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Assessment of Annual Effective Dose from Equilibrium Equivalent Concentration of 222RN and 220RN in Northern Zone of Punjab (India)

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Abstract

Radon (222Rn) and Thoron (220Rn) are prime contributors to the ionizing radiological doses received by the mankind. High concentrations of 222Rn and 220Rn may elevate the risk of radiological exposure to general populace. In Indoor environment, most of the dose has been given by the 222Rn and 220Rn progeny. In the present manuscript, total equilibrium equivalent concentration of 222Rn (EERCA+U) and 220Rn (EETCA+U) has been calculated by using deposition based progeny sensors in the dwellings of North region of Punjab (India). The separate attached and unattached EEC has also been discussed in the manuscript. The estimated (EERCA+U) and (EETCA+U) in the studied region fluctuate in the range from 11 Bq m-3 to 33 Bq m-3 and 0.8 Bq m-3 to 2.2 Bq m-3 respectively. The unattached fractions of EEC are directly responsible for the dose received by organs and target cells. In the present manuscript, unattached fraction and total radiological dose from 222Rn and 220Rn EEC has been estimated. The total inhalation dose originated from EERCA+U and EETCA+U was lower than its recommended limit.

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I. INTRODUCTION

Uranium and it decay products are responsible to contribute almost 52 % of radiation dose to mankind (Singh et al., 2015; UNSCEAR 2000). As per WHO (World Health Organization) reports, these hazardous radionuclides (^{222}Rn and ^{220}Rn) are weighty factors responsible for lung cancer in dwellings (Darby et al., 2005). The risk of gastrointestinal and stomach cancer is increased with the high value of ^{222}Rn (Kendal et. al., 2002). The progenies (^{226}Ra, ^{232}Th, ^{222}Rn and ^{220}Rn) of ^{238}U and ^{232}Th series are directly contribute the radiological dose to distinct organs in different environs (Virk et al., 2016; Bangotra et al., 2018; Mehra et al., 2016). The progenies (^{226}Ra, ^{232}Th, ^{222}Rn, ^{220}Rn) of ^{238}U and ^{232}Th series are directly contributing the radiological dose to distinct organs in different environs (Virk et al., 2016; Bangotra et al., 2018; Mehra et al., 2016). The most of absorbed dose has been received by emitting alpha particles of ^{222}Rn and ^{220}Rn series that are in direct contact with Pulmonary and tracheobronchial region (Bangotra et al., 2019). These newly generated^{222}Rn and ^{220}Rn daughter nuclei form clusters of unattached particles by attaching themselves with distinct range of dust

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particles and reacts with gases or vapours. The unattached fraction of ^{222}Rn and ^{220}Rn is a most significant parameter that correlates with maximum radiological dose obtained by target cells or organs and further absorbed at faster rate into blood (Butterweck et. al., 2002)

There is a worldwide acceptance of LR-115 (Solid stae nuclear track detector) for the estimation ^{222}Rn and ^{220}Rn concentration in indoor air environment (Nyambura et al., 2019; Bangotra et al., 2015). In earlier studies, this passive nuclear track detector was directly deployed in indoor environment or dwellings that cause underestimation of tracks recorded on the film. Further, it was difficult to measure separate ^{220}Rn and progeny concentration of ^{222}Rn and ^{222}Rn. In the present manuscript, deposition based progeny sensors (LR-115 based) are used to estimate the total EEC (equilibrium equivalent concentration) from ^{220}Rn, ^{222}Rn and the radiological dose received by the residents of northern zone of Punjab.

II. GEOLOGY

Punjab (50,362 square kilometer) is a state in northern India and share its border with great Himalyas (east), Jammu and Kashmir (north), Haryana (south) and Rajasthan in southwest. The state is vast alluvial plain and composed of older, newer alluvium and aeolian deposits. They are composed of different layers of clay and fine to coarse grained sandstone (Kochhar et al., 2006). The average PH value of 8.15 from sandy loam to clay is found in Jalandhar, Hoshirpur, Kaurthala and Nawanshahr districts of Doaba region in Punjab. The soil of Kaurthala and Jalandhar district is widely categories as tropical arid brown soil.

III. MATERIALS AND METHODOLOGY

The deposition based ^{222}Rn progeny sensor (DRPS) and ^{220}Rn sensor (DTPS) were used in 15 locations for the measurement of both attached and unattached EEC of ^{222}Rn (EERC) and ^{220}Rn (EETC). Absorbers of appropriate thickness with LR -115 track detectors have been used in DRPS /DTPS sensors. The schematic diagrams of DRPS and DTPS have been given in **Figure 1 - 2**. The absorber of 50 μm aluminized mylar has been used in DTPS that detects only the alpha particles of 8.78 MeV emitted by ^{214}Po. However, for DRPS, the combination of LR-115 and aluminized mylar has been used to detect the alpha particles of 7.67 MeV emitted by ^{214}Po. The sensors were suspended at 20 cm from the walls and 1.5 m from the floor. The registered tracks on LR -115 detectors have been used to estimate the EEC using different sensitivity factors as given by as given in equations (1) and (2) (Mishra et al., 2008; Mishra et al., 2010). A 200 mesh type wire screen capped DRPS/DTPS has been used to measure the attached EEC in studied region (**Figure 2**). After exposure, the LR-115 were retrieved from sensors and further etched (2.5 N NaOH for 90 minute duration at temperature of 60° without stirring) and counted by spark counter.

