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Radon Estimation in Some Lakes and Fraser River Water of British Columbia, Canada using LR-115 Type II Alpha Track Detector

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Abstract

Radon activity levels were measured in the five Lakes and Fraser River water samples collected from different locations of British Columbia in Canada. The purpose of this study was to compare Radon activity levels in all six sources of water. Water was collected in air tight bottles and stored for two weeks before investigation. LR-115 Type II nuclear track detectors of 1.2 cm^2 were used for recording radon alpha tracks. Tracks were counted after etching with 2.5 N NaOH at 60°C for 2 hours, using an optical microscope to determine track density. Radon concentration was estimated using standard calibration factor of 0.0344 track cm^{-2} d^{-1} /Bq m^{-3}. Highest value of radon concentration of 161.5 Bq/m^3 has been found in Como Lake water of Coquitlam and lowest value of 36.34 Bq/m^3 in Wood Lake. The Fraser River recorded a Radon activity level of 48.45 Bq/m^3 near its delta in the Richmond area. The values of radon concentration in all sources under investigation are within the safe limits as recommended by US EPA. A brief description of Lakes under investigation is given in the Appendix.

Keywords: Lake water, Fraser river, radon, LR-115 Type II plastic detector, alpha tracks

INTRODUCTION

Radon is a radioactive noble gas, which is colorless, odourless and tasteless, hence its presence in drinking water is not felt during consumption. It is 7.5 times heavier than air and does not chemically react with other elements. Radon emanation is a well understood phenomenon. The decay products of radon, or its progeny, are highly radioactive and get 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.

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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) represents 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) are known to be contributing to nearly 50% of the global mean effective dose to the public and have been recognized as the main sources of exposure to the public in dwellings from the natural radioactivity. 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].

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 [2].

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 [3–7]. 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 [8–10].

There is hardly any data available on radon conc. in the Lakes and Rivers of British Columbia. Health Canada says the Thompson Okanagan region is a prime generator of radon gas, the second leading cause of lung cancer in Canada [11]. It was reported in the Kelowna Capital news that the Kelowna public forum has started an assessment of excessive radon radiation exposure dangers to public and how to mitigate it. Keeping in view this news item, we collected samples of water from Okanagan lake system in Kelowna and the Wood lake in the Lake city in the Kelowna region during the months of July and October.

It is well known that the 222Rn activity is high in ground water, whereas in surface water the radon content is variable and low. The 222Rn concentration range is expected to be much lower in lakes (0–185 mBq/1) and streams (185–3703 mBq/1). Radon content in surface water may be affected by several factors, such as the geology of the area, bottom sediments, inputs from streams, degree of water turbulence and temperature. For instance, the solubility of radon in water is 510 cm^3 kg^{-1} at 0°C and decreases at higher temperatures [12].

EXPERIMENTAL TECHNIQUE

We preferred to use passive technique as it is the most convenient method to determine radon concentrations over long periods of time. It is also useful for measuring radon levels based on the effects of seasonal, weather, and environmental conditions. For passive and time-integrated measurements, we used the track-etch technique [13–16] which involves Solid State Nuclear Track Detectors (SSNTD) as alpha track recorders. 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 is further classified into two categories based on the thickness of the cellulose nitrate layer. Type I films have a thickness of 6μm 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. LR 115 Type II is designed in such a way that it is sensitive to alphas energy range. 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.

The materials and methods used for experimental investigations of radon in this experiment are the same as reported by the authors in RRJoT [17], with only one difference that etched track holes were counted in LR-115 Type II, instead of track replicas etched on the polyester base, for estimation of track density ρ (tracks/cm^2).

The radon concentrations were estimated by collecting water samples from six different sources (five lakes and Fraser river) and isolating the samples for 30 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 a constant temperature bath using 2.5N NaOH solution for two hours at 60°C. Track density (no. of tracks/cm^2) was then determined using an optical microscope in our house-hold laboratory. The track count was converted into a radon concentration level in Bq/m^3 using the formula: C_{Rn}=ρ(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} [18, 19].

