

Drinking and recreational water exposures among Canadians: Foodbook Study 2014–2015

Rachelle Janicki, M. Kate Thomas, Katarina Pintar, Manon Fleury and Andrea Nesbitt

ABSTRACT

In Canada, over 400,000 enteric diseases related to drinking water occur each year, highlighting the importance of understanding sources of Canadians' drinking and recreational water exposures. To address this need, a population-based telephone survey of 10,942 Canadians was conducted between 2014 and 2015, assessing Canadian's drinking water sources and recreational water exposures using a seven-day recall method. Results were analyzed by province/territory, season, age group, gender, income, education, and urban/rural status. Store-bought bottled water was reported by nearly 20% of survey respondents as their primary drinking water source, while approximately 11% of respondents reported private well. The proportion of private well users was significantly greater than the national average in the Maritime Provinces where approximately 40–56% of respondents reported this as their primary drinking water source. As expected, Canadians' recreational water activities and exposures (e.g., swimming, pool, lake, and waterpark) peaked during summer and were most commonly reported among children aged 0–9 years. Waterborne disease in Canada requires a multi-faceted public health approach. Canadian baseline data on water exposures can inform policy and public health strategies (e.g., recreational water guidelines, private well water testing recommendations) and support research and risk assessment related to mitigating waterborne illness.

Key words | bottled water, drinking water, enteric disease, Foodbook, recreational water, waterborne disease

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INTRODUCTION

While water quality and waterborne disease are often a greater concern in developing nations, a waterborne disease burden exists in developed nations. There are an estimated 20.5 million episodes of enteric disease in Canada each year (Thomas *et al.* 2013), of which, over 400,000 are estimated to be related to drinking water (Murphy *et al.* 2016a, 2016b). The

burden of waterborne disease is often underestimated due to the under-reporting and under-diagnosis of enteric disease (MacDougall *et al.* 2008). Understanding this burden and the main sources of risk associated with drinking and recreational water is critical for public health to better understand the health risks and develop prevention strategies.

Exposure to recreational water is a risk factor for a number of enteric diseases (Fewtrell & Kay 2015). However, the burden of enteric disease associated with recreational water exposures in Canada has yet to be estimated. Accurately determining these exposures, particularly among

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high-risk subgroups of the Canadian population, such as young children, the elderly, and the immunocompromised, is important (Colford *et al.* 2009).

To address the gaps related to water exposures among Canadians, a national survey (Foodbook) was developed and administered in 2014–2015 across Canada. The survey included questions related to drinking and recreational water exposures across various subgroups of the Canadian population, providing valuable baseline data for public health use. The analysis and results described here explore differences between provinces and territories, season, age, household income, education level, and urban/rural status with a focus on three key exposures: recreational water, bottled water, and private wells.

METHODS

Survey design and data collection

Foodbook is a population-based telephone survey conducted in all Canadian provinces and territories from April 2014 to April 2015. The study design and sampling methodology for the Foodbook Study has been described elsewhere (Public Health Agency of Canada 2015). The Foodbook Study was reviewed and approved by Health Canada and the Public Health Agency of Canada's Research Ethics Board (REB 2013-0025) as well as the Newfoundland and Labrador Health Research Ethics Authority to meet a unique provincial legal requirement (HREB 13.238).

Survey participants were asked 23 questions related to water exposure categories: primary drinking water sources (i.e., municipal water, private well water, bottled water, raw water, etc.) and contact with recreational water (i.e., swimming pools, hot tubs, waterparks, lakes, oceans, rivers, hot springs, etc.). The full set of water exposure-related questions is available in Appendix A (available with the online version of this paper).

Analysis

Data were cleaned and analyzed using Stata 14.0 for Windows (StataCorp. 2015) using the survey weight provided by the research company. If respondents answered either

'don't know' or 'refused to answer' to a particular question, these responses were excluded from the analysis of that question. Urban or rural status of respondents was derived from the Census Metropolitan Area (CMA) variable, with urban corresponding to a respondent reporting living within a CMA and rural corresponding to a respondent not reporting living within a CMA. Proportions were weighted using the survey weight available on the data file, as described in the Foodbook Report (Public Health Agency of Canada 2015). Using the Wald chi-square test to assess statistical significance with a p-value cut-off of <0.05, an individual level of a group was compared to the average of all other levels of that group when looking at results by province/territory and urban/rural status. For example, the proportion of British Columbia respondents reporting municipal water as their primary drinking water source was compared to the proportion of respondents from all other provinces and territories, excluding British Columbia, who reported this same exposure. When looking at results by season, household income, education level, age group, and gender, logistic regression was performed using a p-value cut-off of <0.05 to assess statistical significance. Generalized linear models were used instead when sample size per cell was less than five for any individual level of a group.

RESULTS

A total of 10,942 participants completed the telephone survey; the demographics of survey respondents are shown in Appendix B (available with the online version of this paper). All exposure estimates included have been weighted so as to be representative of the Canadian population as reported by the 2011 Census. Only select significant results have been described, with full results available in Tables 1–6 and Appendix C (available online).

DRINKING WATER EXPOSURES

Province and territory

Store-bought bottled water as a primary drinking water source was reported by 18.8% (95% CI 17.0–20.7) of

Table 1 | Weighted reported water sources and recreational water exposure with 95% CIs in the past seven days by province, territory, and nationally for Foodbook, 2014–2015

