Water Quality and Inuit Health: An Examination of Drinking Water Consumption, Perceptions, and Contamination in Rigolet, Canada

by

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ABSTRACT

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Canadian Inuit have often reported concerns about the quality of their municipal drinking water. This research took an EcoHealth approach to investigate drinking water perceptions and consumption patterns, as well as drinking water contamination and its potential associations with acute gastrointestinal illness (AGI) in the Inuit community of Rigolet, Canada. Three census cross-sectional surveys (n=226-246) captured data on AGI, drinking water use, and water storage (2012-2014). Bacterial contamination of household drinking water was assessed alongside the 2014 survey. Concerns regarding taste, smell, and colour of tap water were associated with lower odds of consuming tap water. The use of transfer devices (e.g. small bowls or measuring cups) was associated with household water contamination. No water-related risk factors for AGI were identified. Results of this study are intended to inform safe water management practices, as well as contextually appropriate drinking water interventions, risk assessments, and public health messaging in the Arctic.
ACKNOWLEDGEMENTS

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I would also like to acknowledge the multiple funders and scholarships that made this research possible. These include the Indigenous Health Adaptation to Climate Change (IHACC)\(^1\) and the Inuit Traditional Knowledge for Adapting to the Health Effects of Climate Change (IK-ADAPT)\(^2\) projects, the Ontario Veterinary College Scholarship, the Ontario Graduate Scholarship, and the Arthur D. Latornell Graduate Scholarship.

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STATEMENT OF WORK

STUDY DESIGNS

The September 2012 and May 2013 surveys in Chapter Two were designed by Drs. Sherilee Harper, Victoria Edge, Kate Thomas, James Ford, and Scott McEwen, as well as the Indigenous Health Adaptation to Climate Change (IHACC) research team. The subsection of the May 2013 survey relating to adult perceptions of tap water was developed by Allan Gordon, Khosrow Farahbakhsh, Sherilee Harper, and Victoria Edge. I assisted Dr. Sherilee Harper in the design of the June 2014 cross-sectional survey for Chapter Three. The June 2014 survey also provided data for Chapter Two. These surveys were all designed in collaboration with local Inuit researchers and government.

QUESTIONNAIRES AND DATA COLLECTION

Data from the September 2012 and May 2013 IHACC surveys were collected by local Inuit researchers Marilyn Baikie, Inez Shiwak, and Dina Wolfrey. I worked with guidance from Dr. Sherilee Harper to modify the IHACC questionnaire for the June 2014 survey; the June 2014 questionnaire was pre-tested and administered by local Inuit research partners Inez Shiwak and Charlie Flowers, with assistance from myself and Allan Gordon. All participating households in Rigolet were visited for questionnaire administration. I worked with Inez Shiwak and Charlie Flowers to collect, prepare, incubate, and analyze all drinking water samples on-site in Rigolet; this process was supervised by Dr. Sherilee Harper.

DATA ANALYSIS AND MANUSCRIPT PREPARATION

Data from the September 2012 and May 2013 surveys were partially cleaned by previous users; I combined datasets from the surveys in September 2012, May 2013, and June 2014 to prepare them for analysis in Chapter Two. I prepared and cleaned the data collected in the June 2014 survey (used in Chapters Two and Three). I performed the statistical analyses and prepared this manuscript with guidance and edits from Dr. Sherilee Harper, my advisory committee (Drs. Jan Sargeant and Victoria Edge), and other co-authors, including Drs. Khosrow Farahbakhsh and James Ford, Allan Gordon, Inez Shiwak, and Charlie Flowers. I created all the tables, figures, and original maps included in this thesis (using Microsoft® Office and ArcGIS®).

COMMUNITY ENGAGEMENT AND RESULTS SHARING

Results sharing in Rigolet was planned and conducted in close collaboration with local research partners throughout the study. I designed informational packages that were disseminated in Rigolet at the conclusion of the June 2014 survey, as well as the infographic and stickers distributed in the community (relating to stored drinking water). I worked alongside Manpreet Saini (MSc student), Inez Shiwak, and Charlie Flowers to plan and host a community event to share research results. This thesis work was also showcased through six oral conference presentations: two instances were co-presentations with myself and Inez Shiwak, and I presented three instances at international meetings, including an invited presentation by the Centers for Disease Control and Prevention.
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**Figure 4.1** Required headshot; Carlee Wright (photo credit: Sherilee Harper)

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INTRODUCTION

Clean drinking water is essential for human health, and its necessity is reflected in the United Nations Millennium Development Goals (established in 2000), which aimed to halve the proportion of the global population without access to safe drinking water and basic sanitation by 2015.\(^1\) Since 1990, 2.6 billion people have gained access to improved drinking water;\(^1\) however, it is estimated that 1.8 billion people still use a source of drinking water that is contaminated with fecal matter.\(^2\) Fecal pathogens that can be transmitted through water are broadly categorized into three major groups: viruses, bacteria, and parasites\(^3\) (Table 1.1). Waterborne illness from fecal-contaminated water contributes to a substantial burden of illness globally, and was responsible for a considerable proportion of the 1.5 million deaths attributed to diarrheal disease in 2012.\(^4\) Sustainable sources of clean water in adequate quantities are vital to reducing this global burden, in addition to effective drinking water management at national, provincial, and household levels.

First Nations, Métis, and Inuit are the three constitutionally recognized groups of Indigenous peoples in Canada. In 2011, over 1.4 million people identified as Indigenous, which was 4.3% of the total Canadian population:\(^5\) 60.8% of these individuals identified as First Nations, 32.3% as Métis, and 4.2% as Inuit (the remaining 2.7% identified as another Indigenous identity, or reported more than one Indigenous identity).\(^5\) The geographic distribution of people within these diverse groups ranges across all territories and provinces throughout Canada, in both urban, rural, and remote locations. Approximately 30-50% of Indigenous communities are remotely located,
with many of them accessible only by airplane. In the 2011 National Household Survey (NHS), over 80% of First Nations and Métis people reported living in Ontario or the Western provinces. In contrast, approximately three quarters of Inuit lived in Inuit Nunangat (“the place where Inuit live” in Inuktitut); an area covering over 31% of Canada’s landmass, which is comprised of four settled Inuit Land Claim Areas, extending from the east to north to west coast of Canada (Nunatsiavut, Nunavik, Nunavut, and the Inuvialuit region) (Figure 1.1). Many Indigenous people face inequities in employment, income, housing, education, healthcare, and other determinants of health when compared to non-Indigenous Canadians. For instance, in 2011, the employment rate for Indigenous Canadians averaged 62%, in comparison to almost 76% for non-Indigenous Canadians. The median after-tax income of Métis, Inuit, and First Nations people was over a third less than other Canadians, despite the cost of living being disproportionately higher in remote areas. Indeed, the cost of many items including fuel and food in remote locations are extremely high; for example, in Arviat, Nunavut, researchers reported the cost of a basket of groceries to be over double that of the same basket in Montreal, Québec (compared to a national average of $155 per week). Food security is a growing concern, with prevalence of food insecurity being two to three times higher in Indigenous populations than in non-Indigenous populations, and up to four times higher for Inuit in some areas. Overcrowding is also an issue in many communities, particularly in Inuit settlements, where it has been reported that almost one quarter of households are overcrowded. Furthermore, there is often poor access to high quality education and healthcare services due to the remote location of these communities, high turnover of trained professionals and limited resources.

First Nations, Métis, and Inuit face a disproportionate burden of illness, including chronic and infectious diseases as well as high rates of substance abuse, addiction, and suicide.
Mortality rates in Indigenous communities remain higher than the rest of the country, particularly in children and youth.\textsuperscript{18} Data from the Canadian Mortality Database and Canadian Census show that in 2001 the lifespan of a resident living in an Inuit-inhabited area was over a decade shorter than the average Canadian, and that average lifespan in these areas is not increasing over time as it is throughout the rest of the country.\textsuperscript{19} Chronic diseases including diabetes\textsuperscript{17} and obesity\textsuperscript{6} have become increasingly prevalent in the North; furthermore, infectious diseases such as tuberculosis,\textsuperscript{17,20} sexually transmitted infections,\textsuperscript{21} and diarrheal illness (from water, food, or other sources)\textsuperscript{16,22} have the highest reported rates in Canada, and represent some of the highest rates globally. Infectious diarrheal illness may be of particular concern in Inuit populations as climate change and warming temperature impact the Arctic environment, potentially increasing exposure to waterborne pathogens.\textsuperscript{23}

\textbf{LITERATURE REVIEW}

The goal of this literature review was to systematically summarize and integrate information and research published on various aspects of drinking water in North America, with a focus on Inuit Nunangat in Canada. Specifically, the objectives were to summarize and integrate information on: (1) drinking water supplies, regulations, consumption patterns, and perceptions in North America; (2) waterborne pathogens, water contamination, and interventions for improving drinking water; and (3) acute gastrointestinal illness (AGI) in Canada. Search strings were created for each major topic of review (Table 1.2). The electronic database PubMed was searched for articles in the English language, published within the last ten years (2005-2015). Titles and abstracts were screened for relevance to the review topic, and included articles were read and summarized. References from the articles were also reviewed in order to identify other relevant
literature not captured by the search strings. Government websites, including Health Canada, Statistics Canada, Centres for Disease Control and Prevention, the United States Environment Protection Agency, and the World Health Organization were also searched for relevant regulatory information and global and national-level statistics.

**Drinking water supply and regulation**

*Drinking water sources and distribution systems*

Drinking water, in the broadest sense, can be divided into two types based on its source: groundwater and surface water. Groundwater is found beneath the Earth’s surface in the spaces between soil particles and rock fractures, and is commonly accessed via wells. Surface water includes sources such as lake and river water, and water bound in the form of snow, ice, and glaciers.\(^24\) In Canada, both groundwater and surface water are used to supply municipal tap water,\(^25\) although approximately three-quarters of residents drink from a surface water source.\(^26\)

In Canada, 86% of people have access to a municipal water supply, meaning that their homes are connected to a centralized distribution system that serves the community with piped drinking water.\(^27\) Most water in North America is delivered through underground pipe networks, and is treated through a complex multi-step process, typically involving coagulation, flocculation, sedimentation, filtration, and/or chemical disinfection, whereby particulate matter is removed and microbial contaminants are inactivated.\(^28,29\) Drinking water in some communities, however, undergoes more basic treatment. Approximately 16% of the Canadian population is served by a treatment plant which does not filter water, but relies solely on disinfection or other non-filtration methods of treatment.\(^28\) In 2011, 99% of Canadians with a municipal water source were supplied with treated drinking water, meaning that the remaining 1% were connected to a water system that distributed untreated water (typically from groundwater sources).\(^28\) The most common treatment
applied in both advanced and simple water treatment systems is addition of chlorine, which occurs in 95% of drinking water production in Canada. While a large proportion of Canadians have access to treated municipal water, it is important to note that over four million people are not connected to a water distribution system, and instead rely on private sources of water. The vast majority of non-municipal water comes from private well water, and a small proportion from surface water.

Throughout northern Canada there are several different systems for delivering treated drinking water. The first is a piped water system, which is similar to what is found in southern Canada. The pipes may be buried underground, such as in the Inuit communities of Nunatsiavut, Labrador, or laid above ground, as is the case with the utilidor system that serves some households in Iqaluit, Nunavut. Although most North Americans enjoy piped water as a basic convenience, there are challenges with the practicality and sustainability of piped water systems in some areas of the Arctic. The pipes are subjected to the harsh climate of northern environments, and in some areas underlying permafrost makes it necessary for them to be laid above ground, where they are more prone to physical damage. Freezing is a major issue that can result in costly damage and interruptions in water service. For example, in March 2015 a section of pipe in Iqaluit’s utilidor system froze and left households without running water for several days. Pipes may be heated to prevent freezing, but this is very expensive and the heat can cause permafrost to thaw, which is dangerous for the environment and the structural integrity of the pipes. Furthermore, communities in the North rely on surface water sources, which can freeze in the winter and cause water shortages. The community of Igloolik, Nunavut, faced this challenge recently, when the local reservoir froze over in winter and thawed too slowly to supply an adequate volume of drinking water to residents.
A second method of water delivery that is common through much of northern Canada is the trucked water system, whereby a truck delivers treated water to household storage tanks, which is the case in many communities in Nunavut and Nunavik. In some communities water is delivered daily, although others may only receive service several times per week. Trucks typically remove sewage from a separate tank at the same time that fresh water is pumped in. This method overcomes some of the downfalls of a piped system, but subsequently has its own set of challenges, particularly in regard to water quantity concerns. Based on estimates of the amount of water required to protect public health and reduce excessive incidence of gastrointestinal and skin conditions, a volume of 100 litres per capita per day was recommended in the 1990s, and has been used as a standard in the North ever since. Daily water usage by the average Canadian is approximately three times higher than this northern standard, and so it is not surprising that water shortages are a frequently stated concern for many northern communities: indeed, over half of households in one Nunavut community reported that they were without domestic water at least once per month. Moreover, unplanned delays in water delivery can exacerbate this problem, and these delays are unfortunately common in the Arctic due to bad weather, vehicle breakdown, or unavailability of operators.

Lastly, some northern communities have neither piped nor trucked water and must rely on other methods of water retrieval. For example, in Black Tickle-Domino, Labrador, untreated, non-piped stream and pond water were the only drinking water sources available until a decentralized potable water dispensing unit (PWDU) was installed in 2004. The PWDU uses multiple advanced forms of treatment to filter and disinfect water. It is a self-contained unit that is often housed in a small building within the community, and residents must collect water from the PWDU in their own containers and store it at home for later use. Similar units have been installed in other...
communities since 2014, including in Rigolet, Makkovik, and Postville, Nunatsiavut. While these systems use multiple advanced treatments to provide safe drinking water, they require immense energy and financial resources to maintain, which is a challenge for smaller communities with limited tax bases. While the province paid for the initial instalment of the decentralized systems, the towns are often responsible for their upkeep and associated costs. As an example, the Black Tickle-Domino PWDU has an estimated operating cost of almost $40,000 per year, and government grants are often required to keep it running. In order to pay for some of the operating expenses, residents have been required to pay $2 per litre for this water, which is a financial barrier for many individuals.

While municipally treated water is available in most of northern Canada, there remains a substantial reliance on, and preference for, untreated water surface water in many Inuit communities. This surface water includes brook water or water from other unregulated and unmonitored sources. Consumption of untreated water may be, in part, due to financial inaccessibility of treated water (such as with the Black Tickle-Domino PWDU or bottled water). However, long-standing traditions rooted in Inuit culture also play an important role in this activity: Inuit traditionally lived subsistence lifestyles that relied heavily on the land, and the practice of collecting water from brooks and springs is still continued today by those who prefer the natural sources of drinking water that their ancestors have used for generations.

Consumption of untreated surface waters may also be necessitated when travelling or spending time out on the land, when sources of treated drinking water are not available.

**Drinking water quality guidelines and regulation**

Canada is unique among most high income countries, as it is one of the only Nations without standardized drinking water quality management across its 13 provinces and territories.
Despite the recommendation of the World Health Organization to do so, Canada has no legally enforceable standards for drinking water quality at the national scale. The Federal-Provincial-Territorial Committee on Drinking Water has instead developed the guidelines for Canadian drinking water quality (GCDWQ), a document published by Health Canada, as a reference for recommended quality parameters based on scientific evidence. It is at the discretion of each provincial or territorial jurisdiction, however, to decide whether or not to adopt these recommendations. Several jurisdictions follow and often exceed all recommended parameters, yet others implement only a portion of the guidelines or follow them less stringently than suggested. Furthermore, although all jurisdictions are currently implementing at least a portion of the guidelines, only eight of the 13 enforce them legally. In contrast, the United States has a very unified approach to water management: the United States Environmental Protection Agency is the regulatory body that sets standards across all states, and ensures compliance by public water systems. There are various advantages and disadvantages of either approach to water regulation. It has been argued that having non-enforceable standards increases opportunity for inequalities in water safety, particularly in smaller communities with less financial resources to devote to water treatment. In contrast, it may also be said that regulations implemented at a smaller scale are more contextually appropriate, and are logical given that resource management often occurs at the provincial level.

The 2011 GCDWQ outlines 94 specific microbial, chemical, physical, and radiological parameters for drinking water; however, the microbial aspect is the focus of this review. The guidelines include recommendations for the following microbial parameters: Giardia and Cryptosporidium (enteric parasites), enteric viruses, Escherichia coli (E. coli), total coliforms, and turbidity. Although it is recommended that Giardia and Cryptosporidium be monitored in source
water, there is currently not a reliable and cost-effective method available to detect viable cysts or oocysts in a timely and accurate manner, and most provinces are not currently implementing this recommendation.\textsuperscript{38,41} Furthermore, enteric viruses are also not regularly tested due to logistical, technical, and economic limitations.\textsuperscript{42} \textit{E. coli}, however, is very commonly monitored to detect fecal contamination in drinking water, and is often used as an indicator pathogen due to its ease of testing and specificity to human or animal feces. The guideline states a maximum acceptable concentration (MAC) of zero per 100mL, meaning that no \textit{E. coli} should be detected in a sample.\textsuperscript{43} Total coliforms are the broad group of bacteria within which \textit{E. coli} is found, and have an MAC of “none detectable per 100mL in water leaving a treatment plant or in untreated water leaving a well.”\textsuperscript{44} Most provinces and territories have legally binding standards for \textit{E. coli} and total coliforms, if not for other microbial or chemical contaminants.\textsuperscript{38} Lastly, turbidity refers to the level of organic or inorganic particulate matter in water. Although not necessarily harmful in itself, particulate matter can carry pathogenic microorganisms and protect them during the treatment process, and thus is included in the microbiological parameters.\textsuperscript{45}

Municipal water distribution systems are generally subject to careful monitoring and treatment based on the aforementioned guidelines, but it is important to also acknowledge the several million Canadians who do not rely on municipal water systems, and therefore have an unregulated source of drinking water at home. Individuals with private water sources (mainly from wells supplying ground water) have sole responsibility for monitoring their drinking water and implementing any treatment.\textsuperscript{46} Health Canada recommends regular testing of private water and advises that it adhere to the \textit{GCDWQ}.\textsuperscript{47}

The province of Newfoundland and Labrador implements a portion of the 94 drinking water parameters stated in the \textit{GCDWQ}, although the provincial government does not enforce them
In regards to bacteriological quality, a MAC of no *E. coli* in a 100mL sample is stated (which is consistent with the *GCDWQ*), although the standards for total coliforms differ, in that no consecutive samples, or no more than 10% of samples from a distribution system should test positive for presence of total coliforms (Table 1.3). Tests that exceed either of these guidelines will result in a drinking water advisory (DWA) being put in place, which is intended to be a temporary measure to protect human health. There are three types of DWAs: boil water advisories (BWAs), do not consume advisories (DNCAs), and do not use advisories (DNUAs). Water quality issues have been a persistent problem in Indigenous communities throughout Labrador and Canada. Challenges in delivering safe water in many of these communities has resulted in very poor drinking water, and frequent DWAs, some of which have lasted years or even decades. As of January 2015, there were 1838 DWAs in place in Canada, and despite Indigenous peoples representing less than five percent of the total national population, over 10% of DWAs were in First Nations communities alone (this number excludes the communities of Inuit Nunangat). Additionally, in communities that have small drinking water systems or PWDUs, as is the case in several Nunatsiavut communities, only one sample is required for testing per month. Less stringent provincial testing requirements and non-enforced standards for water quality parameters, may, in part, make drinking water systems in Newfoundland and Labrador particularly vulnerable to poor water quality in comparison to other jurisdictions (Figure 1.2).

Addressing water governance and regulation is important in understanding differences that exist within Indigenous communities and between Indigenous and non-Indigenous communities, and how this impacts water management. In non-Indigenous Canadian populations, it is the provincial government’s responsibility to oversee and enforce water regulations. In Southern First Nations reserves, water governance is a joint responsibility of the First Nations band councils
and the federal government, including the department of Indigenous and Northern Affairs Canada (INAC) and Health Canada. The band council is typically responsible for planning, building, and operating drinking water infrastructure, with a portion of funding for operation, maintenance, and upgrades provided by the government. Regulations to ensure safe drinking water on First Nations reserves (under the Safe Drinking Water for First Nations Act) have not yet been implemented.

In the Northwest Territories and Nunavut, the federal government is also the regulatory body for water management; however, water governance in Yukon was devolved from INAC to the Territorial government in 2003. Although the Government of Canada plays a substantial role in funding drinking water services on First Nations reserves, they do not provide services to Inuit communities in Canada, including the more southern settlements of Newfoundland and Labrador; these communities are managed at the provincial level through the Department of Environment and Conservation.

Overall, researchers have suggested that water management is highly inconsistent throughout Indigenous populations, and there is a general lack of clarity surrounding water management responsibilities in the literature and government documents. Northern regions, in particular, have been criticized for their lack of defined responsibilities for freshwater management, integration with other regions, and appropriate oversight. This lack of coherence increases the vulnerability of drinking water systems to contamination and may impair responses to adverse events, further complicating the already existing issues with drinking water in the North.

