



## Exposure to low-level ionizing radiations in some dwellings and Industrial units of Haryana

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**Abstract:** Radon and its progeny in the atmosphere, soil, ground water, oil and gas deposits contribute the largest fraction of the natural radiation dose to populations. Enhanced interest exhibits in tracking its concentration is thus fundamental for radiation protection. The combustion of coal in various industrial units like thermal power plants, National fertilizer plants, paper mill etc. results in the release of some natural radioactivity to the atmosphere through formation of fly ash and bottom ash or slag. This consequently increases the radioactivity in soil, water and atmosphere around the thermal power plant. Keeping this in mind the measurement of radon, thoron and their progeny concentration in the environment of some industrial unit has been carried out using solid state nuclear track detectors (SSNTD). The specially designed twin cup dosimeter used here consists of two chamber of cylindrical geometry separated by a wall in the middle of each having a length of 4.5 cm and 3.1 cm. The annual effective dose received by the workers in some industrial units and dwellings have been calculated. The results indicate some higher levels in coal handling and fly ash area of plants.

**Keywords:** Radon; thoron; Decay products; SSNTD; Industrial unit; Annual effective dose

### I. Introduction

The measurement of radon and thoron in human's environment is of interest because of its alpha emitting nature. A certain fraction of the radon escapes into the air where, in the outdoors, it is quickly diluted and is of less concern. However, in confined spaces such as homes and office buildings, radon can accumulate to harmful levels. Radon is a naturally occurring odourless, colourless, tasteless inert gas which is imperceptible to our senses. The half life 3.824 days of radon makes it important to study as far as radiation dose is concerned. Radon is able to escape from the soil and building materials cement sand etc. and enter the atmosphere. Many environmental pollutants are classified as cancer-causing solely on the basis of laboratory studies using either animals or cell cultures. In the case of radon and thoron there is direct evidence from human studies of a link between exposure to radon and lung cancer. For this reason radon has been classified by the International Agency for Research on Cancer, World Health Organization [1] as a Group 1 carcinogen. This places radon in the same group of carcinogens as asbestos and tobacco smoke. General public living in dwellings are exposed to radon and its short-lived progeny, because uranium is widely distributed in the Earth's crust [2]. Hence, radon can become a health hazard to the general public living in such environment. Considerable data is generated on the levels of  $^{222}\text{Rn}$  in the environment [3,4]. In contrast, data on  $^{220}\text{Rn}$  is scarce due to the general perception that its level is negligible due to its shorter half life (55 sec), and its contribution to inhalation dose is ignored, in the presence of other more significant natural radiation. This may not be true from the recent studies resulted in the observation of high  $^{220}\text{Rn}$  in the living environments in various countries and it is now increasingly felt that it may be necessary to have information on  $^{220}\text{Rn}$  levels in the environment for obtaining a complete picture of inhalation dose [5]. This makes the necessity of measurement of indoor radioactive pollutants like radon, thoron and absorbed dose to lung including their impact on health.

Electrical energy is the most fundamental requirement and coal, a fossil fuel, is the most abundant resource for electricity generation. Thermal power generation is associated with the dispersal of radionuclides in the environment and the activities of radionuclides discharged in the atmosphere from a thermal power plant depend on a number of factors such as activity concentration in coal, ash content in coal, temperature of combustion and efficiency of the filtering systems etc. In the production of electric power, coal is burnt in furnaces operating at temperature up to 1700°C and by this process most of the mineral matter in the coal is fused into vitrified ash. A portion of ash and incompletely burnt organic matter drop to the bottom of the furnace as bottom ash or slag. The fly ash, however, is carried through the boiler along with the hot flue gases to the stack where some fractions are collected while the rest escape in to the atmosphere. The exposure of population to high

concentrations of radon and its daughters for a long period leads to pathological effects like the respiratory functional changes and the occurrence of lung cancer [6]. Similarly the raw products used in other industries also cause emission of radioactive gas. The goal of the present investigations is the radon, thoron monitoring of various industrial unit and estimate the annual effective dose received by the workers.

