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COMPARATIVE STUDY OF RADON EXHALATION RATE AND RADIATION DOSES IN SOIL SAMPLES FROM THERMAL POWER PLANTS

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Abstract— **To compare the radon exhalation rates of soil from Kasimpur Thermal Power plant and its nearby Panki Thermal Power Plant, samples of soil were collected. 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 for soil samples from inside of the Kasimpur Thermal Power Plant, varies from 4657.14 to 4714.29 Bq m^{-3} with an average value of 4685.72 Bq m^{-3} ,exhalation rate varies from 1674.35 to 1694.90 mBq m^{-2} h^{-1} with an average value of 1684.63 mBq m^{-2} h^{-1} and effective dose equivalent varies from 197.44 to 199.86 µSv y^{-1} with an average value of 198.65 µSv y^{-1} ,while outside power plant radon activity varies from 3088.57 Bq m^{-3} to 4957.14 Bq m^{-3} with an average value of 4122.71Bq m^{-3} ; exhalation rate varies from 1110.42 mBq m^{-2} h^{-1} to 1782.21 mBq m^{-2} h^{-1} with an average value of 1482.21 mBq m^{-2} h^{-1} while effective dose equivalent varies from 130.94 µSv y^{-1} to 210.16 µSv y^{-1} with an average value of 174.78 µSv y^{-1}. Radon activity for soil sample from inside of the Panki Thermal Power Plant power plant varies from 3731.43 to 4500.00 Bq m^{-3} with an average value of is 4107.86 Bq m^{-3}, exhalation rate varies from 1341.54 to 1617.86 mBq m^{-2} h^{-1} with an average value of 1476.87 mBq m^{-2} h^{-1} and effective dose equivalent varies from 158.19 to 190.78 µSv y^{-1} with an average value of 174.15 µSv y^{-1}, while outside power plant radon activity varies from 3094.29 Bq m^{-3} to 4608.57 Bq m^{-3} with an average value of 3755.28 Bq m^{-3} ,exhalation rate varies from 1112.47 mBq m^{-2} h^{-1} to 1656.89 mBq m^{-2} h^{-1} with an average value of 1350.11 mBq m^{-2} h^{-1} while effective dose equivalent varies from 131.18 µSv y^{-1} to 195.38 µSv y^{-1} with an average value of 159.13 µSv y^{-1}.**

Index terms- **LR-115 type II dector, Effective Dose, Kasimpur thermal power plant, Panki thermal power plant.**

I. INTRODUCTION

. Human beings have always been exposed to natural radiations arising from within and outside the earth. The exposure to ionizing radiations from natural sources occurs because of the naturally occurring radioactive elements in the soil and rocks, cosmic rays entering the earth's atmosphere from outer space and the internal exposure from radioactive elements through food, water and air. Natural radioactivity is wide spread in the earth's environment and it exists in various geological formations in soil, rocks plants, water and air [1-6]. 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 [7]. Noble radon gas (^{222}Rn) originates from radioactive transformation of ^{226}Ra in the ^{238}U decay chain in the earth's crust [8]. The rate at which radon escapes or emanates from solid into the surrounding air is known as radon emanation rate or radon exhalation rate of the solid [9]. 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 [10]. Radon moves either by diffusion or by transporation mechanism or by both [11]. However the favored mechanism is controlled by geological structure, underground water flow and meteorological conditions [12]. If uranium- rich material lies close to the surface of earth there can be high radon exposure hazards [13-15]. Radium is a solid radioactive element under ordinary conditions of temperature and pressure. It decays to radon emitting alpha- particles followed by gamma-radiations. It is concentration of radium which governs how many radon atoms are formed. The measurements of radon thus necessitate the need for uranium and radium estimation in the parent source for public health risk measurements.

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 [16]. Plastic track detectors were used to measure the radon concentration and exhalation rate from soil samples [17]. In the present paper radon exhalation rate from soil samples collected from Kasimpur Thermal Power Plant and its nearby 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 [18-20]. 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.