| Exposure | BC | AB | SK | MB | ON | QC | NB | NS | PE | NL | YT | NT | NU | Canada |
|-----------------------------|-----------------------|-----------------------|---------------------|---------------------|----------------------|---------------------|---------------------|-----------------------|---------------------|-----------------------|-----------------------|----------------------|-----------------------|----------------------|
| Recreational water exposure | | | | | | | | | | | | | | |
| Swim or go into any water | 18.6* (13.8, 24.6) | 12.9 (10.4, 15.8) | 9.8* (7.4, 13.0) | 10.7 (7.9, 14.4) | 13.4 (10.7, 16.6) | 11.4 (9.2, 14.0) | 12.9 (9.2, 17.8) | 10.7 (7.8, 14.5) | 11.4 (7.9, 16.3) | 9.1* (6.5, 12.7) | 21.4* (14.6, 30.2) | 12.6 (9.0, 17.4) | 1.2* (0.4, 3.4) | 13.2 (11.7, 14.8) |
| Ocean | 6.7* (3.0, 14.5) | 0.1* (0.0083, 0.4) | 0.0 (-) | 0.0 (-) | 0.5* (0.07, 2.8) | 0.1* (0.03, 0.3) | 0.8 (0.4, 1.7) | 3.5* (2.0, 6.1) | 3.8 (1.9, 7.6) | 0.8 (0.3, 1.7) | 0.4 (0.05, 2.6) | 0.0 (-) | 0.0 (-) | 1.2 (0.6, 2.4) |
| Lake | 3.3 (2.2, 4.8) | 1.7* (1.2, 2.6) | 2.6 (1.4, 5.0) | 2.2 (1.4, 3.5) | 3.0 (2.0, 4.5) | 2.4 (1.5, 3.8) | 2.1 (0.8, 5.3) | 2.0 (1.1, 3.5) | 0.3* (0.07, 1.1) | 2.1 (1.1, 3.8) | 3.2 (1.5, 6.4) | 1.9 (1.0, 3.4) | 0.7* (0.1, 3.0) | 2.6 (2.1, 3.3) |
| River | 0.9 (0.6, 1.6) | 0.8 (0.3, 2.2) | 0.0 (-) | 0.4 (0.1, 1.0) | 0.9 (0.3, 2.4) | 0.7 (0.3, 1.3) | 1.7 (0.7, 4.3) | 0.8 (0.2, 2.4) | 0.6 (0.2, 1.5) | 1.5 (0.8, 2.9) | 0.9 (0.3, 2.5) | 1.4 (0.4, 4.4) | 0.06* (0.009, 0.5) | 0.8 (5.1, 1.3) |
| Natural hot spring | 0.2 (0.04, 0.9) | 0.1 (0.03, 0.7) | 0.0 (-) | 0.0 (-) | 0.5 (0.07, 2.8) | 0.2 (0.07, 0.8) | 0.0 (-) | 0.0 (-) | 0.0 (-) | 0.3 (0.07, 1.2) | 2.1 (0.8, 5.4) | 0.0 (-) | 0.0 (-) | 0.3 (0.08, 0.9) |
| Pool | 13.0 (8.6, 19.3) | 10.2 (8.0, 12.9) | 5.5* (4.3, 7.1) | 8.3 (5.7, 11.8) | 9.4 (7.2, 12.2) | 9.5 (7.5, 11.9) | 9.0 (6.1, 13.1) | 7.3 (5.0, 10.5) | 7.6 (4.9, 11.5) | 6.6* (4.4, 9.7) | 15.0 (9.1, 23.8) | 10.0 (6.9, 14.3) | 0.6* (0.2, 2.5) | 9.7 (8.5, 11.1) |
| Public pool | 7.6 (5.8, 9.9) | 9.3* (7.2, 12.0) | 4.4* (3.3, 5.8) | 4.4* (3.3, 5.9) | 6.1 (4.4, 8.4) | 4.3* (3.1, 6.0) | 4.3 (2.6, 7.1) | 4.6 (2.8, 7.3) | 4.8 (2.7, 8.4) | 5.4 (3.4, 8.5) | 14.7 (8.8, 23.6) | 9.8 (6.7, 14.1) | 0.6* (0.2, 2.5) | 6.0 (5.2, 7.0) |
| Private pool | 3.1 (1.1, 8.1) | 0.4* (0.2, 0.8) | 0.9* (0.5, 1.6) | 1.3* (0.7, 2.6) | 2.8 (1.7, 4.8) | 4.9* (3.4, 6.9) | 4.5 (2.5, 8.0) | 2.4 (1.3, 4.7) | 2.7 (1.4, 4.9) | 1.0* (0.5, 1.9) | 0.2* (0.2, 1.2) | 0.6* (0.2, 2.0) | 0.0 (-) | 3.0 (2.3, 3.9) |
| Commercial pool | 2.6 (0.5, 13.5) | 1.2 (0.4, 3.2) | 0.6 (0.2, 1.6) | 2.9 (1.1, 7.1) | 0.9 (0.5, 1.5) | 0.6 (0.3, 1.5) | 0.6 (0.3, 1.7) | 0.4 (0.2, 0.9) | 0.7 (0.3, 1.5) | 0.5 (0.2, 1.8) | 0.0 (-) | 0.6 (0.1, 2.8) | 0.0 (-) | 1.1 (0.6, 2.0) |
| Indoor pool | 7.5 (5.7, 9.8) | 8.6* (6.6, 11.1) | 4.1* (3.0, 5.5) | 5.8 (3.6, 9.3) | 5.7 (4.3, 7.4) | 4.1* (3.0, 5.6) | 3.8 (2.1, 6.6) | 3.7* (2.5, 5.6) | 4.6 (2.6, 8.2) | 5.1 (3.4, 7.7) | 14.2* (8.3, 23.1) | 9.6* (6.5, 13.9) | 0.6* (0.2, 2.5) | 5.7 (5.0, 6.5) |
| Outdoor pool | 6.1 (2.5, 13.99) | 1.9* (1.1, 3.3) | 1.8* (1.1, 2.9) | 2.6 (1.7, 4.1) | 3.9 (2.4, 6.5) | 5.6 (4.0, 7.7) | 5.5 (3.4, 9.0) | 3.6 (1.9, 6.7) | 3.1 (1.7, 5.3) | 1.6* (0.6, 4.1) | 0.8* (0.3, 2.2) | 0.8* (0.3, 2.2) | 0.0 (-) | 4.2 (3.2, 5.5) |
| Hot tub | 5.7* (4.2, 7.8) | 6.6* (4.7, 9.0) | 3.8 (2.6, 5.4) | 4.3 (2.2, 8.0) | 3.4 (2.1, 5.4) | 1.3* (0.8, 2.0) | 2.0 (1.0, 4.3) | 1.0* (0.4, 2.3) | 1.9* (1.0, 3.3) | 1.1* (0.5, 2.4) | 12.3* (6.6, 21.7) | 6.3 (3.8, 10.3) | 0.0 (-) | 3.5 (2.8, 4.2) |
| Public hot tub | 3.8* (2.7, 5.3) | 4.4* (2.9, 6.5) | 1.7 (1.0, 2.7) | 0.7* (0.4, 1.3) | 1.4 (0.7, 2.8) | 0.2* (0.04, 0.5) | 0.3* (0.1, 1.1) | 0.06* (0.008, 0.4) | 1.2 (0.6, 2.4) | 0.4* (0.1, 1.3) | 10.2* (5.0, 19.8) | 6.3* (3.8, 10.3) | 0.0 (-) | 1.7 (1.3, 2.2) |
| Private hot tub | 1.7 (0.8, 3.5) | 1.6 (0.9, 3.0) | 1.8 (1.0, 3.2) | 1.1 (0.6, 1.9) | 1.8 (0.9, 3.6) | 1.0 (0.6, 1.7) | 1.5 (0.5, 3.9) | 0.8 (0.3, 2.3) | 0.6* (0.2, 1.7) | 0.6* (0.2, 2.0) | 2.2 (0.8, 5.9) | 0.0 (-) | 0.0 (-) | 1.5 (1.1, 2.1) |
| Commercial hot tub | 0.3 (0.2, 0.7) | 1.1 (0.4, 3.1) | 0.3 (0.07, 0.8) | 2.6 (0.9, 7.1) | 0.3 (0.1, 1.0) | 0.1* (0.03, 0.6) | 0.3 (0.06, 1.1) | 0.1* (0.03, 0.5) | 0.1* (0.02, 0.7) | 0.05* (0.007, 0.4) | 0.0 (-) | 0.0 (-) | 0.0 (-) | 0.4 (0.3, 0.7) |
| Indoor hot tub | 4.0* (2.9, 5.5) | 4.0* (2.8, 5.8) | 1.9 (1.2, 2.8) | 3.4 (1.5, 7.4) | 1.6 (0.8, 3.0) | 0.4* (0.2, 0.8) | 0.6* (0.2, 1.5) | 0.2* (0.06, 0.6) | 1.5 (0.8, 2.7) | 0.7* (0.3, 2.2) | 10.5* (5.2, 20.0) | 5.1* (3.4, 7.7) | 0.0 (-) | 1.9 (1.5, 2.4) |
| Outdoor hot tub | 1.8 (0.9, 3.6) | 2.6 (1.4, 4.6) | 1.9 (1.0, 3.4) | 0.9 (0.5, 1.5) | 1.8 (0.9, 3.6) | 0.9 (0.5, 1.6) | 1.5 (0.5, 3.9) | 0.8 (0.3, 2.3) | 0.4* (0.1, 1.5) | 0.2* (0.05, 0.8) | 1.9 (0.6, 5.7) | 1.3 (0.2, 8.4) | 0.0 (-) | 1.6 (1.1, 2.2) |
| Recreational waterpark | 1.3 (0.9, 1.9) | 1.6 (0.8, 3.2) | 1.9 (1.3, 2.8) | 1.2 (0.7, 2.0) | 1.7 (0.7, 3.8) | 1.9 (1.0, 3.8) | 1.1 (0.4, 3.3) | 0.7* (0.3, 1.4) | 0.8 (0.3, 2.6) | 1.3 (0.4, 3.9) | 1.4 (0.7, 2.7) | 1.8 (0.4, 7.1) | 0.0 (-) | 1.6 (1.1, 2.4) |
| Indoor waterpark | 0.6 (0.3, 1.0) | 1.4 (0.6, 3.1) | 1.3* (0.8, 2.1) | 0.2 (0.05, 0.7) | 0.07* (0.02, 0.2) | 0.5 (0.09, 2.4) | 0.0 (-) | 0.2 (0.05, 0.5) | 0.4 (0.09, 1.6) | 0.1* (0.009, 0.5) | 1.1 (0.5, 2.2) | 1.7 (0.4, 7.2) | 0.0 (-) | 0.4 (0.2, 0.7) |
| Outdoor waterpark | 0.7 (0.5, 1.2) | 0.2* (0.09, 0.5) | 0.7 (0.3, 1.3) | 1.0 (0.6, 1.7) | 1.6 (0.7, 3.8) | 1.5 (0.7, 3.0) | 1.1 (0.4, 3.3) | 0.5 (0.2, 1.2) | 0.5 (0.08, 2.6) | 1.2 (0.4, 3.9) | 0.3* (0.08, 1.4) | 0.08* (0.01, 0.6) | 0.0 (-) | 1.2 (0.7, 2.0) |