**Drinking water testing: Use of indicator bacteria**

Given the number of pathogenic organisms that can threaten the safety of drinking water, efficient and timely methods of water quality testing are crucial to protect public health. Indicator bacteria are frequently used as a proxy to assess fecal contamination of drinking water, as it is highly unfeasible to test water for such a large number of potential contaminants.
bacteria are found in fecal material and indicate that fecal contamination of water has occurred, meaning that other potentially harmful pathogens may be present. There are a variety of microbial indicators used to assess water quality, with *E. coli* considered the most ideal (as it is most specific to feces), followed by thermotolerant coliforms. *E. coli* and other thermotolerant coliforms are most appropriate as they occur in high numbers in human and animal excreta, and are rarely found naturally in the environment. Finally, methods to culture and count these indicators are relatively fast, inexpensive, and require minimal training. Total coliforms are the larger group of bacteria within which these thermotolerant coliforms are found. Total coliforms have been used for many years as indicators of fecal contamination, although in recent years they have come under increasing scrutiny. Total coliforms may be found naturally in the environment, meaning they are not exclusive to feces. Furthermore, waterborne outbreaks attributable to drinking water that met total coliform guidelines have been documented, demonstrating that it could be dangerous to rely solely on these microbes as indicators of fecal contamination. Despite these drawbacks, total coliforms are still useful indicators of treatment efficacy or pathogen regrowth: considering that water leaving a treatment plant should be free of bacterial contaminants, total coliforms may be used as a disinfection indicator, or to assess whether microbiologically clean water has been re-contaminated between source and point-of-use.

The coliform system, despite its long history as the accepted standard for assessing drinking water safety, has several limitations. A recent systematic literature review found that presence of thermotolerant coliforms inconsistently predicted diarrheal disease when compared to *E. coli*, indicating that its usefulness as a fecal indicator should be carefully considered. Additionally, presence of coliforms have been scrutinized as a way to accurately predict enteric viruses and protozoa in water, as the growth and susceptibility of bacteria are different than that
of viruses and parasites. The use of indicator viruses has been suggested as a valuable tool for assessing other pathogenic viruses in drinking water, however, there is not currently a practical and cost-effective testing method. Furthermore, coliforms cannot be used to indicate the presence of non-fecal pathogens that occur naturally in water, such as *Legionella* or non-tuberculosis mycobacteria. Advances in research and technology have identified several novel indicators that may have potential for indicating contamination with human excreta, including caffeine and some pharmaceuticals. These indicators may be advantageous as they are exclusive to human waste and do not occur naturally in the environment; however, further research is required to understand how they behave in aquatic environments before and after treatment, and how to effectively concentrate and detect these compounds in water.

**Drinking water use and perceptions in North America**

*Consumption patterns*

There are three predominant types of drinking water used by North Americans: municipally treated tap water, treated tap water with secondary decentralized treatments, and purchased bottled water. Treated tap water refers to water that is consumed unmodified from the tap, but has previously undergone treatment at a municipal water treatment plant. Treated tap water with secondary decentralized treatment is that which is municipally treated, and also subjected to in-home treatments such as filtration, boiling, or other advanced methods. On average, North Americans consume around 1 litre of drinking water per day, although estimates vary by location and range as high as 1.5 litres in some studies. Statistics Canada estimated that in 2011 approximately half of Canadian households reported treating their tap water prior to consumption, and 22% drank primarily bottled water, although a large amount of variation existed between provinces. These national-level statistics are supported by other studies with similar results at
both national and more localized scales. Bottled water use was highest in regions of Southern Ontario, with approximately one third of residents reporting it to be their predominant source of drinking water (i.e. ≥ 75% of daily water intake was bottled water). In British Columbia this value was slightly lower, with 23% of residents using bottled water as a predominant water source. Research conducted in Newfoundland and Labrador has shown that 29% of respondents occasionally drank bottled water, although data were not available regarding its use as a predominant drinking water source. The United States of America follows a similar pattern in regards to bottled water use, and is the largest consumer market for bottled water around the globe. However, there has been a trend in recent years of a decrease in use of bottled water in Canada and the United States, and this may be related, in part, to increased awareness about the potential negative environmental impacts of bottled water.

In 2011, 85% of households in Newfoundland and Labrador had a municipal water supply, yet the province had the largest proportion of residents (66%) choosing to apply additional treatments to their tap water prior to consumption. Seventeen percent of households had boiled water in the past year before drinking, which is substantially higher than values from other provinces, and almost 30% stated that they primarily drank bottled water (although residents were not asked to indicate the percentage of their daily water intake that was bottled). In comparison, a study conducted in Nunatsiavut, Labrador, found that almost half (47%) of interviewed individuals in one Inuit community used store-bought water as a primary drinking water source. The research question addressed in this Nunatsiavut study was qualitative in nature; therefore, interviewees were not randomly sampled, a representative sample was not obtained, and the statistical results presented in this study may not be representative of population level trends.
Various demographic factors impact the use of particular water sources and daily volume of water consumed. Bottled water is more likely to be consumed by younger adults, females, and those with higher household income.\textsuperscript{66,67,70,71,74} The association with age may be due to a combination of generational differences and increased susceptibility to marketing of bottled water in younger adults, compared to older adults.\textsuperscript{70,74} Differences across sex have been attributed to gender differences in risk perception, with females believed to be more aware of health and food-related risks.\textsuperscript{74,76} Increased bottled water use in higher income households may be related to financial accessibility as purchased water is very expensive relative to municipally-supplied water, costing up to 1000 times more in some areas of Canada.\textsuperscript{66} Adult age was negatively associated with water consumption, with older and elderly adults consuming less water than young adults.\textsuperscript{67,68,70,71,77} This may be related, in part, to a decrease in physical activity and thirst in older individuals.\textsuperscript{67,77} In contrast, education was positively associated with water consumption: highly educated individuals were reported to drink more water than those who had less schooling.\textsuperscript{68,70,71} This may be due to an increased awareness of the positive health effects of adequate water consumption.\textsuperscript{68}

\textit{Perceptions of drinking water}

The public’s perception of drinking water can have implications for drinking water consumption patterns, particularly for whether an individual chooses to drink bottled water or tap water. A study of factors that influence public perception of drinking water in the United Kingdom concluded that taste might be the most important factor influencing choice of water, as people often relate sensory characteristics to quality and safety.\textsuperscript{78} This finding is supported by evidence in the United States and Canada, which found that health risks and taste, appearance, and/or odour were the most prominent factors affecting whether people chose to purchase bottled water or
filtered tap water.27,79 The media has a role in influencing perceptions of drinking water, mainly in the light of water safety. Several water contamination events in Canada, including the Walkerton, Ontario *E. coli* and *Campylobacter* outbreak and the North Battleford, Saskatchewan *Cryptosporidium* outbreak in 2000 and 2001, respectively, amassed a great deal of media attention.80,81 Between 1997 and 2002 bottled water sales increased by 15%,70 and this may be related to a tainted public perception of water safety in the period of time following these incidents.70

Approximately 15% of North Americans have stated that they felt their water at home was not safe to drink, or that there was a moderate-to-serious problem with getting sick from tap water.66,74 Despite the fact that municipal water is typically highly regulated, there has been research linking consumption of plain tap water to increased rates of enteric illness, when compared to those who filter their water prior to consumption.61 Furthermore, unpleasant taste and/or smell of tap water was an issue reported by one in three people in Canada, and 14% stated that there were problems with “rusty” colour or sediment.66 These issues have been linked to decreases in tap water consumption, and increases in bottled water use.66 Generally, individuals that mainly chose to drink tap or filtered tap water often had a more favourable perception of the quality of that water.74,82 Women have higher odds of consuming bottled water, and this may be, in part, because women are more likely to perceive bottled water as safer than tap water.66 Aside from perceptions of safety and quality, however, convenience may also play a role in why some people choose to drink bottled water over other sources. A study in Indiana, USA, found that heavy users of bottled water often perceived it as more convenient than tap water; although, non-bottled water users did not feel strongly about its increased convenience.83 According to a Statistics Canada survey in 2006, approximately 15% of First Nations, Métis, and Inuit felt that water at
home was unsafe for consumption. \cite{13} Close to 40\% of all Inuit stated that they felt their drinking water was contaminated at certain times of the year, \cite{13} and this value was 100\% in Rigolet, Nunatsiavut. \cite{84} Commonly stated descriptions of tap water in Rigolet and Nain, Nunatsiavut, included that it was brown, cloudy, and smelled strongly of chlorine. \cite{75} Unfortunately, it often takes a crisis to highlight the need for increased priority to be given to improving drinking water safety; for example, in 2011, silt contaminated Nain’s drinking water supply, leaving the residents dependent on bottled water that had to be flown into the community. \cite{85} For the many people living in remote communities, struggles with contaminated water and water insecurity are a part of daily life, \cite{50} and as a result many people have become mistrustful of their water supply.

Perceptions of unregulated private water supplies appear to be inconsistent in the literature. For example, a 2006 study in southern Ontario reported that over 78\% of respondents rated the safety of their private water as “very good” or “good,” yet 80\% also felt “very concerned” or “concerned” about the overall safety of water from this supply. \cite{86} Similar results were found in a cross-sectional study of private water in Newfoundland and Labrador in 2007. \cite{73} Indeed, as home owners are responsible for the quality of their own water source, a higher level of concern about ensuring its safety could be expected. This discrepancy could also be related to a lack of reliable, consistent, or current information about the state of private drinking water: several studies have determined that a substantial proportion of households either never test their well water, or perform testing very intermittently, and feel they do not need to continually test their water if it had a normal result in the past. \cite{73, 86, 87} Additionally, some stated that they preferred a private water source because they did not need to rely on others to treat their water, and so perceived it to be safer. \cite{88} Water contamination events of municipal water supplies may serve to exacerbate this perception of safety, even though it may be unfounded due to lack of adherence to testing or treatment
recommendations. Perceptions of unregulated, natural sources of water in Inuit communities of Nain and Rigolet, Labrador were found to be generally positive in a recent study, with words used to describe water from the land including “fresh,” “pure,” and “healthy,” among others. Interestingly, only 15% of interviewees stated that store-bought water was their favourite drinking water source, despite its common use in Rigolet. The majority of interviewees (81%) in both study communities said that they preferred to drink untreated water from the land.

**Drinking water contamination**

*Waterborne and water-based pathogens*

An important distinction within the many viruses, bacteria, and parasites that may be transmitted through water is the difference between waterborne and water-based pathogens. Waterborne pathogens infect the gastrointestinal tract of the human or animal host and are spread through contaminated feces via water (although they might also be spread through other fecal-oral routes of transmission such as person-person contact). In contrast, water-based pathogens originate in the environment and require water for at least a portion of the lifecycle. Intake of water or water aerosols is typically required for transmission of water-based pathogens, and other modes of transmission are very rare. The World Health Organization states that of the microbes found in water, those of fecal origin pose the greatest threat to human health. The US Environmental Protection Agency has identified over 500 waterborne pathogens of possible concern to public health.

*Routes of water contamination*

Water can become contaminated with fecal pathogens at various points as it moves from its source to point of consumption in the home. Source water contamination occurs when contaminants enter the water at its origin, either in surface water or groundwater. Surface water is
often more vulnerable to contamination as it is vulnerable to run-off contamination from animals (e.g. aquatic wildlife, livestock, and birds) and sewage discharge. For instance, a recent study assessing source water in Lake Ontario found that up to 50%, 15%, and 36% of influent water samples into water treatment plants contained enteric viruses, Cryptosporidium, and Giardia, respectively. Groundwater is generally considered less prone to contamination due the natural barrier and filtration that the overlying earth provides; however, contamination may still occur through improper disposal of waste, septic tank or landfill leaks, shallow wells, or other factors. Heavy rainfall events are an important contributor to source water contamination and have been linked to increases in waterborne pathogens, as the subsequent runoff results in leaching of fecal material into surface and well water. The well-known Walkerton E. coli and Campylobacter outbreak was attributed, in part, to a heavy rainfall event several days prior to the outbreak. The issues of rainfall-induced runoff may be of particular concern in agricultural areas, where runoff may contain high levels of dissolved particles and zoonotic contaminants from livestock.

In northern Canada, source water contamination may have more direct impacts on the population due to the common practice of consuming untreated surface water. Contamination from animal feces is a concern that may become increasingly relevant as climate change alters the range of wildlife throughout Canada, and increases the frequency, duration, and intensity of rainfall events leading to run-off. These changes may result in an increase in water contamination with zoonotic pathogens from feces; for example Giardia is a zoonotic pathogen commonly associated with beavers and muskrats, which have been expanding their range northward.

Secondary contamination of water occurs when drinking water becomes re-contaminated, either in the distribution system or in the home. Microbiologically clean water exiting the treatment
plant is vulnerable to recontamination within the distribution system: intermittent water supplies, water main damage, maintenance, or other events that result in changes in water flow can result in intrusion of microbial contaminants from the outside environment or from pipelines containing non-potable water. Microbial growth may also occur on the pipe surface, despite adequate chlorination levels. Various pipe materials may leach chemicals that support bacterial growth, including the growth of coliforms. Recontamination may also occur at the household level through contact with unwashed hands or contaminated storage containers or drinking vessels. In some communities, particularly in those that are remote or have limited access to safe tap water, it is necessary for water to be collected and stored in the home. Many studies have assessed the extent of contamination and pathways by which this may occur; although, most are in the context of developing countries, and there appears to be little research on this topic in North America. A systematic review by Wright et al. on microbial recontamination of drinking water in developing regions showed that water quality declined significantly between source and point-of-use in approximately half of the reviewed studies, and in no cases did it improve after collection. Hands and transfer devices have been implicated as a likely source of recontamination through cross-contamination when handling or cleaning containers. Poor cleaning practices may also lead to biofilm growth in storage containers or water pitchers, or contamination just before point of consumption from the drinking cup itself. In northern Canada, secondary contamination of stored water may be of particular importance, as many households rely on stored water for drinking and cleaning purposes. A study in Nunavik, Québec, found that 80% of plastic water containers sampled contained >10 total coliform bacteria per 100mL. It was also noted in this study that most containers appeared poorly cleaned, leading researchers to hypothesize that the vessel was a source of recontamination and called for further research on this matter.
Interventions to protect and improve drinking water

Due to the possibility of failures at treatment plants or inadequate water treatment if the plant is overwhelmed, highly contaminated source waters may pose a risk to public health.\textsuperscript{112} Ensuring a reasonably clean source of drinking water, therefore, is an important aspect of a multi-barrier approach that provides safe water to users.\textsuperscript{113} Source water protection (SWP) strategies to reduce initial contamination are recommended in Canada, after having received much attention since the Walkerton outbreak and its subsequent inquiry.\textsuperscript{114} Several predominant strategies include: vegetated filter strips near source water to absorb pollutants and slow down runoff; pollution control by agricultural practices, storm water management, and fencing to keep humans and animals away from source waters.\textsuperscript{113} In the community of Makkovik, Nunatsiavut, for example, the town’s drinking water supply (a small lake) is fenced off to help prevent contamination from human or animal activity.\textsuperscript{115} Other aspects of a multi-barrier approach to drinking water include water treatment (often through more than one method), ensuring secure distribution systems, and having effective monitoring programs and plans to respond to adverse events or failures.\textsuperscript{114}

Once raw water has been taken from its source, several treatments are often applied to remove physical and microbial contaminants. Chlorination is the most common method of disinfection in Canada and the United States, and has been widely used for over a century due to its efficacy at destroying microbes.\textsuperscript{116} However, chlorine is limited in its ability to destroy all waterborne pathogens: bacterial spores, enteric viruses, and certain protozoa including Cryptosporidium and Giardia are inherently chlorine-resistant and able to survive in water distribution systems despite the presence of residual chlorine.\textsuperscript{117–119} Furthermore, indicator organisms are often highly susceptible to chlorine and so may not be useful for indicating presence of these resistant pathogens.\textsuperscript{117} A multiple treatment method is therefore preferable, and in some
treatment plants in Canada other processes such as chloramination, ultraviolet (UV) light, and ozonation are also applied to disinfect drinking water.\textsuperscript{120}

Chlorination also presents issues in regards to potential health effects from chlorine by-products, also called disinfection by-products (DBPs). These by-products form when chlorine reacts with organic matter that is present in water.\textsuperscript{116} The most common and well known group of DBPs are trihalomethanes (THMs), and to a lesser degree, haloacetic acids (HAAs), although altogether more than 600 DBPs from chlorinated tap water have been identified.\textsuperscript{116} The communities of Nunatsiavut do not filter the municipal drinking water, so it is perhaps not surprising that several of the communities have DBP levels which far exceed Health Canada’s guidelines. In Postville and Rigolet, for example, concentrations of THMs and HAAs were more than double the recommended levels in 2015.\textsuperscript{121,122} Epidemiological studies on long-term exposure to DBPs have shown associations with reproductive toxicity and several types of cancer including bladder, colon, rectal, pancreatic, and brain cancers.\textsuperscript{123} However, these study results have often been inconsistent and further research is needed in order to better understand the causative agents and provide higher quality evidence for the potential effects.\textsuperscript{123}

In addition to the filtration and disinfection that occurs in municipal water treatment plants, many households in Canada choose to perform additional treatments on their tap water, both for safety and aesthetic purposes. Some methods of in-home (also known as point-of-use) treatments in North America include boiling and filtration with activated carbon filters, while advanced methods include reverse osmosis, UV light, ozonation, and distillation. The most common in-home treatment method is the use of a carbon filter, either in a water pitcher or on a tap or refrigerator.\textsuperscript{68,71,73} However, not all filters remove microscopic organisms, and are mainly intended for use in removing unwanted chemicals or by-products and improving taste and odour.\textsuperscript{124–126}
Moreover, using water pitchers may inadvertently increase the risk of secondary contamination if improperly cleaned and handled, potentially negating the effects of prior water treatment. Within Canada, Newfoundland and Labrador had the highest percentage of residents (66%) choosing to use secondary, in-home treatments on municipally supplied tap water in 2011.\textsuperscript{127} This further indicates issues with municipal water quality in the province and negative perceptions of its safety. Little information was found regarding use of in-home treatments in Inuit communities.

**Acute gastrointestinal illness in North America**

**Burden of illness**

Acute gastrointestinal illness (AGI) is a form of enteric illness that may have many causes including infectious pathogens. Generally, it entails acute diarrhea and/or vomiting that can range in severity from mild and self-limiting to fatal illness. There are various definitions in the peer-reviewed literature used to describe what constitutes AGI,\textsuperscript{102,128,129} and unfortunately this can limit comparability between studies that use different case definitions. In 2000, Health Canada began the National Studies on Acute Gastrointestinal Illness initiative (NSAGI),\textsuperscript{130} which used a broad case definition of any self-reported diarrhea or vomiting. Diarrhea was defined as any loose stool or stool with abnormal liquidity, and vomiting as any forcible expulsion of stomach contents out of the mouth.\textsuperscript{129} Individuals with pre-existing illnesses or conditions, diagnosed by a medical doctor, that may result in diarrhea or vomiting were excluded as cases (i.e. considered non-cases).\textsuperscript{129} Use of a consistent definition throughout the initiative has allowed these studies to be compared more effectively in Canada and on a global level.

In 2013, the Public Health Agency of Canada estimated that there were over 20 million cases of AGI per year throughout the country (0.63 cases/person per year), occurring from all sources.\textsuperscript{131} This value is thought to be the most accurate estimate of the burden of AGI in Canada.
to date. Previous studies in Canada have had to extrapolate results from data collected in the United States, which likely resulted in inaccuracies. Another major impediment to approximating the burden of AGI (and waterborne disease in general) is underreporting, as not all individuals seek medical care or report their illness, particularly if their symptoms are mild. Underreporting is especially a problem in studies that make use of data from passive surveillance.

Mortality from diarrheal disease is much less common in developed countries, although it remains an important cause of death in developing nations and was the seventh leading cause of death globally in 2012, causing an estimated 1.5 million fatalities. Acute gastrointestinal illness does, however, represent an important source of morbidity in North America and therefore has substantial economic impacts. A study conducted between 2001-2002 estimated the Canadian national economic burden to be at least 3.7 billion dollars annually. This value includes the direct costs of healthcare and the indirect costs associated with loss of productivity (e.g. missed days of work). These conclusions are supported by research conducted in British Columbia between 2002-2003, which had generally comparable results.

The burden of AGI is not shared equally across all sub-populations. Young children (<5 years of age) comprise the majority of diarrheal disease-related deaths globally, and also have increased rates of illness in developed countries for infections including rotavirus, cryptosporidiosis, and giardiasis. The elderly are also considered to be a high-risk sub-population due to reduced immune function or potentially from age-related behaviours that increase risk of exposure. Finally, immunocompromised or chronically ill individuals also constitute an important at-risk group: these include those with diabetes, cancer patients, organ transplant recipients, as well as HIV infected individuals. These sensitive populations are
increasing in size in the developed world; hence, the burden of AGI in developed countries may also increase in the future.

The burden of AGI is not shared equally among cultural groups in Canada. Recent literature suggests that Inuit communities experience rates of AGI up to three times greater when compared to southern regions of Canada. The estimated annual incidence rate of AGI in Rigolet, Nunatsiavut was approximately 3.8 cases/person per year, compared to incidence rates ranging between 1.2-1.3 cases/person per year in studies conducted in Ontario and British Columbia. It is challenging to determine the fraction of AGI that is caused specifically by water or other exposures, and this is a suggested area of future research in the North. Some work, however, has assessed perceived causes of AGI in northern Canada, and gastrointestinal illness is frequently stated by residents as a perceived outcome related to drinking water.

