the experimental sites.

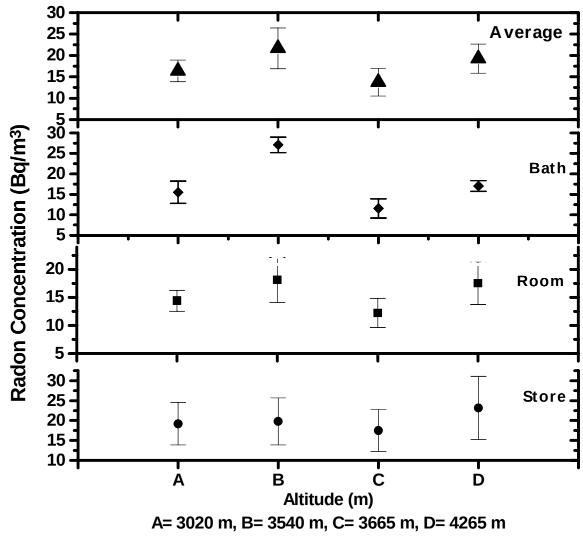

Figure 3. Mean values of radon concentration in the rooms, stores and baths of the buildings at different altitudes in the northern areas of Pakistan. The average value of radon concentration at different altitudes has been shown as Average.

The radon concentrations measured at altitudes 3020 m, 3540 m, 3665 m and 4265 m, were found to be (16.4±2.5) Bq m^{-3}, (21.7±4.8) Bq m^{-3} (13.8±3.2) Bq m^{-3} and (19.3±3.4) Bq m^{-3} respectively. The overall average value of radon concentration is found below 22 Bq m^{-3}. There is slight variation of radon concentration in the rooms, baths and stores of the dwellings whereas radon concentration does not vary with the altitude. The radon concentration is in the safe range recommended by International Commission on Radiological Protection (ICRP).

The radon concentration measurement at comparable altitudes with that of the present study sites has been carried in the dwellings of Skardu city, northern areas of Pakistan, by Akram et al. [17] in which average radon concentration (111.34) Bq m^{-3} has been reported. The radon concentration observed in the present studies is low as compared to [17] because of the difference in construction material of the buildings. In Ref. 17 most of the studies have been done in the mud made houses and in the congested areas of the city where open drainage system contributes in the radon concentration level towards higher side while the dwellings in the present study sites are constructed using cement, concrete stones/bricks having covered sewerage systems. The results of the present study are comparable with the radon concentration measured in the dwellings of Islamabad, Rawalpindi and Lahore which have been reported by Tufail et al. [33].

Table 1. Annual Mean Effective doses due to radon exposure.

House Code	Weighted Average Indoor Radon Concentration (Bqm^{-3})	Annual Mean Effective Doses (H) ($mSv\ y^{-1}$)
1	18.40	0.46
2	18.26	0.46
3	13.62	0.34
4	24.59	0.62
5	17.76	0.45
6	15.02	0.38
7	16.94	0.43
8	13.14	0.33
9	23.28	0.59
10	19.86	0.50
11	19.33	0.49
12	12.38	0.31
13	17.44	0.44
14	18.94	0.47
15	16.19	0.41
16	14.46	0.36
17	22.94	0.58
18	17.59	0.44
19	15.15	0.38
20	16.31	0.41
21	15.37	0.39
22	13.62	0.34
23	18.59	0.47
24	17.12	0.43
25	23.13	0.58
26	24.72	0.62
27	19.24	0.48
28	14.47	0.36
29	19.16	0.48
30	16.56	0.42
31	18.39	0.46

4. Dose Estimation

For the estimation of average effective dose (H) ($mSv.y^{-1}$) to inhabitants due to radon and its progeny, we have used the model given by UNSCEAR (2000) in their report, previously used by Khan et al. [33, 34].

$$H = C \times F \times O \times T \times D$$

Here C stands for weighted average indoor radon concentration in Bq m^{-3}, F (0.4, taken for indoor inhabitants) for equilibrium equivalent concentration (EEC) factor, O for occupancy factor (0.8 as taken in UNSCEAR 2000 report), T for time ($8760\ h.y^{-1}$), and D for dose conversion factor ($9\ nSv.h^{-1}$ per $Bq.m^{-3}$) [34]. Radon doses ranges from 0.31 to 0.62 mSv y^{-1}. Radon doses received by residents are listed in Table 1.

Comparison of radon doses of current study with the world mean dose from environmental ^{222}Rn of 1.15 $mSv.y^{-1}$ [33] suggests that radon doses in the studied area are within safe limit from health hazard point of view. Comparison of the data obtained in the current study with other studies carried out in different parts of Pakistan is made in Table 2.

Table 2. A comparison of indoor radon levels measured in different parts of Pakistan with current study results.

Reference	Location	Results
Qureshi et al. (2000) [35]	Balochistan coal mines, Pakistan	Ranges from 121 to 408 Bq m^{-3}
Khan et al. (2005)[34]	Fatima Jinnah Women University, Rawalpindi, Pakistan	Ranges from 31 to 213 Bq m^{-3} for old buildings. and 27 to 143 Bq m^{-3} for new buildings.
Tufail et al. (1992) [32]	Islamabad, Rawalpindi, Pakistan	23 to 83 Bq m^{-3}(Bed rooms), 20 to 74 Bq m^{-3}(Kitchens), 16 to 56 Bq m^{-3} (Sitting rooms), 12 to 49 Bq m^{-3} (TV Lounges)
Tufail et al. (1992) [32]	Lahore, Pakistan	28 to 93 Bq m^{-3}(Bed rooms), 23 to 86 Bq m^{-3}(Kitchens), 21 to 82 Bq m^{-3} (Sitting rooms), 20 to 69 Bq m^{-3} (TV Lounges)
Jamil and Ali (2001) [36]	Coal mines of Khushab, Punjab, Pakistan	Maximum radon level 782 ± 125 Bq m^{-3}
Akram et al. (2005) [17]	Skardu, Pakistan	Radon level ranges from 76 to152 Bq m^{-3} with an average value of 111 Bq m^{-3}
Matiullah et al. (2003) [37]	Southern Punjab, Pakistan	Bedrooms: 20, 20, 26, 28, 34, 42, 47 Bq m^{-3} and sitting rooms: 24, 26, 27, 26, 37, 40, 43 Bq m^{-3}
Rahman et al. (2007) [38]	NWFP and FATA, Pakistan	Yearly arithmetic mean of 76 ± 37 and 68 ± 25 Bq m^{-3} in bedrooms and drawing rooms respectively
Current Study	Northern areas of Pakistan	The average radon concentration at altitudes 3020 m, 3540 m, 3665 m and 4265 m above sea level, were found to be (16.4±2.5) Bq m^{-3}, (21.7±4.8) Bq m^{-3}, (13.8±3.2) Bq m^{-3} and (19.3±3.4) Bq m^{-3}, respectively

5. Conclusions

The average value of radon concentration is very low as compared to the safe value recommended by ICRP. It indicates that the low radon concentration at the experimental site are due to the factors like excellent ventilation conditions, low radium contents in the soil. Also the factors contributing the low radon concentration are the type of building materials used for the construction of house, bricks made from the soil and concrete used in the floors having less radon source are major contribution in low level of radon measurement. Therefore, it is also concluded that the low temperature (due to snow fall) and other atmospheric conditions (windy area) justify the low value of radon concentration in the dwellings at this experimental site.

Acknowledgements

We acknowledge Pakistan Science Foundation for the financial support provided to carry out this research work.

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