(continued)

Table 1 | continued

| Exposure | BC | AB | SK | MB | ON | QC | NB | NS | PE | NL | YT | NT | NU | Canada |
|---|--------------------|--------------------|--------------------|-------------------|-------------------|--------------------|--------------------|--------------------|--------------------|-------------------|--------------------|-------------------|-------------------|-------------------|
| Swim or go into a swimming facility in the last 4 weeks | 25.5* (20.4, 31.3) | 23.1 (18.7, 28.3) | 18.5 (14.7, 23.0) | 17.3 (13.7, 23.0) | 20.4 (16.5, 25.0) | 13.5* (10.9, 16.6) | 15.2 (11.0, 16.6) | 19.1 (12.8, 27.4) | 15.1 (11.0, 20.5) | 18.5 (13.4, 25.0) | 28.8* (20.8, 38.4) | 22.2 (17.2, 28.3) | 4.0* (1.8, 8.7) | 19.4 (17.4, 21.4) |
| Primary drinking water source | | | | | | | | | | | | | | |
| Municipal water | 77.9* (73.5, 81.8) | 74.6* (70.4, 78.4) | 66.5 (60.9, 71.7) | 63.4 (57.2, 69.3) | 69.5 (64.9, 73.8) | 66.9 (62.9, 70.7) | 33.5* (27.1, 40.6) | 45.2* (37.3, 53.3) | 34.1* (27.2, 41.9) | 63.7 (55.5, 71.2) | 63.4 (53.1, 72.7) | 71.8 (62.2, 79.8) | 76.0 (67.3, 83.0) | 68.5 (66.4, 70.6) |
| Private well | 7.1* (5.3, 9.4) | 6.3* (4.7, 8.3) | 7.2* (5.6, 9.3) | 14.3 (10.2, 19.9) | 8.9* (7.0, 11.2) | 10.2 (7.8, 13.2) | 46.3* (38.7, 54.1) | 40.2* (32.6, 48.2) | 55.7* (47.1, 63.9) | 13.4 (9.4, 18.7) | 18.5* (13.0, 25.6) | 0.1* (0.03, 0.6) | 2.3* (0.9, 5.8) | 10.8 (9.7, 12.0) |
| Store-bought bottled water | 12.1* (9.0, 16.0) | 17.6 (14.3, 21.4) | 24.4* (19.6, 30.1) | 19.5 (15.4, 24.2) | 19.8 (16.1, 24.1) | 21.6 (18.5, 25.1) | 18.4 (12.9, 25.6) | 12.4* (8.8, 17.1) | 9.9* (5.5, 17.2) | 17.0 (11.8, 23.9) | 9.6* (3.7, 22.8) | 17.6 (12.8, 23.7) | 7.3* (4.2, 12.4) | 18.8 (17.0, 20.7) |
| Other water source | 2.9 (1.8, 4.8) | 1.6 (1.0, 2.4) | 1.8 (1.2, 2.8) | 2.8 (1.8, 4.2) | 1.8 (1.1, 2.8) | 1.3 (0.6, 2.7) | 1.8 (0.7, 4.7) | 2.3 (1.1, 4.7) | 3.2* (0.1, 0.9) | 5.9 (2.3, 14.6) | 8.5* (4.0, 16.9) | 10.4 (4.3, 22.9) | 14.3* (8.5, 25.2) | 1.9 (1.5, 2.4) |

*Significant at $p < 0.05$.

Table 2 | Weighted reported water sources and recreational water exposure in the past seven days, by urban and rural residency, Foodbook, 2014–2015

| Exposure | Urban (%) | 95% CI | Rural (%) | 95% CI |
|---|-----------|--------------|-----------|------------|
| Recreational water exposure | | | | |
| Swim or go into any water | 13.0 | 11.1, 15.1 | 13.6 | 11.9, 15.6 |
| Ocean | 1.3 | 0.6, 3.1 | 1.0 | 0.6, 1.7 |
| Lake | 1.7* | 1.2, 2.4 | 4.7* | 3.6, 6.2 |
| River | 0.7 | 3.2, 1.4 | 1.1 | 0.7, 1.7 |
| Natural hot spring | 0.3 | 0.06, 1.4 | 0.2 | 0.08, 0.6 |
| Any pool | 10.4* | 8.8, 12.4 | 8.0* | 6.8, 9.5 |
| Public pool | 6.7 | 5.5, 8.1 | 4.6* | 3.9, 5.4 |
| Private pool | 2.9 | 2.0, 4.1 | 3.2 | 2.3, 4.5 |
| Commercial pool | 1.3 | 0.7, 2.7 | 0.6 | 0.3, 1.2 |
| Other type of pool | 0.0 | 0.0002, 0.01 | 0.1 | 0.01, 0.3 |
| Indoor pool | 6.4* | 5.4, 7.5 | 4.2* | 3.4, 5.0 |
| Outdoor pool | 4.3 | 3.0, 6.2 | 4.1 | 3.1, 5.4 |
| Any hot tub | 3.6 | 2.7, 4.7 | 3.2 | 2.5, 4.0 |
| Public hot tub | 1.7 | 1.2, 2.5 | 1.5 | 1.1, 1.9 |
| Private hot tub | 1.5 | 0.9, 2.4 | 1.5 | 1.0, 2.3 |
| Commercial hot tub | 0.5 | 0.6, 0.9 | 2.5 | 0.1, 0.5 |
| Indoor hot tub | 2.0 | 1.4, 2.8 | 1.7 | 1.3, 2.1 |
| Outdoor hot tub | 1.6 | 1.0, 2.5 | 1.6 | 1.0, 2.4 |
| Any recreational waterpark | 1.9 | 1.1, 3.0 | 1.1 | 0.8, 1.5 |
| Indoor waterpark | 0.4 | 0.2, 0.9 | 0.4 | 0.2, 0.5 |
| Outdoor waterpark | 1.4 | 0.8, 2.6 | 0.7 | 0.5, 1.2 |
| Swim or go into a swimming facility in the last 4 weeks | 20.9* | 18.3, 23.8 | 15.8* | 13.9, 17.8 |
| Primary drinking water source | | | | |
| Municipal water | 77.2* | 74.5, 79.7 | 49.0* | 45.9, 52.2 |
| Private well | 4.1* | 3.2, 5.3 | 25.9* | 23.3, 28.6 |
| Store-bought bottled water | 17.3* | 15.0, 19.9 | 21.9* | 19.6, 24.5 |
| Other water source | 1.4* | 1.0, 2.0 | 3.2* | 2.5, 4.1 |

*Significant at $p < 0.05$.

respondents nationally. Respondents from British Columbia, Nova Scotia, Nunavut, Prince Edward Island, and Yukon were less likely ($p < 0.05$) while respondents from Saskatchewan were more likely (OR 24.4; 95% CI 19.6–30.1; $p < 0.05$)