RESULTS OF RADON STUDY IN LAKES AND RIVER WATERS

Radon alpha tracks are recorded in LR-115 Type II detector as circular holes on the surface of the cellulose nitrate film detector after etching of radiation damage produced by alphas, as shown in the photomicrograph (Figure 1a). The track shape depends on the energy and angle of incidence of alpha tracks. Track counting was carried out in our laboratory using an ordinary student optical microscope with magnification of 400X 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, if we use a magnification of 40X. Radon concentration in water was estimated by using the formula [19]:

C_{Rn} (Bq/m^3) = (ρ/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).

Track density and radon concentration of different sources of water are plotted as histogram in Figure 2. Table 1 summarizes the values of both these parameters along with statistical error in random counting of tracks in all the six sources of water. The results show the highest value (161.50±9.04 Bq/m^3) of Radon concentration in the Como Lake of Coquitlam. The estimated value of Radon in Fraser River water is 48.45±3.88 Bq/m^3 which is lower than the value of Radon concentration in most of the Lakes. Statistical counting errors vary from 5.6 to 8.0 percent in the samples.

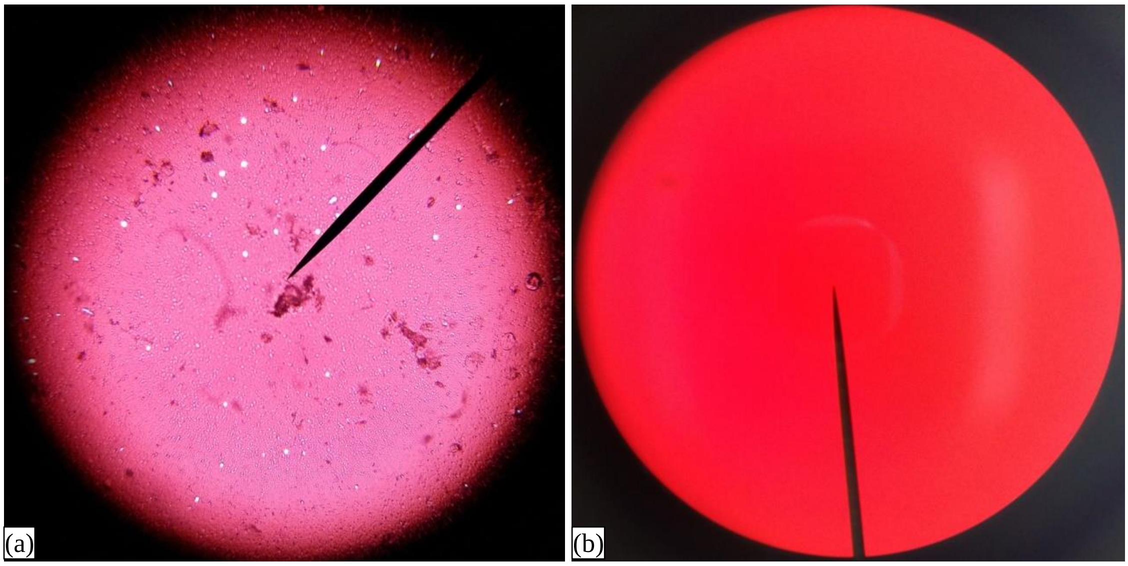

Figure 1. (a) Alpha track holes in LR-115 type II detector, (b) Unexposed detector without tracks.

