ESTIMATION OF ANNUAL EFFECTIVE DOSE DUE ^{222} RN AND ITS PROGENY CONCENTRATION IN DWELLINGS OF BAREILLY CITY.

Anil Kumar[1]*, Praveen Kumar[2], Neeraj Rathour[3], R. B. S. Rawat[4] Alok Kumar Singh[5],

Abstract

Measurement of radon and its progeny concentration was carried out in the residential houses of Bareilly, Uttar Pradesh using solid state nuclear track detector (SSNTD). Radon and its progenies are the most important contributions to human exposure from natural sources. Radon exists in soil gas, building materials, Indoor atmosphere etc. Among all the natural sources of radiation dose to human beings, inhalation of radon contributes a lot. The work presented here emphasizes the measurement of indoor radon & its progeny concentrations using twin cup Rn^{222}/Rn^{220} discriminator dosimeter and direct radon progeny sensor/direct thoron progeny sensor (DRPS/DTPS). Based on result it is found that the value of radon concentration during summer season varies from 9 Bq/m^3 to 58 Bq/m^3 with an average of 36 Bq/m^3. During raining season the radon concentration varies from 21 Bq/m^3 to 69 Bq/m^3 with an average of 44 Bq/m^3. During winter season the radon concentration varies from 16 Bq/m^3 to 79 Bq/m^3 with an average of 54 Bq/m^3. During autumn season the radon concentration varies from 15 Bq/m^3 to 68 Bq/m^3 with an average of 45 Bq/m^3. The value of radon progeny concentration during summer season varies from 6 Bq/m^3 to 23.49 Bq/m^3 with an average of 13.67 Bq/m^{33}. During raining season the radon progeny concentration varies from 10.24 Bq/m^3 to 27.43 Bq/m^3 with an average of 18.05 Bq/m^3. During winter season the radon progeny concentration varies from 8.43 Bq/m^3 to 31.8 Bq/m^3 with an average of 23.46 Bq/m^3. During autumn season the radon progeny concentration varies from 9.95 Bq/m^3 to 28.99 Bq/m^3 with an average of 16.24 Bq/m^3. The values of annual effective dose due to radon and its progeny is varies from 0.34 $mSvy^{-1}$ to 2.53 $mSvy^{-1}$ with an average of 1.02 $mSvy^{-1}$. All the values in the above study have been found under the safe limit laid down by International Commission on Radiological Protection (ICRP) and United Nations Scientific Committee on the effect of Atomic Radiation (UNSCEAR).

[1*]Department of Physics, S S (P.G.) College, Mumukshu Ashram, Shahjahanpur.
[2]Department of Physics, V.R.A.L. Govt. Girls Degree College, Bareilly
[3]Department of physics, Bareilly College Bareilly
[4]Department of Physics, M S College, Saharanpur.
[5]Department of Chemistry, S S (P.G.) College, Mumukshu Ashram, Shahjahanpur.

*** Corresponding author:-** Anil Kumar
*Department of physics, S S (P G) College, Mumukshu Ashram, Shahjahanpur, 242001, India
E-mail: singhakphy586@gmail.com

DOI: 10.48047/ecb/2023.12.si10.00411

INTRODUCTION

Radon is a naturally occurring radioactive gas that is colorless, odorless, and tasteless. It is a product of the radioactive decay of uranium and thorium, which are commonly found in rocks, soil, and water. The inhalation of radon (^{222}Rn) and its decay products contribute to a major fraction (55%) of the natural background radiation dose to humans (UNSCEAR, 2000). When air with radon and its decay products is inhaled, the short-lived decay products deposit in respiratory tract which may lead to the development of lung cancer. Recent epidemiological studies of indoor radon have provided strong evidence of lung cancer risk with respect to radon exposure (Darby et al., 2005; Kreswki et al., 2005). Based on these circumstances, the ICRP and the World Health Organization recommended controlling and setting reference levels for exposure to radon and its progeny in dwellings (WHO 2014, ICRP, 2007). In general, radon exposure control has focused on homes where people spend more time. Measurement of radon concentration using passive detectors is preferred for this purpose since this method allows measuring the radon concentration in a large number of buildings simultaneously for the period of the year, semi-annual, seasonal, etc. Measuring the radon concentration is suitable for estimating upper exposure limits that are adequate for assessing radon exposure in dwellings. The present study was performed in order to estimate the annual effective dose due to radon and its progeny concentration in residential houses of Bareilly City, Uttar Pradesh.

