International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 3 Issue 7, June 2016

ISSN: 2394-4404

Radon Exhalation Rate And Radiation Doses From Fly Ash, Coal, Bottom Ash And Slag Samples Collected From Panki Thermal Power Plant

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Abstract: ***In recent years fly ash has found diversified applications in construction activities such as in the formation of Bricks, as a binding material and in the production of cement etc. Thus, it is quite important to estimate the radiation risk to the population from the radon exhalation rate of fly ash. In the present study, radon exhalation rates in coal, fly ash, bottom ash and slag samples from the thermal power plant at Panki (U.P) have been measured using sealed an technique having LR-115 type II detectors. It is observed that the radon exhalation rate from slag samples is higher than from other samples. Radiation doses from the fly ash, coal, bottom ash, slag have been estimated from radon exhalation rate.***

Keywords: LR-115 type II dector, Effective Dose, Panki Thermal Power Plant.

I. INTRODUCTION

There has been an increasing demand for electricity generation throughout the world with the ever increasing growth in human civilization. With the increasing demand for electricity, coal plays an important role in electric power generation world wide. Coal is burnt in furnaces operating at temperatures of up to about 200K. In the combustion process most of the mineral matter in the coal is fused in to the vitrified ash which is a major environmental problem [1,2,3].

This problem is particularly important for Indian power stations because most of them use poor quality coal with 55-60% ash content. This results in an average production of 100 million tons of ash per annum. In the combustion process, most of the mineral matter in coal is converted into ash. A portion of the heavier ash together with incompletely burnt organic matter drops to the bottom of the furnace as ash or slag. The natural radiocuclides included in the non-combustible mineral matter of coal are portioned among the bottom ash and fly ash, except for the gases and volatile minerals which are incorporated directly into the flue gases. In large power stations, there is about 20% bottom ash and, therefore, 80% fly ash [4,5,6,7] . The natural radionuclides concentrations in ash and slag from coal-fired power plants are significantly higher than the corresponding concentration in the earth's crust [8]. Radiation risk from fly ash is of importance since if used in construction materials it may raise the concentration of airborne indoor radioactivity to unacceptable levels, especially in places having low ventilation rates [9,10]. 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 [11]. 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 [12]. Radon exhalation rate is of prime importance for the estimation of radiation risk from fly ash samples, used for building construction materials [13]. Noble radon gas (^{222}Rn) originates from radioactive transformation of ^{226}Ra in the ^{238}U decay chain in the earth's crust [14]. 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 [15]. In the present paper radon exhalation rate from fly ash, coal, bottom ash and slag samples collected from Panki Thermal Power Plant have been carried out "Sealed Can Technique" using LR-115 type II solid state nuclear track detector.

II. 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 [16-18]. 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.

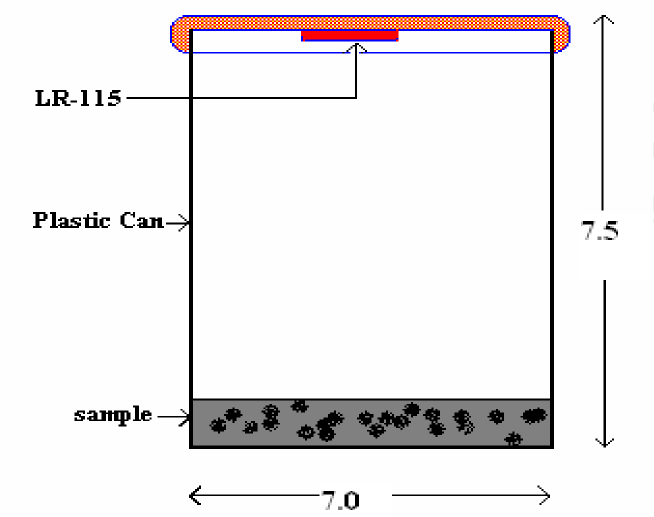

Figure 1: Experimental set up for the measurement of radon exhalation rate using "Sealed Can Technique"

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 [19]. Calibration was done under the simulated conditions like those present in the experiment. The details are given else where. Following expression gives the exhalation rate [20-23]

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

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%.

III. 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 [24]:

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

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 × n × f × C_{Rn} / 170 × 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} [25].

