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Review

A Summary of Natural Radionuclides in Canadian Public Water Supply Systems

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In an effort to better characterize natural radioactivity levels, including total uranium in public water supply systems, drinking water quality data were reviewed for 24 metropolitan areas and cities which cover more than 64% of the total Canadian population. Levels of radioactivity were generally found to be low compared to national and international guideline standards for drinking water quality. The population-weighted average levels are 0.0021 Bq/L for gross alpha, 0.042 Bq/L for gross beta, 0.0017 Bq/L for ^{226}Ra, 0.0068 Bq/L for ^{210}Pb, and 0.23 μg/L (0.0058 Bq/L) for total uranium. The average effective dose resulting from drinking water intake at these levels would be 4.2 μSv per year.

Key words: natural radionuclides, drinking water

1. Introduction

In Canada, the responsibility for ensuring drinking water supplies are safe is shared between the provincial, territorial, federal and municipal governments. The day-to-day responsibility of providing safe drinking water to the public generally rests with the provinces and territories, while municipalities usually oversee the day to day operations of the treatment facilities.

Radionuclides are naturally present in the environment. Natural sources of radiation are responsible for the large majority of radiation exposure (greater than 98%) to the public, excluding medical exposure. The occurrence of natural radionuclides in drinking water is associated most commonly with groundwater. The concentrations are highly variable and are determined by the composition of the underlying bedrock as well as the physical and chemical conditions prevailing in the aquifer. Increased levels of natural radionuclides in surface waters may be linked to industrial processes, particularly uranium mining and milling operations. The Canadian Guidelines for Drinking Water Quality[1] recommend that sampling and analyses for individual radionuclides should be carried out often enough to accurately characterize the annual exposure resulting from radionuclides in drinking water. If measured concentrations are consistent and well below the Maximum Acceptable Concentrations (MACs), sampling frequency can be reduced. In the Guidelines[1], the MACs are calculated using a reference dose level of 0.1 mSv for one year's consumption of drinking water, assuming a consumption of 2 L/day at the MAC.

When radiological characteristics are known for a water source, water samples could be routinely analysed for the presence of radioactivity using gross alpha and gross beta measurements rather than measurements of individual radionuclides. The screening levels are 0.5 Bq/L for gross alpha and 1 Bq/L for gross beta[1].

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In an effort to better characterize natural radioactivity levels, including total uranium in public water supply systems, drinking water quality data were reviewed. Results are summarized here.

2. Data Sources

Water in nature is never pure. Naturally occurring mineral deposits of uranium in the ground are predominantly responsible for the localization of radiological content in drinking water. In addition to gross alpha and beta measurements, some communities have monitored selected individual radionuclides. Almost all water supply systems have monitored total uranium because of the concern associated with the potentially high chemical toxicity for this element. The current review of radiological parameters in drinking water focuses on gross alpha, gross beta and activity concentrations of natural radionuclides in Bq/L, as well as total uranium in μg/L.

The review of drinking water quality was based on water testing reports of the most recent 5 years from major metropolitan areas of populations more than 300,000 and the capital cities of individual provinces and territories which cover more than 64% of the total Canadian population. For most cities, annual water quality reports were available for the most recent 5 years (2012 to 2016). When this was not the case, available reports of most recent years were reviewed. Test results were downloaded from official websites of individual cities, as listed in the appendix of Data Source References.

The radiological effects of multiple radionuclides in the same drinking water source are assumed to be additive. Therefore, when two or more radionuclides are present, the summation formula should be satisfied in order to demonstrate compliance with the Guidelines. For this reason, the Guidelines require that any testing procedure should aim to achieve a detection limit (DL) not greater than 20% of the MAC of any radionuclide likely to be present, assuming that no more than five radionuclides are likely to be present at concentrations approaching their respective MACs. Since all DLs should be low enough, when calculating the averages, zero value is assigned to all samples with non-detectable activity.

