Journal of Environmental Radioactivity 167 (2017) 110–116

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

Seasonal variability of equilibrium factor and unattached fractions of radon and thoron in different regions of Punjab, India

Komal Saini [a, *], Parminder Singh [a], Prabhjot Singh [a], B.S. Bajwa [a], B.K. Sahoo [b]

[a] Department of Physics, Guru Nanak Dev University, Amritsar, 143005, India
[b] Radiological Physics and Advisory Division, Bhabha Atomic Research Centre, Mumbai, 400085, India

ARTICLE INFO

Article history:
Received 18 July 2016
Received in revised form
21 October 2016
Accepted 24 November 2016
Available online 30 November 2016

Keywords:
DTPS/DRPS
Equilibrium factor
Pin hole based twin cup dosimeter
Radon
Thoron
Unattached fraction

ABSTRACT

A survey was conducted to estimate equilibrium factor and unattached fractions of radon and thoron in different regions of Punjab state, India. Pin hole based twin cup dosimeters and direct progeny sensor techniques have been utilized for estimation of concentration level of radon, thoron and their progenies. Equilibrium factor calculated from radon, thoron and their progenies concentration has been found to vary from 0.15 to 0.80 and 0.008 to 0.101 with an average value of 0.44 and 0.036 for radon and thoron respectively. Equilibrium factor for radon has found to be highest in winter season and lowest in summer season whereas for thoron highest value is observed in winter and rainy season and lowest in summer. Unattached fractions of radon and thoron have been found to vary from 0.022 to 0.205 and 0.013 to 0.212 with an average value of 0.099 and 0.071 respectively. Unattached fractions have found to be highest in winter season and lowest in rainy and summer season.

1. Introduction

In context of radiological protection, radon, thoron and their progenies which are pervasive in our environment and imperceptible to our senses, has become an important issue. World average dose due to natural radiation is 2.4 mSv, out of which around 52 percent is contributed by only radon, thoron & their progenies (UNSCEAR, 1993). Chronic exposure to radon is considered as second leading cause of lung cancer behind smoking (WHO, 2009). Correlation between lung cancer & inhalation of radon & its progenies has been well demonstrated (Lubin and Boice, 1997; Pershagen et al., 1994). Concluded studies in North America and Europe have suggested an augmented risk of lung cancer by 0–28% and 3–16% per 100 Bqm^{-3} of Rn^{222} concentration (Darby et al., 2005; Krewski et al., 2005). Moreover, dose imposed by thoron and its progenies has been found to be comparable to that of radon and its progenies in many studies (Khokhar et al., 2008; Steinhäusler, 1996; Porstendorfer, 1994). Due to potential hazards attributed to inhalation of radioactive contaminated air, attention towards the study of assessment of indoor radon, thoron as well as their progenies has been increased tremendously.

Further, progenies are predominantly contributors to the inhalation dose imposed by radon and thoron (Mishra et al., 2014b; Stajic and Nikezic, 2015). Therefore it is very important to estimate equilibrium factor between precursor radon/thoron and their progenies for assessing imposed dose. UNSCEAR (2008) proposed equilibrium factor value for radon is 0.4 but its actual value varies due to its sensitivity to indoor conditions like ventilation rate, particle concentration, temperature, humidity and surface/volume ratio etc. (Mishra et al., 2014a; Iimoto, 2000). Value for thoron is 0.02 (UNSCEAR, 2008), in-fact there is large variability in equilibrium factor of thoron due to its short half life and thoron concentration in any room is independent of air exchange rate (Nuccetelli and Bochicchio, 1998). In the present work, equilibrium factor has been calculated by long term measurement of radon/thoron gas and their progenies concentration and its variation with season has also been analyzed.

Some of the electrically charged progenies of radon and thoron get adhere to water molecules, dust particles or airborne particles. These attached progenies have size range between 100 and 400 nm, whereas median diameter of unattached progenies is below 4 nm (Butterweck et al., 2002) On inhalation, these unattached progenies get logged within respiratory tract due to its high diffusion and their alpha activity causes continue constant damage (Canoba and Lopez, 2000). Thus estimation of unattached fractions of radon and

* Corresponding author.
E-mail address: skomal2304@gmail.com (K. Saini).

http://dx.doi.org/10.1016/j.jenvrad.2016.11.022
0265-931X/

thoron is important in dosimetric point of view.

Radon and thoron are significant poisons that are deteriorating our residential environment where it gathers to harmful levels as compared to outdoor environment. As individual spends maximum time in the indoor environment so it becomes more vital to estimate its level in the dwellings (Jacobs et al., 2007; Brasche and Bischof, 2005). In present work, equilibrium factor and unattached fractions of radon and thoron has been estimated in dwellings of different regions of Punjab state for various seasons. In most of the earlier studies, bare mode technique or twin cup dosimeter with double entry face has been utilized for radon and thoron estimation in Punjab region, which is not so reliable (Sahoo et al., 2013). However in the present work, individual estimation of the concentration of radon, thoron and their attached as well as unattached progenies has been carried out for calculation of equilibrium factor and unattached fractions.