Table 3 | Odds ratios of weighted reported recreational water exposures in the past seven days, by season with summer as the referent group, Foodbook, 2014–2015

| Exposure | Spring | 95% CI | Fall | 95% CI | Winter | 95% CI |
|---|-----------|--------------|-----------|------------|-----------|--------------|
| | (Mar–May) | | (Sep–Nov) | | (Dec–Feb) | |
| Swim or go into any water (days) | 0.3* | 0.2, 0.4 | 0.2* | 0.2, 0.3 | 0.2* | 0.1, 0.2 |
| Ocean | 0.05* | 0.01, 0.2 | 0.1* | 0.03, 0.4 | 0.02* | 0.005, 0.1 |
| Lake | 0.01* | 0.005, 0.03 | 0.1* | 0.1, 0.2 | 0.003* | 0.0004, 0.02 |
| River | 0.02* | 0.005, 0.1 | 0.1* | 0.05, 0.4 | 0.006* | 0.001, 0.05 |
| Natural hot spring | 0.04* | 0.005, 0.2 | 0.05* | 0.006, 0.5 | 0.04* | 0.006, 0.3 |
| Any pool | 0.4* | 0.3, 0.6 | 0.3* | 0.2, 0.4 | 0.3* | 0.2, 0.4 |
| Public pool | 0.9 | 0.6, 1.3 | 0.6* | 0.4, 0.9 | 0.5* | 0.3, 0.8 |
| Private pool | 0.07* | 0.04, 0.1 | 0.1* | 0.1, 0.2 | 0.03* | 0.01, 0.1 |
| Commercial pool | 0.5 | 0.1, 2.3 | 0.4 | 0.08, 2.0 | 0.6 | 0.1, 2.7 |
| Other type of pool | – | – | 11.9 | 0.9, 164.1 | 3.3 | 0.2, 47.0 |
| Indoor pool | 1.8* | 1.2, 2.7 | 1.1 | 0.7, 1.7 | 1.1 | 0.7, 1.7 |
| Outdoor pool | 0.04* | 0.02, 0.08 | 0.07* | 0.04, 0.1 | 0.008* | 0.003, 0.02 |
| Any hot tub | 0.6 | 0.4, 1.1 | 0.5* | 0.3, 0.9 | 0.5* | 0.3, 0.9 |
| Public hot tub | 0.7 | 0.4, 1.5 | 0.7 | 0.3, 1.6 | 0.5 | 0.2, 1.1 |
| Private hot tub | 0.4 | 0.1, 1.2 | 0.4* | 0.1, 0.9 | 0.4* | 0.2, 0.9 |
| Commercial hot tub | 2.6 | 1.0, 7.0 | 2.0 | 0.4, 8.7 | 4.2* | 1.4, 12.7 |
| Indoor hot tub | 0.9 | 0.5, 1.7 | 0.6 | 0.3, 1.4 | 0.8 | 0.4, 1.6 |
| Outdoor hot tub | 0.4 | 0.1, 1.2 | 0.4 | 0.2, 1.0 | 0.3* | 0.2, 0.7 |
| Any recreational waterpark | 0.1* | 0.05, 0.2 | 0.2* | 0.08, 0.6 | 0.06* | 0.03, 0.1 |
| Indoor waterpark | 3.2* | 0.5, 6.8 | 5.4* | 1.6, 18.6 | 1.9 | 0.8, 4.5 |
| Outdoor waterpark | 0.001* | 0.002, 0.009 | 0.06* | 0.02, 0.2 | – | – |
| Swim or go into a swimming facility in the last 4 weeks | 0.5* | 0.4, 0.7 | 0.7* | 0.5, 1.0 | 0.4* | 0.3, 0.5 |

*Significant at $p < 0.05$.

to report this exposure compared to the remaining provinces and territories as a group. Nationally, 10.8% (95% CI 9.7–12.0) of respondents reported private well as their primary drinking water source. Respondents from Prince Edward Island, New Brunswick, Nova Scotia, Yukon, the Northwest Territories, and Nunavut were more likely, while respondents from British Columbia, Alberta, Saskatchewan, and Ontario were less likely to report this exposure when individually compared to the remaining provinces and territories as a group ($p < 0.05$) (Table 1).

Urban/rural status

Rural respondents (21.9%; 95% CI 19.6–24.5; $p = 0.01$) were more likely to report store-bought bottled water as their primary drinking water source than urban respondents (17.3%;

95% CI 15.0–19.9; $p = 0.01$). Rural respondents (25.9%; 95% CI 23.3–28.6; $p < 0.01$) were also more likely to report private well as their primary drinking water source compared to urban respondents (4.1%; 95% CI 3.2–5.3; $p < 0.01$) (Table 2). The weighted proportions of respondents reporting each primary drinking water source by either urban or rural status and by province/territory are shown in Figures 1 and 2.

Drinking water treatments

Respondents reporting private well as their primary drinking water source were most likely to report using some type of in-home drinking water treatment (44.5%; 95% CI 39.1–50.0; $p < 0.01$), followed by respondents reporting municipal water as their primary drinking water source (37.0%; 95% CI 34.0–40.1; $p < 0.01$) (Figure 3).

Table 4 | Odds ratios of weighted reported recreational water exposure in the past seven days, by age group with ages 20–64 years as the referent group, Foodbook, 2014–2015

| Exposure | 0–9 years | 95% CI | 10–19 years | 95% CI | 65+ years | 95% CI |
|---|-----------|-----------|-------------|------------|-----------|------------|
| Swim or go into any water | 4.2* | 3.2, 5.6 | 2.3* | 1.7, 3.1 | 0.4* | 0.3, 0.6 |
| Ocean | 1.0 | 0.4, 2.5 | 0.7 | 0.2, 1.8 | 0.2* | 0.05, 0.6 |
| Lake | 2.7* | 1.7, 4.3 | 2.2* | 1.3, 3.6 | 0.4* | 0.2, 0.8 |
| River | 1.5 | 0.6, 3.5 | 1.7 | 0.8, 4.2 | 2.0* | 0.06, 0.7 |
| Natural hot spring | 0.5 | 0.07, 3.0 | 0.3 | 0.05, 1.9 | 0.07* | 0.01, 0.5 |
| Any pool | 5.3* | 3.8, 7.6 | 2.7* | 1.9, 3.9 | 0.5* | 0.3, 0.7 |
| Public pool | 7.5* | 4.9, 11.5 | 3.2* | 2.0, 5.0 | 0.4* | 0.2, 0.7 |
| Private pool | 2.8* | 1.6, 5.0 | 2.2* | 1.2, 4.0 | 0.6 | 0.3, 1.2 |
| Commercial pool | 1.7 | 0.6, 4.9 | 1.2 | 0.4, 3.7 | 0.4 | 0.1, 1.4 |
| Other type of pool | 0.5 | 0.03, 6.4 | 1.4 | 0.09, 21.0 | – | – |
| Indoor pool | 8.6* | 5.8, 12.7 | 3.8* | 2.5, 5.7 | 0.7 | 0.4, 1.1 |
| Outdoor pool | 2.3* | 1.4, 3.9 | 1.7 | 1.0, 3.0 | 0.3* | 0.2, 0.6 |
| Any hot tub | 2.5* | 1.6, 3.8 | 2.1* | 1.3, 3.3 | 0.4* | 0.2, 0.7 |
| Public hot tub | 3.3* | 1.8, 6.2 | 2.5* | 1.3, 4.7 | 0.3* | 0.1, 0.7 |
| Private hot tub | 1.5 | 0.7, 2.9 | 1.7 | 0.9, 3.5 | 0.5 | 0.2, 1.1 |
| Commercial hot tub | 2.1 | 0.8, 5.5 | 0.8 | 0.3, 2.3 | 0.2* | 0.04, 0.7 |
| Indoor hot tub | 3.8* | 2.1, 6.8 | 2.4* | 1.4, 4.4 | 0.5 | 0.3, 1.1 |
| Outdoor hot tub | 1.3 | 0.7, 2.5 | 1.7 | 0.9, 3.4 | 0.2* | 0.09, 0.6 |
| Any recreational waterpark | 4.9* | 1.9, 12.6 | 2.8* | 1.0, 7.5 | 0.02* | 0.004, 0.1 |
| Indoor waterpark | 6.0* | 1.5, 24.2 | 2.6 | 0.6, 10.9 | 0.09* | 0.01, 0.6 |
| Outdoor waterpark | 4.5* | 1.4, 14.3 | 2.8 | 0.8, 9.6 | – | – |
| Swim or go into a swimming facility in the last 4 weeks | 3.6* | 2.8, 4.7 | 1.9* | 1.4, 2.4 | 0.3* | 0.2, 0.4 |

*Significant at $p < 0.05$.

