How are Perceptions Associated with Water Consumption in Canadian Inuit? A Cross-sectional Survey in Rigolet, Labrador

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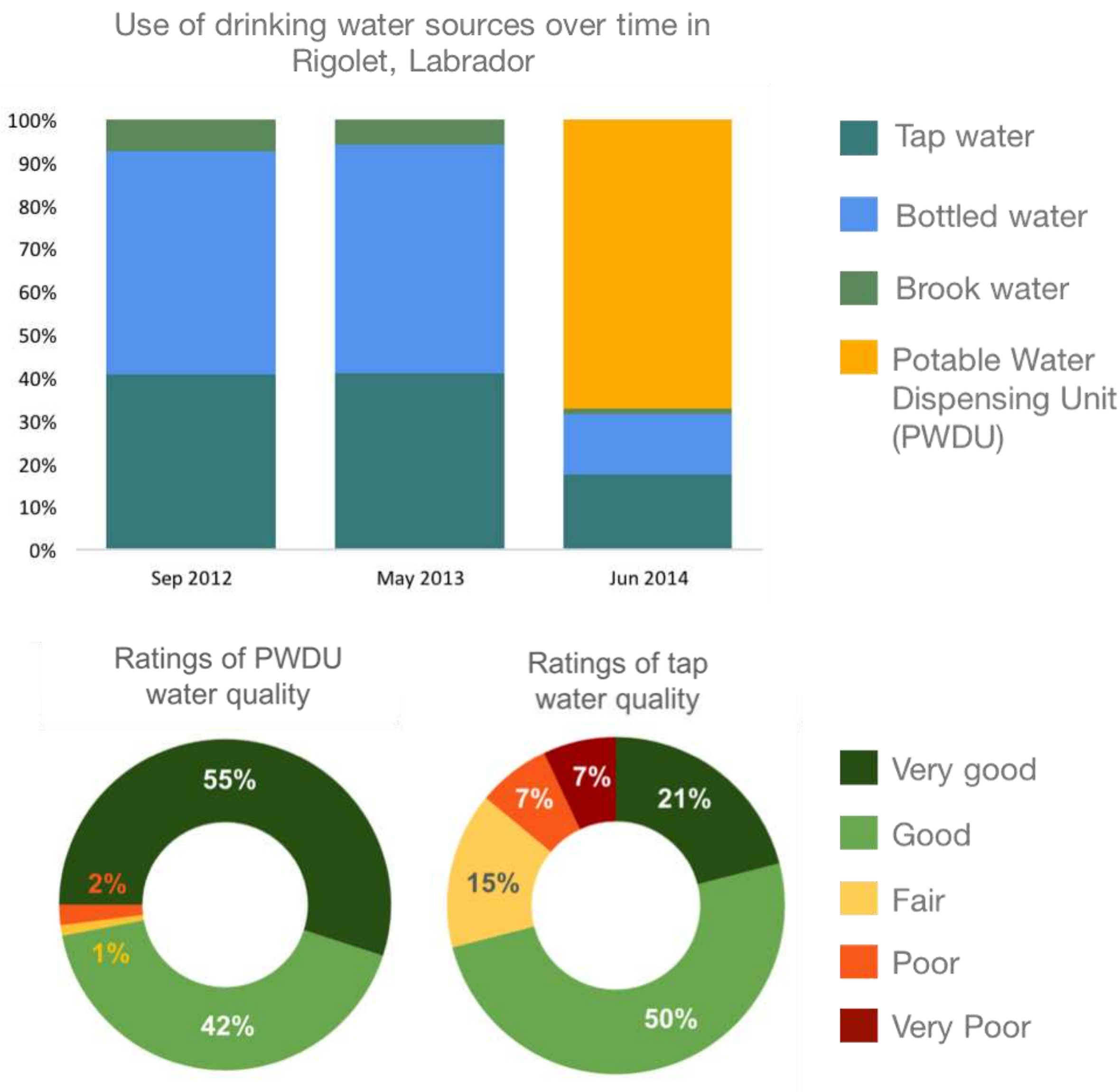
GRAPHICAL ABSTRACT



ABSTRACT

Concerns regarding the safety and aesthetic qualities of one's municipal drinking water supply are important factors influencing drinking water perceptions and consumption patterns (i.e. sources used and daily volume of consumption). In northern Canada, Inuit communities face challenges with drinking water quality, and many Inuit have reported concerns regarding the safety of their drinking water. The objectives of this research were to describe perceptions of municipal tap water, examine use of water sources and changes following the installation of a potable water dispensing unit (PWDU) in 2014, and identify factors associated with water consumption. This study used data from three cross-sectional census surveys conducted between 2012 and 2014. Principal component analysis (PCA) was used to aggregate data from multiple variables related to perceptions of water, and logistic regressions were used to identify variables associated with water consumption patterns. Three quarters of residents reported using the PWDU after its installation, with concomitant declines reported in consumption of bottled, tap, and brook water. Negative perceptions of tap water were associated with lower odds of consuming tap water ($OR_{PCAcomponent1}$ = 0.73, 95% CI 0.56-0.94; $OR_{PCAcomponent2}$ = 0.67, 95% CI 0.49 - 0.93); women had higher odds of drinking purchased water compared to men (OR = 1.90, 95% CI 1.11 - 3.26). The median amount of water consumed per day was 1L. Using brook water (OR = 2.60, 95% CI 1.22 - 5.56) and living in a household where no one had full-time employment (OR = 2.94, 95% CI 1.35 - 6.39) were associated with consuming greater than 2L of water per day. Results of this study may inform drinking water interventions, risk assessments, and public health messaging in Rigolet and other Indigenous communities.

Keywords: Indigenous; Nunatsiavut; Arctic; drinking water; perceptions; consumption patterns

1. INTRODUCTION

Aesthetic characteristics play a major role in influencing perceptions of water quality (Abrahams et al., 2000; Doria, 2010; Doria et al., 2009), with taste often described as the most important factor impacting consumer perceptions (Abrahams et al., 2000; Doria, 2010). Additionally, perceived risk can deter users from particular water sources (Doria, 2010, 2006; Doria et al., 2009), and may be impacted by aesthetic qualities or attitudes towards chemicals or microbial contaminants in water (Doria, 2010). Boil water advisories, contamination events, or experiences of water-related illness can also negatively impact perceptions and consumption patterns (i.e., choices of drinking water sources and volume of water consumption) (Doria, 2010; Griffin et al., 1998). It is important that residents have access to a water supply that is trusted and positively regarded; unfavourable perceptions may lead individuals to drink alternative water sources or beverages (e.g. juice or soda), which may have negative financial and/or health implications (Dupont et al., 2010; Spence and Walters, 2012; World Health Organization, 2011).

