Inhalation Dose Assessment

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Programs Deploying Indigenous DTPS and DRPS

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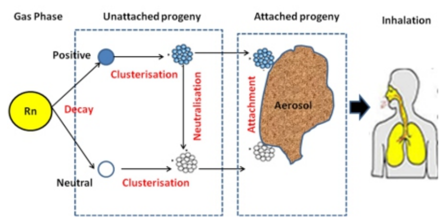

Inhalation dose due to Radon Progeny

ABSTRACT

Inhalation dose assessment has been improved by the development of Direct Radon and Thoron progeny sensors (DRPS and DTPS). These are indigenously developed in RP&AD, BARC. DRPS and DTPS are deposition based, passive, time integrated alpha particle detectors for direct measurement of progeny concentrations. Programs deploying DTPS and DRPS, both in national level surveys and international scientific research collaborations has been undertaken.

KEYWORDS: *Direct Radon Progeny Sensors (DRPS), Direct Thoron Progeny Sensors (DTPS), Inhalation dose*

Introduction

Inhalation of ^{222}Rn, ^{220}Rn and their progeny contribute to more than 50% i.e. 1.29 mSv, out of 2.5 mSv of total annual effective dose to humans from all natural sources of radiation (Fig.1). The primary exposure pathway for ^{222}Rn and its progeny from their exhalation to the absorbed organ dose is shown as a block diagram in Fig.2(a). Specifically, the progeny of ^{222}Rn, ^{220}Rn, that are generated by radioactive decay from the parent gas, exhibit a dynamic behavior by attachment to aerosols followed by segregation into unattached (0.5-5 nm diameter) and attached progeny (100-500 nm). Thus they become a part of indoor aerosol, available for inhalation Fig.2(b). Upon inhalation, the unattached and attached progeny deposit in the different regions of the respiratory tract (Fig.3) and undergo subsequent radioactive decay, contributing to inhalation dose. More precisely, progeny alone contribute to >95% of the total inhalation dose. Inhalation dose is given by:

$$D = (C_g.DCF_g + C_p.DCF_p)\ T.OF$$

where, C_g: Gas (^{222}Rn, ^{220}Rn) activity concentration,

DCF_p: Dose Conversion Factor (g- gas, p- progeny)

T: Exposure time

OF: Occupancy factor

C_p: Progeny (^{222}Rn, ^{220}Rn) activity concentration

The major domain for the measurement of ^{222}Rn, ^{220}Rn and their Progeny are a) Public domain (dwellings, schools, offices) and b) Occupational domains (Uranium mines, Thorium plants). It had been a general practice to measure the gas concentration and estimate the progeny concentration using an assumed equilibrium factor and calculate the inhalation dose. But after the indigenous development of Direct Radon and Thoron progeny sensors (DRPS and DTPS) in RP&AD, BARC, progeny are directly measured for inhalation dose assessment. DRPS and DTPS are absorber mounted SSNTDs (LR115) [1-4] where detection takes place by selective registration of alpha-particle energies emitted from the deposited progeny activity. They can be used in different modes (Fig.4) to extract various progeny parameters. These were calibrated in 8m^3 Radon calibration chamber (Fig.5) installed in RP&AD, BARC (temperature range 20-60°C and humidity range 40-95%) and in real indoor environments.

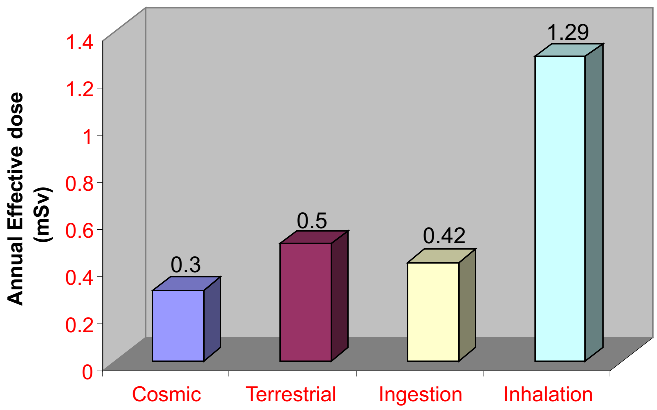

Fig.1: Annual effective dose due to natural sources of radiation.

