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Soil Gas Radon Concentration in a Residential Area of Surrey (BC) Canada using LR-115 Type II Plastic Detector

Hardev Singh Virk[1],*

Abstract

Soil gas radon concentration measurement studies have been carried out globally to determine the health hazard effects of radon due to its seepage in indoor air of dwellings. It is a useful parameter for geochemical exploration of Uranium and earthquake precursory studies. Most of the countries, including Canada, have designed building codes to reduce the radon entry indoors. The purpose of this study is to determine radon concentration in a residential area of Surrey, a fast-developing city of British Columbia (Canada). Plastic detector LR-115 Type II has been used for recording alpha tracks emanated by Radon and its progenies. Track counting was done after etching detector foils of 1.0 cm^2 with 2.5 N NaOH at 60°C for 90 minutes. Track density per unit area per day was determined using optical microscope at magnification of 100 and 400 M, respectively. Radon concentration in the soil gas was estimated using standard calibration factor of 0.0344 track.cm^{-2}.d^{-1}/Bq.m^{-3}. The highest value of radon conc.639.5±32.0 Bq/m^3 was recorded in summer during the month of August 2021 and the lowest value 436±22 Bq/m^3 was recorded during winter months of February-March 2022. Soil gas radon values in Surrey are found to be lower than radon conc. of soil gas in many other countries.

Keywords: Soil Gas Radon, Plastic Detector, Alpha Tracks, Radon Conc., Counting Error

INTRODUCTION

Soil gas radon concentration measurement studies [1–6] have been carried out globally to determine the health hazard effects of radon due to its seepage in indoor air of dwellings. Radon in soil gas has been studied using half a dozen techniques both active and passive [7–10]. Active techniques are faster and are used mostly in indoor radon survey of dwellings to evaluate health risk hazards. Passive techniques are considered to be the most convenient method to determine radon concentrations over long periods of time for estimating radon under seasonal, weather, and environmental conditions. Jon Miles of National Radiological Protection Board of UK has given a summary of both active and passive techniques. For example, active measurement techniques include scintillation cells, ionization chambers, alpha loggers, while passive techniques include charcoal detectors, electrets ion chambers and etched track detectors [11].

Radon is a radioactive gas that is present almost everywhere where Uranium exists. It is a decay product of Uranium and emanates from rocks and soils containing Uranium in traces. It has three isotopes, namely, 222Rn (Radon), 220Rn (Thoron) and 219Rn (Actinon). All three are decay products (daughters) of 238U, 232Th and 235U series, respectively. Radon (222Rn) and its short-lived decay products (218Po, 214Pb, 214Bi and 214Po) are known to be contributing to nearly 50% of the

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global mean effective dose to the public from the natural radioactivity. 222Rn is a long-lived isotope out of the three radon isotopes and is thus more mobile in natural environment than other elements in the uranium series. It is used as an effective tracer in understanding geophysical processes that induce fluid motion in the ground. Our group used radon measurements in soil gas for geochemical exploration of Uranium [12, 13] and earthquake prediction studies [14, 15].

It has been well established that incidence of lung cancer among the mine workers is due to prolonged exposure to radon and its daughter products. In the United States of America, exposure to radon is the second cause of lung cancer after smoking. Scientists estimate that about 20,000 lung cancer deaths per year are related to radon [16]. In fact, approximately 16% of lung cancer deaths in Canada are due to long-term exposure to radon gas indoors. Furthermore, radon gas is the primary cause of lung cancer in non-smokers and the second leading cause in smokers [17].

The track-etch technique uses Solid State Nuclear Track Detectors (SSNTD) for passive and time-integrated measurements [18, 19]. This method is the most widely used technique to monitor low levels of radon in the indoor environment, variation of radon in soil gas with meteorological parameters [20] and time-integrated measurements of radon for monitoring seismic activity [21]. Plastic detector foils were used to record radon in open air at a height of 2 m to evaluate any risk due to pollution of air by radon.