**Exposure to waterborne pathogens**

*Limited or No Water Treatment:* People can come into contact with waterborne pathogens in a variety of situations. Firstly, absence of any drinking water treatment or lack of a multiple-treatment protocol can result in pathogens remaining in the water distribution system. Approximately 4 million Canadians drink private well water, and a further 1.7 million are estimated to be served by a small community drinking water supply (i.e. a system serving less than 1000 people). These water supplies likely present an increased risk to human health due to unregulated or reduced levels of treatment; a Canadian study of water-related outbreaks found that over 65% were associated with semi-private or private water systems. Data from the United States have shown that a large proportion of outbreaks were attributable to drinking contaminated groundwater, which is the most common source of private water in Canada. In facilities that implement only disinfection with no filtration, issues arise with organisms that are resistant to
particular methods of treatment. This is highly relevant in Nunatsiavut communities, which rely solely on chlorination for treatment of piped drinking water. Even with advanced methods such as UV light disinfection there is concern over developing resistance in some viral pathogens.\textsuperscript{141}

\textit{Failures at Treatment Plants}: Failures at water treatment plants can be a result of mechanical breakdown, overwhelmed systems, or human error. A study assessing risk of waterborne illness in the United States estimated that treatment deficiencies were responsible for 32\% of all waterborne outbreaks between 1991-2002;\textsuperscript{90} this value is not surprising given that treatment failures are often cited as the issue (or as one of several interplaying factors) in a substantial proportion of waterborne outbreak investigations.\textsuperscript{139,142,143} These failures have frequently been associated with extreme rainfall events, which cause increased levels of contaminants and organic matter to enter the water system and overload the facility’s capacity to adequately treat drinking water.\textsuperscript{142,144–146} Systems that only chlorinate water are particularly vulnerable, as high levels of organic matter can rapidly degrade free chlorine and potentially leave viable pathogens in the water.\textsuperscript{147} A review of waterborne outbreaks in the United States concluded that extreme rainfall preceded 51\% of waterborne outbreaks from 1948-1994.\textsuperscript{95} Simple water treatment systems in remote areas such as Nunatsiavut are therefore more vulnerable to treatment failures, due to the potential for system overload in extreme rainfall/runoff events. This again stresses the importance of a multi-barrier approach to protection of drinking water. Additionally, many water systems in the Arctic, both simple and advanced, can fail because a simple repair cannot be made.\textsuperscript{9} Frequent breakdowns, lack of trained personnel, delays in repair due to the need to import parts, and the inability of the community to financially support the system all contribute to water treatment failures and the unsustainability of many treatment systems, including PWDUs.\textsuperscript{148}
**Recreation:** Most recreational exposure to waterborne pathogens has been documented in the context of recreational swimming, although water-related activities such as boating and fishing have also been associated with increased risk of AGI.\(^{149}\) Exposure through swimming may occur in both untreated (e.g. natural beaches) and treated water (e.g. pools and waterparks), and it has been estimated that there is a 3-8% risk of developing AGI after swimming.\(^{136}\) The majority (77%) of reported recreational-water associated outbreaks in the United States between 2011-2012 were attributable to treated water, with over half of these events caused by *Cryptosporidium*.\(^{150}\) *Cryptosporidium* is well suited to surviving in treated water as it is highly resistant to chlorine, and this pathogen has been implicated as the suspected agent in a large number of investigations of recreational water-related illness, both in Canada\(^{151,152}\) and worldwide.\(^{152}\) *Giardia* has also been linked to recreational water, although to a much lesser extent than *Cryptosporidium*: between 1999-2008, only 3.5% of recreational-water outbreaks in the United States were attributed to *Giardia*.\(^{143}\) Bacterial and viral agents are more commonly associated with untreated water,\(^{150,153}\) causing at least 53% of untreated recreational-water related outbreaks in the United States from 1999-2008.\(^{143}\) Little research has been conducted assessing recreational exposure to pathogens in the North, although concerns have been raised in some Inuit communities about drinking water contamination resulting from recreational swimming in the local lake (which supplies the community’s drinking water).\(^{115}\)

**Travel:** According to the World Health Organization, diarrhea affects between 20-50% of all travellers each year, with contaminated water and food being the most common source of infection.\(^3\) A study conducted in Waterloo, Canada, found that for cases with an identified risk setting, travel was reported 37% of the time.\(^{154}\) Individuals often travel from industrialized areas to developing regions, where pathogens may be more widespread and concentrated in water.\(^{155}\)
Poor food preparation and hygiene practices in these areas likely play the largest role in contributing to travellers’ diarrhea,\textsuperscript{156} with bacterial agents including \textit{Campylobacter} and enterotoxigenic \textit{E. coli} accounting for approximately 80\% of all reported travel-related enteric illnesses.\textsuperscript{157,158} Interestingly, a study in Rigolet found that travel to local cabins was protective against AGI; this may be related to the positive effects that spending time on the land has on mental and physical well-being, among other factors.\textsuperscript{22} This implies a potential difference between the effects of local versus foreign travel on developing AGI, although further research would be required to investigate this hypothesis.

**Conclusions, study rationale, and research objectives**

This synthesis of research and information illustrates several key issues in regard to drinking water in Inuit populations of northern Canada. Many Inuit have negative perceptions about the safety of drinking water where they live, and feel that it may be contributing to the high rates of AGI experienced in Inuit communities. This perception has effects on drinking water consumption patterns, and has resulted in many people opting to obtain their drinking water from alternative sources, including water from recently constructed PWDUs in three Nunatsiavut communities (Rigolet, Postville, Makkovik). A lack of research exists on drinking water in these three Inuit communities, particularly in regard to the impact of the new water treatment systems. Therefore, the overarching goal of this thesis research was to examine drinking water in Rigolet, Nunatsiavut, and possible relationships with acute gastrointestinal illness. The specific objectives of this thesis research were to:

1. Describe perceptions of municipal tap water, examine the use of water sources, and assess residents’ daily volume of water consumption in Rigolet (Chapter Two); and
2. Assess drinking water collection and storage practices, potential risk factors for water contamination, and the possible association with self-reported AGI (Chapter Three).
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**Table 1.1** Examples of major enteric and non-enteric pathogens transmissible through water.\(^{92,160}\)

<table>
<thead>
<tr>
<th>Pathogen group</th>
<th>Enteric (waterborne)</th>
<th>Non-enteric (water-based)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibrio cholerae</td>
<td></td>
<td>Legionella spp.</td>
</tr>
<tr>
<td>Campylobacter jejuni and coli</td>
<td></td>
<td>Pseudomonas aeruginosa</td>
</tr>
<tr>
<td>Escherichia coli O157:H7</td>
<td></td>
<td>Non-tuberculosis mycobacteria</td>
</tr>
<tr>
<td>Salmonella enterica spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shigella sonnei and flexnieri</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td>Cryptosporidium hominis and parvum</td>
<td>Naegleria fowleri</td>
</tr>
<tr>
<td>Cyclospora cayetanensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giardia lamblia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxoplasma gondii</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td>Rotavirus A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Norovirus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hepatitis A and E virus</td>
<td></td>
</tr>
</tbody>
</table>
Table 1.2 Search strings used in electronic database *PubMed* to identify relevant articles on drinking water in North America and Indigenous populations.

<table>
<thead>
<tr>
<th>Review Topic</th>
<th>Search Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water systems and guidelines</td>
<td>(drinking water OR tap water OR municipal water) AND (North America OR Canada OR Canadian OR United States) AND (distribution system* OR water source* OR quality guideline*)</td>
</tr>
<tr>
<td>Indicator bacteria</td>
<td>(drinking water) AND (indicator bacteria OR indicator organism OR total coliform OR fecal coliform OR thermotolerant coliform) AND (Canada OR United States OR North America)</td>
</tr>
<tr>
<td>Drinking water consumption and perceptions</td>
<td>(drinking water) AND (North America OR Canada OR Canadian OR United States) AND (consum* OR beverage* OR preferen* OR habit* OR pattern* OR perception*) NOT (arsenic OR heavy metals OR alcohol OR ethanol OR rats OR mice)</td>
</tr>
<tr>
<td>Acute gastrointestinal illness (AGI) in Canada</td>
<td>(acute gastrointestinal illness OR gastroenteritis) AND (burden OR cost OR economic OR healthcare OR prevalence OR rate OR incidence) AND (Canada OR Newfoundland and Labrador OR Prince Edward Island OR Nova Scotia OR New Brunswick OR Quebec OR Ontario OR Manitoba OR Saskatchewan OR Alberta OR British Columbia OR Yukon OR Northwest Territories OR Nunavut)</td>
</tr>
<tr>
<td>Indigenous communities and water in Canada</td>
<td>(Canada OR Newfoundland and Labrador OR Prince Edward Island OR Nova Scotia OR New Brunswick OR Quebec OR Ontario OR Manitoba OR Saskatchewan OR Alberta OR British Columbia OR Yukon OR Northwest Territories OR Nunavut) AND (Indigenous OR Aboriginal OR First Nations OR Metis OR Inuit) AND (water)</td>
</tr>
</tbody>
</table>
Table 1.3 Comparison of microbial parameters recommended by the guidelines for Canadian drinking water quality (*GCDWQ*) and water quality parameters in Newfoundland & Labrador, Canada.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GCDWQ</th>
<th>Newfoundland &amp; Labrador</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em></td>
<td>MAC*: None detectable/ 100 mL</td>
<td>MAC: None detectable/ 100 mL</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>MAC: None detectable/ 100 mL in water leaving a treatment plant and in non-disinfected groundwater leaving the well</td>
<td>MAC: No consecutive samples from the same site, or no more than 10% of samples from each distribution system in a given sample set</td>
</tr>
<tr>
<td><em>Giardia and Cryptosporidium</em></td>
<td>Treatment goal: Minimum 3 log removal and/or inactivation of cysts and oocysts</td>
<td>Not implemented</td>
</tr>
<tr>
<td>Enteric viruses</td>
<td>Treatment goal: Minimum 4 log removal and/or inactivation</td>
<td>Not implemented</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Conventional and direct filtration: $\leq 0.3$ NTU; Slow sand and diatomaceous earth filtration: $\leq 1.0$ NTU; Membrane filtration: $\leq 0.1$ NTU</td>
<td>1.0 NTU</td>
</tr>
</tbody>
</table>

* Maximum acceptable concentration (MAC)
Figure 1.1 A map of communities comprising the Nunatsiavut settled Land Claim Area (as of 2016) and the four land claim areas of Inuit Nunangat.
Figure 1.2 Comparison of provincial/territorial populations and drinking water advisories (as of January 2015) as proportions of national totals.
CHAPTER TWO

HOW ARE PERCEPTIONS ASSOCIATED WITH WATER CONSUMPTION IN CANADIAN INUIT? A CROSS-SECTIONAL SURVEY IN RIGOLET, LABRADOR

ABSTRACT

A large proportion of Inuit adults in Canada have reported concerns over the quality of tap water in their home, and feel that it is contaminated at various times during the year. These concerns, along with aesthetic appeal of the water, may influence a person’s drinking water perceptions and consumption patterns. This research aimed to characterize drinking water perceptions and consumption patterns in the Inuit community of Rigolet, Canada. The objectives were to describe perceptions of municipal tap water, examine use of water sources and changes since the implementation of a potable water dispensing unit (PWDU) in 2014, identify factors associated with consuming different water sources, and assess residents’ daily volume of water consumption. This study used data from a series of three cross-sectional census surveys (n= 226-246): two surveys were conducted before the arrival of the PWDU, and one survey was conducted after the PWDU was installed. Descriptive statistics gave insight into perceptions and drinking water use in the community; logistic regressions were used to identify variables associated with water choices and daily water consumption. Prior to the PWDU, most residents drank purchased water (52%). After the installation of the PWDU, 75% of residents reported using it as a source of drinking water, with a concomitant decline in consumption of bottled, tap, and brook water.

4 Article authorship: C.J. Wright; J.M. Sargeant; V.L. Edge; J.D. Ford; K. Farahbakhsh; I. Shiwak; C. Flowers; A.C. Gordon; Rigolet Inuit Community Government; IHACC Research Team; & S.L. Harper
Negative perceptions of municipal tap water were associated with lower odds of consuming tap water ($\text{OR}_{\text{PCACOMPONENT1}} = 0.73$, 95% CI 0.56 – 0.94; $\text{OR}_{\text{PCACOMPONENT2}} = 0.67$, 95% CI 0.49 – 0.93); women had higher odds of drinking purchased water compared to men ($\text{OR} = 1.90$, 95% CI 1.11 – 3.26). The median amount of water consumed per day was two-500mL servings (1.0L). Using brook water ($\text{OR} = 2.60$, 95% CI 1.22 – 5.56) and living in a household where at least one resident had full-time employment ($\text{OR} = 0.34$, 95% CI 0.16 – 0.74) were associated with consuming a large volume of water (i.e. >2L per day). The knowledge generated from this study is intended to increase understanding of factors that affect water consumption patterns in northern Indigenous communities. Results may also inform sustainable drinking water interventions, risk assessments, and public health messaging in Rigolet and other Indigenous communities.

**Keywords:** Indigenous; Inuit; Nunatsiavut; Arctic; municipal water; aesthetic quality; water; perceptions

**INTRODUCTION**

A variety of factors can impact an individual’s perceptions of water quality, choice of drinking water sources, and volume of water consumption. 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 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 lack of understanding still exists in rural and remote locales. This knowledge deficit exists despite the unique and frequent water challenges that rural and remote populations often experience (Bradford et al., 2016; Dunn et al., 2014; Hennessy and Bressler, 2016). While the majority of people in high-income nations have access to reliable, high quality drinking water (Statistics Canada, 2013a), residents in smaller, remote communities often face challenges that prevent the same level of access. 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 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. Inuit communities often face unique
geographical, climatic, financial, human resource, infrastructural, and capacity water-related challenges (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). Lack of trust in water, water quality and quantity issues, along with 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; Martin et al., 2007).

Recently, 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.). Increased funding for infrastructure and water-related research is crucial to achieve improved access to safe water in northern populations, particularly in-light of multiple stresses brought on by climate change and resource development. While well-intentioned, many factors can prevent the adoption of new or improved water systems; indeed, in some Arctic communities, residents have chosen not to use new systems as a source of drinking water (Marino et al., 2009). Local preferences for taste, integration of cultural values and Indigenous knowledge of water, 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 work 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. Therefore, the goal of this research 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.

METHODS

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 2.1). 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 research study was conducted in partnership with the community of Rigolet. Rigolet is a small community with approximately 306 residents (Statistics Canada, 2012), the vast majority of whom identify as Inuit (Statistics Canada, 2013b). 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).

Rigolet residents have access to four different types of drinking water in the community (Figure 2.2). Firstly, municipally treated (chlorinated but unfiltered) surface water is supplied to all households by underground pipes. Secondly, bottled water is available for purchase at the local store. Thirdly, untreated sources of drinking water are also consumed in Rigolet, including surface water from several nearby brooks in the community. 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, a potable water dispensing unit (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 Department of Municipal Affairs, 2017) has enabled several Labrador Inuit communities to implement new PWDU systems, including Makkovik, Postville, and Cartwright (Goldhar et al., 2012; Hanrahan, 2014; Lightfoot, 2014). The PWDU uses multiple advanced methods to treat the incoming tap water, including sand filtration, ozonation, carbon filtration, reverse osmosis, and ultraviolet light (Government of Newfoundland and Labrador Department of Municipal Affairs, 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 containers for storage in the household; there is currently no user fee for residents to fill their containers.

**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). This study used a subset of data from three cross-sectional studies conducted by local Inuit researchers in Rigolet between 2012 and 2014 (Figure 2.3). 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 2.3).

**Questionnaires**

Local Inuit research associates administered and completed all questionnaires on iPads in the preferred language of the respondent (Appendix A). 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 collected information on many topics, including demographics, water consumption, and overall ratings of drinking water quality. 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 2.3). 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 unboiled 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\textsuperscript{st}) and secondary (2\textsuperscript{nd}) 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. 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.

**Consent & ethical approvals**

Written informed consent was obtained by each participant before completing the questionnaires; if a participant was under 18, parental permission was obtained (and 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.
Data analysis

Questionnaire data from the three surveys were combined into a single dataset, linked by individual identification number, and cleaned to prepare for analysis. 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, or who responded ‘refuse to answer’ or ‘unsure’ were excluded from the analysis of that question.

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.

Examining water consumption patterns

Unconditional logistic regressions were first performed on a variety of explanatory variables that were postulated to be associated with outcomes of interest. Unconditional associations with variables that had a p-value <0.2 were retained for analysis, which served as a method of data reduction (see Supplementary Table 2.1 in Appendix B). Multivariable models were then constructed to include the exposure of interest (i.e. explanatory variable), with and age and gender included in the model as confounding variables. Age and gender were 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 \(\chi^2\) 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 \(\chi^2\), 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 consumption.

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.

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, concern, and perceived importance of the taste, smell, and colour of tap water (see Supplementary Table B.1 in Appendix B). 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. 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.

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). Standard logistic regression modelling was used to identify explanatory variables associated with this outcome in June 2014.

RESULTS

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 2.1).

**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; Figure 2.4) 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.” Perceptions of the aesthetic qualities and safety of tap water across various demographic groups in May 2013 are presented in Table 2.2. 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 “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).

**Drinking water sources used over time**

Prior to the installation of the PWDU, purchased water was the primary drinking water source for over half of respondents in Rigolet, followed by tap water and brook water in both September 2012 and May 2013. 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 2.3, Supplementary Table B.2 in Appendix B). Tests of global significance across survey periods were significant, and the
models fit the data well. In contrast to primary water sources, secondary drinking water sources remained relatively consistent over time (Figure 2.5).

**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 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\text{PCA component one} = 0.73, 95% CI 0.56 – 0.94; OR\text{PCA component 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 2.3, Supplementary Table B.2 in Appendix B). Residual diagnostics indicated that these models fit the data well.

**Daily volume of water consumption**

In June 2014, responses regarding the volume of water consumed daily ranged from no water (0 L) (i.e., they did not drink 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 had lower odds of consuming a large quantity of water if they lived in a household where at least one resident had full-time employment (OR = 0.31, 95% CI 0.14 – 0.69) (Table 2.3, Supplementary Table B.2 in Appendix B). Residual diagnostics indicated that the models fit the data well.

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.

Perceptions of tap water

Poor ratings and perceptions of the aesthetic qualities of tap water may be closely related to attitudes toward chlorine (Piriou et al., 2004), which has previously been identified as undesirable in Rigolet tap water (Goldhar et al., 2013) and is 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 may influence risk perceptions and beliefs regarding the safety of drinking water (Doria et al., 2009). 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). 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.

**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 9 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). While PWDU water may be 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 from the PWDU 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); this may also be an important factor influencing the use of the PWDU, although further work assessing this hypothesis would be necessary.

Despite offering a preferred source of drinking water, the PWDU does have several important drawbacks. Firstly, 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), which can be cost prohibitive for small remote communities. 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 potentially make the PWDU unsustainable without regular provincial funding. 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. Lastly, water from the PWDU contains no free chlorine residuals; while this may 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., under review). Future risk assessments, cost-benefit-analyses, and discussions on
water policy and public health messaging should take these contextually unique factors into consideration.

**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). Indeed, 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 odours and flavours (Health Canada, 2012). 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).

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), and is thought to be related to an increased awareness of health-related risks (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; indeed, similar findings and conclusions have been reported in other studies (Dupont et al., 2010; Hu et al., 2011).

**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 in Inuit (Goldhar et al., 2013). Indeed, 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 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).

**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. Despite conducting census surveys, a small source population contributed to low statistical power, which may have limited our ability to detect statistically significant associations;
also, low statistical power impacted our ability to perform multivariable analyses. Furthermore, a substantial number of individuals responded “unsure” when asked about various perceptions of tap water, and this reduced the number of observations available for analysis. Finally, 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.

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 might be explained by a dissatisfaction with tap water and a preference for a chlorine-free source of drinking water. Future risk assessments or public health messaging should consider the continued reliance on alternative water sources, such as untreated brook water. Addressing concerns over chlorine in the piped tap water is likely a crucial step in improving satisfaction with this water source.

ACKNOWLEDGEMENTS

Sincere thanks to the residents of Rigolet for their ongoing participation in the many surveys and research-related events that have taken place in their community over the years. Thank you also to Charlotte Wolfrey, Michele Wood, and the dedicated work of local surveyors over the course of this research, including Marilyn Baikie, & Dina Wolfrey. Survey questionnaires were adapted from questionnaires developed by Health Canada, the Public Health Agency of Canada, and previous studies investigating water consumption in Canada (Jones et al., 2006; Jones et al., 2007). This research was funded by the Indigenous Health Adaptation to Climate Change
(IHACC) project [file nos. 106372-003, 004, 005] and the Inuit Traditional Knowledge for Adapting to the Health Effects of Climate Change (IK-ADAPT) project [application no. 298312]. IHACC is funded by the International Development Research Centre (IDRC) and Canadian Tri-Council Agencies (Canadian Institutes of Health Research [CIHR], Natural Sciences and Engineering Research Council of Canada [NSERC], and the Social Sciences and Humanities Research Council [SSHRC]). IK-ADAPT is funded by CIHR. This work was also supported through the Ontario Graduate Scholarship (to CW), the Latornell Graduate Scholarship (to CW) and the Ontario Veterinary College Scholarship (to CW). The design and conduct of this study were independent of the funding sources.
REFERENCES


Dupont, D., Adamowicz, W.L., Krupnick, A., 2010. Differences in water consumption choices in


Lightfoot, T., 2014. “We got it good here”: exploring the drinking water system in Makkovik, Nunatsiavut. Memorial University, St. Johns.