Although literature describing perceptions and attitudes toward drinking water is well-established in urban populations (Doria, 2006; Doria et al., 2009; Jones et al., 2007; Roche et al., 2012), a gap exists in literature relating to rural and remote locales, including northern Canada and Alaska. This knowledge deficit exists despite the unique and frequent water challenges that rural and remote populations often experience, when compared to urban centers in the same country (Bradford et al., 2016; Dunn et al., 2014; Hennessy and Bressler, 2016). For instance, smaller communities often do not have the financial resources or infrastructure to treat large quantities of drinking water with the advanced treatment methods found in urban regions (Kot et al., 2011). While these challenges have affected many remote communities in general across Canada, Indigenous communities are disproportionately impacted (Dunn et al., 2014; Patrick, 2011). Indeed, substandard, unreliable water services have contributed to issues with insufficient water quantity, water contamination, and frequent and / or long-standing boil water advisories in many Indigenous communities (Daley et al., 2014; Patrick, 2011). In Canada, a growing body of literature exists describing these persistent drinking water issues in First Nations communities (Basdeo and Bharadwaj, 2013; Dupont et al., 2014, 2010, Eggertson, 2008, 2006; Harden and Levalliant, 2008; Metcalfe et al., 2011); however, less is published regarding Inuit communities in northern Canada. Water-related issues in Inuit communities are often due to their unique and challenging geography, climate, financial and human resources, and infrastructure (Marino et al., 2009; Medeiros et al., 2016). Collectively, these challenges have contributed to low consumer satisfaction of municipal water in many Inuit communities (Daley et al., 2015; Garner et al., 2010; Goldhar et al., 2013; Marino et al., 2009). For example, in the 2001 Aboriginal Peoples Survey, 100% of Inuit respondents from Rigolet reported that during certain times of the year, they believed their water was not safe (Statistics Canada, 2004). Water quality and quantity issues (Daley et al., 2014; Martin et al., 2007), lack of trust, and deep-rooted cultural values may encourage the consumption of non-municipal drinking water, such as untreated surface water (e.g. from brooks or rivers) (Goldhar et al., 2014).

In recent years, increased international attention and government funding for improving access to water and sanitation services has enabled some Arctic communities to begin addressing water-related challenges (Alaska Department of Health and Social Services and Alaska Native Tribal Health Consortium, 2015; Health Canada, 2016; United Nations, n.d.). Adequate funding that will support infrastructure and water-related research is crucial to achieving improved access to safe water in northern populations, particularly in-light of increasing stresses brought on by climate change and resource development (Ford, 2012; Instanes et al., 2016). In the past, various approaches have been taken to address water-related challenges. For example, in approximately one third of rural Alaskan villages, residents rely on centrally-located watering points, or “washeterias”, due to lack of in-home water service for drinking or washing (Hennessy et al., 2008). Though well-intentioned, many factors can prevent the adoption of new or improved water systems, leading to residents choosing not to use new systems (Marino et al., 2009). Factors including local preferences for taste, integration of cultural values and Indigenous knowledge of water with water management, and sense of ownership over community water treatment systems often play integral roles in the adoption of new water treatment systems (Marino et al., 2009). Further research is still needed to understand why individuals prefer certain water sources. This is crucial for informing the development of appropriate municipal water systems and identifying potential barriers to their adoption.

Given the disproportionate water-related challenges in northern Canada, and the complex yet poorly understood factors that may impact water consumption patterns in Inuit communities, further work is needed to understand how to improve consumer satisfaction and trust in municipal water. While research exists assessing drinking water contamination in some Inuit communities (Martin et al., 2007; Wright et al., 2017), a gap exists in assessing how perceptions of safety and quality impact water consumption patterns. The goal of this research, therefore, was to characterize drinking water perceptions and consumption patterns in the Inuit community of Rigolet, Canada. The objectives were to: (1) describe perceptions of municipal tap water; (2) describe the use of drinking water sources and changes in water sources over time; (3) identify factors associated with consuming different water sources; and (4) examine residents' daily volume of water consumption. This study is intended to improve our understanding of specific factors that impact drinking water consumption patterns in order to inform sustainable drinking water interventions, water-related risk assessments, and effective public health messaging that considers the unique Indigenous context and history of water-related challenges in northern Canada.

2. METHODS

2.1 Research location

First Nations, Métis, and Inuit are the three constitutionally recognized groups of Indigenous peoples in Canada, comprising 4.3% of the national population (Statistics Canada, 2015). Approximately three quarters of the almost 60 000 Inuit who live in Canada reside in Inuit Nunangat, a region which covers over one third of Canada's landmass (Inuit Tapiriit Kanatami, 2017). The four currently settled Land Claim Areas composing Inuit Nunangat include the Northern Labrador Inuit Land Claims Area (hereafter referred to as Nunatsiavut), Nunavik, Nunavut, and the Inuvialuit Settlement Region, although additional Inuit land claim negotiations are in progress (Figure 1). Nunatsiavut, meaning "Our Beautiful Land" in Inuttitut, gained self-governance in 2005 (Nunatsiavut Government, 2016). The Nunatsiavut Land Claim Area is comprised of five coastal Inuit communities (from North to South): Nain, Hopedale, Postville, Makkovik, and Rigolet. These remote communities are not accessible by road, necessitating all travel by plane or boat or snowmobile in the winter. This study was conducted in partnership with the community of Rigolet, which grew from a decade of environmental health community-based and community-led research collaboration and partnership among the research team. Rigolet is a small community with approximately 306 residents (Statistics Canada, 2012), the vast majority of whom identify as Inuit (Statistics Canada, 2013). The prominence of Inuit culture and the remote nature of the community means that many people in Rigolet have a close relationship with the environment, and rely on and value country foods and other resources from the land for subsistence (Cunsolo Willox et al., 2012).