2. Methodology

2.1. Study area and deployment strategy

Present study has been carried out in 230 dwellings from 62 villages of different regions south west (SW), west (W) and north east (NE) of Punjab state, India as shown in Fig. 1. Equilibrium factor and unattached fractions of radon/thoron has been estimated from radon/thoron gas and its progenies concentration. One pin hole based dosimeter; one bare mode progeny sensor and one wire mesh capped progeny sensor were installed in each dwelling for a period of one complete year. After every four months, dosimeters and sensors were retrieved and replaced with new ones in order to observe seasonal variation in levels of radon, thoron and their progenies. According to temperature and season pattern in study region, detectors were deployed as per following duration.

1. March to July (Summer)
2. July to November (rainy),
3. November to March (winter)

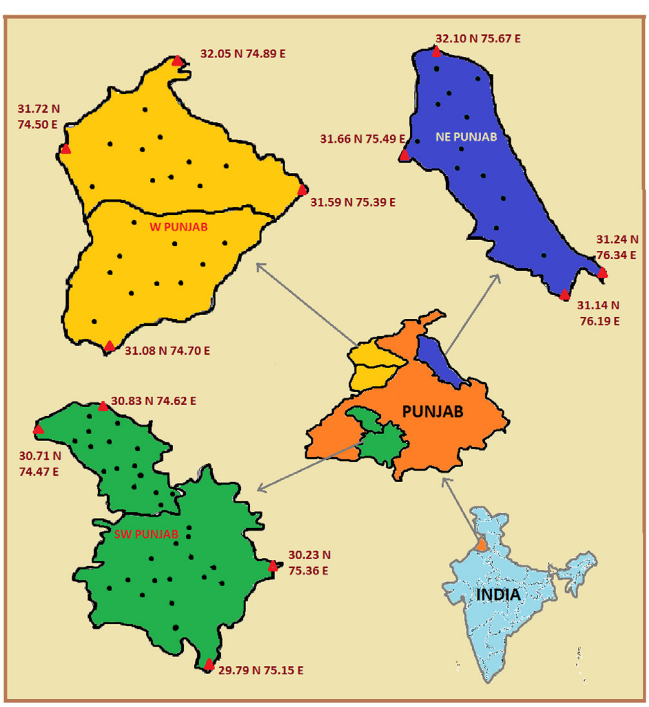

Fig. 1. Map of studied region.

On the average, four dwellings were covered in each village and dwellings in the present studied region are mainly of brick walls with cemented plaster, cemented flooring and roofs. Dosimeters and progeny sensors were deployed in bedrooms of these traditional dwellings and on the average these rooms were having one door and one window. Most of the dwellings were single storied and had no basements in their houses. So detectors were deployed at ground storey. Dosimeters were hanged vertically to ceiling using chain lock system with gas entry face downward at a distance ranging from 30 cm to 50 cm from any of the surface like wall and ceiling. The sensors were clipped to this chain with its face in outward direction.

2.2. Equilibrium factor from radon/thoron gas concentration and equilibrium equivalent radon/thoron concentration

The equilibrium factor (EF) is an important dose relevant parameter, which is generally used in epidemiological studies for dose conversion coefficient. It is ratio between activity of short lived radon/thoron progenies and activity of parent radon/thoron given by relation (1)

$$EF_{Rn222/220} = \frac{EEC_{Rn222(A+U)/Rn220(A+U)}}{C_{Rn222/Rn220}} \quad (1)$$

where $EEC_{Rn222(A+U)/Rn220(A+U)}$ is concentration of attached + unattached progenies of radon/thoron in terms of equilibrium equivalent concentration and $C_{Rn222/Rn220}$ is radon/thoron gas concentration measured by bare mode direct progeny sensors (DRPS/DTPS) and twin cup dosimeters respectively.

2.2.1. Equilibrium equivalent radon/thoron concentration using bare mode progeny sensors

For direct estimation of concentration of radon/thoron progenies in terms of equilibrium equivalent concentration (EEC), deposition based passive progeny sensor with LR-115 detector has been used, which allow selective penetration of alpha particles by mounting energy degrader (Mishra et al., 2010). The schematic diagram of bare mode direct radon/thoron progeny sensor (DRPS/DTPS) is shown in Fig. 2, which records attached + unattached progenies of radon and thoron. SSNTD LR-115 placed in DTPS shielded with 50 μm mylar records tracks for 8.78 MeV alpha particles emitted by thoron progeny ^{212}Po. Whereas in DRPS, LR-115 is shielded with 37 μm absorber (25 μm mylar + 12 μm cellulose

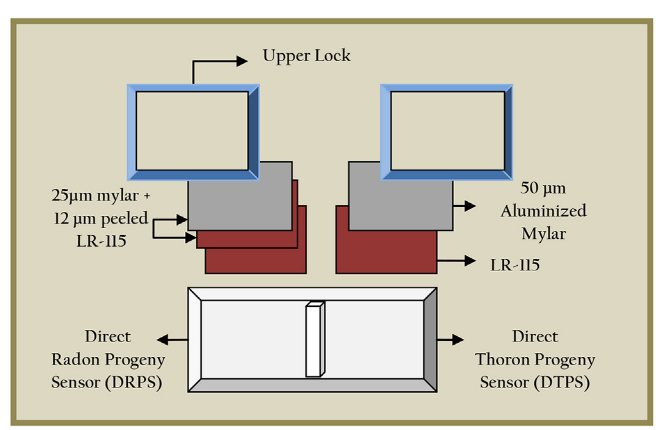

Fig. 2. Schematic diagram of bare mode direct progeny sensor.