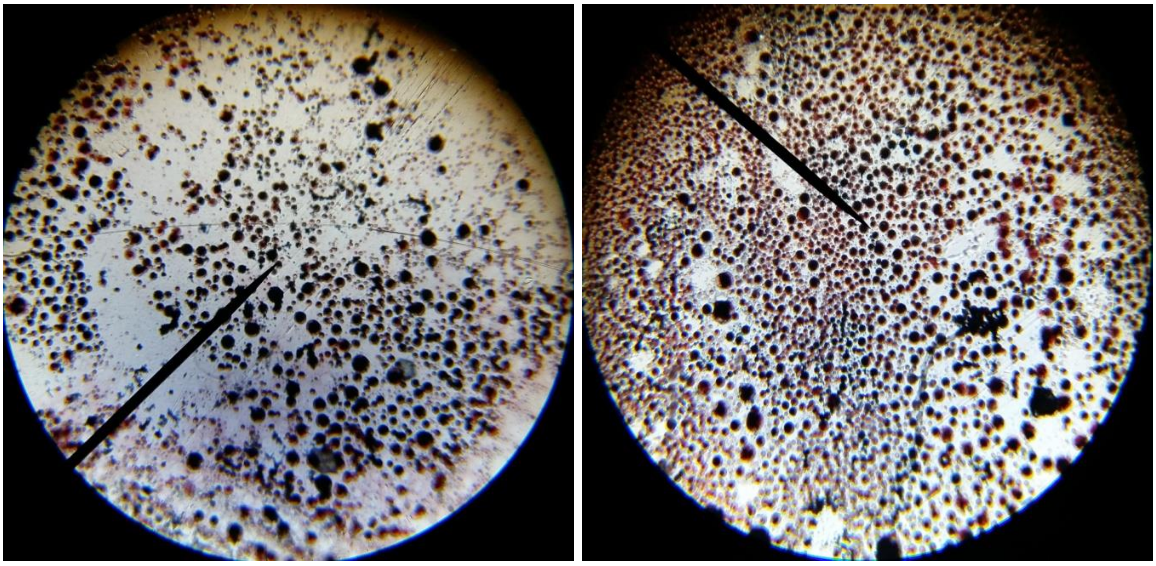

Figure 2. Cellulose Nitrate layer damaged due to over-etching of LR-115 type II detectors.

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

Water Source	Track Density (tracks/cm^2)	Radon Level (Bq/m^3)	Counting Error (%)
Como Lake (Coquitlam)	150	161.50±9.04	5.6
Mundi Lake (Coquitlam)	60	58.14±4.65	8.0
Okanagan Lake (Kelowna)	80	72.67±4.36	6.0
Skaha Lake (Penticton)	72	65.40±3.92	6.0
Wood Lake (Lake City)	40	36.34±2.91	8.0
Fraser River (Richmond)	50	48.45±3.88	8.0

Samples collected in the month of July 2021 were used for estimating the Radon activity levels in Lakes by etching the detectors in 2.5 N NaOH for 90 minutes at 60°C. Fraser River water sample was collected in October and the experiment was repeated in November by etching for 2 hours keeping the other conditions same. Some LR-115 Type II detector samples were damaged due to over-etching as shown in Figure 3. The Como Lake water sample was collected separately from Coquitlam and kept exposed for 27 days only while the other samples were exposed for 30 days. Track density was estimated by counting tracks per cm^2 per day of exposure.

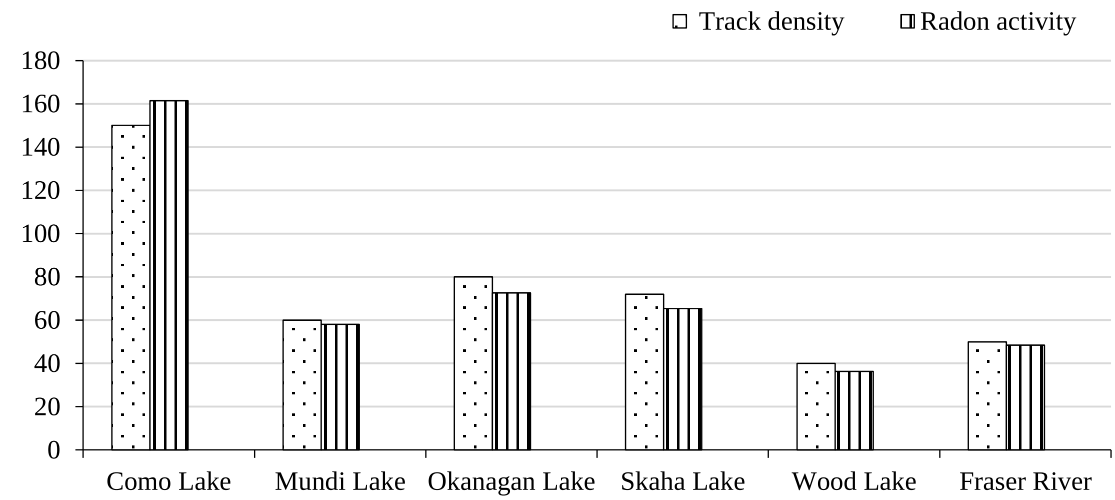

Figure 3. Histogram showing Track density and Radon levels in different water sources.