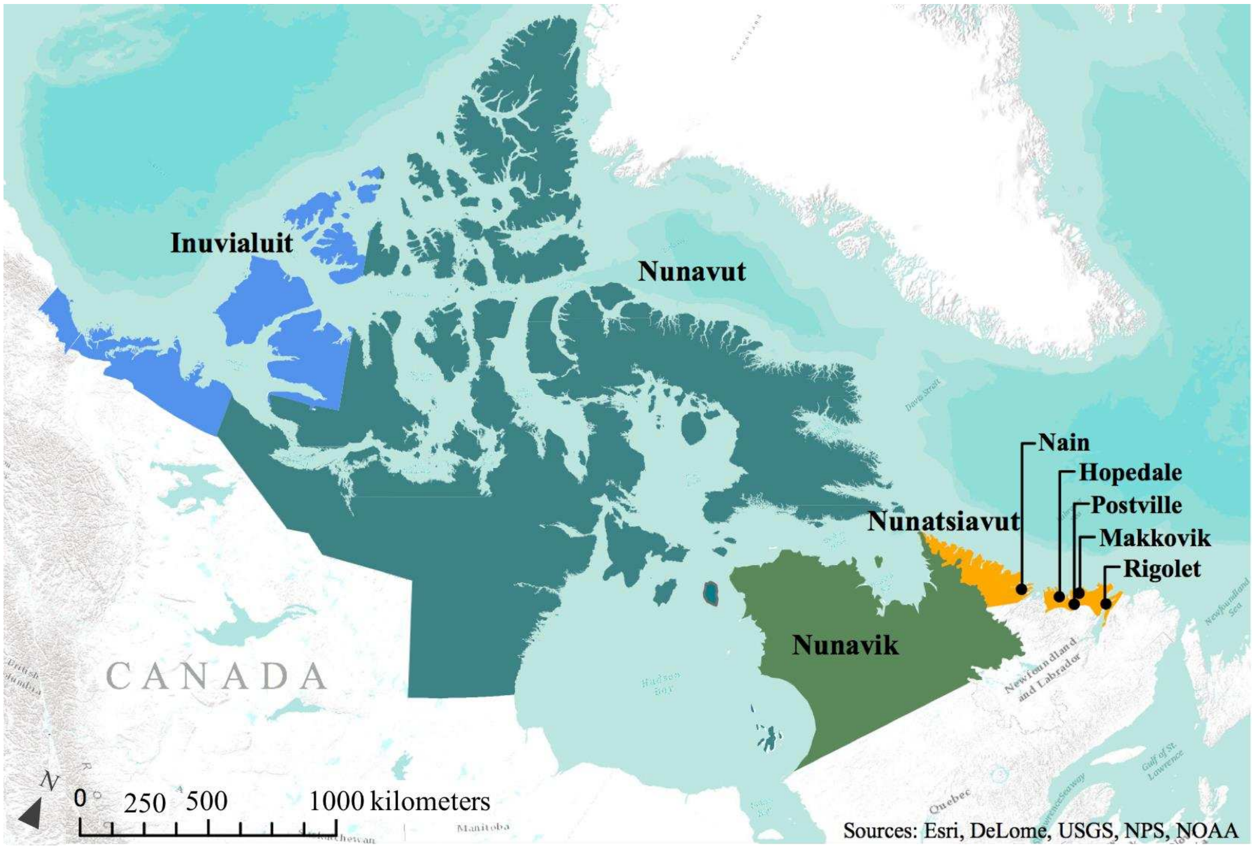


Figure 1 A map of Northern Canada, depicting the four regions of Inuit Nunangat and the five Inuit communities of Nunatsiavut, as of 2017. (2 column-fitting image)

Rigolet residents have access to four types of drinking water in the community (Figure 2): tap water, bottled water, water collected from nearby brooks, and water from a potable water dispensing unit (PWDU). The municipally treated tap water is chlorinated (but unfiltered), and supplies all households via underground pipes. Bottled water can be purchased from the local store. Untreated sources of drinking water are also consumed in Rigolet, including surface water from several nearby brooks in the community (locally referred to as “brook water”). Some Inuit prefer to drink untreated sources of water, or may drink it out of necessity when treated water is not available (for example, when travelling on the land or visiting a cabin) (Goldhar et al., 2014, 2013). In January 2014, the PWDU was constructed, introducing a fourth source of drinking water. The Government of Newfoundland and Labrador’s recent Drinking Water Safety Initiative

(Government of Newfoundland and Labrador, 2017a) has enabled several Labrador communities to implement PWDU systems within the past few years, including Makkovik, Postville, and Cartwright (Goldhar et al., 2012; Hanrahan, 2014; Lightfoot, 2014), although several other small communities on the island of Newfoundland received PWDUs as early as 2000 (CBCL Limited, 2010). Rigolet has a history of long-term boil water advisories and drinking water parameters in exceedance of the Canadian Guidelines for Drinking Water Quality, making it a candidate for this program (Government of Newfoundland and Labrador, 2017b; Health Canada, 2014). The PWDU uses multiple advanced methods to treat the incoming tap water, including sand filtration, ozonation, carbon filtration, reverse osmosis, and ultraviolet light (CBCL Limited, 2010). These processes result in disinfected water that is free of dissolved solids and chlorine residuals. Water from this central facility is then collected by residents in personal containers for storage in the household. Water storage containers vary greatly in size and shape; an examination of water storage in Rigolet is described by Wright et al. (2017).

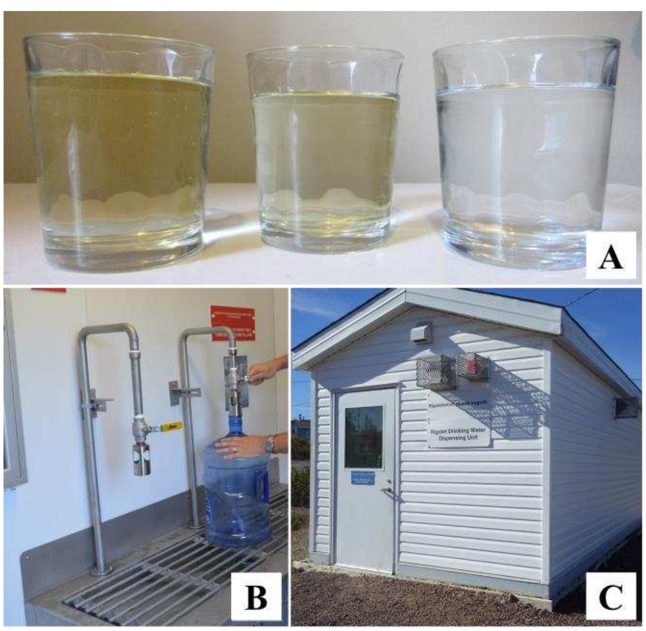


Figure 2 (A) Brook water (left), tap water (center), and PWDU water (right); (B) the interior of the PWDU; (C) the PWDU building in Rigolet, Canada (2014). (1 column-fitting image)

2.2 Data collection

This study was planned and implemented using an EcoHealth research framework, which emphasized community-based, participatory research methods, transdisciplinarity, and systems-thinking (Charron, 2012; Koster et al., 2012), and involved a team of Inuit and non-Inuit researchers, epidemiologists, engineers, and social scientists, as both researchers and co-authors.This study used a subset of data from three cross-sectional studies conducted by local Inuit researchers in Rigolet between 2012 and 2014 (Figure 3). Two of the surveys were conducted before the installation of the PWDU, and the third survey was carried out after its construction. In all instances (except for a subset of questions in May 2013), a census was attempted, meaning that all residents present in the community were eligible and invited to participate (Figure 3).

