STM JOURNALS

Research & Reviews: A Journal of
Toxicology

ISSN: 2231-3834 (Online)
ISSN: 2349-1264 (Print)
Volume 11, Issue 1, 2021
DOI (Journal): 10.37591/RRJoT

http://medicaljournals.stmjournals.in/index.php/RRJoT/index

Research RRJoT

Radon Estimation in Water of Surrey Region of British Columbia, Canada using LR-115 Type II Nuclear Track Detector

Jasmine Virk[1,*], Hardev Singh Virk[2]

Abstract

Radon activity concentrations were measured in the ocean, swamp and well water samples collected from Surrey region of British Columbia in Canada. The purpose of this study was to compare radon activity in all three sources of water. Water was collected in air tight bottles and stored for 2 weeks before investigation. LR-115 Type II nuclear track detectors of 1.5 cm^2 were used for recording radon alpha tracks. Tracks were counted after etching with 2.5 N NaOH at 60°C for 90 min, using an optical microscope to determine track density. Radon concentration was estimated using standard calibration factor of 0.034 $track.cm^{-2}.d^{-1}/Bq.m^{-3}$. Highest value of radon concentration of 1707 Bq/m^3 has been found in sea water and lowest value of 852 Bq/m^3 in well water used for drinking in Surrey region. The values of radon concentration in well water are within the safe limits as recommended by US EPA.

Keywords: Well water, radioactivity, radon, LR-115 type II plastic detector, etching, alpha tracks

INTRODUCTION

Radon is a radioactive noble gas that does not chemically react with other elements. Radon emanation is a well understood phenomenon. It is a colorless, odorless and tasteless gas, which is 7.5 times heavier than air. Hence its presence in drinking water is not felt during consumption. The decay products of radon, i.e., its progeny is highly radioactive and gets absorbed to aerosol particles suspended in water. The range of recoil radon atom in water is about 0.1 μm but it emits alpha particle which has energy 5.5 MeV and can travel up to a few centimeters in air.

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. Thoron and Actinon have very short half-lives (in seconds) and Radon (222) represent the most essential isotope, with a half-life of 3.825 days which allows it to migrate over long distances and get accumulated into the indoor environment. Radon (222Rn) and its short-lived decay products (218Po, 214Pb, 214Bi and 214Po) have been recognized globally as the main sources of exposure to the public in dwellings from the natural radioactivity, contributing to nearly 50% of the global mean effective dose to the public. 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 [1].

Radon decay chain is represented as follows:
$^{226}Ra\ \alpha\ (\text{emission}) \longrightarrow\ ^{222}Rn\ \alpha \longrightarrow\ ^{218}Po\ \alpha \longrightarrow\ ^{214}Pb$

*Author for Correspondence
Jasmine Virk
E-mail: jasminevirk000@gmail.com

[1]Grade X, Semiahmoo Secondary School, Surrey, BC, Canada
[2]Professor of Eminence, Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib, India

Received Date: March 30, 2021
Accepted Date: April 21, 2021
Published Date: April 30, 2021

Citation: Jasmine Virk, Hardev Singh Virk. Radon Estimation in Water of Surrey Region of British Columbia, Canada using LR-115 Type II Nuclear Track Detector. Research & Reviews: A Journal of Toxicology. 2021; 11(1): 7–15p.

Radon is the most important source of naturally occurring radiation exposure for humans. For the world population, radon exposure represents 50% of the total exposure to natural background radiation, followed by earth gamma radiation at 20%, cosmic radiation at 18% and natural radiation from food and water at 12% (Figure 1) [2]. 95% of exposure to radon is from indoor air, with about 1% coming from drinking water [3].