## II. Materials and Methods

For the measurement of concentration of radon, radon and thoron both, and total sum of radon, thoron and their progeny in the dwellings, the radon-thoron mixed field dosimeter popularly known as, 'Twin Chamber Radon-Thoron Dosimeter', developed by Bhabha Atomic Research Centre (BARC) has been employed. The specially designed twin cup dosimeter used in present study consists of two chambers of cylindrical geometry separated by a wall in the middle with each having a length of 4.5 cm and radius of 3.1 cm. This dosimeter employs three SSNTDs out of which two detectors were placed in each chamber and a third one was placed on the outer surface of the dosimeter. One chamber is fitted with glass fiber filter so that radon and thoron both can diffuse into the chamber while in other chamber, a semi permeable membrane made of latex or cellulose nitrate, having a thickness of 25  $\mu\text{m}$  is used. The membrane mode measures the radon concentration alone as it can diffuse through the membrane but suppresses the thoron. The twin cup dosimeter also has a provision for bare mode enabling it to register tracks due to radon, thoron and their progeny in total. Therefore, using this dosimeter we can measure the individual concentration of radon, thoron, and their progeny at the same time (Fig.1).

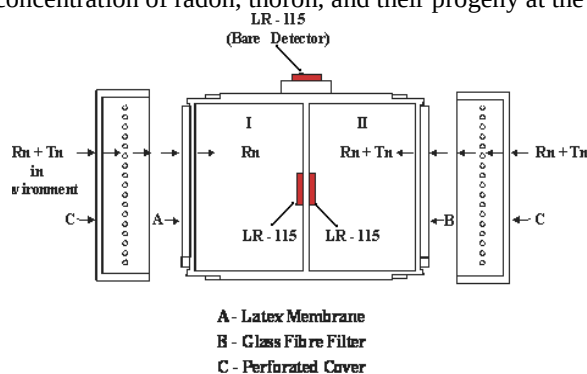


Fig.1 Twin Chamber Radon-thoron dosimeter

The dosimeters were suspended at a height of about 1.5 m in order to evaluate the annual average indoor radon levels. At the end of the exposure time, the detectors were removed and subjected to a chemical etching process in 2.5N NaOH solution at 60°C for 90 minutes. The detectors were washed and dried and the tracks produced by the alpha particles were observed and counted under an optical Olympus microscope at 600X. A large number of graticular fields of the detectors were scanned to reduce statistical errors. The measured track density (Track/cm<sup>2</sup>/day) was converted into radon and thoron concentration using calibration factors [7]. Radon and thoron progeny levels in mWL has also been calculated using indoor equilibrium factor as 0.4 for radon and 0.1 for thoron from UNSCEAR [8]. Annual dose received by the inhabitants in the dwellings under study in mSv was estimated using the relation [9-10]:

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

Where,  $F_R$  = equilibrium factor for radon;  $C_R$  = radon concentration;  $F_T$  = equilibrium factor for thoron and  $C_T$  = thoron concentration

## III. Results and Discussion

The results of the measurement of radon, thoron and their progeny from various industrial units and dwellings are listed in table 1-4. The radon and thoron concentration from Indian Oil refinery, Panipat varied from 30 to 91 and 3 to 48 Bq/m<sup>3</sup> with an average of  $52 \pm 7$  and  $22 \pm 6$  Bq/m<sup>3</sup> respectively. The radon and thoron progeny levels varied from 3.3 to 7.4 mWL and 0.1 to 1.3 mWL with an average of  $5.3 \pm 0.5$  and  $0.6 \pm 0.1$  respectively. The annual effective dose received by the worker of Indian Oil refinery, Panipat due to radon and thoron varied from 1.5 to 2.6 mSv with an average of  $1.9 \pm 0.2$ . The radon and thoron concentration from dwellings of Panipat, Haryana varied from 38 to 91 and 2 to 20 Bq/m<sup>3</sup> with an average of  $52 \pm 4$  and  $22 \pm 6$  Bq/m<sup>3</sup> respectively. The radon and thoron progeny levels varied from 4.1 to 7.4 mWL and 0.1 to 0.6 mWL with an average of  $5.0 \pm 0.3$  and  $0.3 \pm 0.1$  respectively. The annual effective dose received by the worker of dwellings of Panipat, Haryana due to radon and thoron varied from 1.3 to 2.7 mSv with an average of  $1.7 \pm 0.1$  mSv. The radon and thoron concentration from Thermal Power Station, Yamuna Nagar, Haryana varied from 114 to 229 and 61 to 134 Bq/m<sup>3</sup> with an average of  $165 \pm 16$  and  $96 \pm 10$  Bq/m<sup>3</sup> respectively. The radon and thoron progeny levels varied from 12 to 25 mWL and 1.6 to 3.6 mWL with an average of  $18 \pm 2$  and  $2.6 \pm 0.3$  respectively. The annual effective dose received by the worker of Thermal Power Station, Yamuna Nagar, Haryana due to radon and thoron varied from 5.1 to 8.1 mSv with an average of  $6.6 \pm 0.5$  mSv. The radon and