$$\mathrm{EETC}(\mathrm{Bqm^{-3}}) = \frac{\mathrm{T_T} - \mathrm{B}}{\mathrm{t} \times S_T} \qquad (1)$$

$$\mathrm{EERC}(\mathrm{Bqm^{-3}}) = \frac{\mathrm{T_R} - \mathrm{B} - (S_{T'} \times \mathrm{EETC}(\mathrm{Bqm^{-3}}))}{\mathrm{t} \times S_R} \qquad (2)$$

Here t is time exposure. B (background track density), T_T and T_R are track densities that were recorded during exposure of DTPS and DRPS on LR- 115. S_T, S_R and S_T are sensitivity factors (Mishra et al., 2008; Mishra et al., 2010).

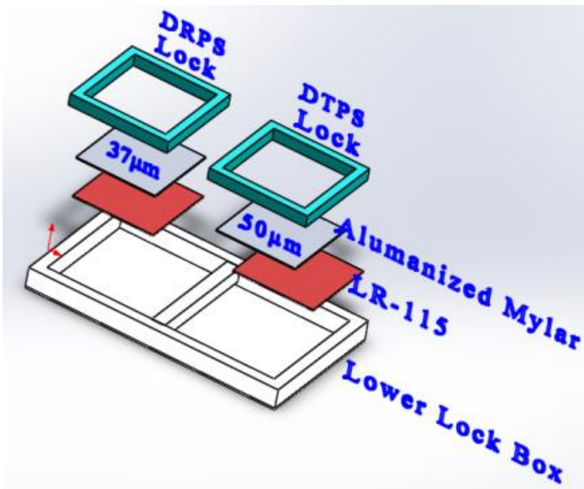

Fig. 1: Schematic diagram of DRPS/ DTPS.

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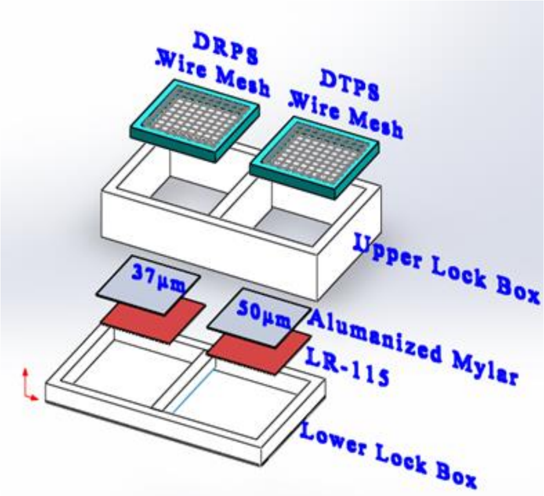

Fig. 2: Schematic diagram of Wire-mesh DRPS/ DTPS.

The EERC have been estimated from DRPS with subtraction of ^{220}Rn progeny contribution. However same methodology is used with different sensitivity factors in case of fine fraction. The minimum detection limit of DTPS and DRPS is 0.1 Bqm^{-3} and 1.0 Bqm^{-3} respectively (Mishra et al., 2014).

IV. RESULTS AND DISCUSSION

The mean values of EERC$_{A+U}$ (total EEC of ^{222}Rn Concentration) and EETC$_{A+U}$ (total EEC of ^{220}Rn Concentration) were 18 Bq m^{-3} and 1.5 Bq m^{-3} (**Table 1**). The separate attached and unattached EEC has been calculated. The EERC$_A$ (attached ^{222}Rn EEC) and EETC$_A$ (attached ^{220}Rn EEC) in the studied region varied 10 Bq m^{-3} to 32 Bq m^{-3} and 0.8 Bq m^{-3} to 1.5 Bq m^{-3} respectively.

Table 1: EEC and unattached fraction of ^{222}Rn and ^{220}Rn.