EXPERIMENTAL TECHNIQUE

The basic features of plastic detector technique are common in all types of media used for radon concentration measurements. However, small variations exist in the employment of detector foils when media changes. For example, in water media, radon detectors are used as reported in our previous studies [22, 23]. In air media, detector foils of 1.0 cm^2 and 1.5 cm^2 were suspended inside rooms at a height of 60 cm from the floor level. In the soil gas, detector foils of 1.0 cm^2 were attached to the bottom of a glass jar of 15 cm height using a double adhesive scotch tape. The glass jar was inverted in a circular hole of 15 cm dia. dug up in the soil. The jar with detector foils was covered with a plastic cylinder of 30 cm height and 12 cm dia. for protection of the glass jar. Normally, for best results of radon conc. in soil gas, the detector foils should be kept exposed in an air column of 60 cm. But in our study the air column was deliberately kept 30 cm to avoid interference of gofers that abound in the soil of our residence. Once or twice, our detector foils were damaged by their channels underground.

Passive techniques are considered to be the most convenient method to determine radon concentrations over long periods of time. Use of LR 115 SSNTD, which is composed of a cellulose nitrate film coated on a 100 μm thick polyester base, was made for radon conc. measurement. The LR 115 detector consists of two categories: Type I films have a thickness of 6 μm and Type II films have a thickness of 12 μm. Furthermore, the cellulose nitrate film of the detector is sensitive to alpha particles and has a chemical composition of $C_6H_8O_6N_{12}$. Alpha particles with an energy range of 1.9–4.2 MeV are recorded by the LR 115 Type II film as it has been designed for a given window of energy range and it is less sensitive to other energies.

LR-115 Type II detector foils were collected from the jar after an exposure time of 30 days. The track detector foils were removed from the scotch tape used for fixing the foils on the inverted jar and etched in a constant temperature bath using 2.5N NaOH solution as etchant for 90 minutes at 60°C. The temperature fluctuation of bath during etching was observed to be ±2°C. Track density (no. of tracks/cm^2) was then determined using an optical microscope with a magnification of 100 and 400 M, respectively. It was observed that some foils get dissolved during etching while some others are either over-etched or under-etched. In both the latter cases, track counting is not possible. The etched foils were removed from the bath and washed in running distilled water for 30 seconds to remove any traces of NaOH. Photomicrographs of alpha tracks were recorded using cell phone camera with an

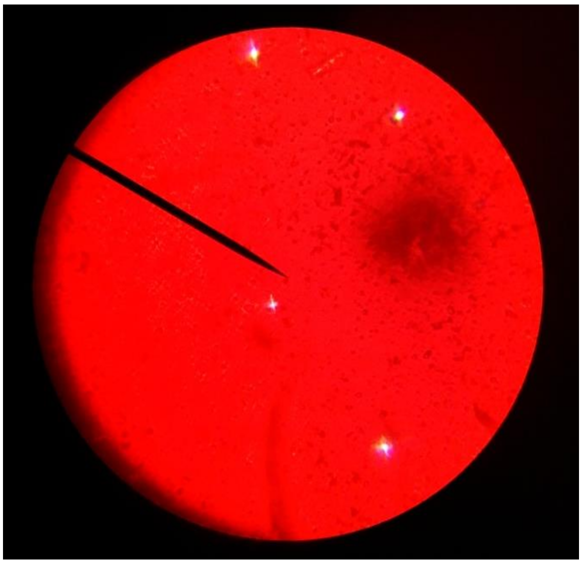

Figure 1. Photomicrograph of Radon alpha tracks in plastic detector at M = 400.