MEASUREMENT TECHNIQUES

1. Measurement of Radon Concentration

Concentration of radon is measured by using pin hole radon / thoron discriminator dosimeter. The pin-holes technique is very useful to design ^{220}Rn discriminator for online radon measuring instrument with optimum response time for ^{222}Rn. By selecting a suitable chamber volume and dimension of pin-holes, it is possible to cut off ^{220}Rn entry into the chamber volume and allow only ^{222}Rn. The new design of this dosimeter system has two compartments separated by a central pin-holes disc, acting as ^{220}Rn discriminator. The schematic diagram of the dosimeter system is shown in Fig. 1. The dosimeter has a single entry through which gas enters the first chamber namely “radon+ thoron” chamber through a glass fiber filter paper (0.56 μm) and subsequently diffuses to second chamber namely “radon” chamber through pin-holes cutting off the entry of ^{220}Rn into this chamber. Each chamber is cylindrical having a length of 4.1 cm and radius 3.1 cm. Chambers are internally coated with metallic powders to have zero electric field inside the chamber volume, so that the deposition of progenies formed from gases will be uniform throughout the volume. This design replaces the use of membrane filter with pin holes based discriminator. It eliminates the possible negative ^{220}Rn concentration previously arrived in some situations, as the same gas diffuses to both the chambers. The measurements can be carried out for a period of 4 months. The retrieved LR-115 films from the dosimeters etched with 2.5 N NaOH solutions at a temperature of 60^0C for 90 minutes without stirring. After etching, the detector should be peeled off from its cellulose acetate base and the track counting can be carried out by spark counter. The operating as well as the pre-sparking voltage of the spark counter should be established prior to these measurements.

The relative factor for the spark counter should also be determined by comparing with the reference spark counter available in BARC laboratory. The radon (C_R) concentration in the filter compartment and the pinholes compartment can be calculated as:

$C_R(Bq/M^3) = T_1/ (d .k_R)$

where,

T_1 is the track density observed in ‘radon’ compartment.

k_R is the calibration factor of radon in ‘radon’ compartment for radon d is the number of days of exposure.

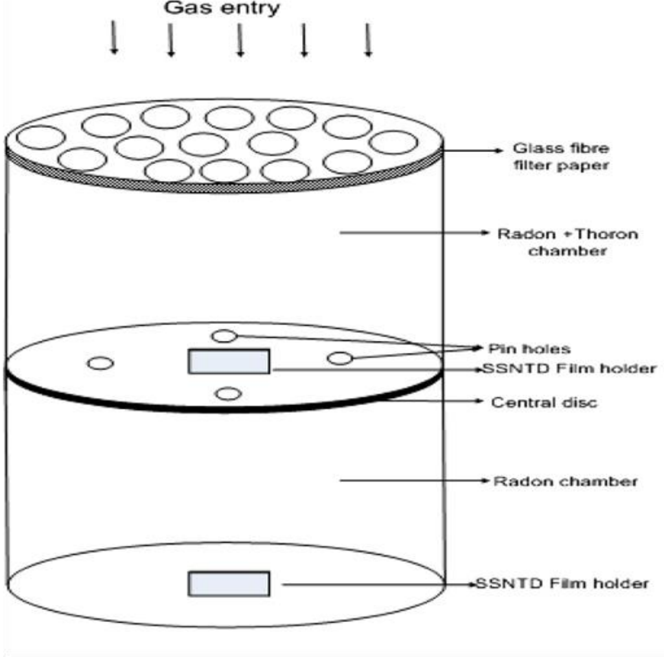

Fig.1 Schematic diagram of pin hole dosimeter**.**

2. **Measurement of Radon progeny Concentration :-** The concentration of radon progeny is measured by using Direct radon and thoron progeny sensor (DRPS/DTPS).