thoron concentration from dwellings of Yamunanagar, Haryana varied from 46 to 69 and 10 to 20 Bq/m<sup>3</sup> with an average of  $60 \pm 3$  and  $16 \pm 1$  Bq/m<sup>3</sup> respectively. The radon and thoron progeny levels varied from 4.9 to 7.4 mWL and 0.3 to 0.7 mWL with an average of  $6.5 \pm 0.3$  and  $0.5 \pm 0.1$  respectively. The annual effective dose received by the worker of dwellings of Yamunanagar, Haryana due to radon and thoron varied from 1.7 to 2.3 mSv with an average of  $2.0 \pm 0.1$  mSv.

**Table. 1 Radioactivity Levels and Annual Effective Dose Received by the Workers of Indian Oil Refinery Panipat, Haryana**

| Location               | Radon Conc.<br>Bq/m <sup>3</sup> | Thoron Conc.<br>Bq/m <sup>3</sup> | Radon Progeny<br>(mWL) | Thoron Progeny<br>(mWL) | Annual Effective<br>Dose (mSv) |
|------------------------|----------------------------------|-----------------------------------|------------------------|-------------------------|--------------------------------|
| Utility Control Room   | 53                               | 36                                | 5.8                    | 0.9                     | 2.2                            |
| Air Monitoring Station | 91                               | 09                                | 7.4                    | 0.3                     | 2.6                            |
| Boiling Area           | 46                               | 12                                | 4.9                    | 0.4                     | 1.5                            |
| Sulphur Treat Unit     | 46                               | 20                                | 4.9                    | 0.6                     | 1.7                            |
| Cooling Tower          | 46                               | 29                                | 4.9                    | 0.8                     | 1.7                            |
| Laboratory             | 53                               | 03                                | 5.8                    | 0.1                     | 1.5                            |
| TPS Control Room       | 30                               | 48                                | 3.3                    | 1.3                     | 1.8                            |
| AM $\pm$ SE*           | $52 \pm 7$                       | $22 \pm 6$                        | $5.3 \pm 0.5$          | $0.6 \pm 0.1$           | $1.9 \pm 0.2$                  |

**Table. 2 Radioactivity Levels and Annual Effective Dose Received by the Residents of Panipat District, Haryana .**

| Location     | Radon Conc.(C <sub>R</sub> )<br>(Bq/m <sup>3</sup> ) | Thoron Conc. (C <sub>Th</sub> ) (Bq/m <sup>3</sup> ) | Radon Progeny<br>(mWL) | Thoron Progeny<br>(mWL) | Annual Effective<br>Dose(mSv) |
|--------------|------------------------------------------------------|------------------------------------------------------|------------------------|-------------------------|-------------------------------|
| PNP-1        | 53                                                   | 03                                                   | 5.8                    | 0.1                     | 1.5                           |
| PNP-2        | 46                                                   | 4                                                    | 4.9                    | 0.1                     | 1.3                           |
| PNP-3        | 46                                                   | 12                                                   | 4.9                    | 0.3                     | 1.5                           |
| PNP-4        | 46                                                   | 20                                                   | 6.6                    | 0.6                     | 1.7                           |
| PNP-5        | 61                                                   | 2                                                    | 7.4                    | 0.1                     | 1.7                           |
| PNP-6        | 91                                                   | 10                                                   | 4.9                    | 0.3                     | 2.7                           |
| PNP-7        | 46                                                   | 12                                                   | 5.6                    | 0.3                     | 1.5                           |
| PNP-8        | 53                                                   | 20                                                   | 5.8                    | 0.5                     | 1.9                           |
| PNP-9        | 46                                                   | 12                                                   | 4.9                    | 0.4                     | 1.5                           |
| PNP-10       | 53                                                   | 11                                                   | 5.8                    | 0.3                     | 1.7                           |
| PNP-11       | 46                                                   | 12                                                   | 4.9                    | 0.3                     | 1.5                           |
| PNP-12       | 38                                                   | 13                                                   | 4.1                    | 0.3                     | 1.3                           |
| AM $\pm$ SE* | $52 \pm 4$                                           | $10 \pm 1$                                           | $5.0 \pm 0.3$          | $0.3 \pm 0.1$           | $1.7 \pm 0.1$                 |

AM (arithmetic mean); \* SE (statistical error)