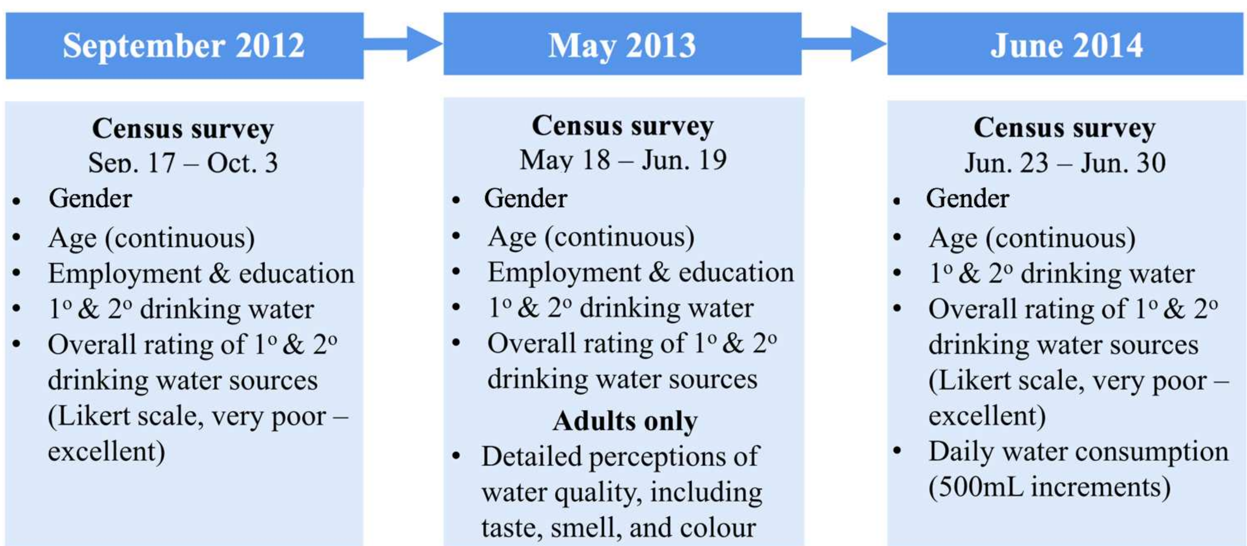


Figure 3 Timeline of data collected in each survey that related to the objectives of this research in Rigolet, Canada (2012-2014). (2 column-fitting image)

2.2.1 Questionnaires

Local Inuit research associates administered and completed all questionnaires on iPads in the preferred language of the respondent (questionnaire available upon request). All respondents answered in English, although translation to Inuttitut was available (but not requested by any participants). Questionnaires contained closed-framed questions, and all questions gave respondents the option to provide an alternate answer or more detail. The questionnaires were pre-tested by local community members, health workers, and academics to ensure that the content was clear and contextually appropriate. Each of the three questionnaires asked a variety of identically-worded questions, which allowed for comparisons over time. The questionnaires were administered to each individual and information on demographics, water, consumption, and overall ratings of drinking water quality were collected. Additionally, the May 2013 questionnaire collected data on adult (i.e. individuals 18 years and older) perceptions regarding the safety and aesthetic quality of municipal tap water (Figure 3). As a census survey, many individuals in Rigolet completed questionnaires in all three survey periods; however, some individuals may not have responded in every survey (for example, if they were not present in Rigolet during one of the survey periods).

The definition used for drinking water in the questionnaires was consistent with other studies assessing water consumption patterns in Canada (Jones et al., 2007, 2006; Roche et al., 2012), and was selected to facilitate comparisons. “Drinking water” was defined as plain unboiled water, or cold drinks made with un-boiled water (e.g. frozen juice concentrate and crystal drink mixes). This definition excluded drinks made with boiled water (e.g. tea, coffee, and hot chocolate), as well as boxed and canned beverages (e.g. soft drinks and juice boxes). In all three questionnaires, respondents were asked about primary (1^{o}) and secondary (2^{o}) drinking water sources consumed (i.e. the most frequently used and second most frequently used water sources, respectively) in the two weeks prior to the survey. Self-reported data on water consumption were only collected in June 2014; volume was measured in 500mL serving increments, with a plastic water bottle being used to demonstrate a single 500mL serving at the time of the questionnaire.

2.2.2 Consent & ethical approvals

Written informed consent was obtained from each participant before completing the questionnaires; if a participant was under 18, parental permission was obtained (with parent present during the interview if desired), and a proxy respondent (parent or primary caregiver) was used for children under 12 years of age. Ethical approval for research protocols was obtained from the Nunatsiavut Government Research Advisory Committee, the Research Ethics Boards of Health Canada, the University of Guelph, and McGill University.

2.3 Data analysis

Questionnaire data from the three surveys were combined into a single dataset and linked by individual identification number. A second dataset was created for assessing changes in the use of drinking water sources over time (i.e. objective two). Data were analyzed using Stata I/C 14.2 (StataCorp LP, College Station, TX, USA) for Mac. Participants who did not drink water (n=6 in September 2012; n=4 in May 2013; n=4 in June 2014), or who responded ‘refuse to answer’ or ‘unsure’ were excluded from the analysis of that question.

2.3.1 Describing perceptions of tap water

Descriptive statistics were used to examine population demographics from the three survey periods, as well as perceptions of municipal tap water from the May 2013 survey. Two-sample tests of proportions were used to compare frequencies between demographic groups, including gender and age.

2.3.2 Examining water consumption patterns

Unconditional logistic regressions were first performed on a variety of explanatory variables postulated to be associated with outcomes of interest. Unconditional associations with variables that had a p-value <0.2 were retained for further analysis, which served as a method of data reduction (Supplementary Resource 1). Multivariable models were then constructed to include the exposure of interest (i.e. explanatory variable), with age and gender forced into all models as a fixed effect, as previous literature has indicated that these variables may act as confounders when investigating water consumption patterns (Dupont et al., 2010; Jones et al., 2007, 2006). Explanatory variables examined included demographic factors as well as water-related habits and perceptions. A significance level of $\alpha \leq 0.05$ and 95% confidence intervals were used to assess statistical significance. Linearity of continuous variables (i.e. age) with the log odds of the outcomes of interest was assessed using locally weighted scatterplot smoothing (lowess curves); variables that did not have a linear relationship with the outcome were categorized based on trends in the lowess curves. Pearson and Deviance χ^2 goodness-of-fit tests were used to assess fit of the models, and scatter plots of predicted values, residuals, deviance, standardized residuals, leverage, delta beta, delta deviance, delta χ^2, and best linear unbiased predictors (BLUPs) were used to visually assess model fit (Dohoo et al., 2012). This process was followed to examine associations of explanatory variables with the (i) use of drinking water sources over time, (ii) use of tap and purchased water, and (iii) daily volume of water consumed.

2.3.2.1 Assessing use of drinking water sources over time

Descriptive statistics were used to examine the frequency of use of different drinking water sources before and after the installation of the PWDU. Changes in use of tap, purchased, and brook water as primary water sources over time were assessed by creating a second dataset with repeated measures for each individual (i.e. one observation per survey), and inputting the survey period (corresponding to September 2012, May 2013 and June 2014) as a categorical fixed effect into mixed logistic regression models, while using random effects at the household and individual levels to control for clustering and repeated measures (Dohoo et al., 2012). A global test of significance was used to assess the overall significance of the "survey period" variable.