Direct Radon and Thoron progeny sensors (DTPS and DRPS)

The inhalation doses due to radon contributed predominantly by its decay products. Hence the cumulative decay product concentrations are the actual measures of exposure. Conventionally the assessment of the dose due to the decay products is typically inferred from the measurement of the gas concentrations and applying equilibrium factor considerations. Deposition based Direct Radon and Thoron progeny sensors (DRPS and DTPS) have been developed for estimating the time integrated progeny deposition fluxes in the environment. These are made of passive nuclear track detectors (LR-115) mounted with absorbers of appropriate thickness. For ^{220}Rn progeny, the absorber is 50 □m aluminized mylar which selectively detects only 8.78 MeV □-particles emitted from ^{212}Po; while for ^{222}Rn progeny, the absorber is a combination of aluminized mylar and cellulose nitrate of effective thickness 37 □m to detect mainly 7.67 MeV α-particles emitted from ^{214}Po. DTPS element is made up of LR-115 (2.5x2.5 cm^2) mounted with 50µm aluminized mylar to selectively detect only 8.78 MeV □-particles emitted from ^{212}Po; while the DRPS has an absorber combination comprising of aluminised mylar and cellulose nitrate of effective thickness of 37µm to detect mainly 7.67 MeV □-particles from ^{214}Po. The basic principle of operation of these sensors is that the LR115 detector detects the alpha particles emitted from the deposited progeny atoms. The tracks recorded in the exposed LR115 film is related to Equilibrium Equivalent Progeny Concentration (EEC) using the sensitivity factor.

The background tracks contributed due to detector shelf-life and during transit should be subtracted from the observed track density.

The number of tracks per unit area per unit time (T) can be correlated to the Equilibrium Equivalent Progeny Concentration (EEC) in air using the Sensitivity factor (S) as:

$$EEC(Bq/m^3) = \frac{T\,(Tracks.cm^{-2}.d^{-1})}{S\,(Tracks.cm^{-2}.d^{-1} \quad / \, EEC\,(Bq.m^{-3})}$$

In the case of radon progeny the sensitivity factor of DRPS is 0.09 Tr cm^{-2}d^{-1}/EERC(Bq m^{-3}).

Annual Eff. Dose) Rn & Progeny (mSvy^{-1}) = EERC (Bq/m^3) × 7000 h × 9 nSv/(Bq.h/m^3) ×10^{-6}

Where

9 nSv/(Bq.h/m3) = Dose conversion factor for Radon & its Progeny.

Direct Radon Progeny Sensor

Absorber

Aluminized Mylar + Cellulose Nitrate

(25µm+12µm=37µm)

214Po - 7.67 MeV (α- Particle)

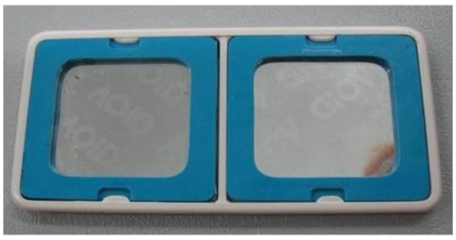

Fig 2. Direct Radon and Thoron progeny sensors

RESULT & DISCUSSION

The work presented here emphasizes the long term measurements of radon and its progeny in the residential houses of the Bareilly city using Solis State Nuclear Track detector (LR 115 type II). Table 1 shows the variation of indoor radon, its progeny concentration and annual effective dose due to radon and its progeny in residential houses of Bareilly city.