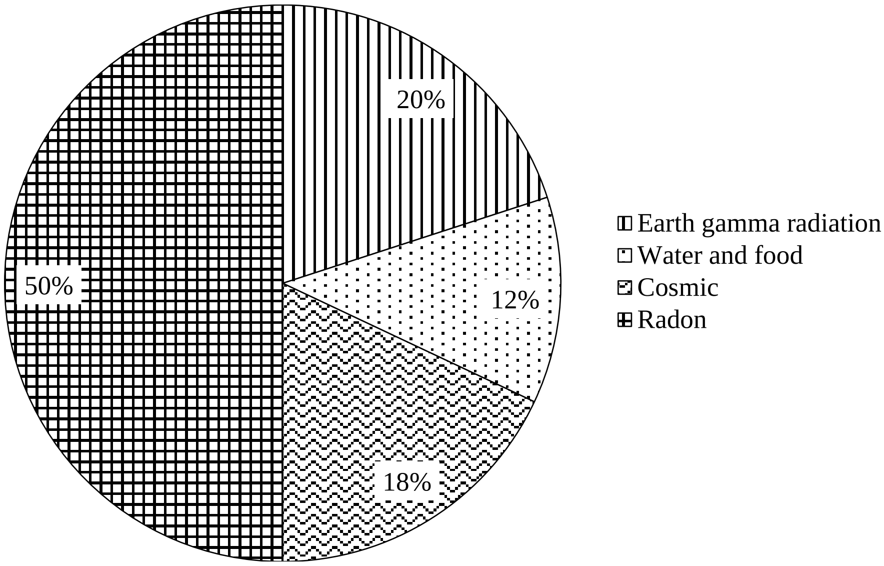

Figure 1. Sources and distribution of natural background radiation for the world population [2].

Radon in domestic water supplies can cause human exposure to a radiation dose both through inhalation and ingestion. Radon is easily released from water into the atmosphere by agitation or heating. Many domestic uses of water result in such a release and can contribute to the total indoor air radon concentration. It has been estimated that 1000 Bq/l of radon in water will, on average, increase the radon concentration in indoor air by 100 Bq/m^3 [4]. It has been observed that the risk of lung cancer increases if the public is exposed to high concentrations of radon in indoor air. The organ at greatest risk from the ingestion of water containing radon and radon decay products is considered to be the stomach [5].

Unfortunately, radon can lead to major health risks via two methods. The first method in which radon can be exposed to the human body is the inhalation of radon that escapes from groundwater to the air of homes. A second method is the ingestion of radon in drinking water. Long-term exposure to radon gas can result in lung cancer. In fact, approximately 16% of lung cancer deaths in Canada are due to long-term exposure to radon gas indoors. Furthermore, the studies reveal that radon gas is the primary cause of lung cancer in non-smokers and the second leading cause in smokers [6].

The associated health risks due to inhalation and ingestion of radon and its progeny when present in enhanced levels in an indoor environment, water and soils surrounding a human dwelling have been well documented [7–11]. There are many factors which influence the radon concentration in dwellings and environment, namely, radium content in the soil, meteorological parameters and the radon emanating from soils and rocks in the surroundings [12–14].

EXPERIMENTAL TECHNIQUE

When it comes to measuring radon levels based on the effects of seasonal, weather, and environmental conditions, passive techniques are the most convenient method to determine radon concentrations over long periods of time. The track etch technique uses Solid State Nuclear Track Detectors (SSNTD) for passive and time-integrated measurements [15–18]. Not only is this method the most widely used technique to monitor low levels of radon in the indoor environment, but it is also durable, simple, and the nature of its response is quick and convenient for the purpose of observing and measuring radon concentrations. One type of SSNTD is LR 115, which is composed of a cellulose nitrate film coated on a 100 µm thick polyester base. The LR 115 detector branches into two categories based on the thickness of the cellulose nitrate layer. 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 film. This energy range is due to the design of the LR 115 Type II and its less sensitive cellular nitrate layer. Additionally, this means that the background tracks from a thin layer of air existing between the film and its protector will not be etched onto the surface of the LR 115 Type II detector.

Materials

- LR-115 Type II Solid State Nuclear Track Detector.
- Glass jars: 12 cm height ×6.5 cm length ×6.5 cm width.
- Water 500 ml each from three different sources *(river, ocean, well).*
- Sodium Hydroxide: 50 gm.
- Optical Microscope.