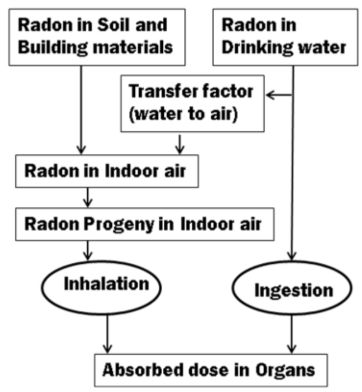

Fig.2(a): Primary Exposure Pathways of Radon towards dose contribution.

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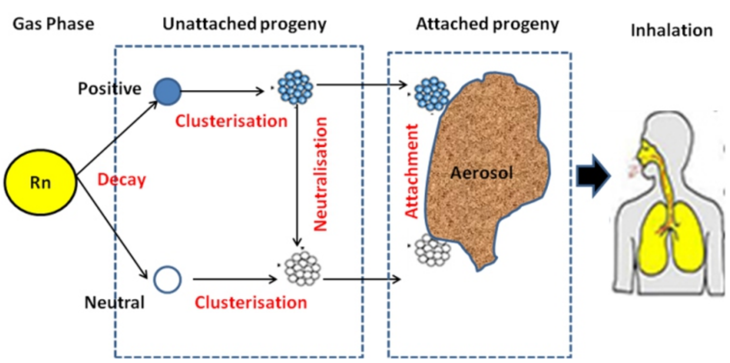

Fig.2(b): Indoor Radioactivity.

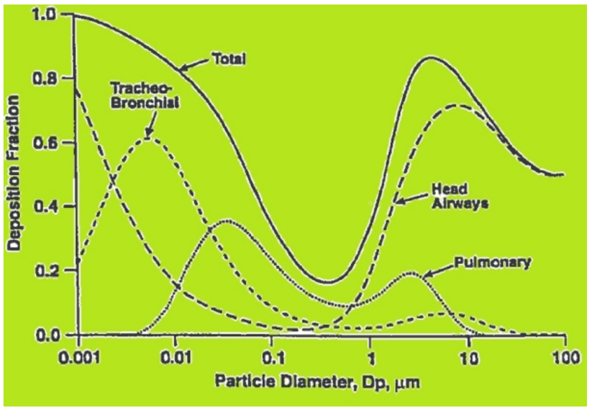

Fig.3: Fractional deposition of inhaled progeny in human respiratory tract.

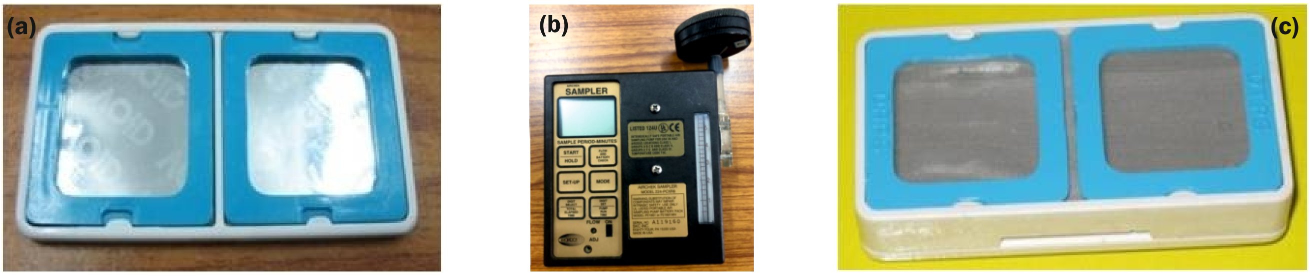

Fig.4: Direct Progeny Sensor a) Bare-mode, b) flow-mode, c) capped-mode.

Fig.5: Outside and inside view of the calibration chamber.

Fig.6: DTPS and DRPS in inside of different types of houses.