The proportion of respondents using carbon filters as a means to treat drinking water for bad taste or odor (38.2%; 95% CI 27.3–50.4; $p < 0.01$) was significantly greater than the proportion of respondents using other treatment types to treat drinking water for the same reason. The proportion of respondents using UV light as a means to treat drinking water for germs or infectious agents (52.9%; 95% CI 35.8–69.3; $p < 0.01$) was significantly greater than the proportion of respondents using other treatment types to treat drinking water for this reason (Figure 4).

RECREATIONAL WATER EXPOSURES

Province and territory

Reported recreational water exposures by province and territory are shown in Table 1. Approximately 13% of Canadians reported swimming or going into any water in the past seven days, while respondents from British Columbia and Yukon were more likely to report this exposure compared to the remaining provinces and territories as a group ($p < 0.05$).

Table 5 | Odds ratios of weighted reported water sources and recreational water exposure in the past seven days, by household income with household income above \$80,000 as the referent group, Foodbook, 2014–2015

| Exposure | < \$30,000 | 95% CI | \$30,000–\$60,000 | 95% CI | \$60,000–\$80,000 | 95% CI |
|---|------------|------------|-------------------|-----------|-------------------|-----------|
| Recreational water exposure | | | | | | |
| Swim or go into any water | 0.3* | 0.2, 0.5 | 0.5* | 0.4, 0.8 | 0.6* | 0.4, 0.8 |
| Ocean | 0.2* | 0.04, 0.8 | 1.5 | 0.4, 6.7 | 0.2* | 0.06, 0.7 |
| Lake | 0.6 | 0.3, 1.2 | 0.9 | 0.4, 1.7 | 0.5* | 0.3, 0.9 |
| River | 0.7 | 0.3, 1.7 | 1.5 | 0.4, 5.3 | 0.7 | 0.3, 1.6 |
| Natural hot spring | 0.1 | 0.01, 1.2 | 6.5 | 0.9, 47.4 | 1.7 | 0.2, 12.5 |
| Any pool | 0.3* | 0.2, 0.5 | 0.5* | 0.3, 0.8 | 0.6* | 0.4, 0.9 |
| Public pool | 0.3* | 0.2, 0.7 | 0.4* | 0.3, 0.7 | 0.6* | 0.4, 1.0 |
| Private pool | 0.3* | 0.1, 0.5 | 0.7 | 0.3, 1.6 | 0.7 | 0.3, 1.4 |
| Commercial pool | 0.1* | 0.03, 0.5 | 0.3* | 0.08, 1.0 | 0.5 | 0.2, 1.6 |
| Other type of pool | 0.02* | 0.001, 0.3 | 0.4 | 0.03, 6.3 | – | – |
| Indoor pool | 0.3* | 0.2, 5.0 | 0.5* | 0.3, 0.8 | 0.8 | 0.5, 1.1 |
| Outdoor pool | 0.3* | 0.1, 0.7 | 0.5 | 0.2, 1.1 | 0.5 | 0.3, 1.0 |
| Any hot tub | 0.2* | 0.1, 0.4 | 0.3* | 0.2, 0.5 | 0.6 | 0.4, 1.1 |
| Public hot tub | 0.2* | 0.06, 0.5 | 0.3* | 0.1, 0.6 | 0.7 | 0.3, 1.3 |
| Private hot tub | 0.2* | 0.09, 0.5 | 0.3* | 0.1, 0.8 | 0.6 | 0.2, 1.7 |
| Commercial hot tub | 0.2 | 0.05, 1.1 | 0.08* | 0.03, 0.3 | 0.6 | 0.2, 2.0 |
| Indoor hot tub | 0.2* | 0.1, 0.5 | 0.3* | 0.2, 0.6 | 0.5* | 0.3, 1.0 |
| Outdoor hot tub | 0.2* | 0.06, 0.4 | 0.3* | 0.1, 0.7 | 0.8 | 0.3, 2.0 |
| Any recreational waterpark | 0.9 | 0.3, 2.7 | 0.3* | 0.1, 0.6 | 0.9 | 0.3, 2.5 |
| Indoor waterpark | 0.07* | 0.02, 0.3 | 0.3* | 0.1, 0.8 | 3.4* | 1.1, 10.8 |
| Outdoor waterpark | 1.0 | 0.3, 3.5 | 0.3* | 0.09, 0.7 | 0.3* | 0.1, 0.8 |
| Swim or go into a swimming facility in the last 4 weeks | 0.2* | 0.1, 0.3 | 0.4* | 0.3, 0.6 | 0.6* | 0.4, 0.8 |
| Primary drinking water source | | | | | | |
| Municipal water | 0.9 | 0.7, 1.3 | 0.9 | 0.7, 1.2 | 0.8 | 0.6, 1.1 |
| Private well | 0.8 | 0.6, 1.2 | 0.9 | 0.7, 1.3 | 0.7 | 0.5, 1.0 |
| Store-bought bottled water | 1.1 | 0.8, 1.7 | 1.2 | 0.8, 1.7 | 1.6* | 1.1, 2.3 |

*Significant at $p < 0.05$.

Season

The full results of recreational water exposures by season are found in Table 3. Summer was the referent group for all seasonal comparisons. Compared to summer, the proportion of respondents reporting swimming or going into any water in the past seven days was lower in all other seasons ($p < 0.001$). The proportion of respondents reporting natural water exposures, including oceans, lakes, rivers, and natural hot springs, in the past seven days was significantly less in all other seasons ($p < 0.05$). Swimming or going into a

swimming facility in the past four weeks was less likely among respondents during spring, fall, and winter ($p < 0.05$).

Hot tub exposure in the past seven days was less likely to be reported among respondents during winter and fall ($p < 0.05$). Recreational waterpark exposure was less likely to be reported by respondents during spring, fall, and winter ($p < 0.01$). Among respondents with recreational waterpark exposure, indoor recreational waterpark exposure was more likely during spring and fall ($p < 0.01$).

Table 6 | Odds ratios of weighted reported recreational water exposure in the past seven days, by education level with high school diploma as the referent group, Foodbook, 2014–2015