Procedure

1. Collect 1000 ml of water in an airtight glass or plastic bottle with dimensions approximately 12 cm height ×6.5 cm length ×6.5 cm width. Take care that there is no bubbling to minimize the escape of radon.
2. Put an LR 115 Type II detector of size 1.5 cm×1.5 cm on the inner side of the lid of the container with the active side facing the water. The active side will be the side that is curved in a concave manner.
3. Seal this container for at least 60–70 days to collect radon by emanation in water.
4. After 70 days, take out the exposed LR films. Then etch the LR films in a constant temperature bath in 2.5 N NaOH at 60°C for 90 min. During the etching period of 90 min, the temperature should be maintained at 60±1°C.
5. To prepare a 2.5 N solution, dissolve 100 gm NaOH in 1000 ml distilled water (Total volume of distilled water and NaOH dissolved should be 1000 ml), or dissolve 50 gm NaOH in 500 ml distilled water. After etching, wash the films with distilled water for 5–10 min.
6. Remove the cellulose nitrate films from the base and count the tracks etched on the polyester base using the optical microscope to find track density ρ (tracks/cm^2).
7. Figures 2–4 illustrate the detector composition, position on the lid, and containers of water samples, respectively.

The radon concentrations were tested by collecting water from three different sources (well, ocean, and swamp) and isolating the samples for 71 days in airtight containers with an LR-115 Type II detector placed in each container. After the exposure time, the track detectors were removed and etched in 2.5N NaOH solution. Track density (no. of tracks/cm^2) was then determined using a microscope. The track count was converted into a radon concentration level in Bq/m^3 using the formula:

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

Where, k is the calibration factor of LR-15 Type II detector (0.034±0.002) track.cm^{-2}.d^{-1}/Bq.m^{-3} [19, 20].

RESULTS OF RADON STUDY IN WATER

Radon alpha tracks are recorded in LR-115 Type II detector as circular dots on the surface of the detector as shown in the photomicrograph (Figure 5). The track shape depends on the energy and angle of incidence of alpha tracks. Track counting was carried out in Semiahmoo School laboratory using an ordinary student optical microscope with magnification of 40X manually. Spark counting is helpful in case of high track density. The track density was estimated by counting tracks in 20 fields of views which approximate an area of 1 cm^2. Radon concentration in water was estimated by using the formula [20]:

$$C_{Rn}\ (Bq/m^3)=(\rho/t.k)$$

Where, k is the calibration constant (0.034 $track.cm^{-2}.d^{-1}/Bq.m^{-3}$), ρ is track density ($tracks/cm^2$), t is exposure period (days).

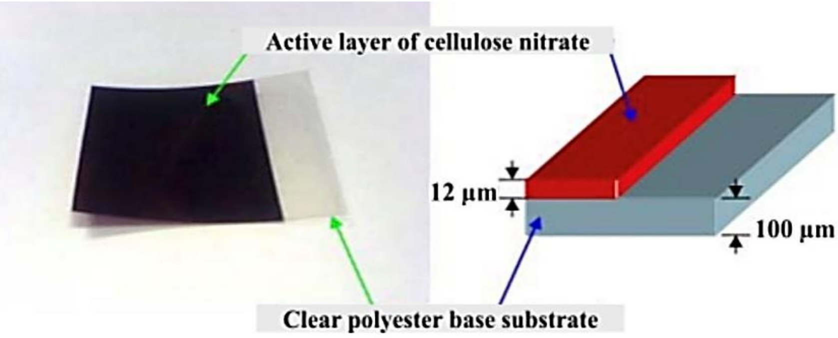

Figure 2. LR-115 Type II detector composition and layout.