National Programs using DRPS and DTPS

DRPS and DTPS were used in National surveys for inhalation dose assessment in indoor environments. Under the scheme of BRNS (Board of Research in Nuclear Sciences: Nationwide project), ~ 4500 houses in 58 districts of 15 states in India were surveyed for direct measurement of progeny concentrations using DRPS and DTPS, over a period of 2-3 years. The program comprised of: a) the study of seasonal variation of progeny activity concentration b) Dependence on indoor conditions like building materials and ventilation rates (Fig.6). Higher radon progeny concentration (EECR) and thoron progeny concentration (EECT) was observed in winter season in the houses of Shivalik hills of Jammu and Kashmir (Fig.7) [5]. Similar trend of higher progeny concentration and inhalation doses were observed for all the dwellings. Fig.8 shows the maximum progeny concentration obtained in the mud-floor houses in Garhwal region [6]. In other parts of India also, we higher progeny concentration were obtained in mud houses. Fig.9 shows the higher progeny concentrations in the poorly ventilated houses of Tehri-Garhwal [7]. In addition, the ventilation rate dependence was more prominent in winter. Ventilation rate and air turbulence in the indoor environments play an important role in controlling the inhalation dose. Effect of good ventilation conditions are observed in the High background radiation areas of Kerala and Odisha, wherein good ventilation conditions contributed to inhalation doses similar to that measured in normal background radiation areas even though the gamma dose rates are ten times higher in HBRAs. Higher progeny concentrations were generally measured in Garhwal Himalayan region of Uttarakhand, which calls for more detailed study in the region. All the relevant data in the projects were compiled for "UNSCEAR global survey for Public exposure 2007-2020".

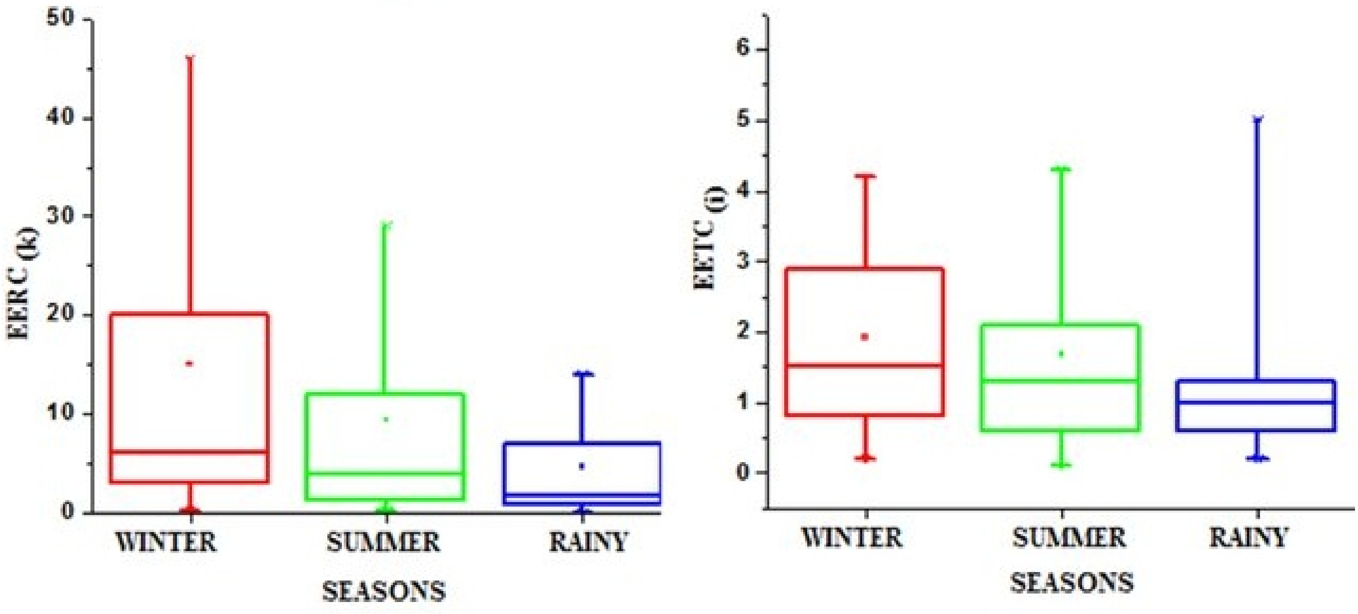

Fig.7: Progeny concentration in different seasons in indoors of Shivalik hills (Jammu Kashmir) [5].

