ANNUAL EFFECTIVE DOSE DUE TO RESIDENTIAL RADON EXPOSURE IN THE DWELLINGS OF ABBOTTABAD

S.U. Rahman*,
R. Muhammad**, F. Khan***,
M. Rafique**** & Z. Wazir*****

ABSTRACT

A study was conducted to measure indoor radon concentrations in dwellings of the Abbottabad city. In this regard, CR-39 based NRPB type radon detectors were installed in drawing rooms and bedrooms of 40 selected houses and were exposed to indoor radon for 3 months. After exposure, the CR-39 detectors were etched for 8 hrs in 6M NaOH solution at 70°C and tracks were counted under an optical microscope. The observed tracks densities were related to radon concentrations using a calibration factor of 2.7 tracks.cm^{-2}.h^{-1}/kBq.m^{-3}. The mean annual estimated effective dose received by the residents of the studied area was found to be 1.48 ± 0.47 mSv y^{-1}. Comparing the current indoor radon results with the published data of international agencies, it was found that the houses surveyed in the present study were within the safe limits.

Keywords: *CR-39 detector, indoor radon concentration, effective dose, calibration factor, dwellings.*

1. INTRODUCTION

Radon is a colorless, tasteless and chemically non-reactive radioactive gas. Radon is all around us as a part of our environment. It is a naturally occurring by-product of decaying uranium, which is scattered through all of Earth s crust. The amount of radon in soil depends on complex soil chemistry that varies from place to place [1, 2]. Radon is a unique natural element being a gas, noble and radioactive in all of its isotopes. Once produced it escapes from the soils and rocks in which it is trapped. It enters into water we drink and the air we breathe. Its concentration levels depend strongly on geological, geophysical conditions and atmospheric factors. Being a noble gas, it has greater ability to migrate freely through soil, air and water [3-5].

Radon produced in the soil and other building materials enters into the indoor environment through exhalation. Radon flows from the soil into the indoor environment from the movement of gases in the soil beneath homes. The amount of radon that escapes from the soil and enter a house depends on the weather, the soil porosity, soil moisture, and the suction within the house. Radon gas can penetrate houses from many sources and in many ways [6, 7]. In indoor air, short-lived decay products of radon may attach to aerosol particles present in the air or deposit on room surfaces. Once inside a building, the radon cannot easily escape. The sealing of buildings to conserve energy reduces the intake of outside air and worsens the situation. Radon levels are generally highest in basements because these areas are nearest to the sources of radon. Radon can seep out of the ground and build up in confined spaces, particularly in basements of buildings [8].

Radon is a known human carcinogen. Prolonged exposure to the elevated radon concentrations inside dwellings may represent a significant health problem in the form of increased cancer risk. The external dose from ^{222}Rn and its air-borne progeny is a very small fraction of the natural external radiation dose received by individuals. However, inhalation of radon and its daughters may be followed by deposition of potentially large amounts of energy, from the short-lived α and β particle-emitting decay products, primarily from ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po [9-14].

The dwellings under study were built, in general, using different materials, cement, sand, stones, and bricks, iron structure, marble and concrete as the construction materials. Several of these materials are expected to contribute significantly to sources of indoor radon. The knowledge of indoor radon levels in dwellings is important in assessing population exposure. In this study, etched track detectors were used to measure indoor radon levels from Abbottabad city area.

2. MATERIALS AND METHODS

Active and passive devices are available for detection and measurement of alpha particles of radon and its daughters. In the present investigations, passive technique is used to measure indoor radon concentrations. Solid State Nuclear Track Detectors (SSNTDs), the most reliable and convenient detectors for the integrated and long-term measurement of radon in the environment were used. These detectors have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating, light, and are low cost. In this regard, CR-39 track detector, which mainly detects the alpha particles, has been used for monitoring of the indoor radon level in the dwellings of Abbottabad.

