MEASUREMENT OF CONCENTRATIONS OF RADON AND ITS DAUGHTERS IN DWELLINGS USING CR-39 NUCLEAR TRACT DETECTOR

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SUMMARY : Various national and international surveys have demonstrated an increase in radon (^{222}Rn) levels in dwellings and consequently there is a continuous growing concern about its health effects on the population. Rn progeny levels in dwellings are likely to be a multiple of outdoor levels. This paper presents the results of the measurements of indoor Rn and daughter levels in houses of different types located in different parts of Bangladesh. The dose to the population from the inhalation of indoor Rn is also calculated. The present measurements have given a geometric mean of 9.5 mWL of potential alpha energy exposure level from Rn daughters, which corresponds to an annual effective dose equivalent of 3.l mSv.

Key Words : PAEE, nuclear track detector, calibration factor, indoor radon, thoron, effective dose equivalent.

INTRODUCTION

Public exposure to radon and its radioactive daughters present in the environment results in the largest contribution to the average effective dose received by human beings (1). It has recently been clearly recognized that elevated levels of ^{222}Rn could be present in certain types of human dwellings. Under specific conditions, such as those existing in the Uranium mining environment, the lung dose arising from the inhalation of ^{222}Rn daughters can be sufficiently high as to cause an increase in lung cancer occurrence (2). It has been suggested that the indoor ^{222}Rn concentration in the USA is responsible for about 10% of the total risk of lung cancer (3). As far as human dwellings are concerned the possible enhanced risk could be expected only in a rather small fraction of homes depending essentially on the building materials, ventilation features and soil characteristics. These factors are directly responsible for enhanced input and subsequent stagnation of ^{222}Rn in indoor air (4).

Several countries have initiated large scale measurements of prevailing indoor ^{222}Rn levels in houses and the reported levels range from a low of 9 Bq.m^{-3} to a high value of the order of 200 Bq.m^{-3} (4). Large scale measurements have since been carried out to identify dwellings having concentration in excess of 190 Bq.m^{-3}, which is the intervention level suggested by the U.S.

Environmental Protection Agency (EPA) (5). It is thought that the prevailing level of indoor ^{222}Rn in dwellings of Bangladesh should be assessed in order to evaluate the dose to the population from the inhalation of indoor Rn. For that purpose we have started a programme of measurement of indoor Rn and daughter levels in houses of different types located in different parts of Bangladesh. Unlike the temperate countries in West, no energy conservation procedures are followed in an average typical Bangladeshi house and the ventilation features are generally such that air exchanges are not districted. Again it is also necessary to have data on the prevailing levels of indoor Rn inside houses for planning any remedial action that may be found necessarily.

Solid State Nuclear Track Detectors (SSNTDs) have been widely used for the measurement of time-integrated radon levels in dwellings under different conditions. The track detector used for this purpose must be calibrated for concentrations of radon and its daughters likely to be found in dwellings. The CR-39 plastic detector used in the present study is sensitive to alpha energy up to 40 MeV, which is quite large compared to the other detectors commonly used for radon measurements, viz, LR-115 (only up to 3.5 MeV).

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EXPERIMENTAL METHOD

In the present study strips of CR-39 film (Pershore Moulding, U.K.; 300 μm thick) were exposed to the indoor environment of a house for a known period of time of the order of 40-60 days, during which time the alphas originating from ^{222}Rn and its progeny would leave tracks on it. The film was exposed in two modes, viz. (i) bare mode and (ii) cup-with-membrane mode (4-6). After retrieving the film, it was etched chemically in 6M NaOH solution at 70°C for 12 h. The tracks were counted using an optical microscope having a magnification of 400X. The ^{222}Rn concentration from cup exposure and the potential alpha energy exposure (PAEE) from the bare exposure were obtained directly from the track density using separate calibration curves. The details of the calibration procedure were described elsewhere (7). For obtaining ^{222}Rn concentration in terms of Bq.m^{-3}, the film, as mentioned above, was exposed within a plastic cup of which the mouth was covered by a semi-permeable membrane (GEC MEM-213) which did not permit the daughters to pass through whereas most of ^{222}Rn gas would enter the interior (6, 8) and along with the daughters formed subsequently will leave tracks on the film. This is a ''radon only'' device (6). The PAEE level in terms of working level (WL) was obtained by exposing it in a bare mode by affixing it on a paper card and hanging in the indoor environment.