**Table.3 Radioactivity Levels and Annual Effective Dose Received by the workers at Thermal Power Station, Yamuna Nagar, Haryana**

| Location        | Radon Conc.<br>Bq/m <sup>3</sup> | Thoron Conc. Bq/m <sup>3</sup> | Radon Progeny<br>(mWL) | Thoron Progeny<br>(mWL) | Annual Effective Dose (mSv) |
|-----------------|----------------------------------|--------------------------------|------------------------|-------------------------|-----------------------------|
| Coal Area       | 206                              | 105                            | 22                     | 2.8                     | 7.9                         |
| Boiler Area     | 114                              | 89                             | 12                     | 2.4                     | 5.1                         |
| Office          | 122                              | 71                             | 13                     | 1.9                     | 4.9                         |
| Generation Area | 168                              | 134                            | 18                     | 3.6                     | 7.5                         |
| Near ENT. Gate  | 168                              | 117                            | 18                     | 3.1                     | 7.2                         |
| Store           | 146                              | 61                             | 16                     | 1.6                     | 5.2                         |
| Fly Ash Area    | 229                              | 94                             | 25                     | 2.5                     | 8.1                         |
| AM $\pm$ SE*    | $165 \pm 16$                     | $96 \pm 10$                    | $18 \pm 2$             | $2.6 \pm 0.3$           | $6.6 \pm 0.5$               |

AM (arithmetic mean);\*SE (statistical error)

**Table. 4 Radioactivity Levels and Annual Effective Dose Received by the Residents of District Yamuna Nagar, Haryana.**

| Location | Radon Conc.(C <sub>R</sub> )<br>(Bq/m <sup>3</sup> ) | Thoron Conc. (C <sub>Th</sub> )<br>(Bq/m <sup>3</sup> ) | Radon Progeny<br>(mWL) | Thoron Progeny<br>(mWL) | Annual Effective<br>Dose(mSv) |
|----------|------------------------------------------------------|---------------------------------------------------------|------------------------|-------------------------|-------------------------------|
| YNG-1    | 53                                                   | 11                                                      | 5.8                    | 0.3                     | 1.7                           |
| YNG-2    | 69                                                   | 18                                                      | 7.4                    | 0.5                     | 2.3                           |
| YNG-3    | 61                                                   | 19                                                      | 6.6                    | 0.5                     | 2.0                           |

|        |      |      |         |         |         |
|--------|------|------|---------|---------|---------|
| YNG-4  | 46   | 20   | 4.9     | 0.7     | 1.7     |
| YNG-5  | 61   | 10   | 6.6     | 0.3     | 1.9     |
| YNG-6  | 69   | 18   | 7.4     | 0.5     | 2.3     |
| YNG-7  | 61   | 19   | 6.6     | 0.5     | 2.0     |
| AM±SE* | 60±3 | 16±1 | 6.5±0.3 | 0.5±0.1 | 2.0±0.1 |

*AM (arithmetic mean);\* SE (statistical error)*

In the present investigations the measurements indicate moderate to some higher levels of radon, thoron and progeny concentration in the environment of plants. It may be seen from the data obtained that the levels are higher in fly ash and coal handling area of the plant due to higher contents of uranium and radium in them. The levels are enhanced in the dwellings adjacent to thermal as compare to the dwellings at distance. In the present case study however, the annual effective dose is less than 20 mSv the recommended occupational dose [11]. The use of fly ash as building material should not be encouraged as it may enhance indoor doses from external irradiation besides inhalation of radon decay products may increase significantly. In a similar study on radiation hazard of coal-slugs as building material in Tatabanya Town (Hungary), it has been reported that the radon concentration in the houses where coal-slugs were used as building material exceeded the world average [12]. The information calls for necessary steps to be taken to minimize the emission of fly ash and coal dust produced in thermal power plants. The workers in thermal power plants are exposed to higher doses compared with other workers due to use of coal and production of fly ash in the plants.

#### IV. Conclusions

Following conclusions are drawn from the present study

1. The radon thoron levels are within ICRP recommended limits in industrial units and dwellings.
2. The radon thoron levels are higher in coal fired thermal power plants compared with other industrial units. It may be due to higher radium contents in the coal.
3. In thermal power plant, the radon levels are higher in coal handling and fly ash area. It may be due to the higher radium contents in coal which are further concentrated in fly ash during its combustion at high temperature.
4. The radioactivity levels in neighbouring soil and water of the area may be enhanced due to their exposure to coal and fly ash dust.
5. Radon levels in dwellings near thermal power station are found to be higher than in other dwellings.

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