JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.93, May 2019, pp.603-606

Assessment of Indoor Radon and Thoron in Dwellings of Nangal Area Using SSNTD

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ABSTRACT

Radon effect on human health need not be overemphasised. In the present study an attempt has been made to measure the concentration of indoor radon, thoron and annual effective dose received by residents of Nangal area of Roopnagar District of Punjab. Radium concentration and Radon exhalation in soil samples are also calculated. Indoor radon concentration varies from 93.1 Bqm^{-3} to 127.0 Bqm^{-3} with an average of 95.4 Bqm^{-3}. The value of thoron concentration varies from 5.4 Bqm^{-3} to 47.2 Bqm^{-3} with an average of 24.0 Bqm^{-3}. The observed annual effective dose varies from 2.3 mSv to 3.7 mSv which lies within safe limits recommended by ICRP (International Commission on Radiological Protection). Radon gas concentration in soil samples vary from 8.4 to 64.1 Bqm^{-3} with an average of 31.4 Bqm^{-3}. The mass exhalation rate in samples vary from 0.2 to 2.7 mBq kg^{-1} h^{-1} with an average of 1.1 mBq kg^{-1} h^{-1}, whereas, surface exhalation rate vary from 6.9 to 52.5 mBq m^{-2} h^{-1} with an average of 23.6 mBq m^{-2} h^{-1}. The radium concentration ranges from 0.5 to 3.5 Bq kg^{-1} with an average of 1.8 Bq kg^{-1}. The observed values of radium concentration in all soil samples are less than the recommended value 370 Bq kg^{-1} by OECD (Organization for Economic Corporation and Development).

INTRODUCTION

Natural radioactivity has become an important issue as it is pervasive and manifested throughout our environment. Uranium and thorium are naturally occurring radioactive elements whose isotopes ^{238}U and ^{232}Th present in soil in varying concentration, which on radioactive decay produces inert radioactive gaseous Radon (^{222}Rn) and Thoron (^{220}Rn). Radon is heaviest noble gas at room temperature (Hunse et al. 2010). As ^{222}Rn and ^{220}Rn are gaseous, so they easily escape from the ground and come out in air. When radon and thoron disintegrate it produces harmful decay products which attach with air or dust particles. However, radon ($t_{1/2}$ = 3.8 days) is more hazardous as compared to thoron ($t_{1/2}$ = 55.6 sec) because of its longer half life (Shika et al. 2018). Radon decay products ^{214}Po and ^{218}Po are most energetic alpha emitters (Beir, 1988). The emission of radiations from these elements is also harmful (Najeeb et al. 2014). These airborne radon decay products deposit in human respiratory system by inhalation and damage the sensitive tissues of respiratory system. Consequently, ^{222}Rn has been classified as first respiratory occupational carcinogen WHO (2009).

Thus, to investigate and to get information about the concentration of radon, thoron and progeny, present study has been done in the dwellings of Nangal area of Punjab. This study is significant as not much data on radon measurement is available for this area. Main focus of this study is to find indoor radon, thoron concentration, annual effective dose, radium concentration and radon exhalation rates in soil samples in the Nangal area of Roopnagar district of Punjab.

GEOLOGY OF STUDY AREA

Punjab, also known as land of rivers is situated in northwest India. Punjab covers 50,362 sq. km of geographical area which is on 19th rank. The state is situated between 29°30' to 32°32' north latitude and between 73°55' to 76°50' east longitude. Most of the land of Punjab is fertile. Roopnagar, one of the ancient towns, situated in eastern part is municipal council and fifth "divisional headquarters" of Punjab. The beautiful town Roopnagar is located on the bank of river Satluj. Geographically it lies between 76°19' and 76°45' north latitude and 30°44' and 31°25' east longitude having area 1440 sq km, Report on aquifer mapping and management plan (2017). The district is also famous for its historical value as a site belonging to Indus valley civilization.

Nangal is the town in Roopnagar district (Fig.1) which connects Chandigarh, Roopnagar and Kiratpur Sahib to Una and further Kangra. It is situated on the foot of Shivalik hills and is surrounded by w ater on three sides and foothills of Shivaliks on the fourth side (rupnagar.nic.in/html/Nangal.htm). Two types of soils are found in this area: reddish chestnut soils and tropical arid brown soils (weakly solonized). The soils are varying in texture generally from loam to silty clay loam (Borana, 2015).

