Available online at http://www.journalijdr.com

IJDR

International Journal of DEVELOPMENT RESEARCH

ISSN: 2230-9926

International Journal of Development Research
Vol. 06, Issue, 07, pp.8303-8306, July, 2016

Full Length Research Article

RADON EXHALATION RATE AND RADIATION DOSE FROM SOIL SAMPLES COLLECTED FROM DIFFERENT PLACES SURROUNDING THE KASIMPUR THERMAL POWER PLANT

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ARTICLE INFO

Article History:

Received 25th April, 2016
Received in revised form
18th May, 2016
Accepted 12th June, 2016
Published online 31st July, 2016

Key Words:

LR-115 type II dector,
Effective Dose,
Radon exhalation rate.

ABSTRACT

Fly ash from a thermal power plant is spread and distributed in the surrounding areas by air and may be deposited on the soil of the nearby region. Thus the radioactivity levels of the soil samples may alter and it is quite important to estimate the changes. Can technique using LR-115 type II solid state nuclear track detector has been employed for the measurement of radon activity and radon exhalation rate. Radon activity varies from 3091.43 Bq m^{-3} to 4997.14 Bq m^{-3} with an average value of 3948.19 Bq m^{-3} . Exhalation rate varies from 1111.44 mBq m^{-2} h^{-1} to 1796.59 mBq m^{-2} h^{-1} with an average value of 1419.47 mBq m^{-2} h^{-1} while effective dose equivalent varies from 131.06 μSv y^{-1} to 211.86 μSv y^{-1} with an average value of 167.38 μSv y^{-1} . The lowest value was found for the soil samples collected from R.R. 37 while the maximum value was found to be for the soil sample collected from Ingraham School, New Colony.

INTRODUCTION

The soil or bedrock beneath a building is one of the major sources of radon gas in the indoor air. The emanation of radon gas from different types of materials can be estimated to some extent if the content of ^{238}U of a samples is known and the ^{226}Ra content is only minorly affected. The true emanation is, however, affected by various parameters, one of these parameters is the possibility for the gas to come out from the grains into the air through the space between the grains of the samples. Soils have different grain size. The soil and the bedrock beneath a building, the building material or the tap water are three main sources of the radon gas which may be present in the indoor air. If the soil has an enhanced content of ^{238}U, the soil may be a potential source of the radon gas present in the soil air. This source is of importance as there are certain parameters connected to the soil, affecting the true level of the radon concentration in the soil air. There are also additional parameters of importance for the transport of the gas in the soil and upwards into a building (Chauhan and Chakarvarti, 2002 ; Tell *et al.,* 1994; Dragovic *et al.,* 1996; Font, 1997). One parameter of importance is the ability of the gas to leave, when produced in the grains of the soil.

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The fraction of radon atoms, generated in the soil grains and reaching the pore volume of the soil is known as emanation coefficient. This coefficient depends basically on the soil grain size-distribution, on the porosity and on the water content of the soil. The geometry and the size of the soil grains and the pores determine the “Static” emanation coefficient in the sense that they do not change in time. In this sense the type of soil determines the general radon level in the soil (Russal, 1957). The water content has a large impact on the emanation coefficient and on the soil transport parameters for radon gas and, therefore, affects the radon concentration in the soil (Stranden *et al.,* 1984; Baixeras *et al.,* 2001 ; Bool *et al.,* 1976). There are several reports on measurements, where the emanation of radon from different kind of materials are studied. These reports focus on materials like soil and bedrock (Tanner, 1980; Wilkening, 1990; Abumurad *et al.,* 1997; Mehra *et al.,* 2007; Sharma *et al.,* 2003; Singh *et al.,* 2005; Akhtar *et al.,* 2005). Existences of three primordial radio nuclides (^{40}K, ^{238}U and ^{232}Th) in building materials cause internal and external exposures to residents. External exposure is caused by gamma radiation emitted from ^{40}K and daughter products of ^{238}U and ^{232}Th (Nassiri *et al.,* 2011). It is well known that as a result of inhalation of ^{222}Rn, a daughter product of decay chain of ^{238}U and its daughter products, equivalent dose to entire lung is higher than the equivalent dose to entire lung is higher than the equivalent dose in other tissues (Sundar *et al.,* 2003). Radon an inert radioactive gas whose predecessor is uranium, is emitted from soil beneath the house and from building materials (Singh *et al.,* 2010). Noble radon gas (^{222}Rn) originates from radioactive transformation of ^{226}Ra in the ^{238}U decay chain in the earth's crust (Vaupotic *et al.,* 2010). Plastic track detectors were used to measure the radon concentration and exhalation rate from soil samples (Mujahid *et al.,* 2010). The assessment of radiological risk related to inhalation of radon and radon progeny is based mainly on the integrated measurement of radon in both indoor and outdoor environments. The exhalation of radon from the earth crust and building materials forms the main source of radon in indoor environment (Gusain *et al.,* 2009). In the present paper radon exhalation rate for soil samples collected from different places surrounding the Kasimpur Thermal Power Plant have been carried out "Sealed Can Technique" using LR-115 type II solid state nuclear track detector.