* Nuclear Medicine, Oncology and Radiotherapy Institute (NORI), Islamabad. ** Federal Urdu University, Islamabad. *** COMSATS Institute of Information Technology, Islamabad. **** University of Azad Jammu and Kashmir, Muzaffarabad. ***** Riphah University, Islamabad

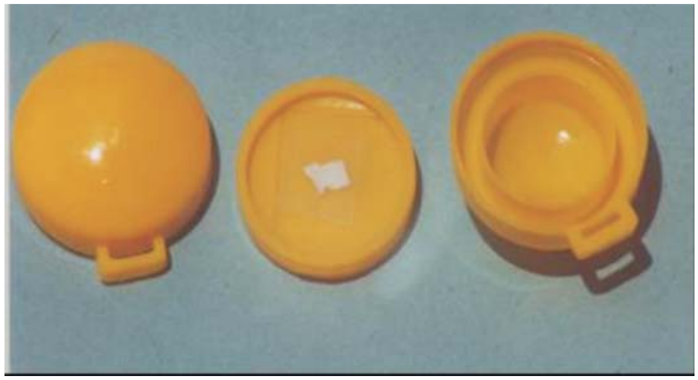

Figure-1: A photograph of the NRPB dosimeter

In order to carry out this study, large sheets of CR-39 detectors were cut and placed in the detector assembly having dimensions 1.5 × 1.5 cm^2. The detector assembly is shown in Figure-1. The design of this type of detector ensures that all the aerosols and radon decay products are kept outside and only radon diffuses into the sensitive volume of the chamber. Representative houses were selected to measure indoor radon levels at different locations. The detectors were installed at a height more than 2 meters above the ground level, about 1 meter below the ceilings and 0.5 meter away from the walls so that the direct alpha particles from the building material of the dwellings do not reach the detector films.

The detectors were installed in the bedrooms and drawing rooms of each house (all at the ground and first floors). After 90 days of radon exposure, the detectors were collected and chemically etched in 6M NaOH solution at 70°C for 8 hours. The tracks density was counted using an optical microscope at 300X magnification. After background correction, track densities were related to the radon concentrations (Bq m^{-3}) using a calibration factor 2.7 tracks cm^{-2} h^{-1}/ kBq m^{-3}[15].

3. RESULTS AND DISCUSSION

The measurements for indoor radon concentration levels were made in 30 dwellings of different ventilation conditions for three months. Table-1 summarizes the results of indoor radon concentration levels, measured in different dwellings covering drawing rooms and bedrooms of ground and first floors. The data shows that the indoor concentration obtained for the study varies from 7 ± 2 to 212 ± 15 Bq m^{-3} with an overall average value of 78 ± 25 Bq m^{-3}, which is lower than the action levels of International Commission on Radiological Protection (ICRP, 1993) recommendations, i.e., 200-600 Bq m^{-3} [16]. Mean, minimum and maximum values are also shown in the Table-1. The radon levels in the bedrooms were seen to vary from 18 ± 3 Bq m^{-3} to 178 ± 12 Bq m^{-3} with an average activity value of 84 ± 23 Bq m^{-3} for the ground floor houses. The radon concentration levels vary from 16±3 Bq m^{-3} to 167±13 Bq m^{-3} with mean values of 69 ± 26 Bq m^{-3} in the bedrooms of first floor. The indoor radon levels in drawing rooms situated on the ground floor varied from 15 ± 3 Bq m^{-3} to 212 ± 15 Bq m^{-3} with an average value of 87 ± 34 Bq m^{-3}. The values of indoor radon concentration for drawing rooms of first floor varied from 7 ± 3 Bq m^{-3} to 160 ± 14 Bq m^{-3} with an average value of 72 ± 28 Bq m^{-3}.

So far, there is no reported/approved criterion for permissible radon levels set for Pakistan. If recommendations set by the International Commission on Radiological Protection (ICRP) are followed (i.e. maximum indoor radon concentration limit of 600 Bqm^{-3}) [16], then it may be concluded that all of the houses surveyed in the Abbottabad district were within the safe limits of radon potential health hazards. On the other hand, if recommendations made by the Health Protection Agency UK and the US EPA (who suggest a maximum indoor radon concentration limit of 200 and 148 Bqm^{-3}, respectively) are followed, then only two houses had elevated value of indoor radon concentrations. The inhabitants of these dwellers were exposed to excessive radon doses. It was considered necessary for these dwellers to use more ventilation during their stay at home.