EXPERIMENTAL PROCEDURE

Indoor Radon Survey

Solid state nuclear track detectors (LR-115) are widely used for the study of indoor radon concentration. These detectors are used as passive measurement technique due to their high durability and stability. The LR-115 (alpha sensitive detector) is basically a thin cellulose nitrate film mounted on a polycarbonate backing produced by DOSIRAD, France (Mayya et al., 1988). These films are fixed in

Fig.1. Map showing studied area Nangal (shaded) in Roopnagar District

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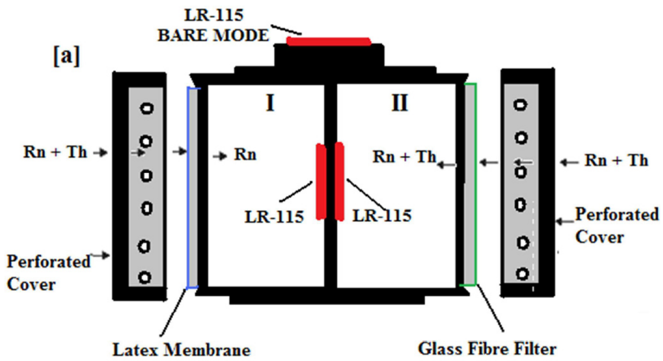

Fig.2. Twin Cup Dosimeter

different chambers of twin cup dosimeters, developed and calibrated at environmental assessment division, Bhabha atomic research center, Mumbai to measure the concentration of indoor radon and thoron (Mehta et al., 2014). The dosimeters consists of three separate modes namely bare mode, filter mode and membrane mode (Fig.2). There are large numbers of fine holes at the ends so that free entry of air inside the chamber is possible. SSNTDs are affixed in each of the mode. The bare mode gives the concentration of radon, thoron and progeny, filter mode gives the concentration of both radon and thoron and membrane mode gives the concentration of radon only. The dosimeters with detectors in each mode are installed inside the room to be monitored at a height of about 2 m from the ground floor, 1 m below from the ceiling of room and 2 m from wall surface (Mehta et al., 2014).

These detectors are then retrieved after an exposure of three months. The exposed detectors are then etched by chemical etching in 2.5 N NaOH solutions at temperature 60 °C for 90 minutes. After etching, the detectors are washed, dried and the tracks produced by the alpha particles are registered/counted with spark counter. The recorded track density is then converted in the Bqm^{-3} by using an appropriate calibration factor (Mehta et al., 2014).

Here, calibration factors are used for converting the observed track density rates of radon and thoron concentration to the activity concentration of the required quantities.

If ρ is the track density of alpha particles observed on a SSNTD due to exposure in a given mode, C is the concentration of a given species for a time t, then

$$\rho = K \times C \times t \tag{1}$$

Where, K is calibration factor.

The concentration of radon and thoron if found using the relation (Mehta et al., 2014).

$$C_R = \frac{\rho_M}{tK_{RM}} \tag{2}$$

$$C_T = \frac{\rho_F - K_{RF} C_R\, t}{tK_{TF}} \tag{3}$$

Where, ρ_M = track density in membrane compartment; ρ_F = track density in filter compartment; t = total exposure time; K_{RM} = calibration factor for radon in membrane mode = 0.021 tr cm^{-2} d^{-1}/ Bqm^{-3}. K_{RF} = calibration factor for radon in filter mode = 0.023 tr cm^{-2} d^{-1}/ Bqm^{-3} . K_{TF} = calibration factor for thoron in filter mode = 0.019 tr cm^{-2} d^{-1}/ Bqm^{-3}

Also, following relations are used to determine the concentration of progeny levels of radon C_R (WL) and that of thoron C_T (WL)

$$\text{Progeny levels of radon (WL)} = C_R\,(Bqm^{-3}) \times F_R/3700 \tag{4}$$

$$\text{Progeny levels of thoron (WL)} = C_T(Bqm^{-3}) \times F_T/3700 \tag{5}$$

Where F_R = equilibrium factor for Radon having value of 0.4; F_T = equilibrium factor for Thoron having value of 0.1 (Prasad et al., 2016)

Dose received due to ^{222}Rn and its progeny, and ^{220}Rn and its progeny, has been estimated using the following relation (Mehta et al., 2014).

$$D = \{(0.17+9F_R)C_R + (0.11+32F_R)\, C_T\} \times 7000 \times 10^{-6} \tag{6}$$

Soil Survey

The measurement of radon gas concentration in soil is completed using "canister technique" (Mehta et al., 2016). In this technique, soil samples from different locations of Nangal are collected and then dried in oven in order to remove moisture. A known amount of sample are then finely powdered and placed in different cylindrical canisters or cans. SSNTDs films of size 2º×2º are fixed on the base of the top of each can in such a way that sensitive side of detector always faces the sample. The can is then tightly closed, sealed from the top and left for the exposure of approximately three months. After exposure time, the films are removed from base and subjected to chemical etching as discussed in indoor radon survey. In order to obtain track density the detectors are thoroughly washed, dried and then registered for alpha counting using spark counter. From track density (track/cm^2), radon concentration is then obtained using appropriate calibration factors in Bqm^{-3}. The radon surface exhalation and mass exhalation rates are also calculated using formulae (Mehta et al., 2015).