For cities with multiple water supply systems, the mean values of radiological measurements are calculated as weighted averages weighted by annual average flow rates in megalitres per day (ML/day).

For population-weighted averages, the 2016 Canadian population statistics were used[2]. Population-weighted averages were only made among cities where radiological measurements were conducted, excluding those results reported as "< MAC".

3. Results and Discussion

Radiological testing results are summarized in Table 1 for public water supply systems in a total of 24 metropolitan areas and cities. Gross alpha and gross beta measurements were reported in 9 out of 24 cities. The test results were generally well below the screening levels.

A few cities have monitored individual natural radionuclides commonly found in water sources, such as ^{226}Ra and ^{210}Pb. The MACs are 0.5 Bq/L for ^{226}Ra, and 0.2 Bq/L for ^{210}Pb[1]. Test results for ^{226}Ra and ^{210}Pb were either below detection limit or well below the respective MACs. Since only 5 cities provided test results for ^{226}Ra and ^{210}Pb, the population-weighted average levels for those two radionuclides may not be representative for all of Canada. However, the summary results do provide exposure levels to those two radionuclides for more than 5 million water consumers.

In the Canadian Guidelines for Drinking Water Quality[1], a guideline for radon in drinking water is not considered necessary, and has not been established. The health risk from ingesting radon-contained drinking water is considered negligible, because most of the radon escapes at the faucet or water outlet, leaving only minimal amounts in the water itself. However, if the radon level in drinking water is sufficiently elevated, it can affect airborne radon concentration indoors. Well-water systems in a few communities have measured radon levels in their treated water. Most testing results were below detection limits, except in 5 small well-water systems in Ottawa. The highest radon level measured was only 33 Bq/L in Kings Park Well system which provides 165 ML/day which represents about 0.057% of the total water production in the Ottawa area.

Based on their knowledge of the radiological characteristics of the drinking water sources, most cities have focused their testing on bacteria and chemical parameters. Concentrations of total uranium were, therefore, routinely reported in all cities except Charlottetown and Iqaluit. Generally speaking, uranium concentrations were well below the MAC of 20 μg/L[1]. Natural uranium is made of a mixture of three isotopes, 99.284% of ^{238}U, 0.711% of ^{235}U and 0.0053% of ^{234}U by mass[3]. A measurement of uranium mass in units μg/L would detect only ^{238}U. Among the natural isotopes of uranium, ^{234}U has the highest specific activity. By percentage activity, there is 48.9% of ^{238}U, 2.2% of ^{235}U and 48.9% of ^{234}U. The population-weighted average uranium concentration of 0.23 μg/L would have a total activity concentration of 5.8 mBq/L (2.84 mBq/L for ^{238}U, 0.12 mBq/L for ^{235}U and 2.84 mBq/L for ^{234}U).

In summary, the population-weighted average levels are 0.0021 Bq/L for gross alpha, and 0.042 Bq/L for gross beta. Results of gross alpha and gross beta are given

Table 1. Summary of natural radionuclides in drinking water supply systems.

