ABSTRACT

Natural radioactivity is present in earth's crust from the beginning of life on the earth. Thus, all inhabitants on the earth are exposed to radiations. Out of these, ionizing radiations are harmful to the humans as these have sufficient energy and irradiate the living cells and cause cellular damage that includes DNA breakage, gene mutation, chromosomal change and genetic instability and may develop tumour. Human population receives ionizing radiations from radioactive radon, thoron and their progeny, cosmic radiations, terrestrial radiations, consumer products, nuclear medicine and medical CT scan, X-rays. However, more than half of total ionizing radiation exposure to general public is due to radon, thoron and their short-lived progeny. It has been estimated that out of 2.2 mSv of dose which an individual receives annually from low-level exposure, 1.27 mSv is due to radon isotopes and their short-lived progeny.

There are shreds of evidence of adverse effects due to radon even before its discovery. In the sixteenth century a large number of workers' deaths in mines of Eastern Europe attracted the attention towards the existence of some gases. In the nineteenth century ten years study was conducted to observe the deaths of uranium mine workers' and about 75% of lung cancer deaths were recorded in Greenberg, Germany (1879). Epidemiological studies by Henshaw et al., (1990) revealed that indoor radon exposure has associated risk of leukaemia and certain other cancers such as melanoma, kidneys, prostate cancer and lung cancer. World Health Organisation has identified radon as a human carcinogen linked to lung cancer. If the concentration of radon and physicochemical parameters in drinking water are higher than permissible limit, then it leads to water borne diseases such as fluorosis, typhoid, jaundice, cholera etc. and also leads to a significant risk of stomach and gastrointestinal cancer.

Considering the importance of these radiations, investigations have been carried out to determine the associated radiological hazards. In India Atomic Energy Regulatory Board (AERB) is looking into the regulation of radiation protection in the country. Bhabha Atomic Research Centre (BARC), Mumbai, India has undertaken various research projects to monitor radon, thoron and their decay products in the environment. Many researchers have contributed towards the studies related to radiation levels in different parts of India for radon mapping and to find high background radiations area. Although good amount of data related to these studies is available for other parts of the country but the data is still scarcely available for the

studied area of Rajasthan. Hence to get the accurate authenticated data with indigenously developed instruments, the present investigations have been conducted under a research project sanctioned by BARC, Mumbai, India.

The present study has been carried out to meet out the major objectives related to the measurements of radon/thoron and their progeny concentration in the dwellings accounting for the seasonal variations under different ventilation conditions, estimation of average annual effective dose, measurement of radon/thoron exhalation rates in the soil samples and activity concentration of radon in water have been carried out for health risk assessment in the Hanumangarh, Sri Ganganagar and Churu districts of Northern Rajasthan. It would also help to identify areas with the higher than the recommended values and provide data for the national pool for further studies.

In the present study, indigenously developed instruments by BARC, Mumbai, India have been used to accomplish the objectives of research work. The Single entry pinhole dosimeters based on radon/thoron discriminating technique has been used for measurements of indoor radon/thoron gas concentration. The deposition based radon/thoron progeny sensors (DRPS/DTPS) and Wiremesh DRPS/DTPS have been used for the measurement of radon/thoron progeny concentration and their attached and unattached fraction, respectively. These progeny sensors work on the principle that the LR-115 detector detects the alpha particles emitted from the deposited progeny atoms. Smart RnDuo has been used for measuring radon in water, radon mass/thoron surface exhalation rates in soil. It is based on the principle of detection of alpha particles which strike the detector and produces scintillations with ZnS:Ag coating inside the cell.

The study has been carried out year wise in each of the three districts for indoor air, soil and water. For the measurement of indoor radon/thoron, their progeny and attached/unattached fractions, the dosimeters were deployed for one-year with the exposure period of 4 month each to study the seasonal variation. The location for dwellings has been selected on the basis of preliminary gamma survey and ventilation conditions. The deployed dosimeters were retrieved after period of four months, thereafter the chemical etching and counting of tracks was done. For the measurement of radon concentration in water, on the spot measurement has been done using Smart RnDuo. For the measurement of exhalation rates in soil, samples has been collected from the studied area as per the protocol given by BARC, Mumbai, India and then were analysed in Radiation Physics Lab, Department of Physics, MRSPTU Bathinda, Punjab, India.