2.3.2.2 Assessing explanatory variables associated with use of tap and purchased water

Mixed logistic regression modelling, using a random effect to control for clustering at the household level, was used to examine associations between explanatory variables and the use of tap water, and in the use of purchased water as primary or secondary water sources. When examining the tap water outcome, principal components analysis (PCA) was conducted to aggregate data from a larger number of similar variables related to individuals' ratings, concerns, and perceived importance of the taste, smell, and colour of tap water. The Kaiser-Meyer-Olkin measure of sampling adequacy was used to assess the appropriateness of a PCA given our data, using a minimum value of 0.5 to indicate that PCA was an acceptable method (Kaiser and Rice, 1974). Components with an eigenvalue over 1.0 were retained (following the Kaiser rule) (Kaiser and Rice, 1974) and considered as explanatory variables in the regression models. Orthogonal rotation of components was used to facilitate interpretations by giving the highest component loadings to the fewest possible variables (Supplementary Resource 2). When constructing regression models with PCA variables, standard logistic regressions with coding to adjust standard errors for household-level clustering were used in lieu of mixed logistic regressions, due to non-convergence of mixed models.

2.3.2.3 Assessing daily volume of water consumption

Descriptive statistics were used to obtain an overview of residents' daily water consumption. For regression analysis, the volume of water consumed daily by survey respondents was dichotomized based on previous literature (Jones et al., 2007, 2006) in order to assess explanatory variables associated with consuming a "large" volume of water (i.e. >2L per day).

Unconditional logistic regression modelling was used to identify explanatory variables associated with this outcome in June 2014. A mixed model was not used to assess this outcome as significant household-level clustering of the outcome was not observed.

3. RESULTS

3.1 Response rates & demographic information

High response rates were achieved for each survey: 92% (226/245), 95% (236/249), and 89% (246/275) of individuals present in Rigolet at the times of the surveys participated in September 2012, May 2013, and June 2014, respectively. In the June 2014 survey, the 10-14 year age group was significantly over-represented, and the 20-24 year age group was significantly under-represented, compared to 2011 Census data from Rigolet (Table 1).

3.2 Perceptions of tap water

Tap water received significantly more “poor” and “very poor” overall ratings of quality compared to purchased water, PWDU water, and brook water ($p<0.05$) in 2014. Furthermore, based on data collected in May 2013, 36% of adult respondents felt that tap water had made them, or someone in their family, “sick.” Ratings of aesthetic qualities, and concerns regarding chemicals, “germs”, and health impacts of drinking water are presented in Table 2. Significantly more females stated that they were concerned or extremely concerned about the presence of “chemicals” and “chlorine” in tap water compared to males ($p<0.05$). Significantly more adults (ages 18-54) stated that they were concerned or extremely concerned about presence of “chlorine” and “pathogens” in tap water, and felt that the tap water had made them or someone in their family “sick” when compared to older adults (age 55+) ($p<0.05$).

3.3 Drinking water sources used over time

Prior to the installation of the PWDU, purchased water was the primary drinking water source for half of respondents in Rigolet, followed by tap water (39.4% and 40.4% in the 2012 and 2013 surveys, respectively) and brook water (7.1% and 5.6% in the 2012 and 2013 surveys, respectively). The PWDU became the most frequently used drinking water source in June 2014, representing the primary source for 67.2% of respondents, with a concomitant decline in consumption of tap, purchased, and brook water. The odds of consuming tap, purchased, and brook water as the primary drinking water sources were significantly lower in June 2014 compared to September 2012 and May 2013; however, no significant differences in the use of primary water sources were observed between 2013 and 2012 (Table 3, Supplementary Resource 3). Tests of the overall significance of the survey period variable in statistical models had p-values less than 0.05; goodness-of-fit tests and visual methods indicated that the models fit the data well. In contrast to primary water sources, the pattern and percent use of secondary drinking water sources remained relatively consistent over time (Figure 4).

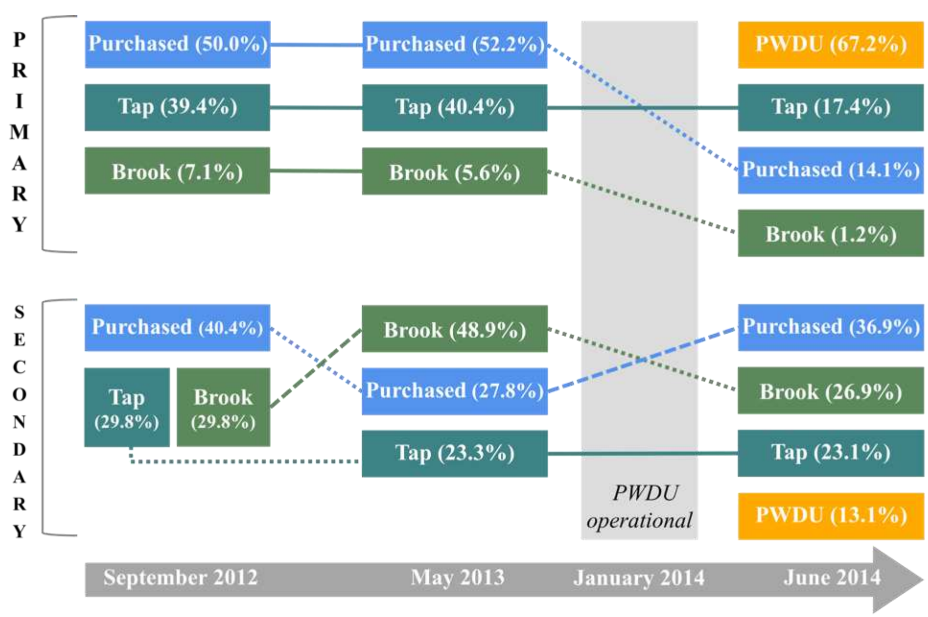


Figure 4 Changes in the rank order of tap, purchased, brook, and potable water dispensing unit (PWDU) water over time, for primary and secondary drinking water sources in Rigolet, Canada (2012 – 2014). Solid lines indicate no

change, dotted lines indicate a decrease, and dashed lines indicate an increase in ranking order. Proportions (%) indicated in brackets. (1.5 column-fitting image)

3.4 Explanatory variables associated with use of tap and purchased water

Individuals who stated that they were "concerned" or "extremely concerned" about chlorine in tap water (OR = 0.23, 95% CI 0.08 – 0.61), and those who rated the perceived quality of tap water for drinking as "very poor", "poor", or "fair" (OR = 0.22, 95% CI 0.08 – 0.58) had decreased odds of consuming any tap water. A Kaiser-Meyer-Olkin sampling adequacy measure of 0.79 indicated that PCA was an acceptable method of data reduction. Two components were retained from the PCA, accounting for 73.7% of the original variance of the data. The first component loaded heavily on (i.e., was most correlated with) individuals' ratings and concerns regarding the taste, smell, and colour of the tap water, and the second component loaded heavily on the perceived importance of taste, smell, and colour of tap water. Both components were associated with reduced odds of consuming tap water ($OR_{PCAcomponent\ one}$ = 0.73, 95% CI 0.56 – 0.94; $OR_{PCAcomponent\ two}$ = 0.67, 95% CI 0.49 – 0.93); that is, as perceptions became increasingly negative (i.e. as the component score increased), the odds of consuming tap water decreased. The odds of consuming store-purchased water were greater in females than males (OR = 1.90, 95% CI 1.11 – 3.26). Additionally, an individual had greater odds of consuming store-purchased water if a member of their household was employed full-time during the 2013 survey (OR = 5.52, 95% CI 2.77 – 10.98) (Table 3, Supplementary Resource 3). Residual diagnostics indicated that these models were well fitted to the data.

