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RADON CONCENTRATION MEASUREMENTS FOR DETERMINATION OF RADIATION DOSE AND ASSESSMENT OF CANCER RISK IN THE PREMISES OF SOME COLLEGES IN LAHORE, PAKISTAN

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Radon concentration has been measured in campus and hostel buildings of some colleges in the city of Lahore. The technique of passive radon measurements was employed using CN–85 etched track detectors in the box type dosimeters. The observed radon concentration in different parts of monitored buildings was within the range 18–61 Bq m^{-3}. The cause of radon in college buildings may be the construction materials, drinking water, natural gas, drainage, sewerage pipes, etc. Moving fans, open doors and windows in summer season diluted the radon concentration, while the air tight arrangement in the winter enhanced the radon concentration level. Alpha dose from radon to the students and supporting staff was estimated as 0.34 and 0.91 mSv y^{-1} in campus and hostel buildings respectively. The corresponding excess lifetime cancer risk attributed to the students and staff in the college campuses was found to be 0.20 %, while the staff and students residing in the hostels of the colleges received the excess lifetime risk of cancer 0.53 % due to radon progenies.

Keywords: Radon, College, CN-85 track detector, Lung cancer risk

1. Introduction

Lahore, the Capital of the Punjab province of Pakistan, is the city of schools and colleges. The buildings of the education institutes in the city are mainly made of baked clay bricks, cement and sand. Radon releases from radium present in trace amount nearly in all type of the building materials and soils [1–3]. In air, radon undergoes alpha decay to produce radioactive decay products. The presence of high concentration of radon in indoor environment poses a significant risk to the general public [4]. When inhaled, a fraction of radon and its decay products are transported to the lungs [5]. These radioactive nuclides produce severe biological damages, which may ultimately cause lung cancer [6–9]. The radiation damages are the result of alpha decay of radon and its decay products during the transit time within the lungs.

Radon can present a large hazard in workplaces such as schools, offices, mines and public places open to visitors [10–12]. During the last few years, much attention has been dedicated to conduct radon surveys and to develop radon mitigation methods in work places and public buildings [12–13].

In Pakistan, surveys have been carried out on large scale for the measurements of radon concentration in houses [14–18], but according to our knowledge, no such a work has yet been reported in literature for schools and colleges in Lahore. In the present work, radon concentration has been measured in different campus and hostel buildings of the colleges in the city of Lahore, Pakistan. The aim of this work was to assess the lung cancer risk associated with radon decay products in these premises and also to impart the precautionary steps in the light of measurement so as the students and staff members of the college campuses and hostels could be protected from the over exposure to radon and its decay products.

A number of techniques have been employed for the measurement of atmospheric radon, which are broadly classified as active and passive. We have employed passive technique for the measurement of radon concentration for present study. The selection of particular technique was

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carried out by keeping in view, the objectives of measurement, availability and cost of equipment [19].

2. Experimental Procedure

Box type dosimeters, described somewhere else [16], were employed for the measurement of radon concentration in the study area. Around 300 dosimeters were installed in different parts of campus and hostel buildings of the colleges. Each dosimeter consists of two pieces of plastic track detector, cellulose nitrate (CN–85) having thickness of 100 μm. The dosimeters were fixed at a height of 60–90 cm based on our experimental observations given in Figure 1 that indicates the maximum radon concentration exists at the lower indoor atmosphere.

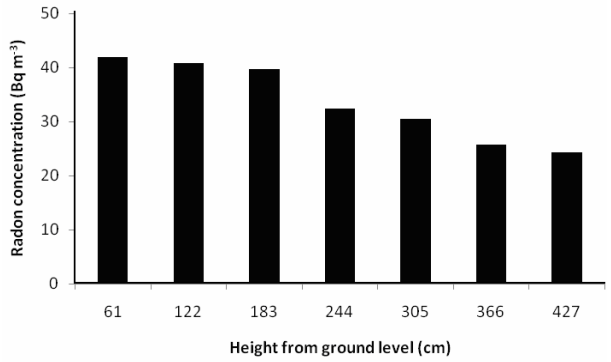

Figure 1. The decrease of radon concentration with increase of height in a room.