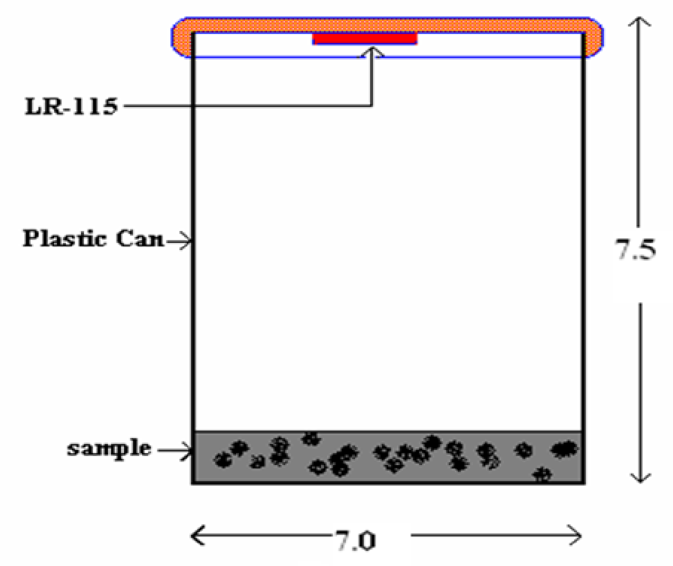

Figure – 1. Experimental set up for the measurement of radon exhalation rate using "Sealed Can Technique"

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 [21]. 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 [22-25]

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

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 [26]:

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

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} [27].

III. Results and Discussion

The data obtained from the measurements are presented in Table 1

Table 1

Radon activity concentration, radon exhalation rate and indoor inhalation exposure (radon)-effective dose from soil samples from inside and outside the Kasimpur thermal power plant, India

	No. of samples	Track Density (track/cm^2 d)	Radon Activity (Bq m^{-3})	Exhalation rate (mBq m^{-2} h^{-1})	Effective dose equivalent (µSv y^{-1})
	Inside Power Plant				
Minimum	20	260.8	4657.14	1674.35	197.44
Maximum	20	264.0	4714.29	1694.90	199.86
Average value	20	262.4	4685.72	1684.63	198.65
S.D	20	2.26	40.41	14.53	1.71
R.S.D%	20	0.86	0.86	0.86	0.86
Outside power plant					
Minimum	20	172.96	3088.57	1110.42	130.94
Maximum	20	277.06	4957.14	1782.21	210.16
Average value	20	230.84	4122.71	1482.21	174.78
S.D	20	32.77	585.87	210.63	24.84
R.S.D%	20	14.19	14.21	14.21	14.21

It is clear from the Table-1 that the Radon activity for soil samples from inside of the Kasimpur Thermal Power Plant, varies from 4657.14 to 4714.29 Bq m^{-3} with an average value of 4685.72 Bq m^{-3} ,exhalation rate varies from 1674.35 to 1694.90 mBq m^{-2} h^{-1} with an average value of 1684.63 mBq m^{-2} h^{-1} and effective dose equivalent varies from 197.44 to 199.86 µSv y^{-1} with an average value of 198.65 µSv y^{-1} ,while outside power plant radon activity varies from 3088.57 Bq m^{-3} to 4957.14 Bq m^{-3} with an average value of 4122.71Bq m^{-3} ; exhalation rate varies from 1110.42 mBq m^{-2} h^{-1} to 1782.21 mBq m^{-2} h^{-1} with an average value of 1482.21 mBq m^{-2} h^{-1} while effective dose equivalent varies from 130.94 µSv y^{-1} to 210.16 µSv y^{-1} with an average value of 174.78 µSv y^{-1}. The lower values were found for the soil samples collected from outside the Power Plant as compared to the value for the soil sample collected from inside the Plant. The variation may be due to different amount of uranium concentration in soils collected from different places in and around the power plant and also on the amount of fly ash collected on the surface. Fig 2 presents the frequency distribution chart of exhalation rate of different samples investigated.