$$E_A = \frac{CV\lambda}{A(T + (1/\lambda)(e^{-\lambda T} - 1)} \tag{7}$$

$$E_M = \frac{CV\lambda}{M(T + (1/\lambda)(e^{-\lambda T} - 1)} \tag{8}$$

Where C is the equilibrium radon activity, V is volume of canister, A is area of cross section of canister, M is mass of sample, l is radon decay constant and T is time of exposure

Radium Concentration

In "canister technique" the radium concentration is found by using the relation (Azam et al. 1993):

$$C_{Ra} = \frac{\rho hA}{KTeM} \tag{9}$$

Where, C_{Ra} is the radium content of the given sample, ñ is alpha particles track density, h is the distance between the detector and the top of the sample (0.06 m), A is the area of cross-section of the canister (0.0241m^2), M is the mass of the sample (0.20 kg), K is the sensitivity factor, which is equal to 0.0245 $tr.cm^{-2}.d^{-1}/Bqm^{-3}$ and Te is the effective exposure time (in hour) which is related to the actual exposure time T and decay constant λ for ^{222}Rn according to the following equation (Azam et al. 1993):

$$T_e = T - \frac{1}{\lambda(e^{-\lambda T} - 1)} \tag{10}$$

RESULTS AND DISCUSSION

The concentration of indoor radon and thoron in dwellings is measured by using twin cup dosimeters and concentration of radon in soil samples is measured by canister technique. The results are given in Table 1 and Table 2 along with latitude and longitude of the location.

It is clear from Table 1 that Indoor radon concentration varies from 93.1 Bqm^{-3} to 127.0 Bqm^{-3} with an average of 95.4 Bqm^{-3}. The value of thoron concentration varies from 5.4 Bqm^{-3} to 47.2 Bqm^{-3} with an average of 24.0 Bqm^{-3}. The observed annual effective dose varies from 2.3 mSv to 3.7 mSv which lies within safe limits recommended by ICRP (ICRP, 1993).

Table 2 shows the radon concentration, radon exhalation rates and radium concentration in soil samples of studied area. Radon gas concentration in soil samples vary from 8.4 to 64.1 Bqm^{-3} with an average of 31.4 Bqm^{-3}. The mass exhalation rate (E_M) in samples vary from 0.2 to 2.7 mBq kg^{-1} h^{-1} with an average of 1.1 mBq kg^{-1} h^{-1},

Table 1. Radon and Thoron concentration from different locations in Nangal area

S. No.	Latitude Longitude	Radon Concen-tration (Bqm^{-3})	Thoron Concen-tration (Bqm^{-3})	Radon Progeny (mWL)	Thoron Progeny (mWL)	Annual Effective Dose (mSv)
1	31°17′N 76°48′E	93.1	37.0	10.1	1.0	3.3
2	31°35′N 76°38′E	84.7	47.2	9.1	2.6	3.3
3	31°38′N 76°37′E	127.0	5.4	13.7	0.1	3.5
4	31°39′N 76°38′E	84.7	28.5	9.1	0.7	2.9
5	31°38′N 76°37′E	76.2	10.7	8.2	0.3	2.3
6	31°38′N 76° 34′E	93.1	18.3	10.1	0.5	2.9
7	31°39′N 76°35′E	84.7	28.5	9.1	0.8	2.9
8	31°16′N 76°35′E	93.1	8.9	10.1	0.2	2.7
9	31°16′N 76°48′E	101.6	26.7	11.0	0.7	3.3
10	31°16′N 76°49′E	101.6	45.4	11.0	1.2	3.7
11	31°17′N 76°47′E	110.1	7.1	11.9	0.2	3.1
	AM±SE	95.4±4.3	24.0±4.6	10.3±0.5	0.8±0.2	3.1±0.1

AM(Arithmetic Mean); SE(Standard Error)

Table 2. Radon concentration, radon exhalation rates (E_M & E_A) and radium concentration in soil samples of Nangal area