Most of the detectors were exposed during the months of February–March (closing of winter). The radon measurement in Islamia College, Lahore was carried out in April-May (start of summer). After an exposure of 70 days, the detectors were brought to the laboratory and etched in 6N NaOH solution at 50±1° C for 90 minutes. These conditions were found suitable for the maximum tracks revelation [14–16]. The etched tracks were counted under an optical microscope for the area scanned 0.07 cm^2. The track density was converted to radon concentration by applying the conversion factor of 0.0092 tracks cm^{-2} h^{-1} per Bq m^{-3} [16].

3. Results and Discussion

The concentrations of radon measured in different portions of the buildings under study are given in Tables 1–2. The estimated effective dose and excess lifetime cancer risk received by the students and workers are given in Tables 3–4.

3.1. Radon Concentration in College Campuses

The average radon concentration (Bq m^{-3}) in different parts of college campuses is summarized in Table 1 as a comparative figure. Chemistry Laboratories have the maximum average radon concentration of 43±8 Bq m^{-3} among the monitored sites in different college campuses. Poor ventilation, lose connections of water and drainage pipes may be responsible for high values of radon in these laboratories.

Class rooms contained the least average value of radon concentration i.e. 24±5 Bq m^{-3}. In class rooms, windows and ventilators remain open throughout the day, provide with good air exchange rate. It is also noted that radon concentration has the highest peak in all parts of Garrison College as compared to that of other parts of different colleges i.e. 36–58 Bq m^{-3} with average value of 48±7 Bq m^{-3}. Such a high peak in radon level seems to be a result of radium rich building material and new construction style having a least number of windows and ventilators. All other colleges have old fashion buildings, with large numbers of windows, ventilators and high roofs.

Radon concentration in the stores of the colleges lie between 36–47 Bq m^{-3} with the mean value of 40±4 Bq m^{-3} and in contrast to our expectations, it is not the maximum value among the other parts of college campuses where radon concentration was measured. The results of radon concentration measurements in different houses of Lahore [15], exhibits maximum radon concentration level in the stores due to poor ventilation. The ventilation in the stores of colleges is also poor, but the observed radon concentration did not appear as maximum in the stores i.e. slightly less than the radon concentration, observed in the Chemistry Laboratories. Instead of poor ventilation, several additional factors such as tap water, natural gas, and drainage and sewerage pipes may have slightly enhanced the concentration of radon in the Chemistry Laboratories.

3.2. Radon Concentration in College Hostels

The average of radon concentration in different parts of college hostels is given in Table 2. On the average, radon concentration has been noted 42±7 Bq m^{-3} in the students' rooms, the minimum value of 27±3 Bq m^{-3} in the students' rooms of Islamia College. The observed radon concentration in the students rooms of remaining seven colleges are

Table 1. Average radon concentration in different sections of college campuses of Lahore, Pakistan

Campus Name	Radon Concentrations (Bq m^{-3})					
	Principal room	Staff room	Class room	Physics laboratory	Chemistry laboratory	Stores
Government College University	33±5	25.30±6	20±4	38±4	47±5	37±4
Lahore College University	25±3	28±4	21±3	27±3	33±3	36±5
Queen Marry College	35±5	37±5	18±4	44±5	40±4	41±4
Islamia College	35±3	29±4	21±3	29±3	40±5	39±5
Fatima Jinnah Medical College	32±4	30±5	24±3	-	-	46±4
Garrison College	48±6	48±5	36±5	51±5	58±4	47±3
Islamia Col. Civil Lines	35±5	32±4	24±6	35±4	45±6	39±5
Forman Christian College	31±3	39±4	25±4	41±3	41±3	39±3
Range	25–48	25–48	18–36	27–51	33–58	36–47
Mean ± Std.	34±6	33±8	24±5	38±8	43±8	40±4

Table 2. Average radon concentration in different sections of college hostels of Lahore, Pakistan