## TABLES

### Table 2.1 Demographic information of Rigolet residents: comparison between 2011 Rigolet census data and survey participants.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2011 Number (%)</td>
<td>n = 226 Number (%)</td>
<td>n = 235 Number (%)</td>
<td>n = 246 Number (%)</td>
</tr>
<tr>
<td>Population</td>
<td>N = 305</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>160 (52.5)</td>
<td>119 (52.7)</td>
<td>121 (51.5)</td>
<td>121 (49.2)</td>
</tr>
<tr>
<td>Male</td>
<td>145 (47.5)</td>
<td>107 (47.3)</td>
<td>114 (48.5)</td>
<td>125 (50.8)</td>
</tr>
<tr>
<td>Age (years)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-9</td>
<td>40 (13.1)</td>
<td>38 (16.8)</td>
<td>43 (18.3)</td>
<td>41 (16.7)</td>
</tr>
<tr>
<td>10-14</td>
<td>15 (4.9)</td>
<td>17 (7.5)</td>
<td>19 (8.1)</td>
<td>24 (9.8)**</td>
</tr>
<tr>
<td>15-19</td>
<td>15 (4.9)</td>
<td>10 (4.4)</td>
<td>11 (4.7)</td>
<td>9 (3.6)</td>
</tr>
<tr>
<td>20-24</td>
<td>25 (8.2)</td>
<td>10 (4.4)</td>
<td>10 (4.2)</td>
<td>7 (2.8)**</td>
</tr>
<tr>
<td>25-64</td>
<td>180 (59.0)</td>
<td>134 (59.3)</td>
<td>140 (59.6)</td>
<td>144 (58.5)</td>
</tr>
<tr>
<td>65-69</td>
<td>10 (3.3)</td>
<td>6 (2.7)</td>
<td>5 (2.1)</td>
<td>10 (4.1)</td>
</tr>
<tr>
<td>≥70</td>
<td>20 (6.6)</td>
<td>11 (4.9)</td>
<td>7 (3.0)</td>
<td>11 (4.5)</td>
</tr>
</tbody>
</table>

*Global p-value = 0.028

**Significant difference between survey and 2011 Census data (p<0.05)
Table 2.2 Adults’ perceptions of tap water in Rigolet, Canada in May 2013.

<table>
<thead>
<tr>
<th>Demographic characteristics*</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Education level</th>
</tr>
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<tbody>
<tr>
<td>AESTHETIC QUALITIES OF TAP WATER</td>
<td></td>
<td>18-54</td>
<td>55+</td>
</tr>
<tr>
<td>Ratings of taste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good, excellent</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 (19.8)</td>
<td>11 (13.3)</td>
<td>95 (81.2)</td>
</tr>
<tr>
<td>Fair, poor, or very poor</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>63 (77.8)</td>
<td>68 (81.9)</td>
<td>16 (13.7)</td>
</tr>
<tr>
<td>Ratings of smell</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good, excellent</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 (22.2)</td>
<td>13 (15.7)</td>
<td>20 (17.1)</td>
</tr>
<tr>
<td>Fair, poor, very poor</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>55 (67.9)</td>
<td>61 (73.5)</td>
<td>84 (71.8)</td>
</tr>
<tr>
<td>Ratings of colour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good, excellent</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14 (17.3)</td>
<td>11 (13.3)</td>
<td>15 (12.8)</td>
</tr>
<tr>
<td>Fair, poor, very poor</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67 (82.7)</td>
<td>68 (81.9)</td>
<td>99 (84.6)</td>
</tr>
<tr>
<td>CONCERNS ABOUT TAP WATER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals/pollutants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concerned/extremely concerned</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>44 (54.3)</td>
<td>51 (61.4)</td>
<td>71 (60.7)</td>
</tr>
<tr>
<td>Somewhat, slightly, not concerned</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>29 (35.8)</td>
<td>18 (21.7)</td>
<td>31 (26.5)</td>
</tr>
<tr>
<td>Chlorine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concerned/extremely concerned</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>46 (56.8)</td>
<td>52 (62.6)</td>
<td>75 (64.1)</td>
</tr>
<tr>
<td>Somewhat, slightly, not concerned</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31 (38.3)</td>
<td>20 (24.1)</td>
<td>35 (29.9)</td>
</tr>
<tr>
<td>“Germs”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concerned/extremely concerned</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 (61.7)</td>
<td>55 (66.3)</td>
<td>82 (70.0)</td>
</tr>
<tr>
<td>Somewhat, slightly, not concerned</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 (30.9)</td>
<td>19 (22.9)</td>
<td>27 (23.1)</td>
</tr>
<tr>
<td>How does chlorine impact health?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive health impact</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 (3.7)</td>
<td>6 (7.23)</td>
<td>5 (4.3)</td>
</tr>
<tr>
<td>Negative health impact</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 (18.5)</td>
<td>17 (20.5)</td>
<td>25 (21.4)</td>
</tr>
<tr>
<td>Positive &amp; negative health impacts</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21 (25.9)</td>
<td>28 (33.7)</td>
<td>42 (35.9)</td>
</tr>
<tr>
<td>No health impacts</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 (8.6)</td>
<td>6 (7.23)</td>
<td>8 (6.8)</td>
</tr>
<tr>
<td>Do you think you or someone in your family has ever gotten sick from drinking tap water?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21 (25.9)</td>
<td>28 (33.7)</td>
<td>41 (35.0)</td>
</tr>
<tr>
<td>No</td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td></td>
<td>47 (58.0)</td>
<td>40 (48.2)</td>
<td>57 (48.7)</td>
</tr>
<tr>
<td>n (per group)</td>
<td>81</td>
<td>83</td>
<td>117</td>
</tr>
</tbody>
</table>

*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 2.3 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 Table B.2 (Appendix B).

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>OR</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome: Tap water as 1st water source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep 2012</td>
<td>91</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 2013</td>
<td>93</td>
<td>1.13</td>
<td>0.630</td>
<td>0.69 – 1.84</td>
</tr>
<tr>
<td>Jun 2014</td>
<td>42</td>
<td>0.16</td>
<td>&lt;0.001</td>
<td>0.09 – 0.28</td>
</tr>
<tr>
<td><strong>Outcome: Purchased water as 1st water source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep 2012</td>
<td>113</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 2013</td>
<td>124</td>
<td>1.13</td>
<td>0.582</td>
<td>0.71 – 1.84</td>
</tr>
<tr>
<td>Jun 2014</td>
<td>34</td>
<td>0.06</td>
<td>&lt;0.001</td>
<td>0.03 – 0.12</td>
</tr>
<tr>
<td><strong>Outcome: Brook water as 1st water source</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey period</td>
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<td></td>
</tr>
<tr>
<td>Sep 2012</td>
<td>16</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 2013</td>
<td>13</td>
<td>0.47</td>
<td>0.176</td>
<td>0.16 – 1.40</td>
</tr>
<tr>
<td>Jun 2014</td>
<td>3</td>
<td>0.05</td>
<td>0.001</td>
<td>0.01 – 0.26</td>
</tr>
<tr>
<td><strong>Outcome: Consumption of tap water as 1st or 2nd water source in June 2014</strong></td>
<td></td>
<td></td>
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<tr>
<td>Concerned or extremely concerned about chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>98</td>
<td>0.23</td>
<td>0.003</td>
<td>0.08 – 0.61</td>
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<tr>
<td>No</td>
<td>51</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rated quality of tap water for drinking as fair, poor, or very poor</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Yes</td>
<td>127</td>
<td>0.22</td>
<td>0.002</td>
<td>0.08 – 0.58</td>
</tr>
<tr>
<td>No</td>
<td>34</td>
<td>Ref.</td>
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<td>-</td>
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<tr>
<td>PCA: component one †</td>
<td>103</td>
<td>0.73</td>
<td>0.017</td>
<td>0.56 – 0.94</td>
</tr>
<tr>
<td>PCA: component two †</td>
<td>103</td>
<td>0.67</td>
<td>0.017</td>
<td>0.49 – 0.93</td>
</tr>
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<td><strong>Outcome: Consumption of purchased water as 1st or 2nd water source in June 2014</strong></td>
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</tr>
<tr>
<td>Gender</td>
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<tr>
<td>Female</td>
<td>121</td>
<td>1.90</td>
<td>0.019</td>
<td>1.11 – 3.26</td>
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<td>Someone in household had full-time employment in May 2013</td>
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<tr>
<td>Yes</td>
<td>99</td>
<td>5.52</td>
<td>&lt;0.001</td>
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<td>93</td>
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<td>-</td>
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<tr>
<td><strong>Outcome: Water consumption &gt;2L/day in June 2014</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drank brook water as 1st or 2nd water source</td>
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<td></td>
<td></td>
</tr>
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<td>-</td>
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<tr>
<td>Someone in household had full-time employment in May 2013</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>127</td>
<td>0.31</td>
<td>0.004</td>
<td>0.14 – 0.69</td>
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<tr>
<td>No</td>
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<td>-</td>
</tr>
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</table>

* 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.
Figure 2.1 A map of Northern Canada, depicting the four regions of Inuit Nunangat and the five Inuit communities of Nunatsiavut, as of 2017.
Figure 2.2 Potable water dispensing unit (PWDU) water (left) and tap water (right); (B) local brook water; (C) the interior of the PWDU; (D) the PWDU building in Rigolet, Canada (2014).
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<td>• Detailed perceptions of water quality, including taste, smell, and colour</td>
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**Figure 2.3** Timeline of data collected in each survey that related to the objectives of this research in Rigolet, Canada (2012-2014).
Figure 2.4. Ratings of the overall perceived quality of water from the potable water dispensing unit (PWDU), purchased water, brook water, and tap water as primary (1°) and secondary (2°) drinking water sources in Rigolet, Nunatsiavut (2014).
Figure 2.5 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.
CHAPTER THREE

WATER QUALITY AND HEALTH IN NORTHERN CANADA: STORED DRINKING WATER AND ACUTE GASTROINTESTINAL ILLNESS IN LABRADOR INUIT\(^5,6\)

ABSTRACT

One of the highest self-reported incidence rates of acute gastrointestinal illness (AGI) in the global peer-reviewed literature occurs in Inuit communities in the Canadian Arctic. This high incidence of illness could be due, in part, to the consumption of contaminated water, as many Northern communities face challenges related to the quality of municipal drinking water. Furthermore, many Inuit store drinking water in containers in the home, which could increase the risk of contamination between source and point-of-use (i.e. water recontamination during storage). To examine this risk, this research characterized drinking water collection and storage practices, identified potential risk factors for water contamination between source and point-of-use, and examined possible associations between drinking water contamination and self-reported AGI in the Inuit community of Rigolet, Canada. The study included a cross-sectional census survey that captured data on types of drinking water used, household practices related to drinking water (e.g. how it was collected and stored), physical characteristics of water storage containers, and self-reported AGI. Additionally, water samples were collected from all identified drinking water containers in homes and analyzed for presence of *Escherichia coli* and total coliforms. Despite municipally-treated tap water being available in all homes, 77.6% of households had alternative

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sources of drinking water stored in containers, and of these containers, 25.2% tested positive for total coliforms. The use of transfer devices and water dippers (i.e. smaller bowls or measuring cups) for the collection and retrieval of water from containers were both significantly associated with increased odds of total coliform presence in stored water (OR\text{transfer device} = 3.4; 95% CI 1.2–11.7, OR\text{dipper} = 13.4; 95% CI 3.8–47.1). Twenty-eight day period prevalence of self-reported AGI was 17.2% (95% CI 13.0–22.5%), which yielded an annual incidence rate of 2.4 cases per person per year (95% CI 1.8 – 3.1); no water-related risk factors were significantly associated with AGI. Considering the high prevalence of, and risk factors associated with, indicator bacteria in drinking water stored in containers, potential exposure to waterborne pathogens may be minimized through interventions at the household level.

**Keywords:** Indigenous; Inuit; Nunatsiavut; drinking water; waterborne disease; point-of-use; coliforms; recontamination

**INTRODUCTION**

Despite progress in recent years, access to safe and reliable sources of drinking water continues to be a global challenge (Hennessy and Bressler 2016), and a problem which is not restricted to developing nations. Indeed, a high overall level of service for water and sanitation infrastructure exists in developed nations (Statistics Canada 2013a; Hennessy and Bressler 2016); however, some smaller subpopulations still experience lower levels of service and water quality challenges (Bradford et al. 2016; Hennessy and Bressler 2016). Frequently, remotely located communities experience challenges related to water infrastructure and water quality and quantity (Dunn et al. 2014; Hennessy and Bressler 2016; Instanes et al. 2016). In Canada, the United States, and Australia, rural and remote Indigenous communities often face disproportionately more
drinking water challenges compared to non-Indigenous populations in the same country (Bailie et al. 2004; Eichelberger 2010; Bradford et al. 2016; Hennessy and Bressler 2016).

Canadian Inuit, along with First Nations and Métis, are three constitutionally recognized Indigenous groups in Canada. In Canada’s First Nations communities, 39% of the water systems are considered “high risk”, and First Nations communities have 2.5 times more boil water advisories (BWAs) than non-First Nations communities (Eggertson 2006; Patrick 2011; Spence and Walters 2012; Dupont et al. 2014). Furthermore, while BWAs are meant to be a temporary measure to protect public health, many Indigenous populations face frequent or long-standing BWAs: between 1995 and 2007, Health Canada reported that the average duration of a BWA in First Nations communities was 343 days (Health Canada 2009), although some communities have faced advisories lasting over 15 years (Health Canada 2016). These issues contribute to public mistrust of municipal water and high rates of bottled water use in many Indigenous communities (Dupont et al. 2014). Inuit populations in the Canadian Arctic face similar issues with water infrastructure, water security, municipal water treatment, and BWAs (Newfoundland and Labrador Department of Environment and Conservation; Bradford et al. 2016; Medeiros et al. 2016). According to Statistics Canada, close to 40% of all Inuit adults in Canada felt their drinking water was contaminated at certain times of the year, and 15% felt that their water at home was unsafe for consumption in 2006 (Garner et al. 2010). Other research has corroborated these concerns, with one study in northern Québec finding more than 30% of drinking water samples to have unacceptable levels of indicator bacteria (Martin et al. 2007), and another study in Northern Labrador finding that tap water often did not meet national water quality guidelines in one Inuit community (Harper et al. 2011).
While water challenges in Indigenous populations remain under-researched (Bradford et al. 2016), it is clear that Canadian Indigenous communities often experience a disproportionate burden of water-associated issues compared to non-Indigenous Canadians (Health Canada 2009; Patrick 2011; Dunn et al. 2014; Dupont et al. 2014; Bradford et al. 2016; Hennessy and Bressler 2016), and these difficulties could present a greater risk of water-related illness. For instance, high rates of shigellosis and giardiasis have also been cited as possible health consequences of poor water quality in First Nations communities (Metcalfe et al. 2011; Patrick 2011). In Arctic regions, compromised access to safe quantities and quality of water has been associated with skin and soft tissue infections, pneumonia, and influenza in Alaska Natives (Hennessy et al. 2008). In the Territory of Nunavut (one of four Canadian Inuit settled Land Claim areas), larger communities such as Iqaluit and Rankin Inlet have utilidor systems and are less susceptible to water shortages (Medeiros et al. 2016); however, some smaller communities rely on trucked water service, which can discourage water use due to potential limits in supply (Daley et al. 2014). Indeed, per capita water usage in one Nunavut community was approximately three times lower than the Canadian national average (Daley et al. 2015), which could increase the risk of hygiene-related diseases (Hennessy and Bressler 2016). Other studies have shown that some Inuit populations experience some of the highest rates of self-reported acute gastrointestinal illness (AGI) in the global peer-reviewed literature (Harper et al. 2011; Harper et al. 2015a; Harper et al. 2015b), with water identified as an important risk factor for enteric illness in Canada’s North (Harper et al. 2011; Pardhan-Ali et al. 2012a; Pardhan-Ali et al. 2012b; Harper et al. 2015a; Harper et al. 2015b). These issues may be further magnified as climate change and warming temperatures impact the Arctic environment (Ford 2012; Prowse et al. 2015). However, studying the proportion of illness attributable to poor water quality and quantity remains challenging. For instance, examining the
extent to which waterborne pathogens contribute to AGI is difficult, as AGI-causing organisms can also be contracted through other exposure routes, such as food, contact with animals, or person-person contact (Health Canada 2011).

Most research in Indigenous communities has focused on the quality of municipally-treated tap water or untreated raw drinking water (Bernier et al. 2009; Harper et al. 2011; Goldhar et al. 2013; Dupont et al. 2014). Less research has examined microbiological recontamination of water between the source and point-of-use (Martin et al. 2007; Bernier et al. 2009). Multiple studies in high and low income countries have shown contamination of stored water to be a public health concern (Clasen and Bastable 2003; Wright et al. 2004; Hoque et al. 2006; Oswald et al. 2007; Rufener et al. 2010; Mellor et al. 2013). Examining the health implications of water contamination between source and point-of-use is particularly relevant and important in remote northern communities, as residents often collect untreated surface water for drinking and store it in containers for later consumption (Marino et al. 2009; Goldhar et al. 2013); however, this research in Indigenous communities is rare. The goal of this research, therefore, was to understand household stored drinking water contamination and practices, and their potential associations with self-reported AGI in the Inuit community of Rigolet, Canada. Specifically, the research objectives were to describe drinking water collection and storage practices, identify potential risk factors associated with water contamination between source and point-of-use, and examine possible associations between drinking water contamination and self-reported AGI. The results are intended to inform sustainable water-related interventions, whilst developing local capacity to understand potential risk factors for waterborne illness in Northern Canada.
METHODS

Study location

Approximately 60 000 Inuit live in Canada (Statistics Canada 2015), with the majority residing in the northern regions of the country, in an expanse of land and water referred to as Inuit Nunangat. This area stretches from Labrador through the Yukon Territory, and currently includes the four settled Land Claim Areas of Nunatsiavut (Labrador), Nunavik (Québec), Nunavut, and the Inuvialuit region (Northwest Territories/Yukon) (Fig. 3.1), plus additional Land Claim Areas that Inuit are currently negotiating with the government. Many Inuit in these regions continue to partake in aspects of a subsistence lifestyle that relies heavily on the land, sea, and ice. Activities such as hunting, fishing, trapping, and gathering of food and water are part of daily life for many Inuit in Canada, and the continuation of these cultural activities are vital to the health and wellbeing of these communities (Cunsolo Willox et al. 2012).

This study was conducted in collaboration with the Inuit community of Rigolet in the Labrador Land Claim Area (hereafter referred to as Nunatsiavut), which is located along the northeast coast of Labrador, Canada (Fig. 3.1). Meaning “Our Beautiful Land” in Inunngitut, Nunatsiavut is a self-governed region established in 2005 (Nunatsiavut Government 2016). Nunatsiavut is composed of five communities (from south to north): Rigolet, Makkovik, Postville, Hopedale, and Nain. These communities are remote; only accessible by air in the winter, or additionally, by boat in the summer months. There are no ice roads or groomed trails connecting communities. In 2011, Rigolet had a population of 306 residents (Statistics Canada 2012), with 85% of individuals self-identifying as Inuit; the number of males and females was approximately equal, and 21.3% of the population was under the age of 18 (Statistics Canada 2013b).
Rigolet is serviced by an underground piped water system, which delivers municipally treated tap water to all households. The source water is obtained from a local lake (i.e. surface water), and is chlorinated before distribution. In January of 2014, a potable water dispensing unit (PWDU) was constructed in the community; PWDUs have been constructed in several Labrador communities as part of the Government of Newfoundland and Labrador’s Drinking Water Safety Initiative, which aims to assist small communities with demonstrated high risk water quality issues (Government of Newfoundland and Labrador Department of Municipal Affairs 2017). While the provincial government provides the PWDU, the municipal government is responsible for running costs and maintenance. These municipal water systems apply multiple treatments to water, including sand filtration, ozonation, carbon filtration, reverse osmosis, and ultraviolet light. Identical units have been installed in the communities of Makkovik, Postville, and Cartwright, and a comparable system was also constructed in Black Tickle-Domino, Labrador (Hanrahan 2014). If residents choose to drink water from the PWDU instead of tap water, they must collect water from this unit, which is housed in a public facility, and then store this PWDU water in personal containers for later consumption. Finally, some residents drink untreated brook water (Fig. 3.2); this water is collected and stored in personal containers (Martin et al. 2007; Goldhar et al. 2014). Water plays a vital role in many Indigenous cultures, and consumption of brook water may be related to culturally rooted preferences for natural sources of fresh water, traditional ecological knowledge, or necessity when travelling on the land, when other sources of treated water are not available (Martin et al. 2007; Goldhar et al. 2014; Medeiros et al. 2016).