3.5 Daily volume of water consumption

In June 2014, responses regarding the volume of water consumed daily ranged from no water (i.e., they did not drink any water) to five or more 500 mL servings (2.5 L or more) per day, and the median amount of water consumed by respondents was two 500mL servings (1.0 L). Overall, 1.2% (n=3) of participants did not drink any water; 26.0% (n=64) drank a "small" quantity of water (<1 L); 55.3% (n=136) drank a "moderate" quantity of water (1-2 L); and 17.5% (n=43) drank a "large" quantity of water (>2 L). Individuals had greater odds of consuming a large quantity of water if they drank brook water as a primary or secondary source (OR = 2.63, 95% CI 1.21 – 5.71), and if they lived in a household where no resident had full-time employment (OR = 2.94, 95% CI 1.35 – 6.39) (Table 3, Supplementary Resource 3). Residual diagnostics indicated that the models fit the data well.

4. DISCUSSION

Residents in Rigolet have several choices of drinking water, including piped tap water, purchased water, untreated brook water, and water from a PWDU that became operational in January 2014. Many factors can impact drinking water perceptions and consumption patterns, particularly in communities with frequent water challenges. New uncertainties in perceptions and consumption patterns can arise with the implementation of a new water treatment system.

4.1 Perceptions of tap water

Poor ratings and perceptions of the aesthetic qualities of tap water are closely related to attitudes toward chlorine (Piriou et al., 2004). Chlorine has previously been identified as undesirable in Rigolet tap water (Goldhar et al., 2013), and these prior findings are further supported by this research. Moreover, the Rigolet tap water has a distinct brown colour due to lack of filtration (Goldhar et al., 2013), and aesthetic perceptions regarding colour can influence people's risk perceptions and beliefs regarding the safety of drinking water (Doria et al., 2009). Risk perceptions are also likely influenced by a history of boil water advisories; Rigolet's water system does have a history of boil water advisories. More recently, the municipal tap water in

Rigolet has been under a boil water advisory since August 2015 (Government of Newfoundland and Labrador, 2017b). Over one third of adults in Rigolet felt that they, or someone in their family, had gotten "sick" from the tap water. In contrast, a national Canadian study found that only 10% of respondents believed their tap water posed a moderate or serious concern for their health or the health of their families (Dupont, 2005). It also should be noted that in the months leading up to the survey in 2013, there was increased media coverage reporting on the presence of chlorine disinfection by-products in Newfoundland and Labrador, which may have resulted in increased awareness and distrust of the municipal tap water (e.g. CBC News, 2013); however, resident's concern about Rigolet tap water was documented as early as 2001 in the Aboriginal Peoples survey (Statistics Canada, 2004). Our results lend support to the heightened concern regarding the safety of tap water in Indigenous communities compared to non-Indigenous communities. Indeed, another study found that First Nations communities had significantly greater odds of believing someone had gotten sick from their tap water, when compared to non-First Nations Canadians (Dupont et al., 2014). Moreover, a study in Nunavik reported that individuals often believed their gastrointestinal illness was attributable to tap water (Martin et al., 2007), further supporting the notion that poor perceptions of municipal water are common across Canadian Indigenous communities.

4.2 Drinking water sources used in Rigolet

Prior to the arrival of the PWDU, purchased water was consumed by the majority of Rigolet residents, and was reflective of bottled water use in some other Canadian Indigenous communities; for example, one study found that, compared to non-First Nations Canadians, Ontario First Nations communities were over nine times more likely to rely solely on bottled water (Dupont et al., 2014). In some instances, Indigenous households are reliant on bottled water due to source water contamination or failures of water treatment systems (Chan et al., 2013; Sarkar et al., 2015). In Rigolet, despite the possible inconvenience of having to collect water from the PWDU station, transport it home, and store it in household containers, the PWDU rapidly became the primary water source for over two thirds of survey respondents. The clear preference for PWDU water may be related to lack of satisfaction with tap water, which was apparent in this study, and continues to be an issue across Indigenous communities in North America (Dupont et al., 2014; Garner et al., 2010; Goldhar et al., 2013; Marino et al., 2009). When the PWDU was introduced in 2014, all Rigolet residents over the age of 18 were required to pay $20 per year towards the operation of the PWDU, which may have also encouraged early adoption of the PWDU as a source of drinking water. While PWDU water is less convenient than tap water, this did not appear to deter users, further supporting the idea that many residents were highly dissatisfied with their tap water. Moreover, choosing to collect drinking water may be a reflection of traditional Inuit culture. Activities such as hunting and gathering of food and water play an essential role in the subsistence culture of Inuit (Pauktuutit Inuit Women of Canada, 2006), facilitating connections with the environment and community (e.g. through gathering and sharing with neighbours and kin) (Collings et al., 2017). While collecting water from the PWDU is certainly different than collecting it from the land, the act of collecting and distributing water could be an important factor influencing the use of the PWDU, although further work assessing this hypothesis would be necessary. Given these findings in Rigolet, further research in other Labrador communities with similar water systems would be valuable for comparison, or for identifying other factors that impact PWDU use. A thorough understanding of PWDU use, sustainability, and perceptions in Labrador would be useful for informing policy surrounding water infrastructure projects and public health in Labrador, and potentially other, Inuit communities.