Experimental Technique

Equal amount of each sample (100g) was placed in the cans (diameter 7.0 cm and height 7.5 cm) similar to those used in the calibration experiment (Mahur *et al.,* 2005; Mahur *et al.,* 2008). In each can a LR-115 type II plastic track detector (2cm x 2cm) was fixed at the top inside of the can and the can was sealed (Fig1). Thus the sensitive lower surface of the detector is freely exposed to the emergent radon so that it is capable of recording the alpha particles resulting from the decay of radon in the can. Radon and its daughters reach an equilibrium concentration after a week or more and thus the equilibrium activity of emergent radon could be obtained from the geometry of the can and the time of exposure.

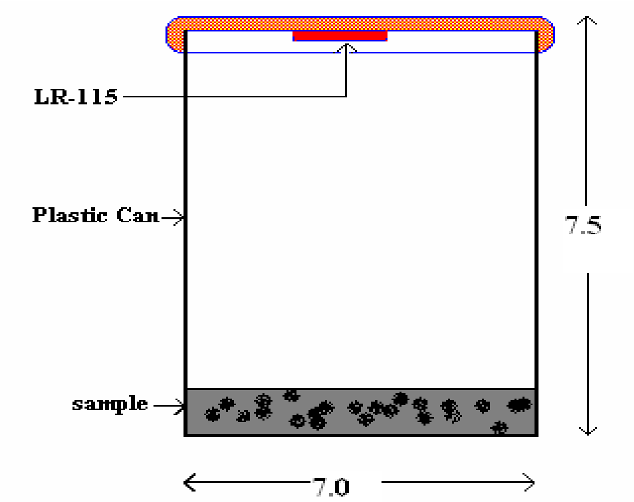

Figure 1. Experimental set up for the measurement of radon exhalation rate using "Sealed Can Technique"

After the exposure for 100 days, the detectors from the cans were retrieved. The detectors were etched in 2.5 N NaOH at 60 ± 1°C for a period of 90 min in a constant temperature water bath to reveal the tracks. Resulting alpha tracks on the exposed face of the detector foils were scanned under an optical microscope at a magnification of 400X. From the track density, the radon activity was obtained using the calibration factor of 0.056 Tr cm^{-2} d^{-1} obtained from an earlier calibration experiment, which was performed at Environmental Assessment Division of Bhabha Atomic Research Centre, Mumbai, India. Experimental set up used is well known for its performance and accuracy (Jojo *et al.,* 1994). Calibration was done under the simulated conditions like those present in the experiment. The details are given elsewhere. Following expression gives the exhalation rate (Khan *et al.,* 1992; Fleischer, 1978; Kumar *et al.,* 2003 and 2005)

$$Ex = \frac{CV\lambda}{A[T + \frac{1}{\lambda}(e^{\lambda t} - 1)]}$$

Where

E_x = Radon exhalation rate (Bq m^{-2} h^{-1});
C = integrated radon exposure as measured by LR-115 type II plastic track detector (Bq m^{-3} h)
V = volume of can (m^3)
λ = decay constant for radon (h^{-1})
T = exposure time (h) and
A = the area covered by the can (m^2)

The errors in radon exhalation rate depend on the track density and are always <5%.

Risk Estimates

The risk of lung cancer from domestic exposure of ^{222}Rn and its daughters can be estimated directly from the indoor inhalation exposure (radon) effective dose. The contribution of indoor radon concentration from the samples can be calculated from the expression (Nazaroff, 1988):

$$C_{Rn} = \frac{E_X \times S}{V \times \lambda_V}$$

Where C_{Rn}, E_x, S, V, and λ_V are radon concentration (Bq m^{-3}), radon exhalation rate(Bq m^{-2} h^{-1}), radon exhalation area (m^2), room volume (m^3) and air exchange rate (h^{-1}) respectively. In these calculation, the maximum radon concentration from the building material was assessed by assuming the room as a cavity with S/V= 2.0 m^{-1} and air exchange rate of 0.5 h^{-1}. The annual exposure to potential alpha energy E_p (effective dose equivalent) is then related to the average radon concentration C_{Rn} by the following expression:

$$E_p\ (WLM\ yr^{-1}) = 8760 \times n \times f \times C_{Rn} / 170 \times 3700$$

Where C_{Rn} is in Bq m^{-3}; n, the fraction of time spent indoors; 8760, the number of hours per year; 170, the number of hours per working month and F is the equilibrium factor for radon. Radon progeny equilibrium factor is the most important quantity when dose calculations are to be made on the basis of the measurement of radon concentration. Equilibrium factor F quantifies the state of equilibrium between radon and its daughters and may have values 0< F < 1. The value of F is taken as 0.4 as suggested by UNSCEAR (1988). Thus the values of n = 0.8 and F= 0.4 were used to calculate E_P. From radon exposure, effective dose equivalents were estimated by using a conversion factor of 6.3 mSv WLM^{-1} (ICRP, 1987).