Table 2 shows the seasonal variation of indoor radon and its progeny concentration in residential houses of Bareilly city.

In present investigation the annual radon concentration varies from 9 Bq/m^3 to 79 Bq/m^3 with an average of 47.36 Bq/m^3 while the radon progeny concentration varies from 6 Bq/m^3 to 42 Bq/m^3 with an average of 16.27 Bq/m^3. Annual effective dose due to radon and its progeny varies from 0.34 mSvy^{-1} to 2.53 mSvy^{-1} with an average of 1.02 mSvy^{-1}.

TABLE- 1. Variation of indoor radon and its progeny concentration in residential houses of Bareilly City.

Measured values of indoor radon and its progeny concentration

	MIN.	**MAX.**	**AVERAGE**
Radon Concentration(Bq/M^3)	9±2.03	79±4.34	47.36
EERC (Bq/M^3)	6± 1.46	42± 2.06	16.27
Annual effective dose due to radon and its progeny (mSvy^{-1})	0.34± 0.02	2.53 ± 0.05	1.02 ± 0.02

TABLE- 2. Seasonal variation of indoor radon and its progeny concentration in residential houses of Bareilly City.

	Winter			Summer			Rainy			Autumn		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Radon concentration (Bq/m^3)	16	79	**54**	9	58	**36**	21	69	**44**	15	68	**45**
EERC (Bq/m^3)	8.43	31.8	**23.46**	6	23.49	**13.67**	10.24	27.43	**18.05**	9.95	28.99	**16.74**