Despite offering a preferred source of drinking water, the PWDU does have several important drawbacks. First, the PWDU is energy intensive: running costs have been estimated to be upwards of $30 000 per year for similar systems in other Labrador communities (Sarkar et al., 2015). This can be cost prohibitive for small remote communities, especially considering that PWDU expenses are in addition to those already incurred by existing municipal water systems, such as piped tap water. In addition to running costs, the municipal government is responsible for repairs and maintenance, including expensive filter replacements (Personal communication, RICG, 2017). These expenses could make the PWDU financially unsustainable; provincial funding agreements to support these systems may be important to overcoming this barrier. Furthermore, as a highly complex system, interruptions in service at the PWDU are possible when components fail or need to be replaced (Personal communication, RICG, 2017). Given the remoteness of the community, parts and repairs are not easily or quickly accessed. This can have implications for water consumption if residents then need to seek out other sources for a period of time. Ensuring that parts required for typical maintenance and repairs are kept in stock in the community may increase resiliency of the system to failure. Lastly, water from the PWDU contains no free chlorine residuals; while this can improve aesthetic appeal, chlorine residuals are crucial for inactivating microbial contaminants that may enter water after initial treatment (Health Canada, 2006). PWDU water is therefore vulnerable to recontamination between source and point-of-use, potentially increasing risk of exposure to waterborne pathogens (Wright et al., 2017). Future risk assessments, cost-benefit-analyses, and discussions on water policy and public health messaging should take these contextually unique factors into consideration.

In addition to these drawbacks it is also important to consider that some respondents, despite the availability of PWDU water, continued to drink bottled, brook, and tap water, particularly as secondary water sources. This sustained reliance on multiple different water sources has important implications for local water policy, risk assessments, and future research. For example, educational messaging and vigilance in monitoring untreated water sources remain highly relevant in the community, and are particularly important moving into the future, as climate change continues to impact Arctic water systems and water quality (Harper et al., 2011). Furthermore, future risk assessments must take into account the continued use of other water sources.

4.3 Explanatory variables associated with the use of tap and purchased water

Perceptions of risk and aesthetic characteristics are known to play a vital role in people's choice of drinking water (Abrahams et al., 2000; Doria, 2010), and were prominent predictors of tap water use in Rigolet. Aversion to chlorine was a recurrent finding in this study, thus, it was not surprising to find that those who were more concerned about chlorine were less likely to consume the tap water. In a previous qualitative study of drinking water in Rigolet, chlorinated water was often described as "unnatural" or "overwhelming" compared to the taste of brook water (Goldhar et al., 2013; Goldhar, 2011). Other studies conducted in several Inuit communities found that individuals frequently collected water from untreated sources due to municipal water shortages or a preference for untreated surface water, which was often described as more familiar, higher quality, and more trustworthy than municipal water (Daley et al., 2015, 2014; Goldhar et al., 2013; Hanrahan, 2014). In Rigolet, this could, in part, be due to the high level of organic matter in the unfiltered tap water that reacts with added chlorine, which can produce undesirable, flavours and chlorine disinfection by-products (Health Canada, 2009). Research from other Inuit communities has also noted residents' dislike for the taste of chlorine, suggesting that chlorine aversion is not uncommon throughout northern Canada (Daley et al., 2015; Martin et al., 2007), as well as other Southern locales (Jones et al., 2007).

In this study, females had higher odds of consuming purchased water than males, and this could reflect gender differences in risk perception. Increased bottled water use in females has also been documented in the United States (Hu et al., 2011). This is thought to be related to an increased awareness of health-related risks, likely reflecting gendered roles, with women often responsible for preparing household meals (Dosman et al., 2001; Hu et al., 2011). The finding relating to employment and use of purchased water may reflect increased financial accessibility to bottled water due to higher household income. Similar findings and conclusions have been reported in other studies (Dupont et al., 2010; Hu et al., 2011).

4.4 Daily water consumption

The median volume of water consumed daily by residents was similar to other research conducted in southern Canada, which reported median water consumption to be between 1.0-1.3L/day (Jones et al., 2007, 2006; Pintar et al., 2009; Roche et al., 2012). Individuals who reported using brook water as a primary or secondary source were more likely to consume a large quantity of water, and this may be related to deeply-rooted cultural beliefs and preferences for natural sources of water among Inuit (Goldhar et al., 2013). In many Indigenous cultures, water is an integral component of not only physical health, but also of spiritual well-being (Kim et al., 2013). Inuit in Rigolet share a close spiritual connection with the land (Cunsolo Willox et al., 2013, 2012), and for generations relied on brook water for sustenance. Even in recent times, a preference for these familiar sources of water has been noted: qualitatively, brook water in Nunatsiavut has been described with words such as “healthy”, “pure”, and “alive” (Goldhar et al., 2013). Nonetheless, brook water consumption also decreased in 2014, which may be related to the closer proximity of a positively regarded water source (i.e. the PWDU). Further examination of key similarities and/or differences between PWDU and brook water may prove useful for informing water infrastructure projects that consider the unique aesthetic qualities that Inuit identify as important in drinking water.

4.5 Limitations

The surveys included in this study were cross-sectional, with each capturing data at one period in time, and these data do not reflect all possible seasonal variations in water consumption patterns (e.g., no surveys were conducted during summer or winter). Consequently, the direction and magnitude of associations between explanatory and outcome variables may differ at other times of the year. Outcomes relating to water consumption (e.g. number of servings consumed per day) were self-reported, potentially resulting in recall bias; however, we chose this self-reported outcome measure to match other Canadian studies to facilitate comparisons. As such, we have assumed that these biases are similar to other water consumption studies using similar methods elsewhere. Despite conducting census surveys, a small source population contributed to low statistical power, which limits the ability to detect statistically significant associations; also, low statistical power impacted our ability to perform multivariable analyses. A substantial number of individuals also responded “unsure” when asked about various perceptions of tap water, and this reduced the number of observations available for analysis. Furthermore, health data and data on current or historical boil water advisories were not assessed in this study, and so we were unable to examine possible associations between perceptions, advisories, and health outcomes; this may be an area of future research. Additionally, these surveys have only been conducted in Rigolet and, considering the heterogeneity among Indigenous communities, extrapolation of research findings to other Inuit communities should be done cautiously. Finally, while our study documented water perceptions and consumption patterns, we did not collect data to characterize the reasons behind these perceptions and consumption patterns. As such, we call for future qualitative research to examine why so many people from Rigolet readily adopted the PDWU, what values drove that, and where these values emerged from.

5. CONCLUSION

This study characterized drinking water perceptions and consumption in the Inuit community of Rigolet, Canada, through three cross-sectional surveys conducted between September 2012 and June 2014. High community use of the PWDU is likely explained by dissatisfaction with tap water and a preference for a chlorine-free source of drinking water. Future risk assessments, public health messaging, and other water-related policy should consider the continued reliance on alternative water sources, such as untreated brook water. Further research in other Inuit communities with similar water systems may be useful for evaluating the sustainability and acceptance of PWDU systems, as well as informing water infrastructure projects in other communities. Addressing concerns over chlorine in Rigolet's piped tap water is likely a crucial step in improving satisfaction with the centralized municipal water source.

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TABLES

Table 1 Demographic information of Rigolet residents: comparison between 2011 Rigolet census data and survey participants.