RESULTS AND DISCUSSION

The calibration experiments were carried out to evaluate the relationship between the track density measured and the radon concentration as well as WL concentrations. The objective was to develop a reliable and simple technique for calibration for time-integrated passive continuous indoor radon level measurements in Bangladeshi dwellings. The results are presented elsewhere (7). Figure 1 shows the variation of track density with radon concentration. The calibration factor obtained from the experiment varied from 0.14 to 0.27 tracks cm^{-2} d^{-1} per (Bqm^{-3}), giving the arithmetic mean of 0.20±0.023 tracks cm^{-2} d^{-1} per (Bqm^{-3}). Figure 2 shows the relationship between the track density on the bare mode detector films and the WL concentrations of radon and its daughters in the exposure chamber. The calibration factor varied from 1192 to 2340 tracks cm^{-2} d^{-1} per (WL), giving the arithmetic mean of 1678±318 tracks cm^{-2} d^{-1} per WL. The estimated calibration factor for radon measurements is in good agreement with those reported by other investigators (6,9,10).

A total of 275 exposures were made in the bare mode in 15 locations and 71 exposures in the cup mode in 6 locations. The total data was collected over a

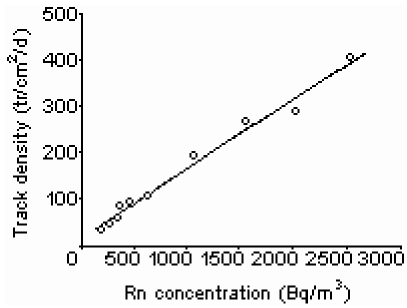

Figure 1: Calibration of the CR-39 detector in cup with membrane mode against radon concentration.

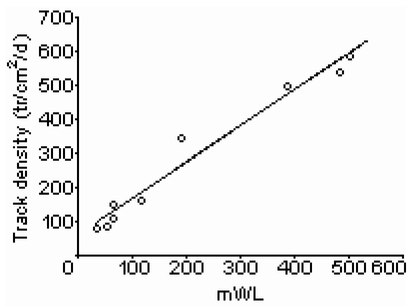

Figure 2: Calibration of the CR-39 detector in bare mode against working level of radon.

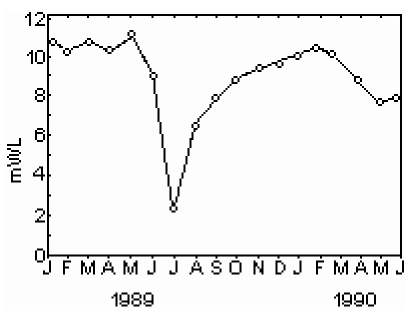

Figure 3: Monthly variation of potential alpha energy exposure level.

Table 1: Potential alpha energy exposure levels at different locations.

Location	No. of data	mWL				Annual effective dose equivalent ($mSv.y^{-1}$)
		Min	Max	GM	GSD	
Rajshahi	15	2.5	18.2	6.9	2.0	2.2
Nawabgai	8	2.0	12.7	5.3	1.8	1.7
Pabna	29	2.6	20.4	9.3	1.7	3.0
Bogra	12	3.7	19.8	10.6	1.9	3.3
Ishwardi	7	2.8	22.0	10.5	2.0	3.3
Khulna	32	1.5	20.9	8.3	1.8	2.6
Daulatpur	37	2.5	20.1	8.1	1.9	2.5
Chittagong	17	3.3	20.9	11.1	2.0	3.5
Johangirnogar	19	3.2	21.3	13.2	1.6	4.1
Dhaka	34	1.7	21.4	10.7	1.8	3.4
Mymansingh	10	3.9	20.5	9.9	2.1	3.1
Sylhet	11	2.0	19.5	11.4	2.2	3.6
Bagerhat	21	1.7	21.5	7.7	2.2	2.4
Jessore	9	3.4	20.9	13.1	1.9	4.1
Khustia	14	4.1	21.5	11.1	1.6	3.5
						Average: 3.1+0.67