| Exposure | < High school | 95% CI | Trade certificate | 95% CI | College or CEGEP | 95% CI | Some university | 95% CI | Bachelor's degree | 95% CI | Postgraduate | 95% CI |
|---|---------------|--------------|-------------------|-------------|------------------|-----------|-----------------|------------|-------------------|-----------|--------------|------------|
| Swim or go into any water | 0.7 | 0.3, 1.5 | 0.7 | 0.3, 1.6 | 2.3* | 1.2, 4.1 | 1.5 | 0.4, 5.0 | 1.9* | 1.0, 3.4 | 2.1* | 1.1, 4.1 |
| Ocean | 0.02* | 0.02, 0.3 | – | – | 1.0 | 0.1, 9.6 | 5.0 | 0.4, 55.8 | 1.8 | 0.2, 14.4 | 0.8 | 0.1, 5.7 |
| Lake | 0.4 | 0.07, 2.3 | 0.1* | 0.02, 0.6 | 1.2 | 0.4, 3.3 | 0.3 | 0.09, 1.0 | 0.7 | 0.2, 1.9 | 0.9 | 0.3, 2.7 |
| River | 2.3 | 0.3, 17.3 | 2.2 | 0.2, 27.8 | 10.4* | 1.3, 84.7 | 2.8 | 0.2, 33.2 | 2.7 | 0.3, 20.4 | 7.1 | 1.0, 51.3 |
| Natural hot spring | 0.2 | 0.01, 2.9 | 0.008* | 0.0005, 0.1 | 5.2 | 0.4, 73.0 | 0.04* | 0.003, 0.7 | 0.4 | 0.03, 6.7 | 0.02* | 0.001, 0.3 |
| Any pool | 0.3* | 0.1, 0.7 | 0.6 | 0.2, 1.7 | 2.0 | 0.9, 4.5 | 1.9 | 0.5, 7.7 | 2.1 | 1.0, 4.4 | 1.4 | 0.6, 3.0 |
| Public pool | 0.5 | 0.1, 1.7 | 0.6 | 0.09, 3.7 | 2.5 | 0.7, 8.7 | 0.9 | 0.3, 2.7 | 2.7 | 0.9, 8.2 | 2.8 | 0.9, 8.4 |
| Private pool | 0.3* | 0.07, 0.9 | 0.6 | 0.2, 2.4 | 1.7 | 0.5, 5.7 | 0.3 | 0.08, 1.1 | 1.9 | 0.6, 6.0 | 0.3 | 0.08, 1.0 |
| Commercial pool | 0.008* | 0.001, 0.05 | 0.4 | 0.07, 2.3 | 0.7 | 0.2, 2.9 | 6.3 | 0.9, 46.3 | 0.6 | 0.09, 3.3 | 0.5 | 0.1, 2.1 |
| Indoor pool | 0.3 | 0.1, 1.0 | 0.2* | 0.06, 0.9 | 1.2 | 0.5, 3.3 | 0.9 | 0.3, 2.6 | 1.5 | 0.6, 4.0 | 1.6 | 0.6, 4.2 |
| Outdoor pool | 0.3 | 0.07, 1.1 | 1.2 | 0.3, 4.4 | 3.1 | 1.0, 9.8 | 3.3 | 0.5, 22.7 | 2.6 | 0.8, 8.3 | 1.0 | 0.3, 3.1 |
| Any hot tub | 0.8 | 0.2, 3.1 | 1.0 | 0.3, 3.4 | 1.1 | 0.4, 2.6 | 0.8 | 0.3, 2.4 | 1.5 | 0.6, 4.0 | 1.6 | 0.4, 7.4 |
| Public hot tub | 0.4 | 0.05, 2.4 | 1.1 | 0.2, 6.1 | 0.3 | 0.08, 1.3 | 0.6 | 0.2, 2.6 | 2.1 | 0.5, 8.8 | 0.2* | 0.03, 0.7 |
| Private hot tub | 2.0 | 0.4, 11.1 | 1.4 | 0.2, 8.3 | 2.6 | 0.8, 8.7 | 0.3 | 0.06, 1.4 | 1.3 | 0.4, 4.3 | 5.0 | 0.9, 27.6 |
| Commercial hot tub | 0.007* | 0.0007, 0.06 | – | – | 0.2 | 0.04, 1.6 | 1.0 | 0.1, 7.4 | 0.5 | 0.06, 4.2 | 0.08* | 0.01, 0.5 |
| Indoor hot tub | 0.4 | 0.1, 1.4 | 0.4 | 0.09, 1.4 | 0.2* | 0.08, 0.7 | 0.8 | 0.2, 3.1 | 1.2 | 0.3, 4.4 | 0.2* | 0.06, 0.7 |
| Outdoor hot tub | 2.3 | 0.3, 17.2 | 3.4 | 0.7, 16.7 | 4.1* | 1.3, 13.1 | 0.6 | 0.2, 2.5 | 2.6 | 0.8, 8.6 | 6.8* | 1.2, 39.5 |
| Swim or go into a swimming facility in the last 4 weeks | 0.4* | 0.2, 0.7 | 2.1 | 0.8, 5.2 | 2.8* | 1.6, 5.0 | 3.6* | 1.6, 8.1 | 2.3* | 1.3, 4.0 | 2.2* | 1.2, 4.3 |

*Significant at $p < 0.05$.

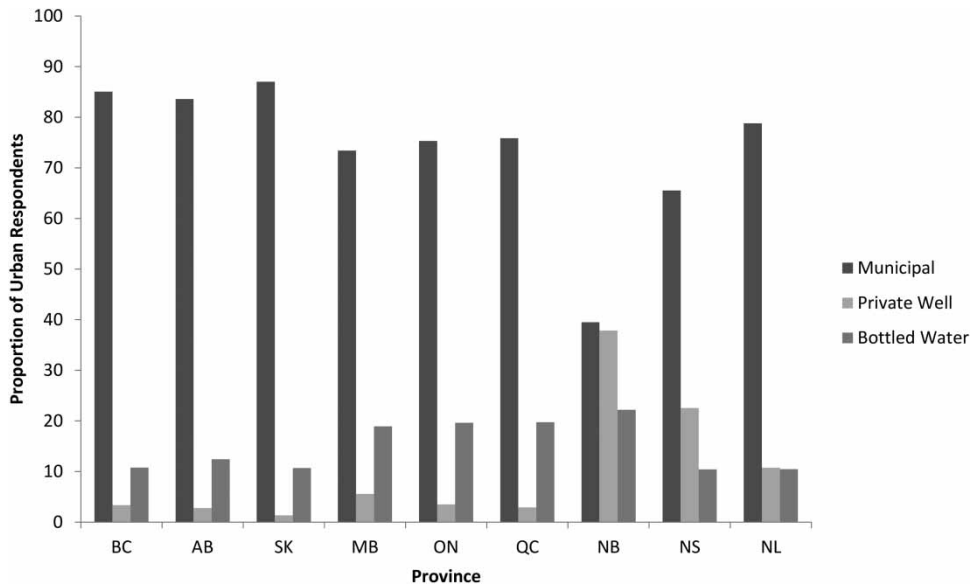


Figure 1 | Weighted proportions of Foodbook urban respondents by reported primary drinking water source and by province, 2014–2015, Canada.

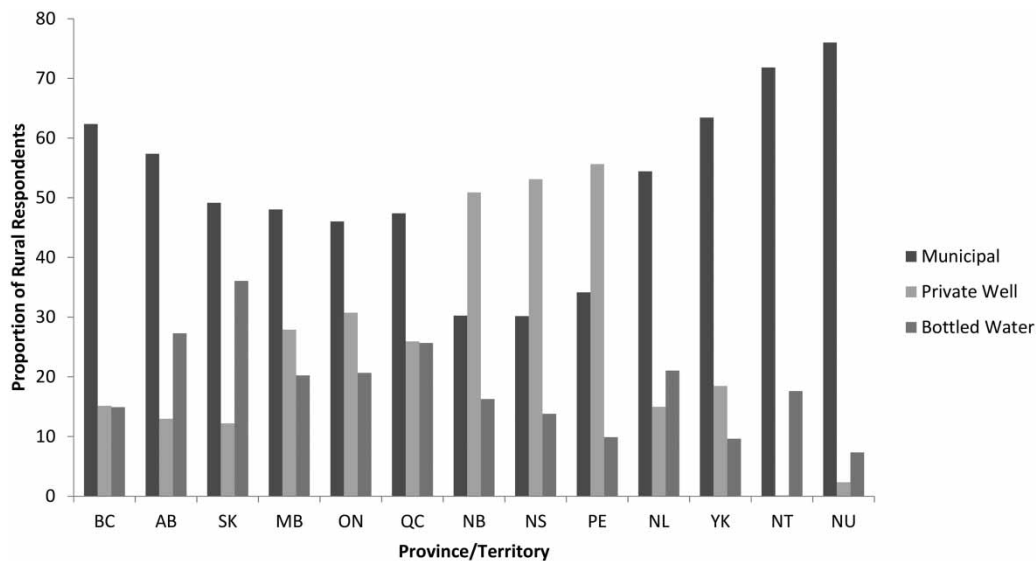


Figure 2 | Weighted proportions of Foodbook rural respondents by reported primary drinking water source and by province/territory, 2014–2015, Canada.