Variable	Rigolet census 2011 Number (%)	Rigolet survey Sep. 2012 Number (%)	Rigolet survey May 2013 Number (%)	Rigolet survey Jun. 2014 Number (%)
Population	N = 305	n = 226	n = 235	n = 246
Gender				
Female	160 (52.5)	119 (52.7)	121 (51.5)	121 (49.2)
Male	145 (47.5)	107 (47.3)	114 (48.5)	125 (50.8)
Age (years)*				
0-9	40 (13.1)	38 (16.8)	43 (18.3)	41 (16.7)
10-14	15 (4.9)	17 (7.5)	19 (8.1)	24 (9.8)**
15-19	15 (4.9)	10 (4.4)	11 (4.7)	9 (3.6)
20-24	25 (8.2)	10 (4.4)	10 (4.2)	7 (2.8)**
25-64	180 (59.0)	134 (59.3)	140 (59.6)	144 (58.5)
65-69	10 (3.3)	6 (2.7)	5 (2.1)	10 (4.1)
≥70	20 (6.6)	11 (4.9)	7 (3.0)	11 (4.5)

*Global p-value = 0.028

**Significant difference between survey and 2011 Census data (p<0.05)

Table 2 Adults' perceptions of tap water in Rigolet, Canada in May 2013.

	Demographic characteristics*					
	Gender		Age (years)		Education level	
AESTHETIC QUALITIES OF TAP WATER	Male	Female	18-54	55+	High school or less	Post-secondary education
Ratings of taste						
Good, excellent	16 (19.8)	11(13.3)	95 (81.2)	34 (75.6)	14 (16.5)	10 (15.2)
Fair, poor, or very poor	63 (77.8)	68 (81.9)	16 (13.7)	11 (24.4)	69 (81.2)	52 (78.8)
Ratings of smell						
Good, excellent	18 (22.2)	13 (15.7)	20 (17.1)	11 (24.4)	13 (15.3)	16 (24.2)
Fair, poor, very poor	55 (67.9)	61 (73.5)	84 (71.8)	30 (66.7)	61 (71.2)	45 (68.2)
Ratings of colour						
Good, excellent	14 (17.3)	11 (13.3)	15 (12.8)	10 (22.2)	14 (16.5)	11 (16.7)
Fair, poor, very poor	67 (82.7)	68 (81.9)	99 (84.6)	34 (75.6)	68 (80.8)	54 (81.8)
CONCERNS ABOUT TAP WATER						
Chemicals/pollutants						
Concerned/extremely concerned	44 (54.3)	51 (61.4)	71 (60.7)	23 (51.1)	51 (60.0)	35 (53.0)
Somewhat, slightly, not concerned	**29 (35.8)**	**18 (21.7)**	31 (26.5)	15 (33.3)	21 (24.7)	22 (33.3)
Chlorine						
Concerned/extremely concerned	46 (56.8)	52 (62.6)	**75 (64.1)**	**21 (46.7)**	51 (60.0)	37 (56.1)
Somewhat, slightly, not concerned	**31 (38.3)**	**20 (24.1)**	35 (29.9)	16 (35.6)	23 (27.1)	25 (37.9)
"Germs"						
Concerned/extremely concerned	50 (61.7)	55 (66.3)	**82 (70.0)**	**21 (46.7)**	50 (58.8)	46 (54.1)
Somewhat, slightly, not concerned	25 (30.9)	19 (22.9)	27 (23.1)	17 (37.8)	24 (28.2)	16 (24.3)
How does chlorine impact health?						
Positive health impact	3(3.7)	6 (7.23)	5 (4.3)	4 (8.9)	6 (7.1)	2 (3.0)
Negative health impact	15 (18.5)	17 (20.5)	25 (21.4)	7 (15.6)	15 (17.6)	14 (21.2)
Positive & negative health impacts	21 (25.9)	28 (33.7)	42 (35.9)	6 (13.3)	17 (20.0)	29 (43.9)
No health impacts	7 (8.6)	6 (7.23)	8 (6.8)	5 (11.1)	7 (8.2)	5 (7.6)
Do you think you or someone in your family has ever gotten sick from drinking tap water?						
Yes	21 (25.9)	28 (33.7)	**41 (35.0)**	**8 (17.8)**	25 (29.4)	22 (33.3)
No	47 (58.0)	40 (48.2)	57 (48.7)	28 (62.2)	42 (49.4)	36 (54.5)
n (per group)	81	83	117	45	85	66

***** Includes data only for adults (18 years and older).

Bolded values indicate significant differences between demographic groups, based on two sample test of proportions ($p<0.05$).

Note: not all comparison groups add to 100%, as individuals who responded "unsure" or "refuse" are not presented here.

Table 3 Results of multivariable analyses examining associations between explanatory variables and odds of using tap, purchased, and brook water, as well as the odds of consuming > 2L water/day in Rigolet, Canada in 2014 (controlling for age and gender as confounding variables). Crude results are presented in Supplementary Resource 3.

		Adjusted* multivariable results		
Variable	n	OR	p-value	95% CI
Outcome: Tap water as 1^{o} water source				
Survey period				
Sep 2012	91	Ref.	-	-
May 2013	93	1.13	0.630	0.69 – 1.84
Jun 2014	42	0.16	<0.001	0.09 – 0.28
Outcome: Purchased water as 1^{o} water source				
Survey period				
Sep 2012	113	Ref.	-	-
May 2013	124	1.13	0.582	0.71 – 1.84
Jun 2014	34	0.06	<0.001	0.03 – 0.12
Outcome: Brook water as 1^{o} water source				
Survey period				
Sep 2012	16	Ref.	-	-
May 2013	13	0.47	0.176	0.16 – 1.40
Jun 2014	3	0.05	0.001	0.01 – 0.26
Outcome: Consumption of tap water as 1^{o} or 2^{o} water source in June 2014				
Concerned or extremely concerned about chlorine				
Yes	98	0.23	0.003	0.08 – 0.61
No	51	Ref.	-	-
Rated quality of tap water for drinking as fair, poor, or very poor				
Yes	127	0.22	0.002	0.08 – 0.58
No	34	Ref.	-	-
PCA: component one †	103	0.73	0.017	0.56 – 0.94
PCA: component two ††	103	0.67	0.017	0.49 – 0.93
Outcome: Consumption of purchased water as 1^{o} or 2^{o} water source in June 2014				
Gender				
Female	121	1.90	0.019	1.11 – 3.26
Male	125	Ref.	-	-
Someone in household had full-time employment in May 2013				
Yes	99	5.52	<0.001	2.77 – 10.98
No	93	Ref.	-	-
Outcome: Water consumption >2L/day in June 2014				
Drank brook water as 1^{o} or 2^{o} water source				
Yes	42	2.63	0.015	1.21 – 5.71
No	204	Ref.	-	-
No one in household had full-time employment in May 2013				
Yes	93	2.94	0.004	1.35 – 6.39
No	99	Ref.	-	-

* Adjusted for age and gender.

† Component one loaded heavily on adults' ratings and concerns regarding the taste, smell, and colour of tap water.

†† Component two loaded heavily on adults' perceived importance of the taste, smell, and colour of tap water.