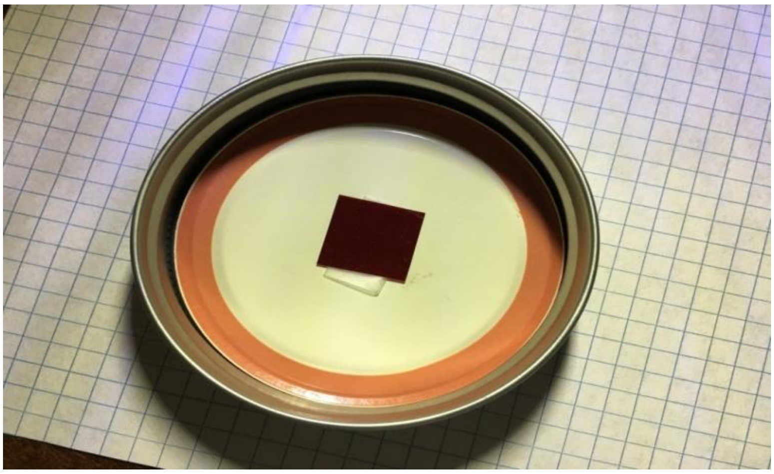

Figure 3. Position of the LR-115 Type II detector on the lid of each container.

Figure 4. Experimental setup for Radon estimation in water.

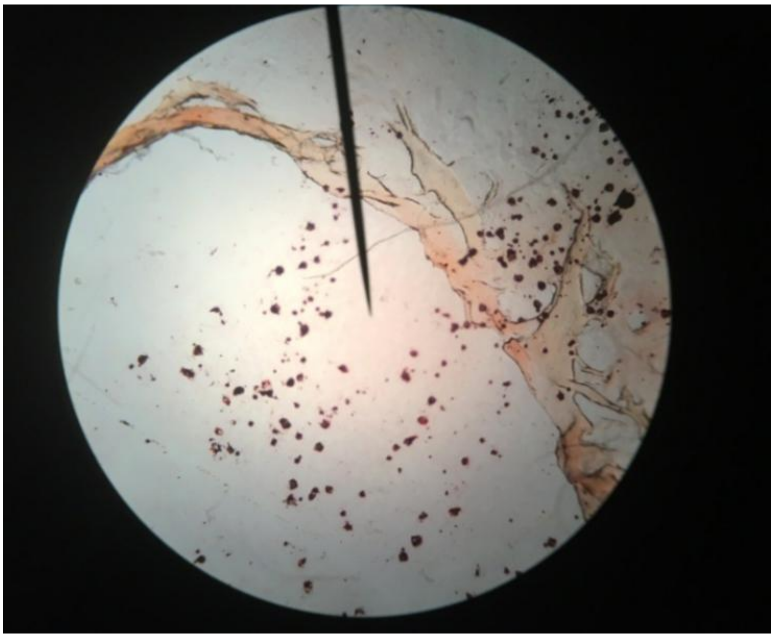

Figure 5. Photomicrograph of Alpha tracks in LR-115 Type II detector for Ocean water.

Track density and radon concentration of different sources of water are plotted as histograms in Figures 6 and 7, respectively. Table 1 summarizes the values of both these parameters along with statistical error in random counting of tracks in the three sources of water. The results show the highest value (1707 Bq/m^3) of radon concentration in the ocean water. The estimated value in swamp water is 1226 Bq/m^3 and in well water, the value of radon concentration is lowest, 852 Bq/m^3. Statistical counting errors are lower than 2.2% in the samples.

Table 1. Comparison of track density, radon level, and counting error of each water source.

Source	**Track Density (No. of Tracks/cm^2)**	**Radon Level (Bq/m^3)**	**Counting Error Estimation**
Ocean	4121	1707 Bq/m^3	1.56%
Swamp	2960	1226 Bq/m^3	1.84%
Well	2057	852 Bq/m^3	2.2%