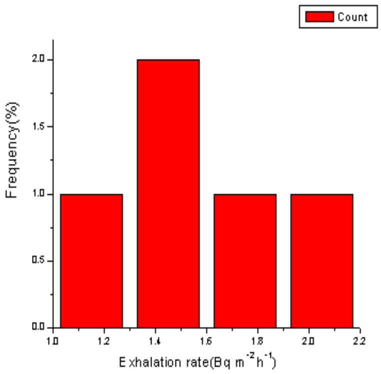

Fig 2 Frequency distribution of radon exhalation rates from soil samples from inside and outside the Kasimpur Thermal Power Plant

Table 2 presents the result of measurements.

Table 2

Radon activity concentration, radon exhalation rate and indoor inhalation exposure (radon)-effective dose from soil samples near Panki thermal power plant, India

	No. of samples	Track Density (track/cm^2 d)	Radon Activity (Bq m^{-3})	Exhalation rate (mBq m^{-2} h^{-1})	Effective dose equivalent (µSv y^{-1})
	Inside Power Plant				
Minimum	27	208.9	3731.43	1341.54	158.19
Maximum	27	252.0	4500.00	1617.86	190.78
Average value	27	230.0	4107.86	1476.87	174.15
S.D	27	18.2	324.34	116.61	13.75
R.S.D%	27	7.9	7.89	7.89	7.89
	Outside power plant				
Minimum	27	173.28	3094.29	1112.47	131.18
Maximum	27	258.08	4608.57	1656.89	195.38
Average value	27	210.29	3755.28	1350.11	159.13
S.D	27	24.81	443.10	159.31	18.73
R.S.D%	27	11.79	11.79	11.79	11.77

It is apparent from Table-2 that, Radon activity for soil sample from inside of the Panki Thermal Power Plant power plant varies from 3731.43 to 4500.00 Bq m^{-3} with an average value of is 4107.86 Bq m^{-3}, exhalation rate varies from 1341.54 to 1617.86 mBq m^{-2} h^{-1} with an average value of 1476.87 mBq m^{-2} h^{-1} and effective dose equivalent varies from 158.19 to 190.78 µSv y^{-1} with an average value of 174.15 µSv y^{-1}, while outside power plant radon activity varies from 3094.29 Bq m^{-3} to 4608.57 Bq m^{-3} with an average value of 3755.28 Bq m^{-3} ,exhalation rate varies from 1112.47 mBq m^{-2} h^{-1} to 1656.89 mBq m^{-2} h^{-1} with an average value of 1350.11 mBq m^{-2} h^{-1} while effective dose equivalent varies from 131.18 µSv y^{-1} to 195.38 µSv y^{-1} with an average value of 159.13 µSv y^{-1}. The maximum value was found to be for the soil sample inside Panki thermal power plant as also observed in the case of Kasimpur thermal power plant.

Fig 3. Shows the frequency distribution chart of exhalation rate of different samples studied.

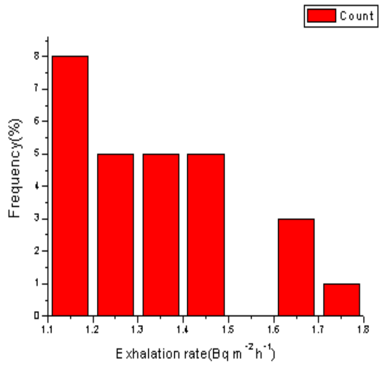

Fig 3. Frequency distribution of radon exhalation rates in soil samples nearby Panki thermal power plant.

IV. CONCLUSIONS

The lower values were found for the soil samples collected from outside the Kasimpur Thermal Power Plant as compared to the value for the soil sample collected from inside the Plant. It is as also observed in the case of Panki thermal power plant. The variation may be due to different amount of uranium concentration in soils collected from different places in and around the power plant and also on the amount of fly ash collected on the surface.

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