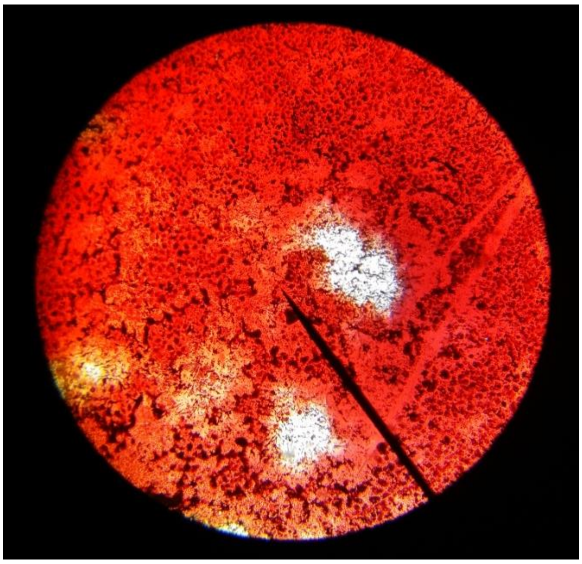

Figure 2. Photomicrograph of damaged Plastic detector due to over-etching

attachment to the optical microscope at a magnification of 400 (40 objective × 10 eyepiece). The circular tracks can be distinguished from other features as shown in Figure 1. Over-etched and damaged detector foils are as shown in Figure 2. The etching of detector foils suspended in open air was carried out under identical conditions. However, no tracks were observed in foils exposed in ambient air of our residence in Surrey.

RESULTS AND DISCUSSION

The experiment for recording of radon in soil gas was started in the summer of 2021 when the humidity was minimum, temperatures were high reaching up to 30°C, weather was dry without any rains. The radon diffusion reaches maximum when the soil is porous and dry. During February to April 2022, it was winter season and rains were in abundance. The radon diffusion decreases due to closure of pores of the soil. The track density during these months confirms our assumption. The day temperatures start rising in May and June resulting in diffusion of more radon in the soil gas. The experiment was disrupted during severe winter and heavy rains; hence no data was collected from November 2021 to January 2022.

Table 1 summarizes the results of track counting and radon concentration in the soil gas. The track density was converted into a radon concentration level in Bq/m^3 using the formula:

$C_{Rn} = \rho$ (no. of tracks/cm^2)/kt(days)

Where;
k is the calibration factor of LR-15 Type II detector (0.0344±0.002) $track.cm^{-2}.d^{-1}/Bq.m^{-3}$ [24, 25].

Table 1. Soil gas radon conc. levels during different time intervals.

S.N.	Time Interval Month and Year	Track Density $Tr/cm^2/d$	Counting Error %	Radon Conc. Bq/m^3
1.	August 2021	22.0	5	639.5±32
2.	October 2021	20.0	4	581±23
3.	February-March 2022	15.0	5	436±22
4.	March-April 2022	16.0	6	465±28
5.	May 2022	18.0	7	523±37
6.	June 2022	18.5	5	538±27

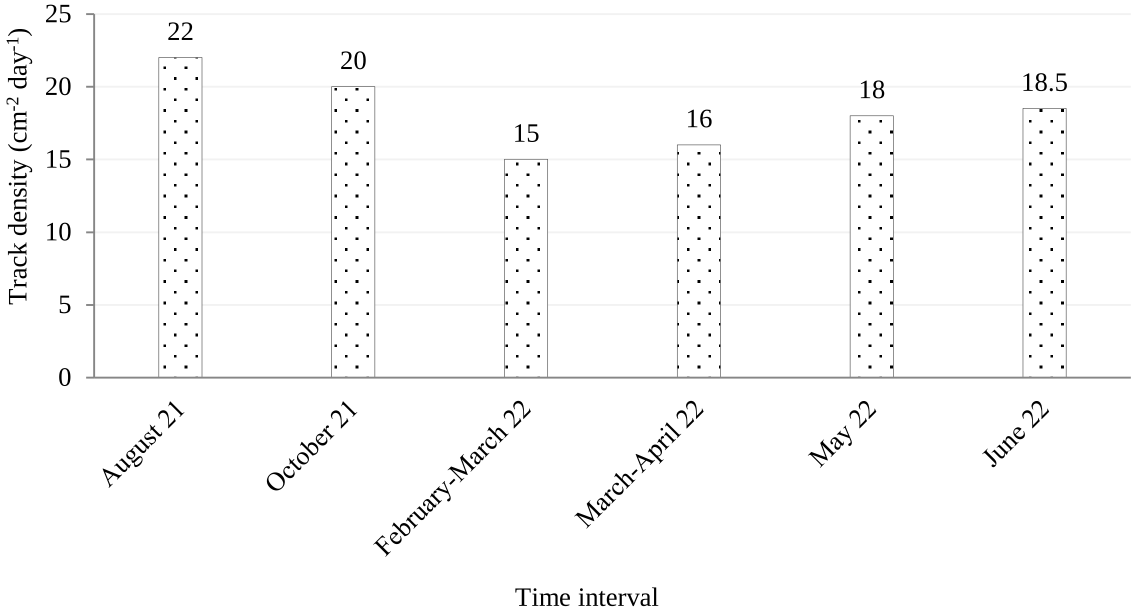

Figure 3. Histogram showing variation of Track density in soil gas with monthly time interval.