DISCUSSION OF RESULTS

The present study is focussed on water samples collected from different lakes of Kelowna region, for example, Okanagan Lake (Kelowna), Skaha Lake (Penticton) and Wood Lake (Lake City); Como Lake and Mundi Lake of Coquitlam County of Vancouver region, and Fraser River flowing near Richmond County of Vancouver in British Columbia (BC), Canada. There is hardly any data available on Radon concentration measurements in the Lakes and Rivers water of Canada where most residents of BC go for bathing and swimming in the summer months.

Our survey of literature fails to get any scientific report regarding Radon concentration in the water samples under investigation. In view of lack of data on Radon in water sources of the BC region, this study assumes significance for future investigations as the baseline data.

However, for sake of comparison, there are reports of Radon investigations in Lake, Spring and River waters in Malaysia and Turkey. Habila Nuhu et al. [20] reported Radon activity in water sources of Perak state, Malaysia in 2020 as follows: The activity concentration ranged from 0.08±0.12–0.45±0.27, 0.04±0.08–0.62±0.32, 0.33±0.23–3.98±0.39 Bq/l, with a mean of 0.24±0.19, 0.30±0.21, 1.26±0.34 Bq/l for lakes, hot springs, and rivers, respectively. The histogram in Figure 4 reports the highest Radon concentration in River water and the lowest value in the Lake water. Our results are just the opposite.

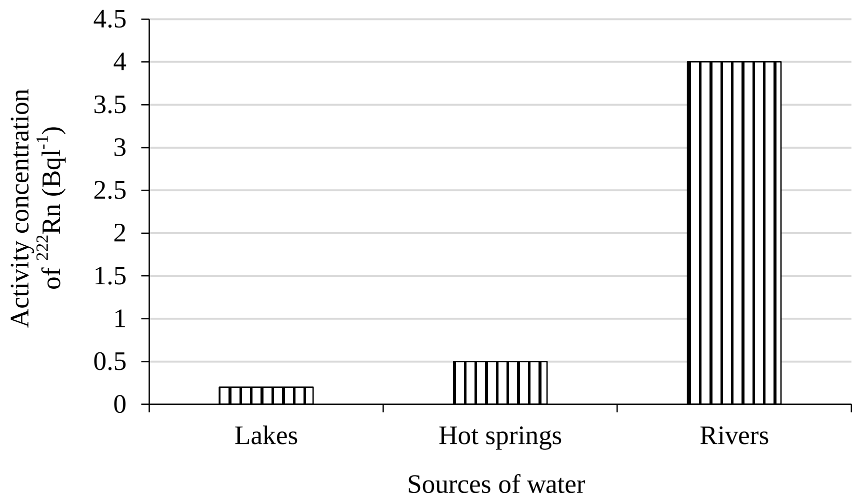

Figure 4. Variation of radon concentration in water sources from the study area [20].

Oner et al. from Turkey **[21]** report Radon activity in water sources of Amasya city. It was found that the concentrations in tap water, spring water and the Yesilirmak River water in Amasya ranged from 0.42±0.14 to 2.4±0.32 Bq/l, 0.39±0.19 to 1.17±0.21 Bq/1 and 0.28±0.04 to 1.0±80.30 Bq/1, respectively. Our Radon values for Fraser River are much lower than the value reported for Yasilirmak river of Turkey. Radon activity of the Lakes of British Columbia are comparable with the values of Radon (222Rn) concentration reported in the English Lake District by Al-Masiri and Blackburn [12].

Health Canada has published its reports on Uranium **[**22], Radon [23], and Environmental Radioactivity in Canada [24]. Radon survey report [25] 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─13700Bq/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".

Radiological aspects of radon are discussed in WHO (World Health Organisation) 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].