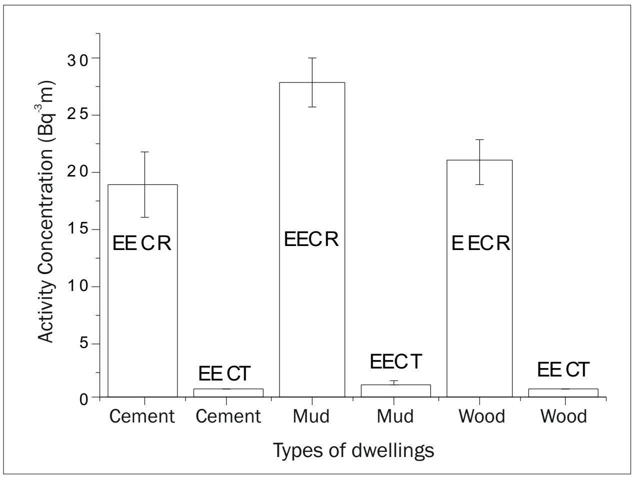

Fig.8: Progeny concentration in different types of houses in Garhwal region [6].

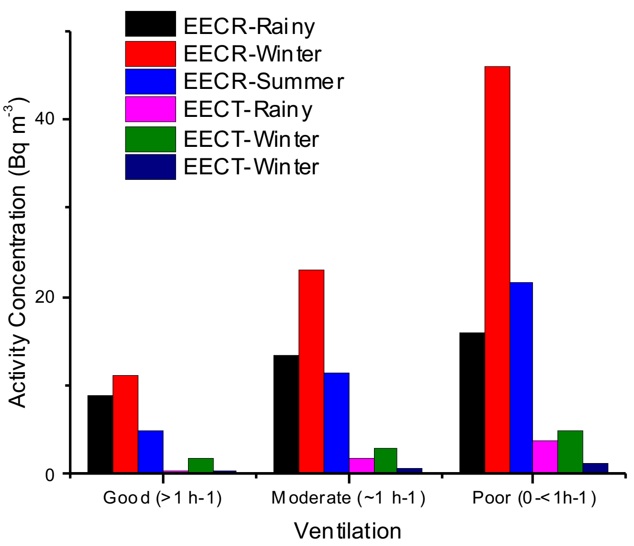

Fig.9: Progeny concentration as a function of ventilation conditions indoors in different seasons in Tehri-Garhwal region [7].

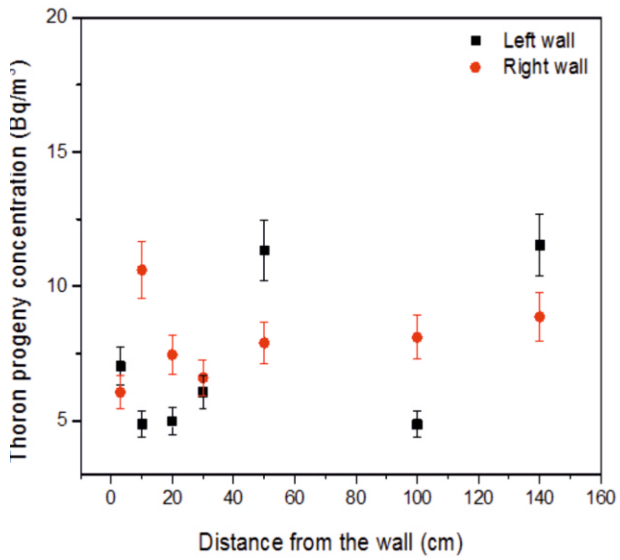

Fig.10(a): Results in HMGU Thoron experimental house by DTPS

International Collaborations

DRPS and DTPS were the first complete system in the world, developed for direct measurement of progeny concentration, which generated a lot of interest in the scientific community. This resulted in research collaborations with institutions from ~10 countries in which DRPS and DTPS were deployed in schools, dwellings, underground laboratories and caves. Under Indo-German collaboration project with Helmholtz Zentrum, Munich, the thoron progeny distribution was studied using DTPS (Fig.10(a)) in their Thoron experimental test-house (Fig.10(b)) [8]. In 25 primary schools of Banja Luka (Republic of Srpska), DTPS and DRPS were used to measure progeny concentration along with RADUET for radon gas measurements (Fig.11(a,b)) and hence long term equilibrium factor was measured [9]. Fig.12 shows the Radon concentration distribution using DRPS along with NRPB (UK), NRPB-SSI detector and Raduet system in ~100 dwellings in Hungary [10]. 'RaThoGamma' kit (Fig.13) comprising of TLDs, Radtrak-Radosys (Hungary), RSKS-Radonova (Sweden) and DRPS/DTPS (India), was used for a case-control study in

Fig.10(b): Thoron Experimental House in Helmholtz Zentrum, Munich [8].