S. No.	Latitude & Longitude	Radon concentration (Bqm^{-3})	Radon exhalation rates(mBqkg^{-1}h^{-1}) E_M	E_A	Radium concentration in soil (Bq kg^{-1})
1	31°17'N 76°48'E	8.4	0.2	6.9	0.5
2	31°35'N 76°38'E	22.1	0.7	19.6	1.2
3	31°39'N 76°38'E	55.6	2.4	43.2	3.1
4	31°38'N 76°37'E	16.1	0.6	12.8	0.9
5	31°38'N 76°34'E	64.1	2.7	52.5	3.5
6	31°16'N 76°35'E	39.3	1.1	21.3	2.2
7	31°16'N 76°48'E	15.9	0.5	11.9	0.9
8	31°16'N 76°49'E	29.3	0.9	20.7	1.6
	AM±SE	31.4±7.1	1.1±0.3	23.6±5.6	1.8±0.4

AM(Arithmetic Mean); SE(Standard Error)

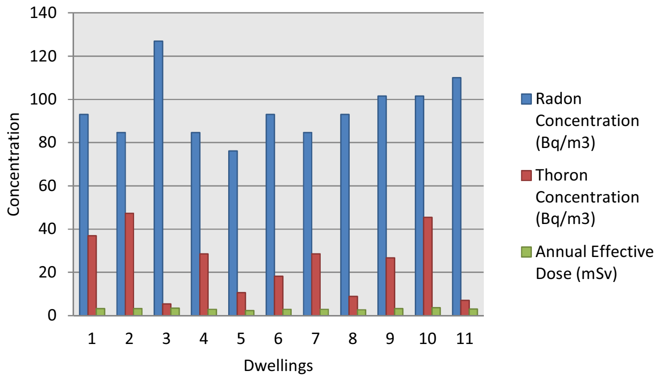

Fig.3. Number of dwellings vs. concentration of radon, thoron and annual effective dose rates in study area

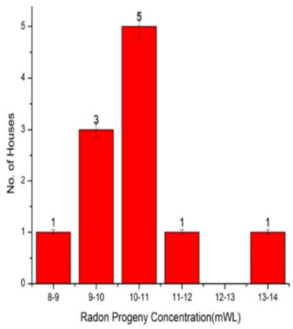

Fig.4. Radon Progeny Concentration vs number of dwellings

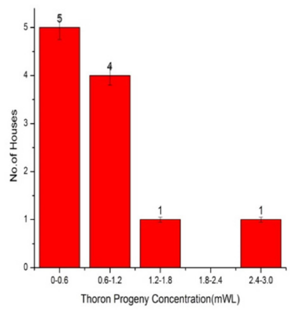

Fig.5. Thoron Progeny Concentration vs number of dwellings

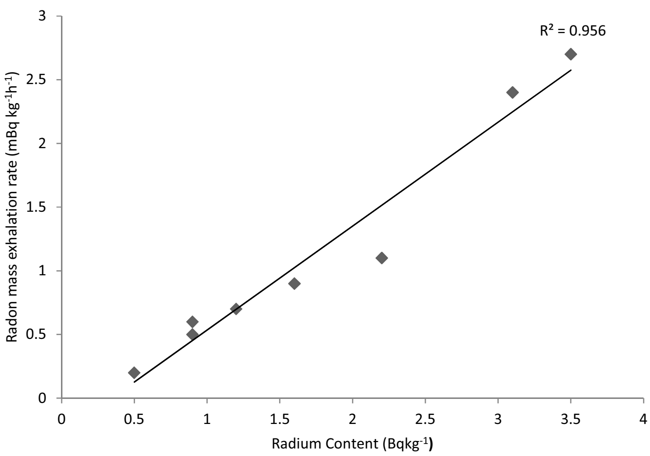

Fig.6. Radium content vs. Radon Mass Exhalation Rate

whereas, surface exhalation rate (E_A) vary from 6.9 to 52.5 mBq m^{-2} h^{-1} with an average of 23.6 mBq m^{-2} h^{-1}. The radium concentration ranges from 0.5 to 3.5 Bq kg^{-1} with an average of 1.8 Bq kg^{-1}.

Figure 3 shows Number of dwellings vs. concentration of radon, thoron and annual effective dose rates in study area.

Figure 4 and 5 shows the frequency distribution of radon progeny concentration and thoron progeny concentration with respective number of houses.

In order to study correlation between radium concentration and radon mass exhalation rate graphs have been plotted. Figure 6 shows correlation between radium concentration and radon mass exhalation rate.

CONCLUSION

From the values reported by above results, it is clear that the concentration of indoor radon, thoron and hence observed dose rates are well below the permissible limits provided by international commission on radiological protection (Azam et al. 1993). The concentration of radium content, radon surface and mass exhalation are also well within the limits. Thus the hazardous effects of radon gas are considered to be on the lower side in this part of the study area.

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(Received: 22 May 2018; Revised form accepted: 24 August 2018)