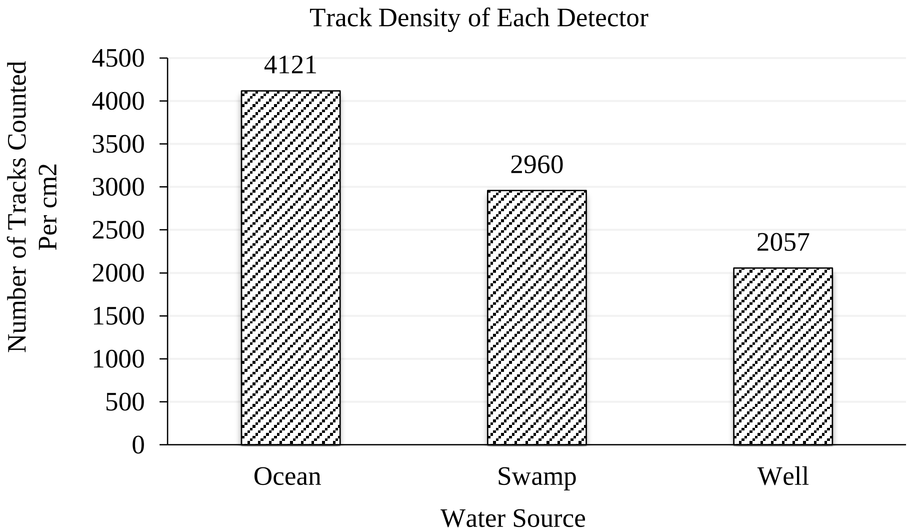

Figure 6. Track density recorded in different water samples using LR-115 Type II detectors.

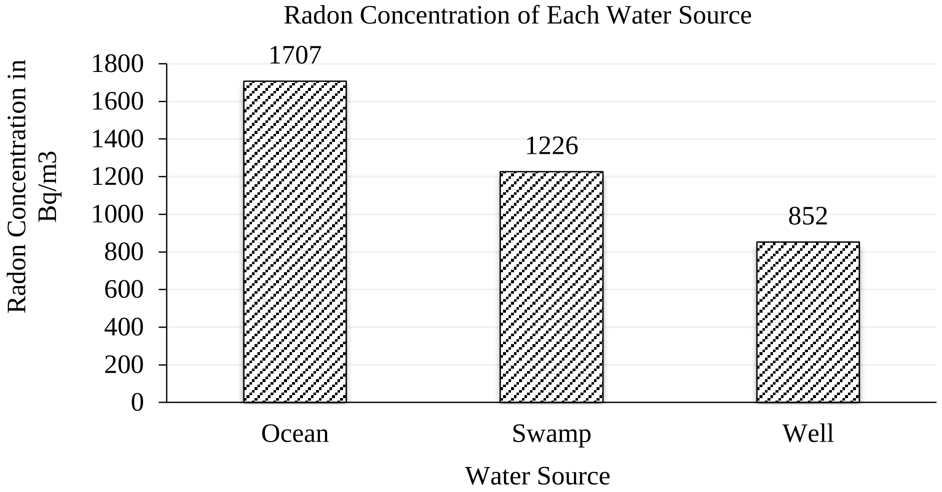

Figure 7. Radon concentration (in Bq/m^3) measured in different water sources.

DISCUSSION OF RESULTS

The present study is focussed on Surrey city and its surroundings where the authors have been living since 2007. There is hardly any data available on radon concentration measurements in the ocean water, where most residents of Surrey and White Rock localities go for bathing. Similarly, there is no investigation carried out on swamp waters of the region. Our survey of literature fails to get any scientific report regarding radon concentration in the well water being used by the Surrey residents. In view of lack of data on radon in water sources of the region, this study assumes significance for future investigations as the baseline data.

Health Canada has published its reports on Uranium [21], Radon [22], and Environmental Radioactivity in Canada [23]. Radon survey report [24] of some selected areas of Ontario and Nova Scotia has been published by Government of Canada, which reports as follows:

"There are few data on radon concentrations in Canadian drinking water supplies. Water drawn from surface water supplies does not generally contain appreciable levels of radon, which are expected to be on the order of 0.01 Bq/l. One survey of Canadian groundwater sources containing elevated levels of radon found radon concentrations in the range of 1700–13700 Bq/l in Halifax County, Nova Scotia. A second survey detected radon at concentrations as high as 3000 Bq/l in well water in Harvey, New Brunswick, with 80% of the wells containing radon concentrations below 740 Bq/l. In a more recent study, as part of a province-wide radio nuclide testing program, levels of radon were measured in the drinking water from 16 schools in Nova Scotia; radon levels reportedly ranged from 120 to 1400 Bq/l, with an average of approximately 600 Bq/l. Levels of radon this high in drinking water can lead to significant levels of 210 Pb in only a few days [25]".