Hostel Owner	Radon concentrations (Bq m^{-3})			
	Warden room	Student room	Dinning room	Kitchens
Government College University	31±5	48±6	37±3	56±6
Lahore College University	39±2	43±3	34±5	50±6
Queen Marry College	36±5	45±4	30±4	55±5
Islamia College	31±3	27±3	34±5	51±7
Fatima Jinaha Medical College	40±2	42±5	34±6	39±5
King Edvard Medical College	38±4	43±5	36±4	61±4
Islamia College Civil Lines	26±3	40±2	41±4	51±6
Forman Christian College	29±4	49±4	35±5	45±7
Range	26–40	27–49	30–41	39–61
Mean±Std	34±5	42±7	35±3	51±7

relatively high i.e. lies between 40–49 Bq m^{-3}. The reason of this high value may be the closure of rooms during daytime i.e. from 8 a.m. to 2 p.m. The dispersion of indoor air containing radon to the outer atmosphere is small which contributes to higher radon concentration inside the students' rooms. In students' rooms of Islamia College, the low radon concentration is the result of good ventilation, because the dosimetery in Islamia College hostels was carried out from April to May. It was the start of summer time and fans moving in the presence of open windows dispersed the radon from the rooms. In all other colleges, radon measurements in hostels were undertaken in winter season, when windows remained closed during the measurement period.

Table 3. Average radon concentration, radon exposure, dose and lung cancer risk for different college campuses of Lahore, Pakistan.

College Campus	Average radon concentration (Bq m^{-3})	Average radon daughter exposure (WLM y^{-1})	Effective dose (mSv y^{-1})	Excess lifetime cancer risk (%)
Government College University	33	0.06	0.32	0.19
Lahore College University	29	0.05	0.28	0.17
Queen Marry College	36	0.06	0.35	0.20
Islamia College	32	0.05	0.31	0.18
Fatima Jinah Medical College	33	0.05	0.32	0.19
Islamia Col. Civil Lines	35	0.06	0.34	0.20
Forman Christian College	36	0.06	0.35	0.20
Garrison College	44	0.07	0.43	0.25
Range	29–44	0.05–0.07	0.28–0.43	0.17–0.25
Mean± Std.	35±4	0.06±0.01	0.34±0.04	0.20±0.03

Table 4. Average radon concentration, radon exposure, dose and lung cancer risk for different college hostels of Lahore, Pakistan

Hostel Owner	Average radon concentration (Bq m^{-3})	Average radon daughter exposure (WLM y^{-1})	Effective dose (mSv y^{-1})	Excess lifetime cancer risk (%)
Government College University	43	0.17	0.97	0.57
Lahore College University	41	0.16	0.94	0.55
Queen Marry College	41	0.16	0.94	0.55
Islamia College	36	0.14	0.80	0.47
Fatima Jinah Medical College	38	0.15	0.86	0.50
King Edward Medical College	44	0.17	1.01	0.59
Islamia College Civil Lines	39	0.15	0.89	0.52
Forman Christian College	40	0.15	0.89	0.52
Range	36–44	0.14–0.17	0.80–1.01	0.47–0.59
Mean±Std	40±3	0.16±0.01	0.91±0.06	0.53±0.04

The average values of radon concentration in wardens' and dinning rooms are 34±5 and 37±7 Bq m^{-3} respectively which are almost comparable and have the least concentration range of 26–41 Bq m^{-3}. The wardens' rooms are painted and well ventilated. Paints and good ventilation are considered as the major factors for reducing the radon level [20-22] in wardens' rooms. Dinning rooms are equally well ventilated, due to the large frequency of opening of the doors and windows. The kitchens have 51±7 Bq m^{-3} the highest value of radon concentration among the different locations of college hostels. In kitchens, the factors contributing to enhance the radon concentration may be the drainage holes, tap water, fuel gas and poor ventilation.