The measured annual average indoor radon concentration has come out to be 26.9, 9.8, 19.5 Bqm^{-3}, thoron concentration 39.9, 19, 19.9 Bqm^{-3}, radon progeny concentration 8.6, 5.5, 5.4 Bqm^{-3}, thoron progeny 2.7, 0.5, 0.6 Bqm^{-3}, attached fraction of radon 5.93, 3.68, 3.43 Bqm^{-3}, attached fraction of thoron 0.43, 0.30, 0.40 Bqm^{-3}, annual effective dose for inhalation 3.41, 1.88, 1.70 μSvy^{-1} in the Hanumangarh, Sri Ganganagar and Churu districts respectively. The calculated annual average equilibrium factor between radon and its progeny is 0.4 and for thoron and its progeny is 0.02, which are comparable to the values as recommended by UNSCEAR (2008). In the studied area, out of 275 dwellings, 12 dwellings (4.36%) having higher indoor annual average radon concentration (40.22 to 99.86 Bqm^{-3}) than the recommended value of 40 Bqm^{-3}. 99% of dwellings having higher indoor annual average thoron concentration (10.65 to 100 Bqm^{-3}) than the world average value of 10 Bqm^{-3}. The concentration of thoron gas is higher in most of dwellings, this presumably may be due to use of thorium rich materials in construction of dwellings of this area. 4.36 % dwellings having higher indoor annual average radon progeny concentration (15.42 to 21.4 Bqm^{-3}) than the world average recommended value the worldwide average value of 15 Bqm^{-3}, while 201 dwellings (73%) having higher indoor annual average thoron progeny concentration (0.5 to 8.7 Bqm^{-3}) than the world's average value of 0.5 Bqm^{-3}. The measured average values for indoor radon, thoron and their progeny concentration in the studied area is higher in winter season as compared to rainy and summer season which may be because of the poor ventilation conditions in winter due to less exchange of gases between indoor and outdoor environments, thereby leading to accumulation of radon gas during winters. The poor ventilation dwellings have higher concentration than the average and well ventilated dwellings. The annual average effective dose for inhalation lies below than recommended value of 14 μSvy^{-1} for the residential places. The concentration of indoor radon/thoron in some areas like Pillibanga, Jandawali, Sangria, Bhagatpura, Dhaba, Kharliya, Bhadra, Rawatsar, and Panniwala of Hanumangarh District and Ratangarh of Churu District of Rajasthan with higher values may be explored further for radiological health effects to the residents of the area.

The measured average radon concentration in the water samples has come out to be 2.07, 0.92 and 1.79 BqL^{-1} in Hanumangarh, Sri Ganganagar and Churu districts respectively, which are lower than the recommended value of 11 BqL^{-1} by USEPA (1991), 100 BqL^{-1} by WHO (2004) and 4-40 BqL^{-1} by UNSCEAR (2008). The annual effective dose for various age groups like infants, children and adults lies below the safe 100 μSvy^{-1} recommended by WHO (2008). For a given concentration of radon in drinking water, the dose was highest in case of infants and followed a decreasing trend with age. The concentration of radon in underground water have higher value than concentration in surface water which may be because of presence of granite, sands, gravel in the bedrock and also for the reason that underground water directly encounters U-238 rich rocks that releases radon in water and cannot escape to atmosphere, whereas in contrast radon in surface water samples can easily escape to atmosphere due to aeration and agitation in water. Hence the water in the studied area is safe for drinking purposes from the radiological risk point of view.

Radon mass and thoron surface exhalation rates have been studied in the soil samples. For radon mass exhalation rates has been done using diffusion mode as the whole mass of the soil sample contributes towards the radon emanation and for thoron, surface exhalation has been studied in flow mode as only thin layer below the surface emanates thoron. The measured radon mass exhalation rates in soil samples comes out to be 33.67, 26.23, 22.13 mBqkg^{-1}h^{-1} and thoron surface exhalation rates 6.07, 4.54, 3.53 kBqm^{-2}h^{-1} in Hanumanagarh, Sri Ganganagar and Churu districts respectively. Out of 70 samples, the radon mass exhalation rate in 1 sample (1.4%) has higher value (62.03 mBqkg^{-1}h^{-1}) than world average value of 57 mBqkg^{-1}h^{-1}, and the thoron exhalation rates in 51 soil samples (72.8%) have higher values (3.67 to 8.57 kBqm^{-2}h^{-1}) than recommended value of 3.60 kBqm^{-2}h^{-1} all the three districts. The variation in the exhalation rates may be because of varied geological locations of soil samples, topography, radon emanation factor and soil porosity. The higher thoron surface exhalation rates may be because of higher thorium rich contents in rocks in the Northern portion of India. The positive weak correlation has been observed between radon/thoron exhalation rates with indoor radon/thoron in three districts of Northern Rajasthan, respectively which may be due to the reason that the soil may be less contributing to the concentration of radon in air and most of the time building materials may be the more responsible for the concentration of radon in air.

The overall conclusion of this study is that in the studied area, most of the values have been found to be within the permissible recommended levels and hence may not pose any radiological health risk to the local population. The available data will further contribute for the radon mapping of the country and for carrying out further studies in the areas, where values have been found to be on higher side for radiation related risk assessment.

Future studies can be carried out in the areas where thoron and radon levels are high for associated health effects to the residents of the area. A diurnal and seasonal measurement of radon activities in groundwater and soil gas through online monitoring devices is essential in predicting earthquakes. Although the study lies in the low risk zone area that is Zone-4, but still for the prediction of earthquakes, radon geo-station centre may be established in this area. Countries like China, India, Japan, Russia, Turkey and the United States are located on plate boundaries of the earth and several such projects are going on in these countries.