IV. RESULTS AND DISCUSSION

The measured data for radon exhalation rate is presented in Table 1

Sample	**Track Density (Track/ cm^2d)**	**Radon Activity (Bq m^{-3})**	**Exhalation Rate (mBq m^{-2} h^{-1})**	**Effective Dose equivalent (μSv y^{-1})**
F1	189.3	3380.00	1215.19	143.29
F2	200.0	3571.43	1224.9	144.35

F3	198.1	3537.14	1271.69	149.96
F4	202.1	3608.57	1297.37	152.99
F5	193.6	3457.14	1242.92	146.57
F6	196.3	3505.71	1260.39	148.63
F7	178.7	3191.43	1147.39	135.30
F8	196.8	3514.29	1263.47	148.98
F9	184.0	3285.71	1181.29	139.29
F10	174.4	3114.29	1119.66	132.03
F11	192.0	3428.57	1232.65	145.36
F12	196.8	3514.29	1263.47	148.99
F13	206.4	3658.71	1325.10	156.26
F14	177.6	3171.43	1140.21	134.45
F15	190.4	3400.00	1222.38	144.14
Average value	191.8	3422.58	1227.21	144.71
S.D.	9.43	165.44	58.72	6.93
R.S.D%	4.92	4.83	4.78	4.79
BF1	252.0	4500.00	1617.86	190.78
BF2	224.0	4000.00	1438.09	169.58
BF3	235.2	4200.00	1510.00	178.06
BF4	208.9	3731.43	1341.54	158.19
Average value	230.0	4107.86	1476.87	174.15
S.D.	18.2	324.34	116.61	13.75
R.S.D%	7.9	7.89	7.89	7.89
C1	198.4	3542.86	1273.74	150.20
C2	187.2	3342.86	1201.84	141.72
C3	174.4	3114.29	1119.66	132.03
C4	162.1	2894.29	1040.57	122.70
Average value	180.5	3223.58	1158.95	136.66
S.D.	15.7	280.79	100.95	11.91
R.S.D%	8.7	8.71	8.71	8.72
S1	260.8	4657.14	1674.35	197.44
S2	264.0	4714.29	1694.90	199.86
Average value	262.4	4685.72	1684.63	198.65
S.D.	2.26	40.41	14.53	1.71
R.S.D%	0.86	0.86	0.86	0.86

F: Fly ash,
BF: Bottom Ash
C: Coal
S: Slag

Table 1: Radon activity concentration, radon exhalation rate and indoor inhalation exposure (radon)-effective dose in coal, flyash, bottom ash and slag samples from Panki thermal power plant in U.P., India

It is clear from the Table-1 that the radon activity for fly ash samples varies from 3114.29 Bq m^{-3} to 3658.76 Bq m^{-3} with an average value of 3422.58 Bq m^{-3}, Exhalation rate varies from 1119.66 mBq m^{-2} h^{-1} to 1325.10 mBq m^{-2} h^{-1} with an average value of 1227.21 mBq m^{-2} h^{-1} while effective dose equivalent varies from 132.03 µSv y^{-1} to 156.26 µSv y^{-1} with an average value of 144.71 µSv y^{-1}. For bottom ash radon activity varies from 3731.43 Bq m^{-3} to 4500.00 Bq m^{-3} with an average value of 4107.86 Bq m^{-3}; exhalation rate varies from 1341.54 mBq m^{-2} h^{-1} to 1617.86 mBq m^{-2} h^{-1} with an average value of 1476.87 mBq m^{-2} h^{-1} while effective dose equivalent varies from 158.19µSv y^{-1} to 190.78µSv y^{-1} with an average value of 174.15 µSv y^{-1}. For coal samples radon activity varies from 2894.24 Bq m^{-3} to 3542.86 Bq m^{-3} with an average value of 3223.58 Bq m^{-3}, exhalation rate from 1040.57 mBq m^{-2} h^{-1} to 1273.74 mBq m^{-2} h^{-1} with an average value of 1158.95 mBq m^{-2} h^{-1} while effective dose equivalent varies from 122.70 µSv y^{-1} to 150.20 µSv y^{-1} with an average value of 136.66µSv y^{-1}. For slag samples radon activity varies from 4657.14 Bq m^{-3} to 4714.29 Bq m^{-3} with an average value of 4685.72 Bq m^{-3}, exhalation rate from 1674.35 mBq m^{-2} h^{-1} to 1694.90 mBq m^{-2} h^{-1} with an average value of 1684.63 mBq m^{-2} h^{-1} while mean effective dose , is 198.65 µSv y^{-1}. The maximum value was found to be for the slag samples collected from inside the thermal power plant. The higher value of radon exhalation rate of slag may be due to their grain size and uranium concentration.

ACKNOWLEDGEMENT

Prof. Rajendra Prasad wishes to thank, all India Council of Technical Education, Government of India for providing Emeritus Fellowship to carry out this work.

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