RESULTS AND DISCUSSION

The results for the radon activity and radon exhalation rate in soil samples are presented in Table 1.

soil will be different at different places and the variation may be attributed to different amount of fly ash in the soil and also uranium concentration in them. Fig 2 presents the frequency distribution chart of exhalation rate of different samples studied.

Table 1. Radon activity concentration, radon exhalation rate and indoor inhalation exposure (radon)-effective dose from soil samples(different places) around Kasimpur thermal power plant, India

S. No.	Places	Track Density (tracks/cm^2 d)	Radon Activity (Bq m^{-3})	Exhalation rate (mBq m^{-2} h^{-1})	Effective dose equivalent (μSv y^{-1})
1	H-12, Old colony	244.96	4374.29	1572.66	185.45
2	H-16, Old Colony	220.16	3931.43	1413.44	166.67
3	R-R 37 Old Colony	173.12	3091.43	1111.44	131.06
4	Park Old Colony	224.96	4017.14	1444.26	170.31
5	H-10, Old colony	252.48	4508.57	1620.94	191.14
6	Hospital, new Colony	234.56	4188.57	1505.89	177.58
7	Park, New Colony	199.04	3554.29	1277.85	150.69
8	H-17, Old Colony	207.68	3708.57	1333.32	157.23
9	Mandir Market, Old Colony	189.28	3380	1215.19	143.29
10	H-11, Old Colony	207.20	3700	1330.24	156.86
11	J.E. Club, New Colony	217.12	3877.14	1393.93	164.37
12	Operating Club, New Colony	212.48	3794.29	1364.14	160.86
13	Guest House, Old Colony	192.48	3437.14	1235.73	145.72
14	Compound No.1 Old Colony	261.12	4662.86	1676.41	197.68
15	Ingraham School, New Colony	279.84	4997.14	1796.59	211.86
	Min.	173.12	3091.43	1111.44	131.06
	Max	279.84	4997.14	1796.59	211.86
	Average value	221.09	3948.19	1419.47	167.38
	S.D.	29.14	520.33	187.07	22.06
	R.S.D%	13.18	13.18	13.18	13.18

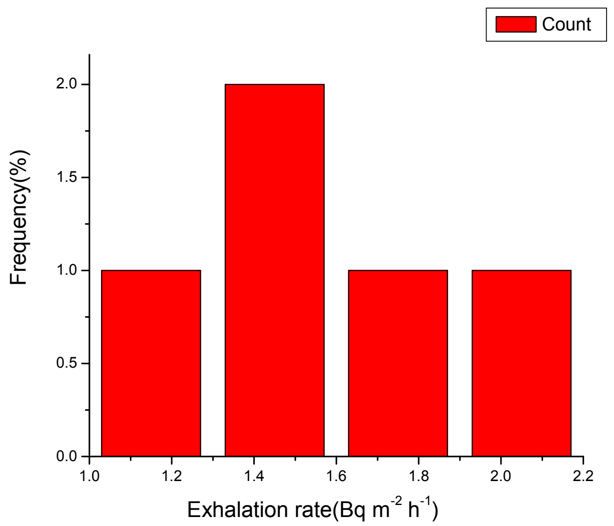

Fig. 2. Frequency distribution of radon exhalation rates from soil samples(different places) surrounding the Kasimpur thermal power plant

It is clear from the table that the radon activity varies from 3091.43 Bq m^{-3} to 4997.14 Bq m^{-3} with an average value of 3948.19 Bq m^{-3}. Exhalation rate varies from 1111.44 mBq m^{-2} h^{-1} to 1796.59 mBq m^{-2} h^{-1} with an average value of 1419.47 mBq m^{-2} h^{-1} while effective dose equivalent varies from 131.06 μSv y^{-1} to 211.86 μSv y^{-1} with an average value of 167.38 μSv y^{-1} . The lowest value was found for the soil samples collected from R.R. 37 while the maximum value was found to be for the soil sample collected from In graham School, New Colony. The places are at different distances from the power plant where from fly ash spreads. Thus the amount of fly ash in the

Acknowledgement: The authors thank, Chairman, Department of Applied Physics, Aligarh Muslim University, Aligarh, for providing the facilities for this work.

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