Location	**EECR$_{A+U}$ Bq m^{-3}**	**EECR$_A$ Bq m^{-3}**	f_p^{Rn}	**EECT$_{A+U}$ Bq m^{-3}**	**EECT$_A$ Bq m^{-3}**	f_P^{Th}
Doraha	33 ± 1.3	32 ± 1.5	0.04	1.7 ± 0.2	1.6 ± 0.8	0.06
Philur	27 ± 1.1	26 ±1.4	0.04	1.5 ± 0.5	1.3 ± 0.3	0.13
Cheru	15 ± 1.2	14 ± 1.2	0.04	1.8 ± 0.1	1.6 ± 0.6	0.11
Hoshiarpur	17 ± 1	15 ± 1.6	0.11	1.6 ± 0.6	1.4 ± 0.2	0.13
Kartarpur	11 ± 1.4	10 ± 1.2	0.08	1.0 ± 0.2	0.9 ± 0.1	0.10
Kapurthala	13 ± 1	12 ±1.4	0.08	1.1 ± 0.4	1.0 ± 0.3	0.09
Amritsar	15 ±1.3	14 ± 1	0.06	1.4 ± 0.3	1.2 ± 0.1	0.14
Kapurthala	22 ± 1.2	20 ± 1.7	0.09	0.9 ± 0.2	0.8 ± 0.2	0.11
Dharamkot	23 ± 1.5	22 ±1.3	0.02	2.2 ± 0.8	2.0 ± 0.5	0.09
Adampur	32 ± 2	29 ± 1.1	0.08	1.7 ± 0.5	1.6 ± 0.3	0.06
Jalandhar	12 ±1.1	11 ± 1	0.09	1.9 ± 0.3	1.7 ± 0.4	0.11
Maqsudan	15 ± 1.3	13 ±1.7	0.13	0.8 ± 0.2	0.7 ± 0.1	0.13
Shahkot	11 ± 1	10 ±1.4	0.07	2.0 ± 0.4	1.9 ± 0.6	0.05
Moga	14 ± 1.5	13 ± 1.2	0.05	1.6 ± 0.6	1.5 ± 0.5	0.06
Jagraon	17 ± 1.2	15 ± 1	0.13	1.5 ± 0.3	1.4 ± 0.2	0.07

The subtraction of EERC$_A$ from EERC$_{A+U}$ is known as EERC$_U$. The EETC$_A$ (unattached decay product concentration) has also been similarly calculated as EERC$_U$. Aerosol parameters, tidal volume, unattached fractions of ^{222}Rn (f_p^{Rn}) and ^{220}Rn (f_P^{Th}) are the key parameter for the assessment of inhalation lung dose.In this manuscript, f_p^{Rn} and f_P^{Th} have been calculated from the ratio of

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unattached EEC to total EEC (Bangotra et al., 2019). The arithmetic means of f_p^{Rn} and f_P^{Th} in the studied regions were 0.07 ± 0.03 and 0.10 ± 0.02 respectively (**Table 1)**. The annual inhalation dose for ^{222}Rn and ^{220}Rn has been calculated by dose conversion factors given in equations (Unscear 2008).

$$AED^{Rn}(mSva^{-1}) = EERC_{A+U}(Bq\ m^{-3}) \times OT \times (DCF^{Rn}) \quad (3)$$

Where $AED^{Rn}(mSva^{-1})$ is annual effective dose for ^{222}Rn, *OT* is the average indoor occupancy time per person *(7000 h y*$^{-1}$*)* and DCF^{Rn} $(9\ nSv\ h^{-1}\ (Bq\ m^{-3})^{-1})$is the dose conversion factor for ^{222}Rn exposure.

$$AED^{Tn}\ (mSva^{-1}) = EETC_{A+U}(Bq\ m^{-3}) \times OT \times (DCF^{Tn}) \quad (4)$$

Where $AED^{Tn}\ (mSva^{-1})$ is the annual effective dose for ^{220}Rn, $DCF^{Tn}(40\ nSv\ h^{-1}(Bq\ m^{-3}))$ is the dose conversion factor for ^{220}Rn exposure. The $AED^{Rn}(mSva^{-1})$ and $AED^{Tn}\ (mSva^{-1})$) in the studied area vary from 0.7 $mSva^{-1}$ to 2.1 $mSva^{-1}$ and 0.2 $mSva^{-1}$ to 0.6 $mSva^{-1}$ respectively as shown in **Fig 3**.

V. CONCLUSION

The estimated average EERC was less than as per reported by Ramola et al. (2017) in Uttrakhand region and Bangotra et al. (2019) in southern Punjab (India). However, the average value for EETC is almost similar as compared to Uttrakhand and southern Punjab region. The average value of f_p^{Rn} (0.07 ± 0.03) was lower than to 0.08 as reported by Nikezic et al. (2002). The $AED^{Rn}(mSva^{-1})$ in the study area was slightly lower than the recommended action level of 1.26 mSv a^{-1} (0.2–10) (Unscear 2008). **Fig 3** revealed that it is mandatory to estimate thoron progeny along with radon progeny due to its contribution in radiological doses. In the light of above discussion, the surveyed area is safe for human beings as per the concerned health hazard effects due to ^{222}Rn and ^{220}Rn.

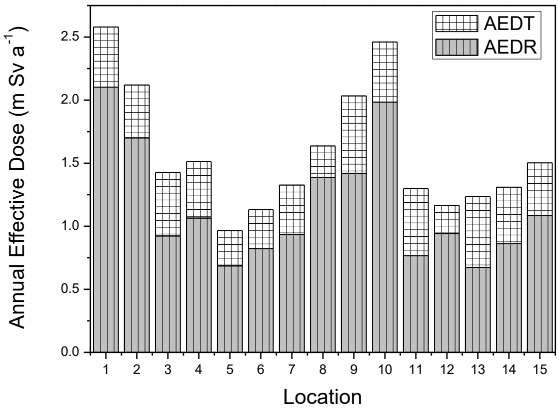

Fig 3: Annual Effective doses in Studied area

VI. ACKNOWLEDGEMENT

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