period of one and a half years. The geometric mean PAEE level obtained is 9.5 mWL wit a geometric standard deviation of 1.9. The geometric mean value of PAEE obtained for each location along with geometric standard deviation, minimum, maximum and number of samples are presented in Table 1. The monthly variation of the geometric mean of PAEE is presented in Figure 3. The seasonal variation in the PAEE, as seen from Figure 3, does not show any fixed trend except for a dip in the monsoon months of July and August. The winter period of December to February has shown higher values.

We have made an attempt to assess the dose to the lung arising from the inhalation of indoor Rn daughters to the occupants of the houses where these measurements are done. From the PAEE level, the annual effective dose equivalent has been estimated by using the conversion factor of 9 mSv per WLM. This value has been obtained from the relationship between the dose equivalent and the breathing rate as depicted in Figure 6 of ICRP-50 (11). The annual effective dose equivalent obtained for each location is also included in Table 1.

In order to see whether the levels of PACEE measured in the present study indicate any abnormally high dose to the occupants, we have compared the

Table 2: Radon concentration ($Bq.m^{-3}$) at different locations.

Location	No. of data	Min	Max	GM	GSD
Rajshahi	10	7.9	130.5	38.3	2.8
Khulna	16	14.2	105.2	48.7	1.9
Dhaka	12	37.2	170.1	92.2	1.7
Chittagong	8	12.4	160.9	95.6	2.0
Mymensingh	5	26.3	198.2	81.3	1.8
Jessore	20	29.6	160.2	67.7	2.4

values with the limits suggested by US EPA. The EPA has suggested that immediate intervention is required only if the ^{222}Rn level is above 190 Bqm^{-3} and that intervention may be considered when the level is between 40 and 190 Bqm^{-3} and that below 40 Bqm^{-3} no intervention is required (3,4,12,13). Assuming that these are equilibrium equivalent Rn concentration values, the corresponding PAEE levels will be 50 mWL and 10 mWL respectively. These values are obtained by using our value for the "Equilibrium Factor", F (7). The average PAEE level obtained from the total data is 9.5 mWL which does not call for any intervention. However, the individual averages for each location (Table 1) show that in 8 out of 15 locations intervention may be considered and in others no intervention is called for. The Rn concentrations at the six locations as seen from Table 2 are equal or less than the equilibrium equivalent Rn concentration as suggested by EPA.

Table 3: Potential alpha energy exposure level (mWL) in houses according to type of construction.

Construction material	No. of data	Min	Max	GM	GSD
Mud, brick, bare floor	24	2.2	22.1	11.3	1.8
Brick, cement	41	1.8	20.9	9.2	1.7
Brick, stone floor	15	6.7	17.6	12.8	1.5
Brick, mud, wooden, floor	28	1.7	21.9	8.8	1.9
Rock, granite	7	8.4	21.6	15.2	1.5
Mud, brick, tinshed	12	3.9	14.7	10.1	2.1

The annual effective dose equivalent obtained for each locations is shown in Table 1. The average effective dose equivalent of (3.1 ± 0.67) $mSv.y^{-1}$ for all the locations is 2.4 times higher than the normal background value of 1.3 $mSv.y^{-1}$ given by EPA.

However, it does not call for any intervention since EPA has recommended no intervention up to 3.5 $mSv.y^{-1}$. In some locations it does seem that follow-up measurements are required, taking the seasonal variations also into considerations. Based on the present results further measurements on a larger scale in the country as a whole are planned.

Attempts have also been made to see the variation in the PAEE levels according to different type of construction of house. The results are presented in Table 3. Houses made with rock and granite and with brick and stone have shown comparatively higher levels of PACEE than those made with brick, mud, wood and RCC.

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