Research approach

This study is premised on a community-identified research question, with data collection, results interpretation, and knowledge mobilization conducted in partnership with local Inuit
community members and governments. An EcoHealth approach guided the research process that emphasized transdisciplinary, community-based, participatory, knowledge-to-action, and systems-thinking research methods (Charron 2012).

Data collection

A cross-sectional study, comprised of a questionnaire and water sampling, was conducted in Rigolet between June 23rd and June 30th, 2014. Cross-sectional study designs are useful for generating and testing hypotheses, and are suitable when attempting to explore a variety of potential risk factors and outcomes (Dohoo et al. 2012). A census survey was attempted, meaning that every individual present in the community during the study period was invited to participate directly, or for children under 12 years, by proxy. Water samples were collected from all drinking water storage containers within participant homes, and questionnaires were administered in the homes of the participants.

Questionnaires

A transdisciplinary team of epidemiologists, engineers, and local Inuit researchers co-developed and administered the electronic questionnaires on iPads (Apple Inc., Cupertino, CA, USA), which were modified from a prior burden of AGI study led by the Rigolet Inuit Community Government (Harper et al. 2015a). The questionnaire was extensively pre-tested by local Inuit researchers for clarity and content, and was divided into two sections: the first section was completed by all participants, or by an adult proxy in the household (i.e. a parent or main caregiver), and contained questions concerning AGI and individual drinking water habits and preferences; the second section was completed by one adult per household and contained questions regarding water storage containers in the home and potential household-level risk factors for
contamination (Table 3.1). All questionnaires were completed in English; translation to Inuttitut was available but not requested by any participants.

The AGI case definition was consistent with previous surveys in Rigolet (Harper et al. 2015a), the Canadian National Studies on Acute Gastrointestinal Illness (Thomas et al. 2008), and several international studies (Jones et al. 2007; Adlam et al. 2011). AGI was defined as any self-reported vomiting or diarrhea (i.e. loose stool) experienced in the last 28 days not attributed to pregnancy, medication/alcohol/drug use, or diagnosed chronic conditions (e.g. irritable bowel syndrome, Crohn’s disease, gastritis or ulcers from \(H. pylori\) infection, and/or diverticulitis) (Thomas et al. 2008). If an individual experienced more than one episode of AGI during the recall period, they were asked to describe only the most recent occurrence. Cases were categorized as mild, moderate, or severe based on criteria described by Majowicz et al. (2006).

In the questionnaire, drinking water was defined as plain unboiled water, or cold drinks made with unboiled water (e.g. frozen juice concentrate and crystal drink mixes). Questions were asked about each drinking water storage container identified within a household. Information was captured on water-handling practices for each container, including the sources of water (e.g. PWDU, brook location), location of storage, container cleaning practices, and if transfer devices or dippers were used (transfer devices refer to tools used during collection of water from the source, and dipper is a local term used for a smaller bowl or measuring cup used to retrieve water from a container for drinking). Physical characteristics of containers were also noted, such as size and material (Table 3.1, see Table C.1 in Appendix C for more detail).

**Water sampling and testing**

At the time of the questionnaire, water samples were taken from every drinking water storage container in each house, as well as from tap water if one or more individuals in the
household identified it as a source of drinking water. One hundred milliliter (100mL) samples were drawn and dispensed into sterile bottles according to how the resident would obtain water for consumption (e.g. using the dipper if it was normally used to draw water from a larger bucket or dispensing water directly from a water cooler or tap). Samples were processed by two individuals trained in use of IDEXX Colilert®, following the manufacturer’s instructions to detect presence/absence of total coliforms and E. coli (IDEXX Laboratories 2015). All samples were processed in Rigolet shortly after their collection from residents’ households (within 4 hours of collection).

**Ethics and consent**

The research protocol was approved by the Nunatsiavut Government Research Advisory Committee and the University of Guelph Research Ethics Board. Written informed consent was obtained from all participants; for individuals 12-18 years of age parental permission was required, and a proxy respondent was used for children under 12 years of age. A small honorarium was offered to each household for participating in the survey; this compensation was determined through consultation with local Inuit researchers.

**Data analysis**

Participants who responded ‘refuse to answer’ or ‘unsure’ were excluded from the analysis of that question. Two-sample tests of proportions were used to evaluate differences in demographic data between the June 2014 survey, and 2011 Census data from Rigolet. Prevalence, estimated annual incidence rate, and annual incidence proportion of AGI were calculated using formulas presented in Appendix D (Rothman and Greenland 1998).

Two models were built; the first model examined the presence / absence of total coliforms in household stored water containers as the outcome variable, and the second model examined the
presence / absence of self-reported AGI during the previous 28-days as the outcome variable. All independent variables underwent univariable logistic regression analysis to explore unconditional associations with each outcome variable. In order to reduce the number of explanatory variables offered to a multivariable model, variables with a p-value ≤0.2 in the univariable regressions were considered in multivariable analysis, which was conducted using a manual backwards stepwise model-building approach (Dohoo et al. 2012). A significance level of α ≤0.05 and 95% confidence intervals (i.e. p<0.05) were used to assess statistical significance in the multivariable models. Linearity of continuous variables with the log odds of the outcome was assessed using locally weighted scatterplot smoothing (lowess curves), and if the relationship was not linear, the variable was categorized based on biologically-plausible cut-points or trends in the lowess curve (Dohoo et al. 2012). Collinearity of independent variables was assessed using Spearman’s rank correlation, using a cut-off of |0.7| to classify variables as collinear (Dohoo et al., 2012). If two independent variables were deemed collinear, the more proximal independent variable with greatest biological plausibility was considered in the model building (Dohoo et al. 2012). Likelihood ratio tests were performed after the removal or addition of each variable to assess whether the full and reduced models were significantly different. Additionally, we assessed Akaike Information Criterion (AIC) in each step to confirm that the fit of the model improved as variables were removed. Confounding was also assessed at each step in the backwards selection process; if removal of a variable resulted in a 30% or greater change in regression model coefficients, the variable was considered a confounder and remained in the model regardless of its statistical significance (Dohoo et al. 2012). Two-way interactions were tested with biologically plausible variables, as well as all variables that had a p-value ≤0.05 in univariable analysis. For the model examining AGI as the outcome variable, mixed logistic regression models were built to examine whether significant clustering of the
outcome occurred at the household level (i.e. examining household as a random effect, and comparing the mixed model to a regular logistic regression model using a likelihood ratio test). Fit of the models was assessed using Pearson and Deviance $\chi^2$ goodness-of-fit tests. Lastly, we visually explored how well the models fit the data through plotting predicted values, residuals, deviance, standardized residuals, leverage, delta beta, delta deviance, and delta $\chi^2$; this allowed us to examine outliers and covariate patterns with high leverage. Data were cleaned and analyzed using Stata I/C 13.1 (StataCorp LP, College Station, TX, USA) for Mac.

RESULTS

Response rate and participant demographics

A total of 275 people in 105 households were present in Rigolet during the survey period. Of those, 246 agreed to participate from 98 households, resulting in an individual response rate of 89.4% (i.e. 246/275) and a household response rate of 93.3% (i.e. 98/105). Using a two sample test of proportions, the 10-14 year age group was significantly over-represented, and the 20-24 year old age group was significantly underrepresented in our 2014 survey compared to the 2011 Canadian Census data for Rigolet (Statistics Canada 2012) (Table 3.2).

Drinking water sources and water-related practices

Water from the PWDU was the most frequently used source of drinking water in the community, consumed as a primary (i.e. most commonly used water source) or secondary (i.e. another water source used, apart from the primary source) water source by 74.8% of respondents (Fig. 3.3). While most sources of water were typically rated as “good” or “very good,” tap water had the highest proportion of “fair,” “poor,” and “very poor” ratings of perceived quality (Fig. 3.4).
Nearly 80% of households had drinking water stored in containers at the time of the survey. Many different types and sizes of containers were used to store water, including wide-mouthed buckets and narrow-mouthed jugs, although almost all were plastic (98.1%; Fig. 3.2). Approximately equal numbers of respondents stored water inside and outside of the refrigerator. Frequency of container cleaning was low; 67.0% of sampled containers were cleaned once per month or less; and 43.0% of containers had never been cleaned. Of containers that had been cleaned, the most common method was soap and water (36.0%), followed by using the rinsing nozzle located inside the PWDU filling station (15.0%), which sprays water inside of the containers (Table 3.3).

Coliforms in drinking water

There were 76 houses with water storage containers; water samples from 104 water storage containers in these 76 houses were obtained. There were 21 households who reported drinking tap water; 22 tap water samples were collected from these 21 households, as well as at the local school. Total coliforms were detected in 25.2% of samples from water storage containers, and in 18.2% of tap water samples. Of samples positive for total coliforms, one stored water sample and one tap water sample tested positive for presence of *E. coli*. In the final multivariable model, the use of a dipper and transfer device was significantly associated with the presence of total coliforms in stored water samples (OR_{dipper} = 13.4; 95% CI 3.8–47.1 & OR_{transfer device} = 3.4; 95% CI 1.2–11.7) (Fig. 3.5, see Table C.2 in Appendix C for more detail). No significant interaction terms were identified, and the model fit the data well.

Acute gastrointestinal illness

A total of 46 people reported symptoms of AGI in the 28-day recall period. Four individuals reported symptoms of AGI but were excluded due to conditions or medications that they believed
had caused their symptoms; therefore, 42 individuals met the case definition for AGI and the 28-day period prevalence was 17.2% (95% CI 13.0–22.5%). Of those who met the case definition, the proportion of mild, moderate, and severe cases were 47.6%, 23.8%, and 28.6%, respectively. The estimated annual incidence of self-reported AGI was 2.4 episodes per person per year (95% CI 1.8 – 3.1) and the annual incidence proportion was 91.3%. While four water-related variables had a positive association with AGI, no variables were significantly associated with AGI at the $\alpha=0.05$ level in univariable or multivariable analysis (Fig. 3.5, see Table C.2 in Appendix C for more detail).

**DISCUSSION**

The PWDU represented a new drinking water source in Rigolet in 2014, requiring residents to collect water and store it in personal containers for later consumption. Although treated tap water was available in all households, the majority of people chose to consume water from the PWDU, and most households had water stored in containers at the time of the survey.

The high consumption of PWDU water, despite its reduced convenience compared to piped tap water, may be due to several reasons. First, previous research has documented lack of trust and a dislike of municipally-supplied tap water in Rigolet (Goldhar et al. 2013), which could explain the low tap water consumption documented in this study. Second, the high PWDU usage could be due to a perception that water collection and storage are not perceived as overly inconvenient tasks in this community; or, at the least, water collection and storage did not prevent people from using the PWDU as their primary source of drinking water. Centralized piped drinking water infrastructure is a relatively recent amenity in Rigolet: some buildings were first serviced with tap water as late as the 1990s, and before this time, collecting water from a location outside of the
home and storing it in personal containers was common-practice (personal communication, R. Shiwak, 2016). Furthermore, opting to gather water may be a choice that reflects Inuit lifestyles and culture, in which subsistence activities are an integral part of daily life that provide sustenance, connection to the local environment, and reinforce important sharing networks and values (e.g. through collecting and sharing water with family, neighbours, or Elders) (Wenzel 2000).

Total coliforms were detected in several tap water samples, and a substantial proportion of stored water containers, and this finding could indicate that water contamination occurred between source and point-of-use. Water recontamination after treatment is particularly relevant in Rigolet since the implementation of the PWDU, as residents are required to store this water in personal containers. Multiple international studies have shown that coliforms may re-enter stored drinking water through contact with hands or dippers when individuals retrieve water from wide-necked containers, such as buckets (Wright et al. 2004; Trevett et al. 2005; Mellor et al. 2013; Schriewer et al. 2015). Indeed, dippers and transfer devices were associated with significantly increased odds of total coliform present in water containers in Rigolet. Container material and the use of lids to cover storage vessels have also been implicated as risk factors for contamination between source and point-of-use (Wright et al. 2004); these were not associated with coliform presence in Rigolet, potentially because almost all containers were plastic and had lids, resulting in very little variation in the data. Unwashed containers can also be a source of water recontamination (Wright et al. 2004), as biofilms can grow on container walls and transfer microbial contaminants into clean water when it is collected (Jagals et al. 2003). Although a significant association between cleaning practices and coliform presence was not identified in this study, survey participants reported infrequent cleaning of storage containers, which could present a potential risk of recontamination. A similar observation regarding cleaning of personal water storage containers in Nunavik was
made by Martin et al. (2007). Moreover, water collected from the PWDU may be particularly vulnerable to recontamination from dippers or unwashed containers, as the PWDU removes residual chlorine from the municipal water. Chlorine residuals in drinking water are important in ensuring that the water is safe until consumption, as the chlorine inactivates microbial contaminants that re-enter the water between source and point-of-use (Health Canada 2006).

Given the vulnerability of stored water to recontamination and the low frequency of container cleaning found in this study, a public health campaign to disseminate research findings was carried out in the community, in collaboration with local governments. As per the EcoHealth approach (Charron 2012), this campaign was developed emphasizing the Ecohealth pillar of knowledge-to-action, and in the public health campaign design and implementation, we considered the cultural importance and nuances surrounding drinking water in the community. This campaign was also based on the precautionary principle, which states that where there is risk of negative impacts, cost-effective precautionary measures are justified despite a lack of scientific certainty (Environment Canada 2010). Infographics with action-oriented information on how to keep stored water clean were distributed in the community, including in the PWDU station. Additionally, each household was given stickers containing information for preparing and using a bleach solution to clean water storage containers, which could be put on containers to serve as a reminder to clean them regularly (Appendix E).

It is important to note that most coliforms are not dangerous to human health; however, they are frequently used in water testing to indicate presence of other harmful fecal pathogens (such as Giardia, Cryptosporidium, enterotoxigenic E. coli, or other waterborne agents that can cause AGI) (Yates 2007). Some studies, however, dispute the efficacy of using coliforms as an indicator of fecal contamination (Yates 2007; Lin and Ganesh 2013; Gruber et al. 2014), as they
are not exclusive to feces and may not accurately predict presence of some types of pathogens in water (Health Canada 2012). Furthermore, future research should prospectively sample source water to ascertain if it is free of microbial contaminants before collection, in order to confirm that contamination is occurring between source and point-of-use. Additionally, the finding of coliforms in some tap samples warrants further investigation; collecting more detailed data and samples of tap water would be useful for obtaining a better understanding of this water source. Considering the limitations of using coliforms, it would be useful in future studies to test for specific pathogens, including enteric bacteria, parasites, and viruses, in order to examine specific AGI-causing organisms that may be present in stored water.

The estimated annual incidence rate of AGI, 2.4 cases per person per year, represents a substantial burden of illness in the community. This rate of AGI is comparable with past research in the Canadian Arctic (Harper et al. 2011; Harper et al. 2015a; Harper et al. 2015b), and is 2-6 times higher than in more southern, non-Indigenous populations in Canada (Majowicz et al. 2006; Thomas et al. 2006; Sargeant et al. 2008; Thomas et al. 2008) and other countries (Hall et al. 2006; Jones et al. 2007; Prieto et al. 2009; Ho et al. 2010; Adlam et al. 2011; Doorduyn et al. 2012; Müller et al. 2012). No water-related risk factors were significantly associated with AGI in this study. Similarly, other international studies have failed to associate drinking water with gastrointestinal illness, despite finding high levels of microbial contaminants in stored water (Kirchhoff et al. 1985; Roberts et al. 2001; Pickering et al. 2010). This finding could indicate that water sources were not a risk factor for AGI during the study period. Indeed, there are many sources of AGI-causing pathogens, and water is only one route of exposure. Contaminated food, zoonotic transmission, or contact with an infected individual are also potential sources of AGI (World Health Organization 2011), and may play important roles in this context. Additional
research assessing other potential transmission routes may prove valuable in furthering our understanding of unique risk factors for AGI in Inuit. An alternative explanation for the lack of association between drinking water and AGI in our study could be related to temporal limitations of cross-sectional studies; that is, a respondent could have developed AGI from contaminated water, but cleaned and/or refilled the water container before a water sample was collected in this study, thereby resulting in a negative test for total coliforms. Given the findings from this study, precautionary measures, such as the public health campaign implemented in the community, could serve to minimize risk of exposure to AGI-causing organisms. Follow-up work to assess the effectiveness of this campaign could be beneficial to understanding its impact on stored water contamination.

This study contributes to the limited literature that exists on drinking water and health research in Indigenous communities (Bradford et al. 2016). Several limitations should be considered. Firstly, data were collected over a short period in June 2014, and it is possible that drinking water sources, storage practices, and the incidence rate of AGI varies by season. Therefore, these results may be an over- or underrepresentation of the incidence rate of AGI at other times of year. This study design precluded establishing a temporal sequence between exposures and outcomes; this is a limitation of cross-sectional studies generally; therefore, results should not be taken to imply cause and effect. The associations evaluated in this study may be further investigated using a prospective study design. Second, the health outcome in this study was self-reported, and this leads to potential issues with misclassification, recall limitations, and reporting biases. It is possible that undiagnosed chronic AGI cases were misclassified as acute AGI or vice versa. However, any biases impacting the frequency or incidence rate of AGI in this study likely affected other burden of AGI studies in a similar manner, as the same criteria were
used to define cases. Third, although this was a census survey with a high response rate, the total number of observations was fairly small (n=246), and this may have limited the ability to detect significant associations between risk factors and outcomes due to low statistical power, when a true association could exist. Moreover, there are a variety of methods available to handle missing data. Similar to other AGI studies in Canada (Thomas et al. 2006; Harper et al. 2015a), when participants answered “unsure” or “refuse to answer” for a question, we omitted them from the analysis of this question. We acknowledge, however, that this method can result in a skewed distribution when data from different people are used in different analyses. Lastly, this research was only carried out in Rigolet, and so extrapolation of the results to other populations should be done with caution. Nonetheless, several other communities in Labrador have a PWDU, and many Alaskan villages are served by comparable systems, which require residents to collect and store water within the household (Thomas et al. 2013). These communities may experience similar issues with water contamination between source and point-of-use; this research, therefore, may resonate with, and have implications for, Arctic communities across North America.

CONCLUSIONS

We assessed potential water-related risk factors for water contamination between source and point-of-use, as well as self-reported AGI in the Inuit community of Rigolet. The use of dippers and transfer devices were significantly associated with increased odds of total coliform presence in stored water. Many water-related variables had a positive association with AGI; however, no statistically significant water-related risk factors were associated with AGI in June 2014. Considering the high prevalence of, and risk factors associated with, indicator bacteria in drinking water stored in containers, a simple EcoHealth public health campaign on the importance of
cleaning containers and transfer devices regularly was implemented in the community. This study contributes to an improved understanding of stored drinking water and risk factors for water contamination in an Arctic context, and adds to limited published literature on water and Inuit health. Ultimately, this study may help to inform communities, public health decision makers, and future research related to water and/or AGI.

COMPLIANCE WITH ETHICAL STANDARDS

Informed consent: Informed consent was obtained from all respondents, or a proxy respondent for children under 12 years of age.

Conflicts of interest: The authors declare that they have no conflict of interest.

ACKNOWLEDGEMENTS

Sincerest thanks are extended to the residents of Rigolet for welcoming us into their community and homes, and for their ongoing support of research in Nunatsiavut, which is part of the larger international Indigenous Health Adaptation to Climate Change (IHACC) project. Thank you also to Rob Jamieson and Lisbeth Truelstrup Hansen for lending their expertise in water testing and analysis. This research was funded by the Indigenous Health Adaptation to Climate Change (IHACC) project (funded by the International Development Research Centre and Canadian Tri-Council Agencies [Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and the Social Sciences and Humanities Research Council]), and the Inuit Traditional Knowledge for Adapting to the Health Effects of Climate Change (IK-ADAPT) project (funded by the Canadian Institutes of Health Research). The design and conduct of this study were independent of the funding sources.
REFERENCES

Goldhar C, Bell T, Wolf J (2013) Rethinking existing approaches to water security in remote


### TABLES

**Table 3.1** Variables considered in statistical models as potential risk factors for the outcomes of interest in Rigolet, Canada, in the June 2014 survey.