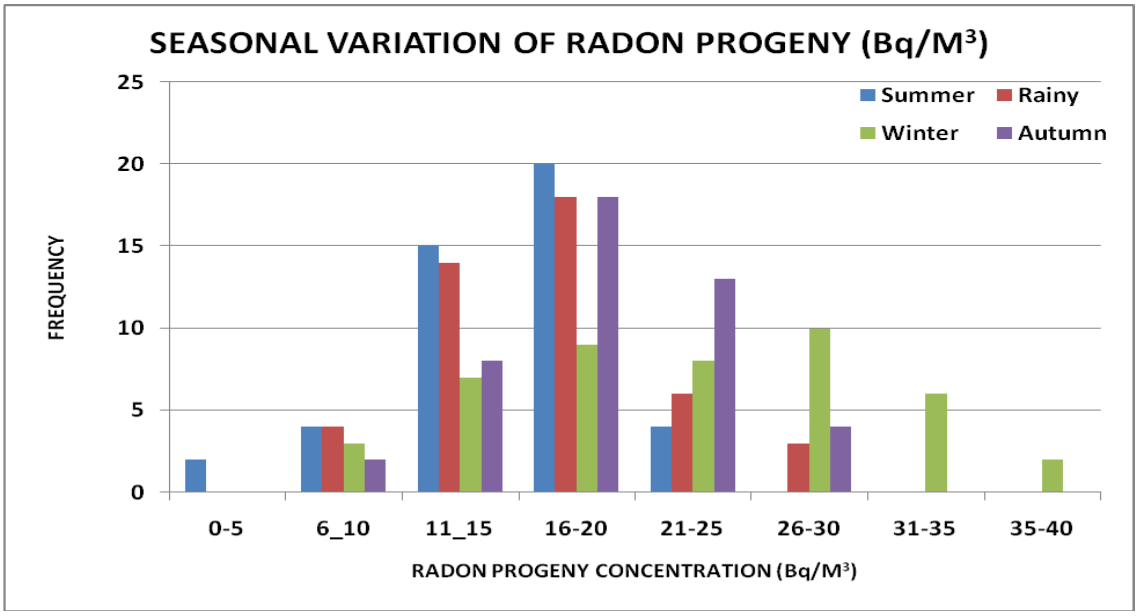

Fig. 3 Seasonal variation of radon concentration

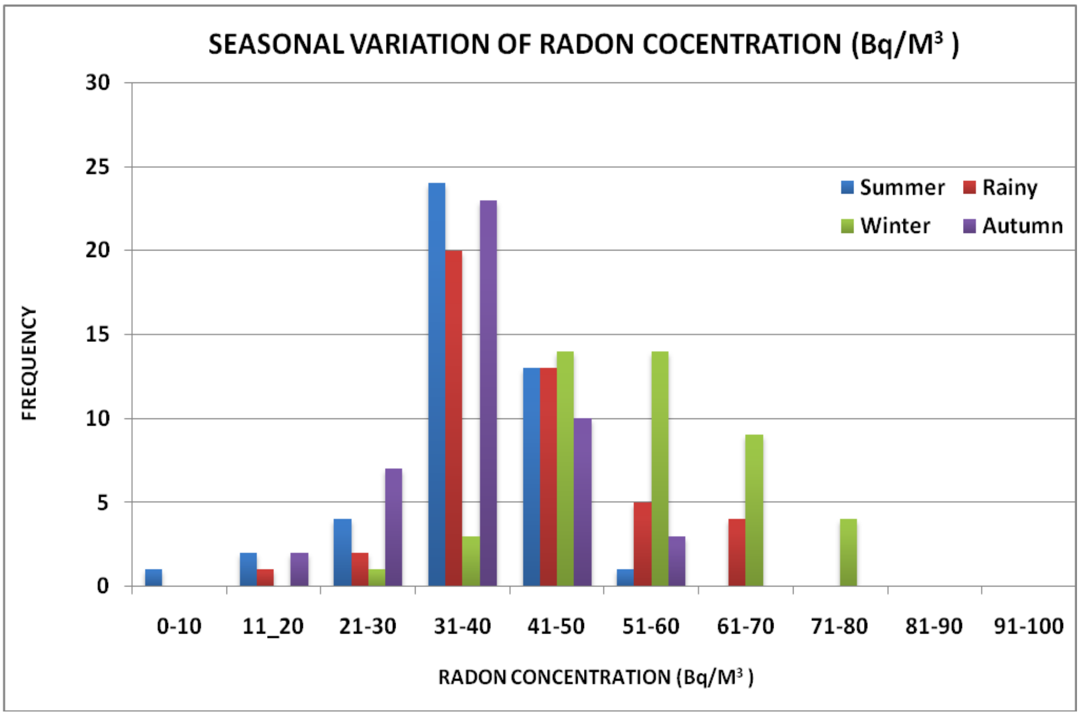

Fig. 4 Seasonal variation of radon progeny concentration

CONCLUSIONS AND SUGESSIONS:-

Based on the result it was observed that in winter season the majority of houses (about 60%) has radon concentration from 31 – 60 Bq/m^3 while 26 % houses has the value greater than 60 Bq/m^3. During summer season 48 % houses has the radon concentration 31 – 40 Bq/m^3. In rainy season the majority of houses (40%) has radon concentration 31 – 40 Bq/m^3. In autumn the majority of houses (46%) have radon concentration between 31- 40 Bq/m^3 (Fig 3).

During summer season about 40 % houses has the value of radon progeny concentration between 16 – 20 Bq/m^3 while during winter season 48 % houses has the value between 21 – 35 Bq/m^3. During rainy season about 64 % houses has the value of radon progeny concentration between 11 – 20 Bq/m^3 while in autumn season 60 % houses has the value between 16 - 25 Bq/m^3 (Fig. 4).
The number of houses with higher radon concentration is greater in the winter than in the summer and autumn.