CONCLUSIONS

1. The purpose of this study is to create a data bank for future investigations.
2. Most of the Lakes in Kelowna, Penticton and Lake City are used as tourist spots for bathing. The Radon levels are within the safe limits set by the WHO.
3. The Radon concentration in the Como Lake of Coquitlam is found to be higher than other lakes of the BC Province. The reason for this high value needs to be investigated by undertaking geochemical and geomorphologic studies.
4. Fraser River water Radon levels are lower than Lake-water radon levels but higher than Wood Lake radon level.
5. Radon levels are much lower than the safe limits of the U.S. Environmental Protection Agency's standard guideline of radon levels (1100 Bq/m^3) in drinking water.
6. Meteorological parameters (temperature, pressure, humidity) play a predominant role in case of radon estimation in air and soil only. We ignored their influence in the present study dealing with radon conc. in surface water.

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APPENDIX

Description of Lakes

Okanagan Lake

It is a large, deep lake in the Okanagan Valley of British Columbia, Canada. The lake is 135 km long, between 4 and 5 km wide, and has a surface area of 348 km². Major inflows include Mission, Vernon, Trout, Penticton, Equesis, Kelowna, Peachland and Powers Creeks. The lake is drained by the Okanagan River, which exits the lake's south end via a canal through the city of Penticton to Skaha Lake, whence the river continues southwards into the rest of the South Okanagan and through Okanogan County, Washington to its confluence with the Columbia river in USA.

The lake's maximum depth is 232 metres (761 ft) near Grant Island. Some areas of the lake have up to 750 metres (2,460 ft) of glacial and post-glacial sediment fill which were deposited during the Pleistocene Epoch. Cities bordering the lake include Vernon in the north, Penticton in the south, and Kelowna, as well as the municipalities of Lake Country (north of Kelowna), West Kelowna (west of Kelowna), Peachland (south of West Kelowna), and Summerland (north-west of Penticton). Many parks and beaches are found along the shores of the lake, which make boating and swimming very popular activities.

Skaha Lake

It is historically known as Dog Lake and, prior to that, as Lac Du Chien, is a freshwater lake located in the Okanagan Valley and connected to Okanagan River by a 6.1 km long Penticton canal. It has a surface area of approximately 20 km^2, with a maximum depth of 55 metres. The lake is situated directly south of Okanagan Lake and forms the southern shoreline and boundary of the city of Penticton, British Columbia. The lake lies as the boundary between the Okanagan dry forests to the northeast and the Cascade Mountains to the west.

Como Lake

It is a small lake in Como Lake Park in the city of Coquitlam, British Columbia. It forms the headwaters of the Como watershed and is an urban fishing and recreation area in the city of Coquitlam as well as the Lower Mainland.

The small lake in central Coquitlam was originally shown as 'Welcome Lake' on maps as early as 1887 and subsequently changed to 'Como Lake' in 1912. There was a speculative “land boom” underway in 1912 and the name-change may have been made for marketing purposes. When the French Canadians arrived in the early 1900s to begin work and a new life at Fraser Mills, they brought with them their love of hockey and skating. Many early residents recall skating on Como Lake whenever an extended freezing spell thickened the ice. By the 1960s, the Como Lake had become a vibrant park for the growing community. The District introduced a playground, water taps, picnic tables, and trout for fishing.

Wood Lake

Wood Lake is a lake in a chain of five major lakes which occupies portions of the Okanagan Valley in the interior of British Columbia, Canada. The lakes of the Okanagan Valley were formed by about 8900 BP. Wood Lake is immediately south of Kalamalka Lake and in 1908 was connected to it by a dredged channel (the Oyama canal). Situated between Oyama and Winfield, it has a solid reputation for rainbow trout fishing. The lake is named after Tom Wood, who settled on the south end of the lake around 1860.

Mundi Lake

Mundy Lake and Nature Interpretive Trail Loop is a 2.4 km moderately trafficked loop trail located near Coquitlam, British Columbia, Canada that features a lake and is good for all skill levels. The trail is primarily used for hiking, nature trips, and bird watching and is accessible year-round.