<table>
<thead>
<tr>
<th>Model One: Total coliforms</th>
<th>Model Two: Acute gastrointestinal illness (AGI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
<td><strong>Outcome</strong></td>
</tr>
<tr>
<td>Presence of total coliforms in personal stored water containers (dichotomous variable: present/absent)</td>
<td>Self-reported AGI in past 28 days (dichotomous variable: yes/no)</td>
</tr>
<tr>
<td><strong>Exposure variables considered</strong></td>
<td><strong>Exposure variables considered</strong></td>
</tr>
<tr>
<td>- Age and sex of individual who collected the water</td>
<td>- Demographic information (age, sex, household ID)</td>
</tr>
<tr>
<td>- Water source</td>
<td>- Main &amp; secondary sources of drinking water</td>
</tr>
<tr>
<td>- Characteristics of container (e.g. size, material)</td>
<td>- Daily volume of water consumption</td>
</tr>
<tr>
<td>- Location of storage container</td>
<td>- Water-handling practices (e.g. water collection, retrieval, in-home treatments)</td>
</tr>
<tr>
<td>- Water collection practices</td>
<td>- Overall ratings of perceived water quality</td>
</tr>
<tr>
<td>- Water retrieval from container</td>
<td></td>
</tr>
</tbody>
</table>
Table 3.2 Demographic information of Rigolet residents: comparison between 2011 Canadian census data and 2014 survey participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rigolet census (2011) Number (%)</th>
<th>Rigolet survey participants (2014) Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>$n = 305$ (100)</td>
<td>$n = 246$ (100)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>160 (52.5)</td>
<td>121 (49.2)</td>
</tr>
<tr>
<td>Male</td>
<td>145 (47.5)</td>
<td>125 (50.8)</td>
</tr>
<tr>
<td>Age group (years)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-9</td>
<td>40 (13.1)</td>
<td>41 (16.7)</td>
</tr>
<tr>
<td>10-14</td>
<td>15 (4.9)</td>
<td>24 (9.8)**</td>
</tr>
<tr>
<td>15-19</td>
<td>15 (4.9)</td>
<td>9 (3.7)</td>
</tr>
<tr>
<td>20-24</td>
<td>25 (8.2)</td>
<td>7 (2.8)**</td>
</tr>
<tr>
<td>25-64</td>
<td>180 (59.0)</td>
<td>144 (58.5)</td>
</tr>
<tr>
<td>65-69</td>
<td>10 (3.3)</td>
<td>10 (4.1)</td>
</tr>
<tr>
<td>≥70</td>
<td>20 (6.6)</td>
<td>11 (4.5)</td>
</tr>
</tbody>
</table>

*Globally significant ($p=0.028$)
**Proportion significantly different from 2011 census (using a two-sample test of proportions)
Table 3.3 Types of stored drinking water in Rigolet, Canada in 2014. Excludes purchased water.

<table>
<thead>
<tr>
<th>Water Storage</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households with stored water</td>
<td>76 (77.6)</td>
</tr>
<tr>
<td>Households without stored water</td>
<td>22 (22.4)</td>
</tr>
<tr>
<td>Number of container samples taken</td>
<td>104</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Sources</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWDU</td>
<td>100 (96.1)</td>
</tr>
<tr>
<td>Tap water</td>
<td>2 (1.9)</td>
</tr>
<tr>
<td>Brook water</td>
<td>2 (1.9)*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Storage containers</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td></td>
</tr>
<tr>
<td>Plastic</td>
<td>102 (98.1)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (1.9)</td>
</tr>
<tr>
<td>Type</td>
<td></td>
</tr>
<tr>
<td>Bucket (wide-mouthed)</td>
<td>13 (12.5)</td>
</tr>
<tr>
<td>Clear (narrow-mouthed)</td>
<td>48 (46.2)</td>
</tr>
<tr>
<td>Opaque (narrow-mouthed)</td>
<td>43 (41.3)</td>
</tr>
<tr>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>&lt;1 Gallon</td>
<td>24 (23.1)</td>
</tr>
<tr>
<td>1-3 Gallons</td>
<td>48 (46.1)</td>
</tr>
<tr>
<td>&gt;3 Gallons</td>
<td>32 (30.8)</td>
</tr>
<tr>
<td>Location of storage container</td>
<td></td>
</tr>
<tr>
<td>In the refrigerator</td>
<td>44 (42.7)</td>
</tr>
<tr>
<td>Outside the refrigerator</td>
<td>59 (52.7)</td>
</tr>
</tbody>
</table>

| Stored water contamination |       |
| Presence of total coliforms | 26 (25.2) |
| Presence of E. coli | 1 (0.96) |

<table>
<thead>
<tr>
<th>Cleaning practices</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of cleaners</td>
<td></td>
</tr>
<tr>
<td>Bleach/chemical cleaners</td>
<td>1 (1.0)</td>
</tr>
<tr>
<td>Soap</td>
<td>36 (36.0)</td>
</tr>
<tr>
<td>Plain water (hot or cold)</td>
<td>5 (4.8)</td>
</tr>
<tr>
<td>PWDU rinsing nozzle</td>
<td>15 (15.0)</td>
</tr>
<tr>
<td>Frequency of cleaning</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>43 (43.0)</td>
</tr>
<tr>
<td>Once per year or less</td>
<td>16 (16.2)</td>
</tr>
<tr>
<td>&lt; Once/week</td>
<td>12 (12.1)</td>
</tr>
<tr>
<td>≥ Once/ week</td>
<td>28 (28.3)</td>
</tr>
</tbody>
</table>

* Note: In some circumstances, the water that individuals reported drinking as secondary water in the past two weeks (displayed in Fig 3), was no longer (or not) stored in the household at the time of data collection.
Figure 3.1 A map of the four settled Inuit Land Claim Areas in Canada, and the five Inuit communities comprising the Nunatsiavut settled Land Claim Area, as of 2016.
Figure 3.2 Drinking water sources in Rigolet include tap water (a), store-purchased water (b), local brook water (c), and potable water dispensing unit (PWDU) water (d). Common types of storage containers include narrow-mouthed 3-gallon jugs (e), plastic buckets with dippers (f & g), and 5-gallon jugs with hand pumps (h).
Figure 3.3 Use of various water sources as primary and secondary drinking water in Rigolet, Nunatsiavut, Canada (2014). Sources available in the community include water from the potable water dispensing unit (PWDU), municipally-supplied tap water, store-purchased water, and brook water.
Figure 3.4 Ratings of overall quality for primary (1°) and secondary (2°) drinking water sources in Rigolet, Nunatsiavut, Canada (2014).
Model Results

**Model 1: Total coliform presence**

- Dipper used
- Transfer device used
- Bucket used to store water
- Water was collected directly from PWDU
- Container was ≥3 gal.
- Direct transfer from container to cup to drink
- Container was opaque (vs. clear)

**Model 2: AGI**

- Stored secondary drinking water
- Drank any tap water in past 2 weeks
- Sex (Female)
- Drank any purchased water in past 2 weeks

*OR = 13.39; 95% CI 3.81–47.06
* OR = 10.56; 95% CI 3.20 – 34.87
* OR = 3.36; 95% CI 1.15 – 11.65
OR = 2.41; 95% CI 0.85 – 6.78

* OR = 9.37; 95% CI 2.29 – 46.78
* OR = 0.31; 95% CI 0.12 – 0.76
* OR = 2.57; 95% CI 1.01 – 6.51
OR = 0.47; 95% CI 0.19 – 1.17
OR = 1.84; 95% CI 0.73 – 4.63

OR = 1.96; 95% CI 0.78 – 4.95
OR = 0.41; 95% CI 0.14 – 1.17
OR = 1.86; 95% CI 0.94 – 3.68
OR = 1.80; 95% CI 0.91 – 3.57

*p<0.05
† Odds ratios adjusted for age and sex

**Figure 3.5** Results of univariable and multivariable analyses assessing the impact of independent variables on odds of (1) presence of total coliforms in stored water containers, and (2) self-reported AGI in Rigolet, Canada (2014). Figure includes odds ratios for liberally significant variables (p ≤ 0.2). Odds ratios adjusted for age and sex are presented for AGI outcome.
DISSERTATION SUMMARY

**Thesis title:** Water Quality and Inuit Health: An Examination of Drinking Water Consumption, Perceptions, and Contamination in Rigolet, Canada

**Institution:** University of Guelph (Department of Population Medicine)

**Degree:** MSc epidemiology

**Abstract:** Canadian Inuit have often reported concerns about the quality of their municipal drinking water; research has also shown that some Inuit communities experience some of the highest incidence rates of self-reported acute gastrointestinal illness (AGI) in Canada and globally. The goal of this thesis research was to investigate drinking water perceptions and consumption patterns, as well as water contamination and potential associations with AGI in the Inuit community of Rigolet, Canada. Three census cross-sectional surveys captured data on AGI, drinking water, and water storage (2012-2014); additionally, bacterial contamination of household drinking water was assessed alongside the 2014 survey. Concerns regarding the taste, smell, and colour of tap water were associated with lower odds of consuming tap water. The use of transfer devices (i.e. small bowls or measuring cups) was associated with household water contamination; while no water-related risk factors for AGI were identified, incidence of AGI was high compared to southern Canada. This thesis research provides a valuable contribution to the limited literature assessing drinking water and health in the Arctic. Ultimately, this work is intended to inform safe water management practices, as well as contextually appropriate drinking water interventions, risk assessments, and public health messaging in the Canadian Arctic.

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7 Formatted for submission to *International Journal of Circumpolar Health, dissertation summary*
FIGURES

Figure 4.1 Required headshot; Carlee Wright (photo credit: Sherilee Harper)
Chapter Five

Summary of Research, Recommendations, and Conclusion

Summary of Research

This thesis presented a critical evaluation of various aspects of the drinking water literature in North America with a focus on Canadian Inuit (Chapter One), and, through two research studies, considered various aspects of drinking water and its potential health implications in the Inuit community of Rigolet, Canada. The first study (Chapter Two) examined perceptions of municipal tap water, assessed the use of drinking water sources and changes over time, and residents’ daily volume of water consumption; the second study (Chapter Three) described drinking water collection and storage practices, identified risk factors associated with water contamination between source and point-of-use, and examined possible associations between drinking water contamination and self-reported acute gastrointestinal illness (AGI).

Perceptions of drinking water

Chapter Two investigated the perceptions and consumption of various types of drinking water in Rigolet. This chapter compiled data collected from multiple cross-sectional surveys, which were conducted as a part of the Indigenous Health Adaptation to Climate Change (IHACC) project. Analysis revealed that tap water was the most poorly regarded water source in the community. The arrival of a potable water dispensing unit (PWDU) operated by the town council presented a more favourable option, which was generally well-accepted by residents. Similar to a variety of literature examining drinking water perceptions, aesthetic characteristics were

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important factors impacting tap water consumption in Rigolet. Gender and age differences in perceptions of water quality and risk were also evident; future research should examine these further, particularly in the context of cultural changes and the varying perceptions of chlorine in drinking water.

The surveys in Chapter Two were developed and implemented in close partnership with local Inuit researchers and government, emphasizing community-based participatory methods. A history of colonialism, marginalization, and lack of consideration for Indigenous cultures and values has justifiably contributed to concerns and uncertainties about the ways in which research is conducted with Indigenous communities. The community-based participatory approach is increasingly being recognized as critical to producing knowledge that positively impacts research communities and society at large. Furthermore, the research study in Chapter Three was based on principles of EcoHealth research, and is part of a larger research initiative (IHACC) which focuses heavily on participatory research methodologies. Various projects have been implemented in Rigolet and other IHACC partner communities following these principles, and the relationships formed through thoughtful collaboration and engagement in prior work have undoubtedly contributed to the success of IHACC research studies, including those presented in this thesis.

Chapter Two also highlighted the importance of considering the Indigenous context of many northern communities, and current and historical drinking water issues when assessing or implementing new water systems. Factors that impact water consumption are highly complex and interrelated, and a better understanding of these factors can help inform water projects and policies that are relevant for Inuit communities. While centralized water systems are generally valued and sought after for the conveniences they offer, failure to appreciate unique local concerns and cultural influences can, for example, result in a drinking water source (e.g. running tap water), that
is not desired or used regularly by residents. In small communities with limited resources, it is particularly important that resource planning is done efficiently and effectively. The results of Chapter Two could be used to inform the development of sustainable and relevant drinking water interventions, risk assessments, and public health messaging in Rigolet and other Indigenous communities.

**Stored drinking water and AGI**

The research presented in Chapter Three assessed household-stored drinking water and AGI; this chapter was the result of a community-identified research question, and involved extensive collaboration and consultation with the community government and local Inuit research partners. Similar to Chapter Two, the study in Chapter three also focused heavily on utilizing community-based participatory methods, emphasizing the crucial role that they have in research.

The research question in Chapter Three was addressed through a census survey that gathered data on water-related practices and contamination of stored water with *Escherichia coli* and total coliforms. The use of transfer devices, both when collecting water from the source and when drawing water from containers for drinking, were significantly associated with increased odds of total coliform presence in stored water. This finding is in agreement with several other research studies conducted in tropical countries, and provides an important perspective in an Arctic context. However, no significant water-related risk factors were identified for AGI in June 2014; this was an interesting finding considering the high prevalence of indicator bacteria in stored water. These results warrant further investigation of specific fecal pathogens and their transmission through water and other exposure routes, such as food and animals.

While there were no statistically significant associations with AGI in this study, it is well-known that water is an important exposure route for enteric pathogens. Total coliforms are
common indicator bacteria used to identify fecal contamination of water, which can include enteric pathogens. The high prevalence of total coliform contamination in stored water found in Rigolet prompted the implementation of a health promotion campaign, which focused on the importance of cleaning containers and transfer devices regularly (Figure 5.1). Following the precautionary principle, this prompted an education campaign aimed to reduce recontamination of drinking water after collection, and minimize potential risk of exposure to waterborne pathogens. These types of water-related education campaigns have been proven effective at reducing diarrheal illness, and were therefore incorporated into the knowledge mobilization process of this research in Rigolet, as per the EcoHealth approach.

Chapter Three highlighted the importance of knowledge mobilization within communities, and furthermore, the importance of sharing research findings in a contextually relevant manner. Results sharing was incorporated into multiple stages of the project, and made use of infographics and other visually-based materials, which have been cited as a preferred form of educational material in First Nations and Inuit communities. Moreover, results dissemination was integrated into a larger community event to encourage participation and discussion of the research. Community gatherings have previously been used to share information in Rigolet, and may be particularly appropriate for the community-based culture of Inuit.

**Thesis Research Limitations**

There are several overarching limitations to consider in this thesis research. All studies used data collected from cross-sectional surveys; this study design limited the ability to establish a temporal sequence between exposures and outcomes. In order to confirm that exposures preceded the outcomes of interest, a prospective study design would be required. Furthermore, in Chapter Three, only water-related exposures were assessed, and we could not make inferences
about other potential AGI exposure routes (e.g. person-to-person contact, contaminated food, and contact with contaminated animals). Additionally, many outcomes were self-reported by respondents (i.e., self-reported AGI and water consumption), and this may have resulted in information bias (e.g. misclassification biases related to recall and/or reporting), which can impact measures of association. Furthermore, while census surveys achieved very high response rates, the total number of observations remained small. This is a limitation of research performed in small communities such as Rigolet (N=306), and it may have impacted our ability to detect significant associations due to low statistical power (although a true association may have existed in reality). Lastly, this thesis research was conducted in a single community, and given the heterogeneous nature of Inuit communities in northern Canada, results should be extrapolated with caution.

RECOMMENDATIONS

Based on the literature review (Chapter One), the study of drinking water perceptions and consumption patterns (Chapter Two), and the study of household stored water and AGI (Chapter Three), the following recommendations are made:

Recommendations for policy-makers

- **Create clear, coherent, and transparent water management strategies and policies for Indigenous communities:** Through summarizing drinking water guidelines and regulations in Canada (Chapter One), it was evident that many people describe water policy in Indigenous communities to be “piecemeal” and divided between multiple regulatory bodies. Studies have suggested that this may potentially create issues with appropriate oversight, increasing the vulnerability of communities to water contamination events and poor water quality. Furthermore, dialogues surrounding Indigenous drinking water challenges often focus on First
Nations. Efforts to consolidate the responsibilities of governing bodies for Inuit, and to highlight water issues in Canada’s Inuit communities will be an important step forward in improving water policy in the Arctic.

- **Support small communities in meeting drinking water standards:** Research suggests that increased provincial and territorial accountability for achieving and maintaining drinking water quality guidelines is important for protecting the water supplies of small communities, which may not be capable of achieving these standards on their own due to limited physical and financial resources. Provincially enforced water quality standards, complimented by appropriate funding, is reported to stimulate greater harmonization in water management strategies and increase efforts to develop drinking water policies and infrastructure for small communities; this recommendation aligns with the views of the World Health Organization.

- **Consider local contexts and preferences for drinking water:** It is critical to consider the unique geography, climate, history, and culture of Inuit in Canada when creating water policies and implementing new water systems. Unique water challenges in northern communities impact consumer perceptions of municipal water, and consumer preferences and ideals differ from those in southern regions. Consequently, standard best practices and technologies from southern regions often are not sufficient, on their own, to provide sustainable solutions to the unique water challenges in the Arctic. Solutions that incorporate Inuit values and address the community concerns identified from this thesis (Chapters Two and Three), and other research, will be essential to improving and maintaining consumer satisfaction with municipal water.

- **Prioritize the development of water safety plans (WSPs) for small communities:** A water safety plan (WSP) is a proactive water management strategy designed to protect the quality of drinking water from source to point-of-use. A WSP involves extensive engagement with the
community to create water safety teams, identify hazards from source to point-of-use, and continuously monitor risks;\textsuperscript{32} this differs from a traditional \textit{reactive} approach to water management, which focuses solely on treatment to remove contaminants that may already exist in water. The development of WSPs may be particularly relevant in small communities, which generally have limited resources to effectively and consistently treat municipal drinking water.\textsuperscript{28} Furthermore, engaging community members in water management could positively impact sense of ownership, trust, and perceptions of municipal water.

\textbf{Recommendations for researchers}

- \textit{Test fecal-specific pathogens in people, water, food, and the environment}: Results from this research (Chapter Three) warrants further investigation into specific fecal pathogens that are known to cause AGI. Previous research has shown unique food, water, and animal-related risk factors for AGI in Inuit,\textsuperscript{33} and further work to characterize these food, water, and environmental systems in northern communities will be vital to understanding and responding to the high burden of AGI reported in the Arctic. Pathogens of particular concern may include \textit{Giardia duodenalis, Cryptosporidium spp., Campylobacter spp., and Clostridium difficile}, as previous literature suggests these pathogens may be highly prevalent in the Arctic.\textsuperscript{34,35}

- \textit{Make knowledge translation and extension (KTE) a central component of the research process}: Knowledge translation and extension is the process of turning research knowledge into action, and it is about “accelerating the capture and practical application of the knowledge uncovered by research”.\textsuperscript{36} This principle of knowledge-to-action is a pillar of EcoHealth research,\textsuperscript{8} and is an inherent component of community-based participatory research.\textsuperscript{37} Unfortunately, short funding timelines and limited resources are often critiqued as impediments to consistently employing these methods.\textsuperscript{37} Failure to incorporate KTE into the research process
can limit the practical applications of research knowledge, if it is not readily useable by communities and policy makers; therefore, it is vital that research is centered around how to create and share useable knowledge. This is particularly important in underserved communities, where accelerated application of research knowledge can have large impacts in addressing health inequities.

**CONCLUSION**

In conclusion, this thesis research serves as an important contribution to the limited literature that exists examining drinking water and its impacts on health in Indigenous, and more specifically, Inuit, populations. This work is an example of how successful, long-term partnerships can result in mutually beneficial research that serves the particular interests of Indigenous communities, and increases local capacity to drive research and understand factors that impact water and health-related outcomes in the Canadian Arctic.
REFERENCES


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**Figure 5.1** (A) Results sharing event in Rigolet, Canada; (B) Infographic displaying information about research findings; (C) container with sticker that provides directions for container cleaning and disinfection.
Appendix A. Survey questionnaires

May 2013 (adult perceptions of tap water questionnaire)
7: Multi Select
Where do you usually get information about Boil Water Advisories in Rigolet? Select all that apply.
- Specify Answer
- Min Answers- 1

8: Single Select
Do you usually follow Boil Water Advisories? (e.g. you boil your water at a rolling boil for 1 minute).
- Answer Required

9: Text Input
Why do you usually follow Boil Water Advisories?
- Answer Required

10: Text Input
Why don't you usually follow Boil Water Advisories?
- Answer Required

11: Single Select
How do you feel when Rigolet is under a Boil Water Advisory?
- Answer Required
- Not concerned
- Somewhat not concerned
- Neutral
- Somewhat concerned
- Concerned
- Don't know
- Refused to answer

12: Information
The following questions are about tap water in Rigolet

13: Grid Scale
How important is it that Rigolet tap water...
- Answer Required
- Has good taste
- Has good smell
- Has the right colour
- Has the right clarity/cloudiness
- Not important
- Slightly not
14: **Grid Scale**

Please rate the quality of Rigolet tap water for the following...

- Taste
- Smell
- Colour
- Clarity/Cloudiness
- Safety for you to drink

Answer Required

15

Very poor
Poor
Fair
Good
Excellent
Don’t Know
Refuse to answer

15: **Grid Scale**

How is the quality of Rigolet tap water for the following uses?

- Drinking
- Bathing/Showering
- Cooking
- Doing Laundry
- Food Preparation
- House Cleaning
- Making Tea
- Flushing Toilets

Answer Required

16

Very poor
Poor
Fair
Good
Excellent
Don’t know
Refuse to answer

16: **Information**

Other communities say they have problems with their drinking water systems. I am going to ask you questions to see whether or not Rigolet has any of the same issues.