3.1 Dose Estimation

The range of dose conversion factors for radon, derived from epidemiological studies and physical dosimetry varied from 6 to 15 nSv $(Bq\ h\ m^{-3})^{-1}$. For the estimation of average effective dose [H] (mSv y^{-1}) to the inhabitants of Abbottabad due to the indoor radon

Table-1: Indoor Radon Concentrations (Bq m^{-3}) in Drawing Rooms and Bedrooms

Types of Rooms	Ground floor		Mean	First floor		Mean
	Min.	Max.		Min.	Max.	
Bedrooms	18±3	178±12	84 ± 23	16±3	167±13	69 ± 26
Drawing rooms	15±3	212±15	87 ± 34	7±3	160±14	72 ± 28

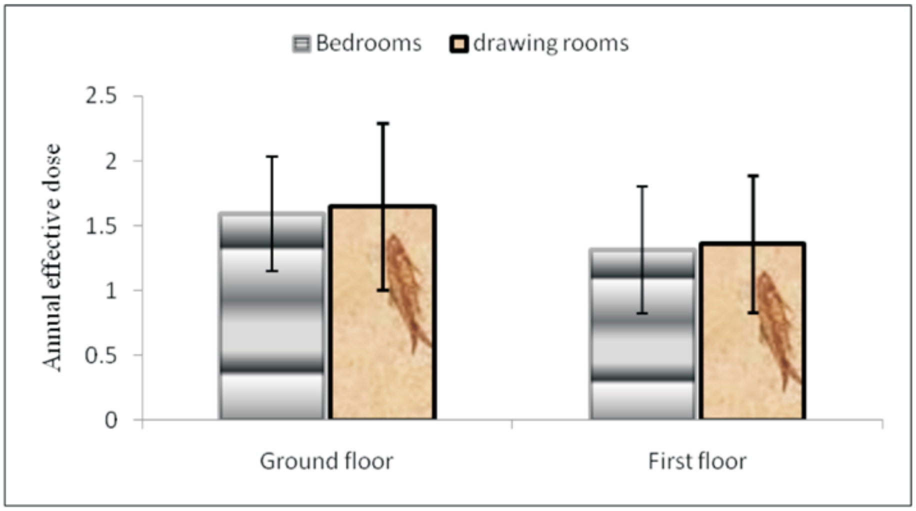

Figure-2: Annual Effective Indoor Radon Doses for Different Dwellings

and its progeny, the following model was used [15, 17,18]:

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

where C is the ^{222}Rn concentration (Bq m^{-3}), F is an equilibrium factor (0.4), O is the occupancy factor, T is the number of hours in a year (8760 h y^{-1}) and D is the dose conversion factor (9.0 nSv h^{-1}per Bq m^{-3}). In the study, the value of O was estimated to be 0.6, because it was assumed that out of 24 hrs per day, inhabitants of the area spend about 60% time indoors and 40% outdoors. Substituting the measured average radon concentration value of 78 ± 25 Bq m^{-3} in the above-mentioned equation, the overall average effective annual dose in the studied area came out to be 1.48 ± 0.47 mSv y^{-1}. The annual effective dose in bedrooms and drawing rooms for ground and first floor is shown in Figure-2. It can be seen from Figure-2 that annual effective doses have higher values for ground floor as compared to the first floor. It is also clear from the same figure that annual effective doses were higher in drawing rooms as compared to the bedrooms. These values were below the recommended action level (i.e. 3-10 mSv y^{-1}) [16].

4. CONCLUSIONS

Indoor radon concentrations were measured in 30 dwellings in the Abbottabad region using CR-39 based NRPB type radon detectors. Indoor radon concentrations varied from 7 ± 2 to 212 ± 15 Bq m^{-3} with an average activity concentration of 78 ± 25 Bq m^{-3}. The radon levels in drawing rooms were found to be higher than in bed rooms. It was also observed that indoor radon concentrations were higher in ground floor as compared to first floor. The mean annual effective dose equivalent due to the indoor radon concentration in the dwellings of studied area was found to be 1.48 ± 047 mSv y^{-1}, which was below the action level. Consequently, the health hazards related to indoor radon levels were found to be negligible. Occupants of these dwellings were therefore, relatively safe. Proper regulatory standards should be implemented to make the dwellings safer and it is recommended to carry out similar studies in this region.

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