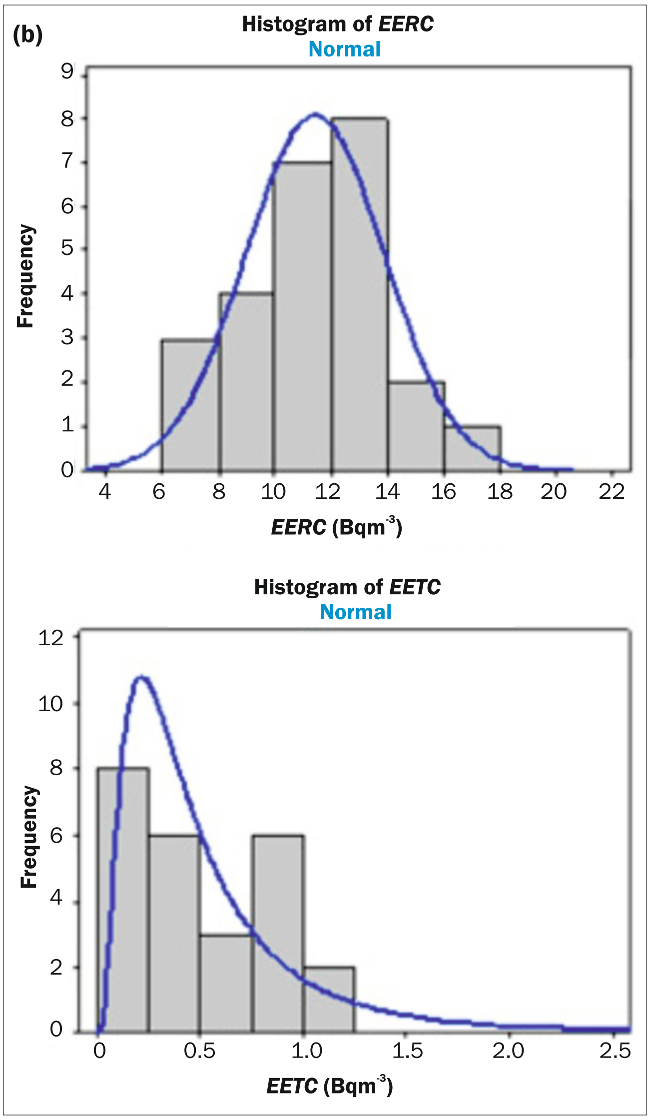

Fig.11: (a) DRPS and DTPS set deployed in schools, b) Histograms of EERC and EETC in 25 primary schools of Republic of Srpska [9].

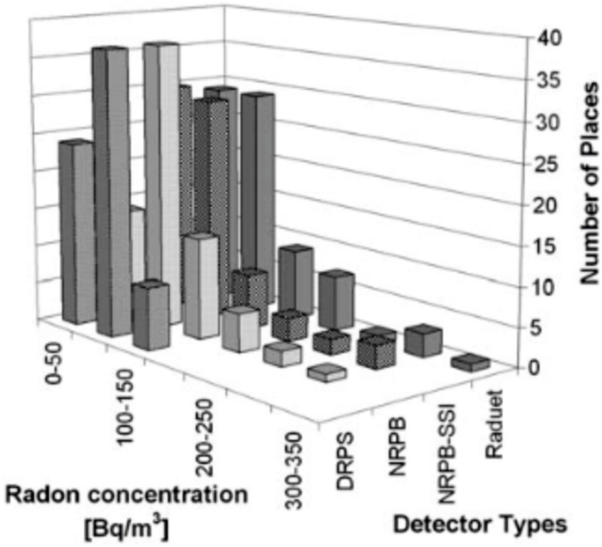

Fig.12: Radon concentration distribution using DRPS (India), NRPB (UK, NRPB-SSI and Raduet detectors. [10].

Fig.13: DRPS/DTPS in RaThoGamma kit of environmental radioactivity measurement in Romania [11].

Uranium mine area of Bihor county, Romania, in which annual effective doses were measured to be 3 times higher in the case-sample compared to control-sample and ~4 times higher than the world average [11].

Conclusion

The development of DTPS and DRPS has led to an improvement in inhalation dose assessment by directly measuring the progeny concentration. Multiple programs using DRPS and DTPS both in national level and through International collaborations has resulted in country-wide mapping, large number of publications and Ph.D programs.

Acknowledgements

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