The United States set a Maximum Contaminant Level (MCL) for radon in drinking water of 150 Bq/l for radon concentration in drinking water from private water supplies, The European Union Commission recommended Action Level of 1000 Bq/l. This is set so that the risk to a typical person drinking such water is similar to the risk from breathing air which contains radon at the Action Level of 200 Bq/m^3. There is no agreement between action levels set by different countries for average radon levels from all sources in homes, as listed in Table 2 [3].

Radiological aspects of radon are discussed in WHO report of 2008 [26]. Similarly, US Environmental Protection Agency (EPA), International Commission on Radiation Protection (IARP) and National Council on Radiation Protection (NCRP) have published natural background radiation survey reports, including radon, the last one compares the scenario in both USA and Canada [27].

Table 2. Domestic radon concentrations and Action Levels in different countries.

Country	Average Radon Conc. in Homes (Bq/m^3)	Action Level (Bq/m^3)
Czech Republic	140	200
Finland	123	400
Germany	50	250
Ireland	60	200
Israel	*	200
Lithuania	37	100
Luxembourg	*	250
Norway	51–60	200
Poland	*	400
Russia	19–250	*
Sweden	108	400
Switzerland	75	400
United Kingdom	20	200
European Community	*	400
USA	46	150
Canada	*	800

**shows that data not available at the moment*

CONCLUSIONS

1. This is our preliminary study of radon in different sources of water in the Surrey region.
2. The purpose of this study is to set the baseline data for future investigations.
3. Contrary to our expectations, the surface waters (Ocean and Swamp) contain higher concentrations of radon as compared to well water being used for drinking purposes.
4. The radon concentration (852 Bq/m^3) in the well water in Surrey region of BC, Canada is within safe limits of the US Environmental Protection Agency's standard guideline of radon levels (1100 Bq/m^3) in drinking water.
5. Influence of meteorological parameters (temperature, pressure, humidity) has been ignored in this study as they are predominant in case of radon estimation in air and soil only.

Acknowledgements

The authors offer their thanks to Dr Navjit Sharma of DAV College, Jallandhar for the supply of LR-115 Type II plastic detector sheets. The experiment was carried out by the first author independently in Surrey, BC, with inputs of the senior author at the execution stage. Jasmine Virk expresses her sincere thanks to her parents (Navdeep Virk and Sukhwinder Virk) and her sister Anureet Virk for logistic and moral support during these investigations. Most of this study was carried out at the make-shift laboratory at the residence of Jasmine Virk except track measurements which were carried out in Semiahmoo school laboratory. She is grateful to her Science teacher, Susan Hunter Jivung, for providing the optical microscope.

REFERENCES

1. American Cancer Society (Sep 23, 2015). Radon and Cancer. [Online] Available from: https://www.cancer.org/cancer/cancer-causes/radiation-exposure/radon.html.
2. UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) (26 Jun 2016). 2000 Report to the General Assembly. Vol. I. Annexure A & B. New York: 2000. [Online] Available from: https://www.unscear.org/unscear/en/publications/2000_1.html
3. WHO (2004) Radon and health information sheet. World Health Organization, Geneva. March. Available at: www.who.int/phe/radiation/en/2004Radon.pdf.
4. Eur-Lex. European Commission Recommendation of 20 December 2001 on the protection of the public against exposure to radon in drinking water supplies (notified under document number C(2001) 4580).