3.3. Radon Concentration Comparison in Campus and Hostel Buildings

From Tables 3–4, it can be seen that total average radon concentration 35±4 Bq m^{-3} in the college campuses is considerably low as compared with 40±3 Bq m^{-3} in the college hostels. The reason of this low concentration peak may be that the college buildings were generally well ventilated except that of Garrison College. The tap water, loose joints of drainage pipes, fuel gas in the kitchens and poor rate of ventilation in the students' rooms may contribute in the raising of radon concentration level in the hostels.

3.4. Radiation Dose and Lung Cancer Risk

The exposure to radon daughter (E_R) can be calculated from the measured concentration of radon using the following equation based on the methodology of EPA [23] :

$$E_R = F \cdot n \cdot C_R \cdot (2.7 \times 10^{-4}) \times \frac{8766}{170} \quad (1)$$

where C_R is the radon concentration (Bq m^{-3}), F is the equilibrium factor (0.4 for indoor), n is the occupancy factor (0.3 and 0.7 for the students, staff and workers in college campuses and hostels respectively), 2.7×10^{-4} is the conversion of radon concentration to working level (WL per Bq m^{-3}), 8766 are hours in a year (h y^{-1}), and 170 are working hours in mine in a month (h M^{-1}).

The effective dose has been estimated using the following formula [24]:

$$D_E = E_R \times DCF \quad (2)$$

where, D_E is the effective dose (mSv y^{-1}), E_R is the exposure to radon WLM per year (calculated by Eq. 1), and DCF is the dose conversion factor (mSv per WLM). For the determination of effective doses in the hostels and campuses of the colleges, the dose conversion factor of 5.75 mSv per WLM [2] has been used.

The excess lifetime cancer risk (ELCR) due to radon exposures of the staff and students in campus and hostel buildings can be determined using the following relation based on the methodology described by EPA [23]:

$$ELCR = E_R \times T \times F_R \quad (3)$$

where E_R is the radon daughter exposure in WLM per year (calculated by Eq. 1), T is the average lifetime expectancy (according to UNICEF the average lifetime expectancy in Pakistan is about 67 years, www.unicef.org), and F_R is the risk coefficient for exposure to ^{222}Rn gas in equilibrium with its progeny. Based on the recommendation of the ICRP (International Commission on Radiological Protection), F_R is taken as 5×10^{-4} per WLM [25].

Using Eqs 1–3, radon daughter exposure, effective dose and corresponding lung cancer risk in the campus and hostel buildings of the colleges have been estimated and summarized in Tables 3-4. An average dose in the campus and hostel buildings was found to be 0.34±0.04 and 0.91±0.06 mSv y^{-1} respectively. Effective radon dose received by the students and supporting staff of hostels was found large because of higher average concentration and also due to large time spent in the hostels. In the present study, we assumed that the students spent about 70% time in the hostels in contrast with the time spent in the college campus which is about 30%. Estimated average annual effective dose due to radon decay products received by the students, staff and workers of college campuses and hostels has been found lower than the upper annual dose limit of 1 mSv, recommended by the ICRP [26].

The excess lifetime cancer risk attributed to the students and staff of the colleges has range 0.17–0.25 % with an average value of 0.20±0.03 % while the staff and students residing in hostels of

the colleges received the excess lifetime cancer risk due to radon progenies in the range 0.47–0.59 % with an average value of 0.53±0.04 %. The estimated risks are very small as compared with the estimated risk of 2.3 for entire population from the lifetime exposure at 4 pCi/l (148 Bq m^{-3}), which is the action level proposed by EPA [23].

4. Conclusion

From the radon concentration measured in hostel and campus buildings of some colleges of Lahore, Pakistan, it is concluded that radon concentration exhibit the least values in the portions which are well ventilated. Tap water, drainage system, fuel gas and paints seem to have affected the indoor radon concentration in some parts of study buildings. The measured radon concentration in the college and hostel buildings under study has been found much below the reference levels described by radiation protection organizations and some countries of the world [27], including the reference level of 300 Bq m^{-3} for radon gas in dwellings proposed by ICRP in 2009 [25]. The corresponding doses and excess lifetime risk of cancer due to radon progeny received by the students and supporting staff has been found below the action level as described by the ICRP [26] and EPA [23].