- Chemicals or Pollutants like PCBs left over from the military
- Chlorination By-Products like THMs or HAA
- Germs / Bacteria
- Colour
- Smell
- Mercury, Lead or other minerals
- Taste
- Clarity/Cloudiness
- Chlorine

Answer Required

16

Not concerned
### Question 18: Single Select
How do you think chlorine in tap water impacts your health?
- Slightly concerned
- Somewhat concerned
- Concerned
- Extremely concerned
- Don’t Know
- Refuse to Answer

### Question 19: Grid Scale
How do you feel about the following...
- Quality of water in the lake
- Tap water treatment
- Condition of the underground water pipes
- Results of tap water tests
- Cost of running the water treatment plant

<table>
<thead>
<tr>
<th>Not concerned</th>
<th>Slighty concerned</th>
<th>Somewhat concerned</th>
<th>Concerned</th>
<th>Extremely concerned</th>
<th>Don’t Know</th>
<th>Refuse to Answer</th>
</tr>
</thead>
</table>

### Question 20: Grid - Single Select
Do you think you, or anyone in your family has got sick from drinking water from...
- Rigotet tap water
- Brook water from around town
- Bottled water
- Store water
- Brook water from your cabin

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Don’t Know</th>
</tr>
</thead>
</table>
21:  How often do you use the following sources for drinking water in your home?

- Water straight from your tap (not treated with anything else)
- Tap water treated with a Brita jug filter, tap mounted filters, boiling or other
- Bottled water (e.g., Desani, Evian, Aquafina, or mineral water)
- Store water (filtered water from Northern)
- UNTREATED water collected from brooks
- TREATED (Brita, Boiled etc) water from brooks

Answer Required

- Never
- Rarely
- Sometimes
- Often
- Always
- Don’t Know
- Refuse to Answer

22:  Do you use a Brita filter in your home?

Answer Required

- No
- Yes
- Don’t Know
- Refuse to Answer

23:  How often do you usually change the Brita filter?

Answer Required

Specify Answer

- Once a Year
- Twice a year
- Once every 2 months
- Once a month
- Once a week
- Don’t know
- Other (specify)
- Refuse to answer
- Never change the filter

Specify Answer

- Improve Taste
- Improve Smell
24. Grid - Single Select
What are the reasons you use a Brita?
- Reduces Germs / Bacteria
- Reduces Mercury, Lead or other minerals
- Reduces chemicals like PCBs in the water
- Reduces Chlorine By-products like THMs or HAAAs
- Reduces the Cloudiness of the water
- Reduces the Colour of the water
- Reduces Hardness of the water
- It is cheaper than bottled/store water

Yes
No
Don't Know
Refuse to Answer

25. Single Select
Note to Dina: please take out the glass to show to the participant

Answer Required

26. Single Select
How many glasses of TAP water do you drink in a normal day?

Answer Required

None
1 to 2 glasses
3 to 4 glasses
5 to 6 glasses
Don't Know
Refuse to Answer
More than 6 glasses

27. The following questions are about bottled water and filtered water that you can buy from the Northern store.

28. Single Select
Do you ever drink bottled water or water from the store?

Answer Required

Yes
No
Don't Know
Refuse to Answer

29. Single Select
How many glasses of bottled water or water from the store do you drink in a normal day?

Answer Required
What are the reasons you drink bottled water or water from the store?

- Improved Taste
- Improved Smell
- Reduced Germs / Bacteria
- Reduced Mercury, Lead or other metals
- Reduced chemicals like PCBs
- Reduced Chlorine By-Products like THMs or HAAs
- Reduced Cloudiness of Water
- Reduced Hardness of Water
- Reduces Colour of the water
- Better safety testing of the bottled water
- Convenience of bottled water
- Bottles are a more trusted source of drinking water

The following questions are about drinking BROOK water while in town. The questions are NOT about drinking brook water at your cabin or while out on the land.

Do you ever drink Brook water at home? This could be water collected from local brooks or brought back from your cabin.

- Yes
- No
- Unsure
- Don't Know
- Refuse to Answer

Do you treat the Brook water before drinking it at home (e.g. Brita, boiling, filtering)?

- Answer
- Specify Answer
34: How many glasses of Brook water do you drink in a normal day?

- None
- 1-2 glasses
- 3-4 glasses
- 4-5 glasses
- More than 6 glasses
- Don't Know
- Refuse to answer

35: Why do you drink brook water at home?

- Improved taste
- Improved smell
- Reduced Germs/Bacteria
- Reduced Lead, Mercury or other metals
- Reduces Chemicals like PCBs
- Reduced Chlorine
- By-Products like THMs and HAAs
- Reduced Cloudiness of water
- Reduced Colour of water
- More natural water source
- More trusted water source than tap water
- Cheaper than bottled water
- More environmentally friendly than bottled water
- More trusted water source than bottled water
- Yes
- No
- Don't Know
- Refuse to answer

36: How do you normally store brook water at home? Select all that apply.

- In water cooler
- In jugs
37: Multi Select
Where do you normally store brook water at home? Select all that apply.
- In small containers
- Don’t Know
- Refuse to answer
- Other (specify)
- In buckets

38: Grid - Single Select
How many glasses of other drinks do you drink in a normal day?
- Pop/Cola/Iced Tea (diet or regular)
- Hot Tea (e.g. Tetley)
- Juice/Gatorade
- Coffee
- Milk

39: Grid - Single Select
How much do you normally spend on drinking water each week?
- Money spent on bottled water (e.g. Desani, Evian, Aquafina, or mineral water)
- Money spent on filtered water from Northern
- Money spent on fuel getting brook water

- $0
- $1 - 10
- $11 - 25
- $25 - 40
- $41 - 60
How important is it that you get more information on the following...

- The quality of the water in the lake
- How the tap water is treated
- Condition of underground water pipes
- Results of tap water tests
- Chlorine By-Products (THMs, HAAs)
- Quality of local brook water
- Quality of alternatives to the lake

Not important
Somewhat important
Important
Don't Know
Refuse to Answer

The survey is almost done! There are just a few more questions.

What is the best way for Rigot to make a long term plan for its drinking water system to ensure we have good and safe water in the future? Select all that apply.

- Hold community meetings and ask residents what they want
- Have small focus group discussions
- Organizers should go to peoples’ homes to talk about it
- Create digital stories about drinking water and what makes good water
- Work together with university researchers and other experts
- Don't Know
- Refuse to Answer
43: **Grid - Single Select**

**What could you do to help make a long term drinking water plan in Rigollet?**

- I could be on the planning committee
- I could help PLAN community events
- I could go to community meetings
- I could go to focus group discussions
- I could help set up / clean up after community events
- I could prepare some snacks or meals for a community meeting
- I could babysit so other adults could participate
- I could share stories with people about water
- I could make a digital story
- I could help build or construct different treatment options for testing
- I would not want to be involved

**Answer Required**

Yes
No
Maybe
Don't Know
Refused to answer

---

44:

The survey is complete! Thanks so much for participating.

Conclusion
Indigenous Health Adaptation to Climate Change (IHACC) questionnaire administered in September 2012 and May 2013 in Rigolet, Nunatsiavut
6: Grid - Single Select

When you have diarrhea or vomiting, what do you usually do?
- Consult a Inuit traditional healer
- Visit local health clinic
- Take medications (e.g. Advil, Tylenol, etc)
- Do nothing

Answer Required

7: Multi Select

In general, when you have diarrhea or vomiting, who do you consult or ask advice from? Select all that apply.
- Answer Required
- Specify Answer
- Min Answers- 1

Female friend
Male friend
Husband/Boyfriend
Wife/Girlfriend
Dad
Mom
Grandfather
Grandmother
Uncle
Aunt
Brother
Sister
Other (specify):
Nobody

8: Single Select

Are there any foods that you eat to help treat diarrhea or vomiting?
- Answer Required
- Specify Answer

No
Unsure
Refused to answer

9: Single Select

Is there anything else that you usually do when you get diarrhea or vomiting?
- Answer Required
- Specify Answer

No
Unsure
Refused to answer
Yes (specify what they usually do)
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the past TWO WEEKS, did you have vomiting or diarrhea?</td>
<td>Yes, No, Unsure, Refused to answer</td>
<td>101</td>
</tr>
<tr>
<td>In the past MONTH, did you have vomiting or diarrhea?</td>
<td>Yes, No, Unsure, Refused to answer</td>
<td>111</td>
</tr>
<tr>
<td>What was the date you first got sick?</td>
<td>Unsure, Refused to answer</td>
<td>121</td>
</tr>
<tr>
<td>Did you vomit?</td>
<td>Yes, No, Unsure, Refused to answer</td>
<td>131</td>
</tr>
<tr>
<td>Are you still vomiting?</td>
<td>Yes, No, Unsure, Refused to answer</td>
<td>141</td>
</tr>
<tr>
<td>How many days did the vomiting last?</td>
<td>2 days, 3 days, 4 days, 5 days, 6 days, 7 or more days, Unsure, Refused to answer</td>
<td>151</td>
</tr>
<tr>
<td>No.</td>
<td>Question</td>
<td>Options</td>
</tr>
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<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>16</td>
<td>When your vomiting was the worst, how many times did you vomit in one day? (Note: one day = 24 hours)</td>
<td>1 time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 times</td>
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<td>3 times</td>
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<td>4 times</td>
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<td></td>
<td></td>
<td>Constant vomiting</td>
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<td></td>
<td>Unsure</td>
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<td></td>
<td></td>
<td>Refused to answer</td>
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<tr>
<td></td>
<td></td>
<td>More than 4 times</td>
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<tr>
<td>17</td>
<td>Have you been diagnosed with an illness or condition that causes vomiting? [Prompt for H. pylori, gall bladder disease, pregnancy, colitis, diverticulitis, Crohn's disease, irritable bowel syndrome, or other chronic conditions]</td>
<td>Yes</td>
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<td>No</td>
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<td>Unsure</td>
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<td></td>
<td></td>
<td>Refused to answer</td>
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<tr>
<td>18</td>
<td>Do you think that your vomiting was due to that illness or condition?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
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<td>Unsure</td>
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<tr>
<td></td>
<td></td>
<td>Refused to answer</td>
</tr>
<tr>
<td>19</td>
<td>Are you taking any medications or receiving any treatments that might cause vomiting?</td>
<td>Yes</td>
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<tr>
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<td></td>
<td>No</td>
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<td>Unsure</td>
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<tr>
<td></td>
<td></td>
<td>Refused to answer</td>
</tr>
<tr>
<td>20</td>
<td>Do you think that your vomiting was due to that medication or treatment?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unsure</td>
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<tr>
<td></td>
<td></td>
<td>Refused to answer</td>
</tr>
<tr>
<td>21</td>
<td>Now I would like to ask you some questions about diarrhea.</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>When you were sick did you have diarrhea? [Interviewer: Diarrhea is ANY loose stools in a 24 hour period.]</td>
<td>Yes</td>
</tr>
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<td></td>
<td>No</td>
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<td>Unsure</td>
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<td></td>
<td>Refused to answer</td>
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<tr>
<td>Question</td>
<td>Options</td>
<td>Reference</td>
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<tr>
<td>-------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>23: Do you still have diarrhea?</td>
<td>Yes, No, Unsure, Refused to answer</td>
<td>24</td>
</tr>
<tr>
<td>24: How many days did the diarrhea last?</td>
<td>1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 7 or more days, Unsure, Refused to answer</td>
<td>25</td>
</tr>
<tr>
<td>25: When your diarrhea was the worst, how many times did you have diarrhea in one day?</td>
<td>1 time, 2 times, 3 times, 4 times, More than 4 times, constant diarrhea, Unsure, Refused to answer</td>
<td>26</td>
</tr>
<tr>
<td>26: Did you have any blood in your diarrhea?</td>
<td>Yes, No, Unsure, Refused to answer</td>
<td>27</td>
</tr>
<tr>
<td>27: Have you been diagnosed with an illness or condition that causes diarrhea? [Interviewer: Prompt for: H. pylori, pregnancy, colitis, diverticulitis, Crohn's disease, irritable bowel syndrome, or other chronic conditions]</td>
<td>Yes, No, Unsure, Refused to answer</td>
<td>28</td>
</tr>
<tr>
<td>28: Do you think that your diarrhea was due to that illness or condition?</td>
<td>Yes, No, Unsure</td>
<td>29</td>
</tr>
<tr>
<td>Question</td>
<td>Answer Options</td>
<td>Page</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>------</td>
</tr>
</tbody>
</table>
| 29: Are you taking any medications or receiving any treatments that might cause diarrhea? | - Yes
- No
- Unsure
- Refused to answer | 30   |
| 30: Do you think that your diarrhea was due to that medication or treatment? | - Yes
- No
- Unsure
- Refused to answer | 31   |
| 31: When you were sick, did you have...                             | - Nausea?
- Stomach cramps or pain?
- Fever?
- Chills?
- Muscle or joint pain or stiffness?
- Headache?
- Excessive thirst?
- Extreme tiredness?
- Sore throat or runny nose?
- Coughing or sneezing? | 32   |
| 32: Did you have any other symptoms?                          | - No
- Unsure
- Refused to answer | 33   |
| 33: When you were sick, could you perform all your usual activities (e.g. working, cooking, cleaning, hunting, etc.)? | - Yes
- No
- Unsure | 34   |
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>34: Single Select How many days of usual activities did you miss?</td>
<td>Refused to answer 34</td>
</tr>
<tr>
<td></td>
<td>1 day</td>
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<tr>
<td></td>
<td>2 days</td>
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<td>3 days</td>
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<td>6 days</td>
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<td>7 or more days</td>
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<td>Unsure</td>
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<td></td>
<td>Refused to answer 35</td>
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<tr>
<td>35: Single Select When you were sick, did you miss any work or school?</td>
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<td>No</td>
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<tr>
<td></td>
<td>Refused to answer 37</td>
</tr>
<tr>
<td>36: Single Select How many days did you miss?</td>
<td>1 day</td>
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<td>2 days</td>
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<td>7 or more days</td>
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<td>Unsure</td>
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<td></td>
<td>Refused to answer 37</td>
</tr>
<tr>
<td>37: Single Select When you were sick, did you miss any traditional/recreational activities (e.g. hunting, fishing, crafting, spending time at cabin, etc.)?</td>
<td>Yes</td>
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<tr>
<td></td>
<td>No</td>
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<td></td>
<td>Unsure</td>
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<tr>
<td></td>
<td>Refused to answer 39</td>
</tr>
<tr>
<td>38: Single Select How many days did you miss?</td>
<td>1 day</td>
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<td>2 days</td>
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<td>7 or more days</td>
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<td>Unsure</td>
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<td>Refused to answer 39</td>
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<tr>
<td>Question</td>
<td>Answer Options</td>
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<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>39: When you were sick, did anyone in your family miss any days of work or school to take care of you?</td>
<td>Yes 40</td>
</tr>
<tr>
<td></td>
<td>No 41</td>
</tr>
<tr>
<td></td>
<td>Unsure 41</td>
</tr>
<tr>
<td></td>
<td>Refused to answer 41</td>
</tr>
<tr>
<td>40: How many days did they miss?</td>
<td>1 day 41</td>
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<tr>
<td></td>
<td>2 days 41</td>
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<tr>
<td></td>
<td>3 days 41</td>
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<td>6 days 41</td>
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<td></td>
<td>7 or more days 41</td>
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<td></td>
<td>Unsure 41</td>
</tr>
<tr>
<td></td>
<td>Refused to answer 41</td>
</tr>
<tr>
<td>41: When you were sick, did you talk to any family or friends for advice? Select all that apply.</td>
<td>Male friend 42</td>
</tr>
<tr>
<td></td>
<td>Female friend 42</td>
</tr>
<tr>
<td></td>
<td>Husband/Boyfriend 42</td>
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<td></td>
<td>Wife/ Girlfriend 42</td>
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<td>Father 42</td>
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<td>Aunt 42</td>
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<td>Brother 42</td>
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<tr>
<td></td>
<td>Sister 42</td>
</tr>
<tr>
<td></td>
<td>Other (specify):</td>
</tr>
<tr>
<td>42: When you were sick, did you see a doctor, nurse, or other health care provider?</td>
<td>Yes 44</td>
</tr>
<tr>
<td></td>
<td>No 43</td>
</tr>
<tr>
<td></td>
<td>Unsure 48</td>
</tr>
<tr>
<td></td>
<td>Refused to answer 48</td>
</tr>
<tr>
<td>43: What was the reason you decided not to see a doctor, nurse, or other health care provider? [Interview: Do not read the list aloud. Select the boxes that best describe what the participant said.]</td>
<td>Yes 44</td>
</tr>
<tr>
<td></td>
<td>No 43</td>
</tr>
<tr>
<td></td>
<td>Unsure 48</td>
</tr>
<tr>
<td></td>
<td>Refused to answer 48</td>
</tr>
</tbody>
</table>
Was not serious enough to seek health care services  
Was out on the land or at cabin  
Not available in the area, don't have a physician  
Not available at the time required (e.g., doctor or nurse on holidays, inconvenient hours)  
Waiting time too long  
Felt it would be inadequate / wouldn't make a difference to the outcome  
Too busy  
Didn't get around to it / symptoms were or illness was over before care could be sought  
Transportation problems  
Language problems  
Personal or Family responsibilities  
Dislikes or distrusts doctors or nurses, afraid  
Unsure  
Refused to answer  
Other (specify):

<table>
<thead>
<tr>
<th>44: Did the health care provider ask you to collect a stool sample?</th>
<th>Answer Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Select</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>45</td>
</tr>
<tr>
<td>No</td>
<td>46</td>
</tr>
<tr>
<td>Unsure</td>
<td>46</td>
</tr>
<tr>
<td>Refused to answer</td>
<td>46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>45: Did you submit the stool sample?</th>
<th>Answer Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Select</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>46</td>
</tr>
<tr>
<td>No</td>
<td>46</td>
</tr>
<tr>
<td>Unsure</td>
<td>46</td>
</tr>
<tr>
<td>Refused to answer</td>
<td>46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>46: When you were sick, were you admitted to the</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Response Options</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Single Select hospital?</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>Suffix-DAYS</td>
</tr>
<tr>
<td>47: Numeric Input</td>
<td>How many days were you in the hospital?</td>
</tr>
<tr>
<td></td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>Specify Answer</td>
</tr>
<tr>
<td>48: Single Select</td>
<td>When you were sick, did you take any medication (e.g. Tylenol, Advil, Immodium, Gravol, etc)?</td>
</tr>
<tr>
<td></td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>Specify Answer</td>
</tr>
<tr>
<td>49: Single Select</td>
<td>When you were sick, did you use any traditional medicine?</td>
</tr>
<tr>
<td></td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>Specify Answer</td>
</tr>
<tr>
<td>50: Single Select</td>
<td>Was there any type of food that you ate to treat your diarrhea and vomiting?</td>
</tr>
<tr>
<td></td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>Specify Answer</td>
</tr>
<tr>
<td>51: The next few questions relate to travel.</td>
<td></td>
</tr>
<tr>
<td>52: Single Select</td>
<td>In the last month, did you go out on the land or visit a cabin? [Interviewer: the last month = 28 days]</td>
</tr>
<tr>
<td></td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Unsure</td>
</tr>
<tr>
<td></td>
<td>Refused to answer</td>
</tr>
</tbody>
</table>

144
<table>
<thead>
<tr>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you get sick before, during, or after you were away?</td>
<td>Before travelling, While travelling, After returning to town, Unsure, Refused to answer</td>
</tr>
<tr>
<td>In the last month, did you travel to another community in Canada?</td>
<td>Yes, No, Unsure, Refused to answer</td>
</tr>
<tr>
<td>Did you get sick before, during, or after you were away?</td>
<td>Before travelling, While travelling, After returning to town, Unsure, Refused to answer</td>
</tr>
<tr>
<td>In the last month, did you travel outside of Canada?</td>
<td>Yes, No, Unsure, Refused to answer</td>
</tr>
<tr>
<td>Did you get sick before, during, or after you were away?</td>
<td>Before travelling, While travelling, After returning to town, Unsure, Refused to answer</td>
</tr>
<tr>
<td>In the last month, did you go out on the land or visit a cabin?</td>
<td>Yes, No, Unsure, Refused to answer</td>
</tr>
<tr>
<td>In the last month, did you travel to another community in Canada?</td>
<td>Yes, No, Unsure, Refused to answer</td>
</tr>
</tbody>
</table>
59: Single Select  Bay, Nain, Postville, Toronto, etc. The last month = 28 days]  Answer Required

60: Single Select  In the last month, did you travel outside of Canada? [Interviewer: e.g. another country, like USA, Mexico, etc. the last month = 28 days]  Answer Required

61: Image  The next questions are about drinking water. By drinking water, we mean plain unboiled water or cold drinks made with unboiled water, like frozen juices and crystal drink mixes. We don't mean drinks made with boiled water like tea, coffee, or hot chocolate, and not pop or other bottled drinks.