Based on the result it is concluded that the indoor radon concentration in study area is found to be little higher than the average global level of radon concentration = 40 Bq/m^3 (UNSCEAR, 2000) and average national level (42 Bq/m^3, Mishra et al., 2009). The similar results are also observed for the radon progeny concentration and found higher than average global level of EERC = 10 Bq/m^3 (Mishra 2009). The study on seasonal variation of indoor radon and its progeny measurement indicates that the radon levels tend to fluctuate throughout the calendar year due to factors like temperature, humidity, ventilation building materials and ventilation conditions of the residential houses. Higher levels is observed during the winter season because, in winter season the houses are closed for long time and radon accumulated inside the room. Progeny measurements show the similar trends, with potential health risk being higher during periods of elevated radon concentration. Conclusion of the study suggest that understanding the seasonal patterns of indoor radon and its progeny is essential for making informed decisions about their air quality and potential health risk. The findings highlight the need for continuous monitoring to capture fluctuations and ensure accurate exposure assessment. Further research could explore specific factors driving the refine strategies for radon management in indoor environments.

REFERENCE

1. D. Krewski, J.H. Lubin, J. M. Zielinski, M. Alavanja, V.S. et.al. Residential radon and risk of lung cancer: a combined analysis of 7 Nirth American Case – control studies., Epidemiol., 16 (2005) pp. 137-145.
2. Darby S, Hill D, et all., Radon in homes and risk of lung cancer: collaboreative analysis of individual data from 13 Europian case – control studies (2005) pp. 223- 228.
3. ICRP (1993) International Commission on Radiological Protection. “Protection against radon-222 at home and at work”, ICRP Publication 65, Annals of the ICRP 23(2), Pergamon Press, Oxford.
4. ICRP (1988) Lung Cancer Risk for Indoor Exposure to Radon Daughters.ICRP Publication 50, Pergamon Press, Oxford.
5. Lubin, J.H., Boice, J.D.Jr., Edling, C., Hornung, R.W., Howe, G., Kunz, E., Kuziak, R.A., Morrison, H.T., Radford, E.P., Samet, J.M., Timarche, M., Wood Ward, A., Yao, S.X., Pierce, D.A. (1995) Lung Cancer in radon exposed miners and estimation of risk from indoor exposure. J Natl cancer Inst. 87, 817-827.
6. Ramola, R.C., Rawat, R.B.S., Kandari, M.S., Ramachandran, T.V. & Choubey, V.M. 1997. Measurement of indoor radon levels around Uttar Kashi and Pauri Garhwal areas using nuclear track detectors techniques. Indian Jour. Environmental Protection, 17 (7), 519-526.
7. Ramola, R.C. Rawat, R.B.S., Kandari, M.S., Ramachandran, T.V., & Choubey, V.M., 1998. A study of seasonal variation of radon levels in different types of houses. Jour. Environ. Radioactivity. 39 (1), 1-7.
8. UNSCEAR (1988), Sources, effects and risks of ionizing radiation. United Nations Scientific Committee on Effects of Atomic Radiation. Report to General Assembly with annexes. United Nations sales Publications E. 88.IX.7. United Nations New York.
9. UNSCEAR (1993), Sources and effects of ionizing radiation. United Nations Scientific Committee on Effects of Atomic Radiation. Report to General Assembly with annexes. United Nations sales Publications E.94.IX.2. United Nations New York.
10. UNSCEAR (2000), United Nations Scientific committee on the effects of Atomic Radiations, Report to the General Assembly, United Nations, New York
11. World Health Organization (2007). *International Radon Project Survey on*

Radon Guidelines, Programmes and Activities. WHO, Geneva.

12. World Health Organization (2007). *International Radon Project Survey on Radon Guidelines, Programmes and Activities*. WHO, Geneva
13. World Health Organization (2008). *WHO Report on the Global Tobacco Epidemic - The MPOWER package*. WHO, Geneva.
14. WHO handbook on indoor radon a public health perspective: WHO Press, Geneva, Switzerland, 2014
15. The 2007 recommendations of the International Commission on Radiological Protection. ICRP publication 103