References

[1] A.V. Nero and W.W. Nazaroff, Radiat. Prot. Dosim. **7** (1984) 123.

[2] United Nations Scientific Committee on the Effect of Atomic Radiation, Sources and Effects of Ionizing Radiation. UNSCEAR Report to the General Assembly, with Scientific Annexes. United Nations Publication, New York (2000).

[3] W.M. Telford, L.P. Gldart, R.E. Sherif and D.A. Keys, Applied Geophysics, Cambridge University Press, Cambridge (1978).

[4] D. Bodansky, M.A. Robkin and D.R. Stadler, Indoor Radon and Its Hazards, University of Washington Press, London (1987).

[5] H.A Khan, I.E. Qureshi and M. Tufail, Health, International Conference on High Level of Natural Radiation, Ramsar, Islamic Republic of Iran, November (1990) 293.

[6] United Nations Scientific Committee on the Effect of Atomic Radiation. UNSCEAR Report to the General Assembly, with Scientific Annexes. United Nations Publication, New York (1988).

[7] J. Sevic, E. Kunz, L. Tomesek, V. Placek and J. Horacek, Health Phys. **25** (1988) 27.

[8] F.E. Lundin, J.K. Wagoner and V.E. Archer, National Technical Information Service, U.S., Department of Commerce, Spring Field, Virginia (1971).

[9] Biological Effects of Ionizing Radiation (BEIR) VI, National Academy Press, 2101 Constitution Avenue, N.W., Lock Box 285, Washington, DC, 20418, (1999).

[10] G. Espinosa, J.I. Golzarri, A. Angeles and R.V. Griffith, Radiat. Meas. **44** (2009) 1051.

[11] M.A. Lopez, L. Currivan, R. Falk, P. Olko, C. Wernli and C.M. Castellani, Radiat. Prot. Dosim. **112** (2004) 121.

[12] C.A. Papachristodoulou, D.L. Patiris and K.G. Ioannides, Radiat. Meas. **45** (2010) 865.

[13] Council of the European Union, Council Directive 96/29/ EUR-ATOM, No. L159 (1996).

[14] M. Tufail, M.A. Khan, N. Ahmad, H.A. Khan and M.S. Zafar, Radiat. Prot. Dosim. **40** (1992) 39.

[15] A. Mahmood, H.A. Khawaja, Z. Zahid, M.S. Zafar and M. Tufail, Sci. Int. **6** (1993) 5.

[16] M. Tufail, H.A. Khan, A.A. Qureshi and S. Manzoor, Nucl. Tracks. Radiat. Meas. **19** (1991) 429.

[17] M. Faheem and Matiullah, Radiat. Meas. **43** (2008) S380.

[18] S.U. Rahman, J. Anwar and Matiullah, Radiat. Meas. **43** (2008) S401.

[19] H.A. Khan, I.E. Qureshi and M. Tufail, Radiat. Prot. Dosim. **16** (1993) 149.

[20] G. Carrera, M. Garavaglia and S. Magoni, J. Environ. Radioactivity **34** (1997) 149.

[21] A. Rawat, P.J. Jojo, A.J. Khan, R.K. Tyagi and R. Prasad, Nucl. Tracks Radiat. Meas. **18** (1991) 391.

[22] Environmental Protection Agency, EPA 402/K–09/002, U.S. Environmental Protection Agency, Washington, DC 20460 (2009). www.epa.gov.

[23] Environmental Protection Agency, EPA 400–R–03–003. U.S. Environmental Protection Agency, Washington, DC 20460 (2003).

[24] W.W. Nazaroff and Jr A.V. Nero, John Wiley & Sons (1987).

[25] International Commission on Radiological Protection, ICRP Press Release, ICRP Ref 00/902/09 (2009).

[26] International Commission on Radiological Protection, ICRP Publication 103, Ann. ICRP (2007).

[27] World Health Organization (2004) http:// www. who.