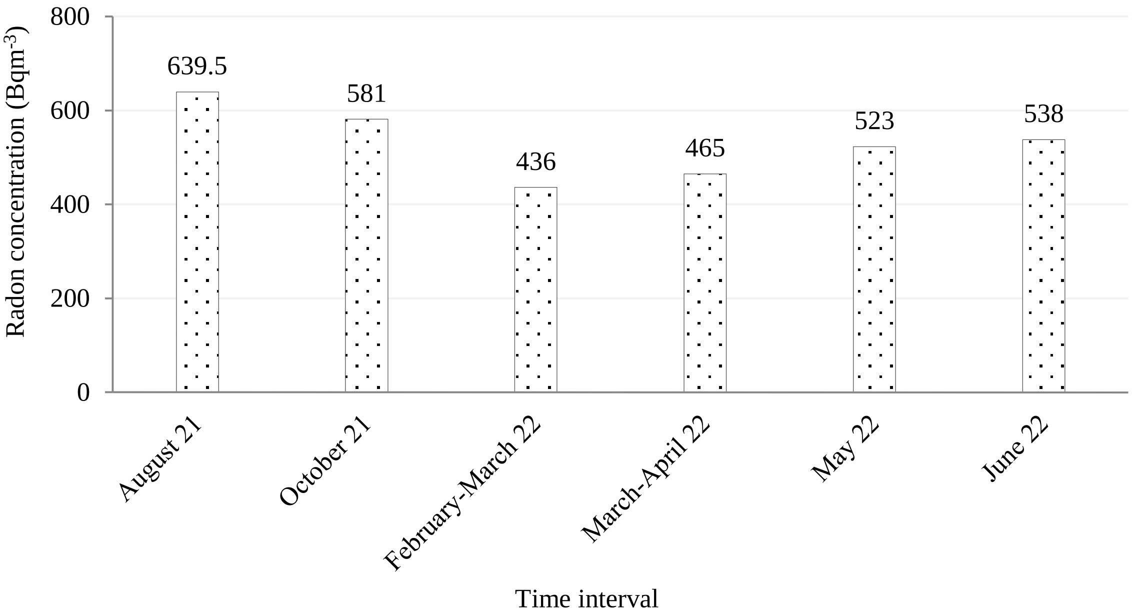

Figure 4. Histogram showing variation of Radon activity in soil gas with monthly time interval.

The highest value of radon conc. in soil gas (639.5±32 Bq/m^3) was recorded in summer during the month of August 2021 and the lowest value (436±22 Bq/m^3) was recorded in winter months of February-March, 2022. Figures 3 and 4 are histograms to represent variation of track density and radon activity in soil gas with variation of time interval, respectively.

Radon gas has been found as a component of soil gas in all regions of Canada in varying degrees. Health Canada guidelines recommend mitigation when exposure levels exceed 200 Bq/m^3 [26]. Compared with radon conc. of soil gas in many other countries, our values are much lower [27]. Chen et al. [28] found radon activity of 6800–74700 Bq/m^3 in soil gas at two reference sites in Ottawa. They also determined correlation of soil radon and permeability with indoor radon potential in Ottawa [29]. Our aim is also to determine correlation of indoor radon in dwellings with soil gas radon in Surrey area of BC, Canada.

CONCLUSIONS

1. Radon concentration in soil gas is maximum (639.5±32.0 Bq/m^3) during summer month of August 2021. It attains its minimum value (436±22 Bq/m^3) in winter rainy season.
2. The radon in ambient air outside the residence is below the detection limit. Hence it is not causing any pollution in atmospheric air outside the residence.
3. The radon recording needs to be done at a minimum depth of 60 cm to get an optimum estimate of radon activity in soil gas.
4. Effect of meteorological parameters (temperature, pressure, humidity and wind) must be taken into account in future surveys.
5. Correlation between radon concentration in soil gas and indoor air of Surrey residence will be a useful study to be undertaken.

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