5. Khursheed A. Doses to systemic tissues from radon gas. Radiat Prot Dosimetry. 2000; 88(2): 171–181.
6. British Columbia Centre for Disease Control (Dec 2011). Radon in Household Well Water: Contributions to Indoor Air Radon Concentrations. [Online] Available from: https://www.ncceh.ca/sites/default/files/BCCDC-Radon_Well_Water_Dec_2011.pdf
7. UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiations, and effects of ionizing radiation. Report to the General Assembly, with Scientific Annexes, United Nations, New York, 1993.
8. Durrani SA. The use of Solid State Nuclear Track Detectors in Radiation Dosimetry, medicine and biology. *Nuclear Tracks.* 1982; 6(4): 209–228.
9. Rejah Basim Khalaf, *et al*. Estimate Level of Radon Concentration for Drinking Water in Some Regions of Baghdad City. *Arab J Sci Eng*. 2018; 43: 3831–3835.
10. Elzain AEA. A study on the radon concentrations in drinking water in Kassala State(Eastern Sudan) and the associated health effects. World Appl Sci J. 2014; 31(3): 367–375.
11. Musah Isam Salih M. Radon in Natural Waters. Department of Medicine and Care, Linköping University; 2003; Ph.D Thesis ISSN 0345–0082p.
12. Elzain AEA. Radon Monitoring in the Environment. Intech Open; 2017; 25–41. https://www.intechopen.com/books/radon/radon-monitoring-in-the-environment. [Accessed 11 Oct 2020].
13. Idriss H, Salih I, Abdulaziz AS, Abdelgalil MY, *et al*. Study of radon in soil gas, trace elements and climatic parameters around South Kordofan state, Sudan. Environ Earth Sci. 2014; 72(2): 335–339.
14. Singh M, Ramola RC, Singh NP, Singh S, Virk HS. Influence of meteorological parameters on soil gas radon. J Assoc Explor Geophys. 1988; 9(2): 85–90.
15. Caresana M, *et al.* Evaluation of Etching Correction Factor for LR115 Cellulose Nitrate Films from Track Parameters. Radiat Prot Dosimetry. 2005; 113(4): 354–358.
16. Ramola RC, *et al.* Radon Pollution Studies in the Environs of Radioactive Areas by Using Solid State Nuclear Track Detectors. Nuclear Geophysic. 1989; 3(4): 297–298.
17. Ramola RC, Manwinder Singh. Measurement of Indoor Radon Concentration using LR-115 Plastic Track Detector. Indian J Pure Appl Phys. 1987; 25(3): 127–129.
18. Ramola RC, *et al*. Efficiency of Radon Detector LR-115. Indian J Pure Appl Phys. 1987; 25(5): 235–236.
19. Singh M, Singh NP, Singh S, Virk HS. Calibration of radon detectors. Nucl Tracks Rad Meas. 1986; 12(1–6): 739–742.
20. Rasheed EM. Determination the Concentration of the Radon in some Drinking Bottled Water in Baghdad using LR-115 Detector. Baghdad Science Journal. 2012; 9(4): 744–749.
21. Health Canada (May 2019). Guidelines for Canadian Drinking Water Quality supporting documentation. Ottawa. [Online] Available at: www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/uranium/index-eng.php.
22. Health Canada (7 Nov 2017). Radon gas: it is in your home. https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/radiation/radon-your-home-health-canada-2009.html.
23. Health Canada. (2000). Environmental radioactivity in Canada 1989-1996. Environmental Radiation Hazards Division, Radiation Protection Bureau, Health Canada, Ottawa [see also earlier editions of Environmental radioactivity in Canada (1973-79)]. [Online] Available at: https://inis.iaea.org/collection/NCLCollectionStore/_Public/11/558/11558929.pdf?r=1&r=1
24. Health Canada (Dec 2010). https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-radiological-parameters/page-4-guidelines-canadian-drinking-water-quality-guideline-technical-document-radiological-parameters.html.

25. Drage J, Baweja A, Wall P. Naturally occurring radio nuclides in Nova Scotia ground water. Canadian Radiation Protection Association Bulletin. Part 1;26(3);15-21 and Part 2;26(4);13-22
26. WHO. (2008). Guidelines for drinking-water quality. 3rd Edn. Vol. 1. Recommendations. Incorporating first and second addenda. [Online] Available at: https://www.who.int/water_sanitation_health/publications/gdwq3rev/en/
27. NCRP (1987). (NCRP Report No. 94). Exposure of the population in the United States and Canada from natural background radiation. National Council on Radiation Protection and Measurements, Bethesda, MD.