Age group

The full results of recreational water exposures by age group are found in Table 4. Respondents aged 20–64 years were the referent group for all age comparisons. Respondents aged 0–9 years (OR 4.2; 95% CI 3.2–5.6, $p < 0.01$) and 10–19 years (OR 2.3; 95% CI 1.7–3.1; $p < 0.01$) were more

likely to report going swimming or into any water in the past seven days. Lake exposure was more likely to be reported among respondents aged 0–19 years ($p < 0.01$), while all natural water exposures (ocean, lake, river, and natural hot spring) were less likely to be reported among respondents aged 65 years and above ($p < 0.01$). Respondents aged 0–9 years ($p < 0.01$) and those aged 10–19

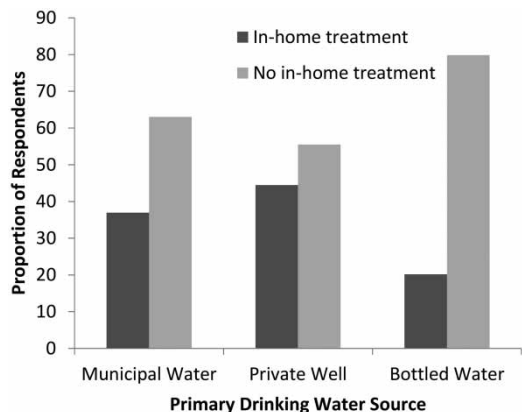


Figure 3 | Weighted proportions of Foodbook respondents reporting use of some type of in-home drinking water treatment by primary drinking water source, 2014–2015, Canada.

years ($p < 0.05$), were more likely to report any pool, public, private, or indoor pool exposure. Respondents aged 65 years and above were less likely to report any pool, public, or outdoor pool exposure ($p < 0.01$). Swimming or going into a swimming facility in the past four weeks was more likely among respondents aged 0–9 years (OR 3.6; 95% CI 2.8–4.7; $p < 0.01$) and those aged 10–19 years (OR 1.9; 95% CI 1.4–14.3; $p < 0.01$).

Hot tub exposure in the past seven days was more likely to be reported by respondents aged 0–19 years ($p < 0.01$), while it was less likely to be reported by respondents aged

65 years and above ($p < 0.01$). Among respondents with hot tub exposure, those aged 0–19 years were more likely to report either indoor or public hot tub exposure ($p < 0.01$).

Recreational waterpark exposure in the past seven days was more likely to be reported by respondents aged 0–9 years (OR 4.9; 95% CI 1.9–12.6; $p < 0.01$) and respondents aged 10–19 years (OR 2.8; 95% CI 1.0–7.5; $p < 0.05$) and less likely among respondents aged 65 years and above (OR 0.02; 95% CI 0.004–0.1; $p < 0.01$). Among those with recreational waterpark exposure, respondents aged 0–9 years were more likely to report an indoor (OR 6.0; 95% CI 1.5–24.2; $p < 0.05$) or outdoor recreational waterpark (OR 4.5; 95% CI 1.4–14.3; $p < 0.05$).

Household income

The full results of recreational water exposures by household income are shown in Table 5 with the referent group being respondents reporting household incomes above \$80,000. Swimming or going into any water in the past seven days was less likely to be reported among all respondents with household incomes of less than \$80,000 ($p < 0.01$). Hot tub exposure in the past seven days was less likely to be reported among respondents with household incomes of less than \$60,000 ($p < 0.01$). Recreational waterpark

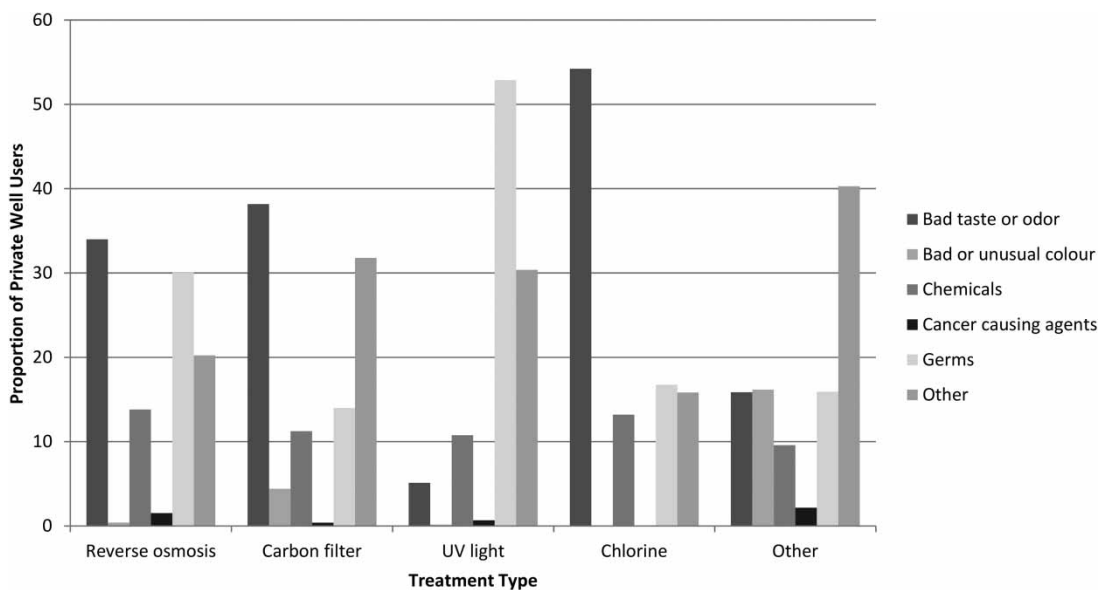


Figure 4 | In-home drinking water treatment types employed by Foodbook respondents reporting private well as their primary drinking water source by primary reason for in-home drinking water treatment, 2014–2015, Canada.

exposure was less likely among respondents with household incomes of \$30,000–\$60,000 (OR 0.3; 95% CI 0.1–0.6; $p < 0.01$).

Education level

The full results of recreational water exposures by education level are shown in Table 6 with the referent group being respondents with a high school diploma or equivalent. Swimming or going into any water in the past seven days was more likely among respondents with either a college diploma, a bachelor's degree, or a postgraduate certification ($p < 0.05$). Respondents with less than a high school education were less likely to report exposure to any pool, private pool, or commercial pool ($p < 0.05$). Swimming or going into any swimming facility in the past four weeks was less likely among respondents with less than a high school education (OR 0.4; 95% CI 0.2–0.7; $p < 0.01$), while it was more likely among respondents with either a college diploma, some university, a bachelor's degree, or a postgraduate certification ($p < 0.05$).

Urban or rural

The full results of recreational water exposures by urban and rural status are shown in Table 2. Lake exposure in the past seven days was greater among rural (4.7%; 95% CI 3.6–6.2; $p < 0.01$) than urban respondents (1.72%; 95% CI 1.2–2.4; $p < 0.01$). Pool exposure was greater among urban (10.4%; 95% CI 8.8–12.4; $p = 0.04$) than rural respondents (8.0%; 95% CI 6.8–9.5; $p < 0.01$). Similarly, public and indoor pool exposure was higher among urban respondents compared to rural respondents ($p < 0.02$). Swimming or going into a swimming facility in the last four weeks was more likely among urban respondents (20.9%; 95% CI 18.3–23.8; $p < 0.01$) than rural respondents (15.8%; 95% CI 13.9–17.8; $p < 0.01$).

DISCUSSION

Bottled water consumption

Store-bought bottled water was reported to be the primary drinking water source of nearly 20% of Foodbook

survey respondents. This is lower than previous studies, where approximately 27% of respondents in Hamilton, Ontario (Jones *et al.* 2006) reported bottled water as their primary drinking water source and 34% of respondents in the Waterloo Region of Ontario reported exclusively drinking bottled water (Pintar *et al.* 2009). The higher proportions of respondents reporting bottled water as their primary drinking water source may be influenced by proximity in both geography and time of these studies to well-known waterborne disease outbreak events, such as the Walkerton, Ontario municipal drinking water outbreak in 2000 (Schuster *et al.* 2005). Public trust in municipal drinking water influences water consumption behaviors, and may have been reduced as a result of incidents such as Walkerton (Doria 2006). While reasons for bottled water consumption were not addressed in this survey, concerns about municipal drinking water safety influence the public's bottled water consumption (Doria 2006; Hu *et al.* 2011). Greater public awareness of the environmental impacts of bottled water in recent years may have reduced the proportion of respondents reporting bottled water as their primary drinking water source, as bottled water consumption is more likely among individuals who are less environmentally conscious (Leveque & Burns 2017).