City	Population x1000	Gross α Bq/L	Gross β Bq/L	^{226}Ra Bq/L	^{222}Rn Bq/L	^{210}Pb Bq/L	Uranium μg/L	Based on reports	Data Source Reference
Toronto (Ont.)	6,242.3	0.004 (<DL, 0.05)	0.06 (0.05, 0.11)				0.3 (0.2, 0.6)	2012 - 2016	1
Montréal (Que.)	4,093.8						0.35 (0.32, 0.38)	2012 - 2016	2
Vancouver (B.C.)	2,548.7	<DL	0.021 (<DL, 0.07)	<DL	<DL	0.013 (<DL, 0.16)	0.005 (<DL, 0.014)	2013 - 2016	3
Calgary (Alta.)	1,469.3			0.0028 (<DL, 0.01)	<DL		0.26 (<DL, 1.0)	2012 - 2016	4
Edmonton (Alta.)	1,392.6	<DL	0.011 (<DL, 0.11)	0.004 (<DL, 0.03)		<DL	0.1 (<DL, 0.6)	2012 - 2016	5
Ottawa (Ont.)	1,323.8	0.0012 (<DL, 0.24)	0.028 (<DL, 0.25)		9.5 (<DL, 33)		0.002 (<DL, 3)	2012 - 2016	6
Winnipeg (Man.)	811.9						0.04 (<DL, 0.5)	2012 - 2016	7
Québec (Que.)	807.2						<MAC	2015 - 2016	8
Hamilton (Ont.)	778.4						0.29 (0.03, 0.54)	2016	9
Kitchener-Cambridge-Waterloo (Ont.)	517.3						0.63 (<0.2, 2.26)	2012 - 2016	10
London (Ont.)	512.4						0.14 (0.032, 0.50)	2012 - 2016	11
Halifax (N.S.)	425.9	6.0E-5 (<DL, 0.3)	6.4E-5 (<DL, 0.4)			<DL (<0.02, <0.1)	0.0008 (<0.10, 10.5)	2012 - 2016	12
St. Catharines-Niagara (Ont.)	411.7						<DL	2014 - 2016	13
Oshawa (Ont.)	394.0						0.20 (<DL, 0.4)	2012 - 2016	14
Victoria (B.C.)	370.9	<DL	0.038 (<DL, 0.11)				<DL	2012 - 2016	15
Windsor (Ont.)	340.3						0.051 (0.007, 0.09)	2012 - 2016	16
Saskatoon (Sask.)	315.2	<DL	0.13 (<DL, 0.18)	<DL		<DL	1.6 (0.4, 14)	2012 - 2016	17
Regina (Sask.)	247.2			0.00014 (<DL, 0.0009)	<DL	0.0009 (<DL, 0.11)	0.4 (0.02, 1.6)	2012 - 2016	18, 19
St. John's (N.L.)	217.5	<DL	<DL				<DL	2016 winter - 2017 winter	20
Fredericton (N.B.)	58.2						0.03	2016	21
Charlottetown (PEI)	44.7							2012 - 2016	22
Whitehorse (YK)	25.1	0.017 (<DL, 0.033)					0.37 (<DL, 2.6)	1999-2002, 2013	23
Yellowknife (NWT)	19.6						0.2	2010 - 2014	24
Iqaluit (NU)	7.7							2012	25
Population weighted mean		0.0021	0.042	0.0017	2.3	0.0068	0.23		

here for monitoring information only. For individual radionuclides, the population-weighted average levels are 0.0017 Bq/L for ^{226}Ra, 2.3 Bq/L for ^{222}Rn, 0.0068 Bq/L for ^{210}Pb, and 0.23 μg/L (0.0058 Bq/L) for total uranium. The average effective ingestion dose resulting from radionuclides found in drinking water at these levels would be 4.2 μSv per year[4].

4. Conclusions

Canadian drinking water supplies are generally of excellent quality. However, water in nature is never pure. Radionuclides are naturally present in the environment. Drinking water quality data on radiological parameters were reviewed for the most recent 5 years reported from major metropolitan areas of populations more than 300,000 and the capital cities of individual provinces and territories which cover more than 64% of the total Canadian population. Population-weighted averages indicate that Canadians are typically exposed to 1.7 mBq/L of ^{226}Ra, 6.8 mBq/L of ^{210}Pb, and 0.23 μg/L of total uranium in drinking water from publicly-operated systems. The annual effective dose resulting from natural radionuclides in drinking water, assuming drinking water intake of 2 L per day, would be 4.2 μSv, which is a relatively small contribution to the typical annual effective dose due to natural background radiation which is in the range of 1–10 mSv with 2.4 mSv being the central estimate[5].

By providing a better understanding of background exposures, this summary will contribute to the population dose assessment due to background radiation, the environmental impact assessment of future activities/projects, and radiological emergency preparedness and response.

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Appendix - Data Source References

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