Our study found bottled water consumption is associated with education level, with bottled water consumption least likely among respondents reporting the highest level of education. This finding supports previous results by Leveque & Burns (2017), who found that individuals with lower education levels were more likely to consume bottled water. While bottled water consumption has been previously associated with higher household income (Dupont *et al.* 2010), this result was not replicated in our study, with no significant associations between household income and bottled water consumption found. However, a positive association was previously established between the use of in-home drinking water treatment and household income (Leveque & Burns 2017). Our findings support this association, with individuals with household incomes of \$80,000 or more significantly more likely to report using some type of in-home drinking water treatment system compared to individuals with lower household incomes.

Private well use

The proportion of respondents reporting private well as their primary drinking water source was significantly higher among the Maritime Provinces. While the Canadian average was nearly 11%, 55.7% of Prince Edward Island respondents, 46.3% of New Brunswick respondents, and 40.2% of Nova Scotia respondents reported this exposure. The proportion of respondents reporting private well as their primary drinking water source was also significantly greater among rural respondents compared to urban respondents, with 25.9% of rural respondents and 4.1% of urban respondents reporting this exposure. As the Maritime Provinces have a higher proportion of their population living in rural settings compared with the Canadian average (Statistics Canada 2011), this likely impacted the proportion of private well users in the Maritime Provinces. As private well use is a risk factor for waterborne enteric disease (Murphy *et al.* 2016b), awareness campaigns targeted towards populations on private well could help increase the number of private well users complying with Canadian federal guidelines to test their well two to three times per year (Government of Canada 2008). Key barriers identified by Imgrund *et al.* (2011) to private well water testing by users are complacency, inconvenience, and lack of a perceived problem. While information about the importance of well water testing only bears slight influence on future actions, public health can use information about private well exposures to develop further testing incentives (Imgrund *et al.* 2011). Future surveys related to water exposure may wish to include an additional question about frequency of well water quality testing to further inform risk communication efforts.

Recreational water exposures

At present, limited baseline data are available regarding recreational water exposures among the Canadian population to inform our understanding of the burden of recreational waterborne disease. Waterborne disease outbreaks associated with recreational water have been on the rise since reporting began in 1978 (Yoder *et al.* 2008). This is due at least in part to increased use of recreational water facilities, increased participation in recreational water-based

activities, and the emergence of new waterborne pathogens (Yoder *et al.* 2008). Statistics Canada (2014) reported that in 2005, 2.0% of the Canadian population went swimming on any given day, a significant increase from the 0.9% of Canadians reporting this exposure in 1992. Results from this analysis showed that children aged 0–9 years tended to report the greatest recreational water exposures compared to other age groups. For instance, the national average of respondents reporting swimming or going into any water in the past seven days was 13.2%, while among children aged 0–9 years this proportion rose to 32.3%.

Recreational water exposures (i.e., pool, hot tub, recreational waterpark, and natural water) were considered, and tended to be reported most frequently by children aged 0–9 years. This finding is consistent with the results of Arnold *et al.* (2016), who found that children aged 0–10 years had the highest levels of recreational water exposure as well as the largest burden of enteric disease. Children are more likely to be affected by waterborne pathogens, for both physiological and behavioral reasons. Children's immune systems are not yet fully developed, rendering them more susceptible to enteric disease and at an increased risk for developing more severe symptoms of illness compared to a healthy adult (Sinclair *et al.* 2009). Furthermore, children often spend greater amounts of time in recreational water and are more likely to swallow water, increasing their risk for enteric disease (Dufour *et al.* 2017). Children aged 6–10 years ingested nearly four times as much water as adults when spending equal amounts of time in recreational water (Dufour *et al.* 2017). There are multiple preventative public health policies that can be put in place in Canada, such as recreational beach advisories and recreational water inspection, to reduce public health risks from recreational water (Health Canada 2012). However, there can still be risks from recreational water in Canada and there is a need to better understand this burden.

Public health messaging that targets parents and caregivers of young children may reduce the occurrence of enteric illness due to recreational water exposure among this age group. Fecal accidents in recreational water, ill bathers, and diaper-aged children using these facilities are the source of many recreational waterborne disease outbreaks (Craun *et al.* 2005). As such, public

health messaging that raises awareness of risks associated with these behaviors and encourages individuals to keep themselves and their children out of recreational water facilities (including recreational waterparks and hot tubs) when ill may reduce the occurrence of enteric illness in facility users. Furthermore, this burden of waterborne disease acquired in recreational water facilities emphasizes the importance of sound operational management and ensuring robust disinfection and cleaning procedures are adhered to, as poor facility maintenance was found to be implicated in 52% of waterborne disease outbreaks in treated recreational water facilities (Craun *et al.* 2005).

The various recreational water exposures examined in this study increased during the summer months of June, July, and August, with nearly 30% of respondents reporting swimming or going into any water in the past seven days in the summer. In the USA, the number of waterborne disease outbreaks attributed to recreational water sources was also found to peak during the summer (Yoder *et al.* 2008). From 2009 to 2010, 81 outbreaks associated with recreational water exposure were reported to the United States Centers for Disease Control and Prevention, with 44% of these outbreaks beginning in either July or August (Hlavsa *et al.* 2014). Given these findings, there may be opportunity for the prevention of waterborne illness through targeted public education and awareness campaigns during known periods of peak recreational water exposure.

Study results show that children aged 0–9 years and males aged 10–19 years are most likely to report hot tub exposure in the past seven days. Children face additional risks from hot tub exposure due to their reduced ability to regulate internal body temperature (HealthLinkBC 2015), and children under five years are most likely to have a near drowning experience in a hot tub in the USA (Alhajj *et al.* 2009). With these known hazards, health education campaigns could be focused on raising awareness among parents and caregivers of young children about the risks of exposing their children to hot tubs.

Future directions and limitations

There were some limitations to this study. First, due to the survey method, the results were not representative of

Canadians without access to either a land line or a cell phone. There may have also been under-representation of individuals who inhabit remote areas of the country without telephone access, such as Northern Quebec, Northern Ontario, and the territories (Yukon, Northwest Territories, and Nunavut). Furthermore, if individuals were unable to communicate in one of the survey languages available, they would have been excluded from the survey. Second, due to the nature of the survey, asking respondents about previous exposures within the past seven days, the risk of recall bias and inaccurate recall was present (Coughlin 1990). Third, only respondents aged 25 and above were asked for their highest education level obtained in the survey, resulting in a reduced sample size of 5,855 for education level.

Future research could build from the findings presented in this paper by including additional questions about the quantity of drinking water consumed in order to quantify exposure and the duration of swimming based on Health Canada regulations needs. In addition, nearly 30% of respondents selected ‘other’ as the primary reason they chose to treat their home’s drinking water from a list of options. Future surveys should review other options, such as treating water hardness, which may be appropriate to include within this question, or provide an open-text response field to determine why in-home drinking water treatment is occurring.

CONCLUSION

The findings presented in this study will serve to inform future research by providing baseline data about drinking and recreational water exposures of Canadians. In future, this information may be used to inform our understanding of the burden of waterborne enteric disease in Canada, and in particular, which sub-populations (e.g., parents and caregivers of young children, private well users, etc.) would benefit most from public health education and awareness efforts to reduce risks associated with both drinking and recreational water. In addition, these results help to guide our understanding of the frequency of recreational water use among Canadians, and further reinforce the importance of disinfection practices and operational protocols to ensure the water in hot tubs, pools, and other

recreational venues is safe. These results provide insight into the typical weekly water exposures of the Canadian population and how these exposures relate to the true burden of waterborne enteric disease experienced by Canadians.

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