62: Single Select  In the past two weeks, what was your main source of drinking water?  Answer Required  Specify Answer

63: ABC Text Input  Where do you get your brook water from? (specify location)  Answer Required

64: Interval Scale  How would you rate the quality of that water? [Interviewer prompt: The water quality overall, considering different things like taste, colour, odour, etc]  Answer Required

65: Single Select  Does your household treat this drinking water (e.g. boiling, Brita filter, etc)?  Answer Required
66: **Single Select**
How do you usually store this water?  
○ Answer Required

- Yes 66
- No 66
- Unsure 66
- Refused to answer 66

67: **Interval Scale**
Of all the water consumed yesterday, how much was from that source?  
○ Answer Required

- None of the water (0%) 68
- Some of the water (25%) 68
- About half of the water (50%) 68
- Most of the water (75%) 68
- All of the water (100%) 68
- Unsure 68
- Refused to answer 68

68: **Single Select**
In the past two weeks, did you drink water from another source?  
○ Answer Required

- Yes 69
- No 76
- Unsure 76
- Refused to answer 76

69: **Single Select**
What was the source of that drinking water?  
[Interviewer: If many other sources, pick the second most common source.]  
○ Answer Required  
○ Specify Answer

- Tap water 71
- Water from a brook, river, or stream 70
- Melted ice or snow 71
- Melted iceberg 71
- Store bought bottled water 71
- Unsure 71
- Refused to answer 71
- Other (specify): 71
70: **Text Input**
Where do you get your brook water from? (specify location) 71

71: **Interval Scale**
How would you rate the quality of that water? [Interviewer prompt: The water quality overall, considering different things like taste, colour, odour, etc]

- Answer Required
- Very poor 72
- Poor 72
- Fair 72
- Good 72
- Very Good 72
- Unsure 72
- Refused to answer 72

72: **Single Select**
Does your household treat that drinking water (e.g. boiling, Brita filter, etc)?

- Answer Required
- Yes 73
- No 73
- Unsure 73
- Refused to answer 73

73: **Single Select**
How do you usually store that water?

- Answer Required
- In a container in the fridge 74
- In a container outside of the fridge 74
- I do not store my water in a container 74
- Unsure 74
- Refused to answer 74

74: **Interval Scale**
Of all the water consumed yesterday, how much was from that source?

- Answer Required
- None of the water (0%) 75
- Some of the water (25%) 75
- About half of the water (50%) 75
- Most of the water (75%) 75
- All of the water (100%) 75
- Unsure 75
- Refused to answer 75

75: **Image**
The next question is about animals.

In the past month, have you come close to any
76: **Single Select**

**Live animals?** [Interviewer: Possible clarification: Have you had physical contact or been within one metre of an animal within the last 4 weeks?]

- Yes
- No
- Unsure
- Refused to answer

77: **Grid - Single Select**

**What live animals were you close to?**

- Geese,
- Ducks, or other Birds
- Caribou
- Seal,
- Whale, or other Marine mammals
- Fish
- Dog - pet
- Dog - working dog/sled dog
- Cat
- Dog - puppy

- Yes
- No
- Unsure
- Refused to answer

78: **Single Select**

**Were you close to any other types of live animals?**

- No
- Unsure
- Refused to answer

79: **Image**

The next questions are about the meals that you eat. This includes snacks that are eaten on a regular basis.

80: **Single Select**

**In the past month, how many meals included freshly caught fish?**

- None
- Less than half of the meals
- About half of the meals
- More than half of the meals
- All of the meals
- Unsure
- Refused to answer
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the past month, how many meals included meat from the land?</td>
<td>None, Less than half of the meals, About half of the meals, More than half of the meals, All of the meals, Unsure, Refused to answer</td>
</tr>
<tr>
<td>In the past month, how many meals included fish from the store?</td>
<td>None, Less than half of the meals, About half of the meals, More than half of the meals, All of the meals, Unsure, Refused to answer</td>
</tr>
<tr>
<td>In the past month, how many meals included meat from the store?</td>
<td>None, Less than half of the meals, About half of the meals, More than half of the meals, All of the meals, Unsure, Refused to answer</td>
</tr>
<tr>
<td>In the past month, how many meals included fruit or vegetables (from the store or the land)?</td>
<td>None, Less than half of the meals, About half of the meals, More than half of the meals, All of the meals, Unsure, Refused to answer</td>
</tr>
<tr>
<td>Question</td>
<td>Options</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>85: Single Select packaged, processed, or ready-to-eat food from the store? Answer Required</td>
<td>None 86&lt;br&gt;Less than half of the meals 86&lt;br&gt;About half of the meals 86&lt;br&gt;More than half of the meals 86&lt;br&gt;All of the meals 86&lt;br&gt;Unsure 86&lt;br&gt;Refused to answer 86</td>
</tr>
<tr>
<td>86: Single Select In the past month, how many meals included dairy products (e.g. milk, cheese, yogurt)? Answer Required</td>
<td>None of the meals 87&lt;br&gt;Less than half of the meals 87&lt;br&gt;About half of the meals 87&lt;br&gt;More than half of the meals 87&lt;br&gt;All of the meals 87&lt;br&gt;Unsure 87&lt;br&gt;Refused to answer 87</td>
</tr>
<tr>
<td>87: Single Select In the past month, did you eat any eggs from the land? Answer Required</td>
<td>Yes 88&lt;br&gt;No 90&lt;br&gt;Unsure 90&lt;br&gt;Refused to answer 90</td>
</tr>
<tr>
<td>88: Single Select Did you eat any of the eggs raw? Answer Required</td>
<td>Yes 90&lt;br&gt;No 89&lt;br&gt;Unsure 89&lt;br&gt;Refused to answer 89</td>
</tr>
<tr>
<td>89: Single Select When you cooked the eggs, was the yolk runny? Answer Required</td>
<td>Yes 90&lt;br&gt;No 90&lt;br&gt;Unsure 90&lt;br&gt;Refused to answer 90</td>
</tr>
<tr>
<td>90: Single Select In the past month, did you eat any eggs from the store? Answer Required</td>
<td>Yes 91</td>
</tr>
</tbody>
</table>
91: Did you eat any of the eggs raw? Answer Required
- Yes 92
- No 92
- Unsure 92
- Refused to answer 92

92: When you cooked the eggs, was the yolk runny? Answer Required
- Yes 93
- No 93
- Unsure 93
- Refused to answer 93

93: In the past 2 weeks, did you eat fish that was...
   Answer Required
   - Cooked
   - Raw
   - Fermented
   - Dried
   - Frozen
- Yes 94
- No
- Unsure
- Refused to answer

94: In the past 2 weeks, did you eat meat that was...
   Answer Required
   - Cooked
   - Raw
   - Fermented
   - Dried
   - Frozen
- Yes 95
- No
- Unsure
- Refused to answer

95: The next questions are about your life in general.

96: Taking it all together, how satisfied are you currently with your life as a whole? Answer Required
   Left label: Very dissatisfied
   Right label: Very satisfied
- Very weak 97
- Weak
- Strong
- Very strong
- Unsure

97: How would you describe your sense of belonging to your local community? Would you say that it is:
   Answer Required
- Very weak 98
- Weak
- Strong
- Very strong
- Unsure
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Required</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>98:</strong> How often do you wash your hands with soap before eating?</td>
<td>Answer Required</td>
<td>99</td>
</tr>
<tr>
<td>99: Are you responsible for food preparation in the house?</td>
<td>Answer Required</td>
<td>100</td>
</tr>
<tr>
<td>100: How many people live in this house?</td>
<td>Answer Required</td>
<td>101</td>
</tr>
<tr>
<td>101: How many rooms are in this home, including the kitchen &amp; living</td>
<td>Answer Required</td>
<td>102</td>
</tr>
<tr>
<td>102: Is your home...</td>
<td>Answer Required</td>
<td>103</td>
</tr>
<tr>
<td>103: Does your home have a problem with mold OR is it in need of major</td>
<td>Answer Required</td>
<td>104</td>
</tr>
<tr>
<td>104: In the past 12 months, have you had someone stay with you...</td>
<td>Answer Required</td>
<td>105</td>
</tr>
</tbody>
</table>

- **Private housing**
  - [e.g. home owner]
  - Renting [e.g. private rental]
  - Government housing [e.g. teacher, RCMP housing, etc]
- **Mold**
- **Major repairs**
- **Mold AND major repairs**
- **Neither mold nor major repairs**
- **Unsure**
- **Refused to answer**
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the past month, did anyone in your household receive income support (e.g., Province of Newfoundland and Labrador income support program)?</td>
<td>Yes, No, Unsure, Refused to answer</td>
</tr>
<tr>
<td>Can you tell me approximately how much your household usually spends in an average WEEK on store-bought food?</td>
<td>Less than $150, $150-$300, $301-$450, $451-$600, Over $1,050, Unsure, Refused to answer</td>
</tr>
<tr>
<td>Can you tell me approximately how much your household usually spends in an average WEEK to obtain or buy country food? (e.g., gas, ammunition, supplies, equipment and/or country food)</td>
<td>Less than $150, $150-$300, $301-$450, $451-$600, Over $1,050, Unsure, Refused to answer</td>
</tr>
<tr>
<td>Last MONTH approximately how much did your household pay for rent, mortgage, electricity, heating fuel, gas, water and sewage, garbage, skidoo parts and oil, bullets, naphtha and material?</td>
<td>Less than $200, $201-$500, $501-$800, $601-$1,100, $1,101-$1,400, $1,401-$1,700, $1,701-$2,000, $2,001-$2,200, Over $2,200, Unsure, Refused to answer, $2,201-$2,500</td>
</tr>
</tbody>
</table>
114: Image
Now I would like to ask you a question about food preparation in your household.

115: Single Select
How long do you store leftovers (refrigerated or not)?
- Answer Required
  - 0 days
  - 1-2 days
  - 3-4 days
  - More than 4 days
  - Unsure
  - Refused to answer

116: Multi Select
How do you clean your kitchen counter and cutting board after preparing raw meat? [Interviewer: Do not read the answers out loud. Choose all that apply.]
- Answer Required
  - Specify
  - Answer
  - Min Answers
- 1
  - Rinse with water
  - Soap and water
  - Bleach and water (or other disinfectant like "Mr. Clean")
  - Dishwasher
  - Nothing - I don’t clean my kitchen after preparing raw meat
  - Unsure
  - Refused to answer
  - Other (specify):

117: Scale
How often do you wash your hands with soap before preparing food?
- Answer Required
  - Left label: Never
  - Right label: Always

118: Single Select
Have you heard of the Rigotet Community Freezer Program? [Interviewer note: Select 'yes' if they have heard of it at all - even just the name]
- Answer Required
  - Yes
  - No
  - Unsure
  - Refused to answer

119: Interval Scale
How familiar with the program are you?
- Answer Required
  - Very unfamiliar
  - Somewhat unfamiliar
  - Neutral
  - Somewhat familiar
  - Very familiar
120: Single Select
Does your household get food from the Rigollet Community Freezer?  Answer Required
- Often 121
- Sometimes 121
- Unsure 121
- Refused to answer 121
- Never 121

---

122: This section asks questions about being able to afford food for your household. Some of the questions are very personal. This information will help develop better programs to improve food security. All the information we collect is confidential and your name will not be shared with anyone outside the research team. You don't have to answer any questions you don't want to. You are free to skip any question.

123: These are statements people have made about their food situation at home. For these statements, please tell me whether the statement was often true, sometimes true, or never true for your household.

124: Single Select
In the last month, did YOU ever worry whether the food for you and your family would run out before you have money to buy more?  Answer Required
- Often true 124
- Sometimes true 124
- Never true 124
- Don't know 124
- Refused to answer 124

125: Single Select
In the last month, were there times when the food for YOU and your family just did not last, and there was no money to buy more?  Answer Required
- Often true 125
- Sometimes true 125
- Never true 125
- Don't know 125
- Refused to answer 125

126: Single Select
In the last month, were there times when YOU and your family could not afford to eat healthy food?  Answer Required
- Often true 126
- Sometimes true 126
- Never true 126
- Don't know 126
- Refused to answer 126

127: Single Select
In the past month, has anybody under 18 years of age lived in your house?  Answer Required
- Yes 127
- No 144
127: Single Select
In the last month, were there times when you could only feed your CHILDREN less expensive foods because you were running out of money to buy food?
Answer Required

128: Single Select
In the last month, were there times when it was NOT possible to feed the CHILDREN a healthy meal, because there was not enough money?
Answer Required

129: Single Select
Interviewer: Did the respondent answer "sometimes" or "often" to any of the previous questions?
Answer Required

130: Single Select
In the last month, were there times when the CHILDREN in the house were not eating enough food because there was no money to buy enough food?
Answer Required

131: Single Select
In the last month, did YOU ever cut the size of your meals or skip meals because there wasn’t enough money for food?
Answer Required

132: Single Select
How often did this happen?
Answer Required

133: Single
In the last month, did YOU ever eat less than you felt you should because there wasn’t enough food?
Answer Required
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the last month, were you ever hungry but didn’t eat because you couldn’t afford enough food?</td>
<td>Yes 134</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>No 134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Don’t know 134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Refused to answer 134</td>
<td></td>
</tr>
<tr>
<td>In the last month did you lose weight because you didn’t have enough money for food?</td>
<td>Yes 136</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>No 136</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Don’t know 136</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Refused to answer 136</td>
<td></td>
</tr>
<tr>
<td>Interviewer: Did the respondent answer “yes”, “often” or “sometimes” to any of questions above?</td>
<td>Yes 137</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>No 153</td>
<td></td>
</tr>
<tr>
<td>In the last month, did you or other adults in your household ever not eat for a whole day because there wasn’t enough money for food?</td>
<td>Yes 138</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>No 139</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Don’t know 139</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Refused to answer 139</td>
<td></td>
</tr>
<tr>
<td>How often did this happen?</td>
<td>Almost every day of the month 139</td>
<td></td>
</tr>
<tr>
<td></td>
<td>About half the days during the month 139</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A few days of the month 139</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Don’t know 139</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Refused to answer 139</td>
<td></td>
</tr>
<tr>
<td>In the last month, did you ever cut the size of your children’s meals because there wasn’t enough money for food?</td>
<td>Often true 140</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>Sometimes true 140</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Never true 140</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer Options</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>140: In the last month, did any of the CHILDREN ever skip meals because there wasn't enough money for food?</td>
<td>Don't know 140, Refused to answer 140</td>
<td></td>
</tr>
<tr>
<td>141: How often did this happen?</td>
<td>Almost every day of the month 142, About half the days during the month 142, A few days during the month 142, Don't know 142, Refused to answer 142</td>
<td></td>
</tr>
<tr>
<td>142: In the last month, were the CHILDREN ever hungry but you just couldn't afford more food?</td>
<td>Yes 143, No 143, Don't know 143, Refused to answer 143</td>
<td></td>
</tr>
<tr>
<td>143: In the last month, did your CHILDREN ever not eat for a whole day because there wasn't enough money for food?</td>
<td>Yes 153, No 153, Don't know 153, Refused to answer 153</td>
<td></td>
</tr>
<tr>
<td>144: Interviewer: Did the respondent answer &quot;sometimes&quot; or &quot;often&quot; to any of the previous food security questions?</td>
<td>Yes 145, No 153</td>
<td></td>
</tr>
<tr>
<td>145: In the last month, did YOU ever cut the size of your meals or skip meals because there wasn't enough money for food?</td>
<td>Yes 146, No 147, Don't know 147, Refused to answer 147</td>
<td></td>
</tr>
<tr>
<td>146: How often did this happen?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

160
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer Options</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the last month, did YOU ever eat less than you felt you should because there wasn't enough money to buy food?</td>
<td>Yes, No, Don't know, Refused to answer</td>
<td>148</td>
</tr>
<tr>
<td>In the last month, were YOU ever hungry but didn't eat because you couldn't afford enough food?</td>
<td>Yes, No, Don't know, Refused to answer</td>
<td>149</td>
</tr>
<tr>
<td>In the last month did YOU lose weight because you didn't have enough money for food?</td>
<td>Yes, No, Don't know, Refused to answer</td>
<td>150</td>
</tr>
<tr>
<td>Interviewer: Did the respondent answer &quot;yes&quot; to any of the questions above?</td>
<td>Yes, No</td>
<td>151</td>
</tr>
<tr>
<td>In the last month, did YOU or other adults in your household ever not eat for a whole day because there wasn't enough money for food?</td>
<td>Yes, No, Don't know, Refused to answer</td>
<td>152</td>
</tr>
<tr>
<td>How often did this happen?</td>
<td>Almost every day of the month, About half the days during the month, A few days during the month, Don't know</td>
<td>153</td>
</tr>
</tbody>
</table>
I just have a few more questions, which should only take another minute. The answers to these questions will help us get a profile of all respondents from Rigollet.

154: Single Select

What is your highest level of formal education?

- No formal schooling
- Some years of elementary school (not completed)
- Elementary school completed
- Some years of secondary (not completed)
- Secondary school completed
- PARTIAL training in community college, a trade school or a private commercial college, a Nunavut Sivuniksavut program, a technical institute, a nursing school, or a normal school (teaching school)
- Diploma or certificate from a community college, a trade school or a private commercial college, a technical institute, a Nunavut Sivuniksavut program, a nursing school, or a normal school (teaching school)
- Some university (not completed)
- University degrees (completed), Certificate, Bachelor, Masters, PhD
- Unsure
- Refused to answer

155: Single Select

What is your ethnic origin?

- Inuit

Refused to answer 153
<table>
<thead>
<tr>
<th>156:</th>
<th>Single Select</th>
<th>Are you employed?</th>
<th>○ Answer Required</th>
<th>157</th>
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<td></td>
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<td>Full-time employment</td>
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<td>Part-time employment</td>
<td>157</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Seasonal employment</td>
<td>157</td>
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<tr>
<td></td>
<td></td>
<td>Odd-jobs</td>
<td>157</td>
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<tr>
<td></td>
<td></td>
<td>Not employed</td>
<td>159</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Unsure</td>
<td>157</td>
<td></td>
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<td></td>
<td></td>
<td>Refused to answer</td>
<td>157</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Retired</td>
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<table>
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<tr>
<th>157:</th>
<th>Single Select</th>
<th>Are you currently employed?</th>
<th>○ Answer Required</th>
<th>158</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>158</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>No</td>
<td>158</td>
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<tr>
<td></td>
<td></td>
<td>Refused to answer</td>
<td>158</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>158:</th>
<th>Single Select</th>
<th>What is your main job?</th>
<th>○ Answer Required</th>
<th>159</th>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Name of job:</td>
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<table>
<thead>
<tr>
<th>159:</th>
<th>Multi Select</th>
<th>How would you like the results of this research shared with you? SELECT ALL THAT APPLY</th>
<th>○ Answer Required</th>
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<td>Website</td>
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<td></td>
<td></td>
<td>Flyer</td>
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<td>Facebook</td>
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<td>Community</td>
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<td></td>
<td>Event/Open House</td>
<td></td>
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<td></td>
<td></td>
<td>Other (specify):</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>I don't want to know the results of this research</td>
<td></td>
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<td></td>
<td></td>
<td>Radio</td>
<td></td>
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</tbody>
</table>

<p>| 160: | ABC | Do you have any comments or questions that you wish to bring to our attention? | ○ Answer |       |</p>
<table>
<thead>
<tr>
<th>161: Single Select</th>
<th>Interviewer: Did you put the participant's name in the draw and give them the gift card?</th>
<th>Answer Required</th>
<th>Specify Answer</th>
<th>Conclusion</th>
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<td>Yes - Northern giftcard</td>
<td>162</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes - Grub Box giftcard</td>
<td>162</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes - Gas giftcard</td>
<td>162</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other (specify):</td>
<td>162</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
June 2014 water quality and health questionnaire conducted in Rigolet, Canada.

Water Quality & Health Survey | Individual

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General Instructions

This survey will be completed by each member of the household. Please answer the following questions to the best of your ability. You may skip any question you are not comfortable answering. Your answers will help in understanding water storage and stomach illness in your community. All data collected from this survey will be strictly confidential, and there will be no way to link any names to the results. The survey should take about 10 minutes.
Part 3: Individual Questions | Filled out for every member of the household

A. Demographic Questions

Date and Time
_______/____/____ ____:____ ____(YYYY/MM/DD HH:MM AM/PM)

Interviewer Name

Household ID

Gender of respondent
☐ Male
☐ Female
☐ Refuse to answer

How old is respondent?
Enter number only
Simple Skipping Information
• If \([q12]\) In the past 2 weeks, did you drink any water from ... = No then Skip to Page 4
• If \([q12]\) In the past 2 weeks, did you drink any water from ... = Unsure then Skip to Page 4
• If \([q12]\) In the past 2 weeks, did you drink any water from ... = Refuse to answer then Skip to Page 4

Branching Information
• If not \([q12]\) In the past 2 weeks, did you drink any water from ... = Yes then Hide \(q12a\)
• If not \([q12]\) In the past 2 weeks, did you drink any water from ... = Yes then Hide \(q12b\)
• If not \([q12]\) In the past 2 weeks, did you drink any water from ... = Yes then Hide \(q12c\)
• If not \([q12]\) In the past 2 weeks, did you drink any water from ... = Yes then Hide Of all the water you drank yesterday, how much was...
  • If not \([q12]\) In the past 2 weeks, did you drink any water from ... = Yes then Hide How would you rate the quality of your secondary d...
  • If not How do you usually store the water from the main s... is one of \([u'0', u'1', u'3', u'4']\) then Hide How do you retrieve water from your main storage c...
  • If not \([q12b]\) How do you store the water from the secondary sour... is one of \([u'0', u'1', u'3', u'4']\) then Hide How do you retrieve water from your secondary stor...

B. Water Consumption Questions

For the following questions, when I refer to drinking water, I mean plain unboiled water. I don’t mean drinks made with boiled water like tea, coffee, or hot chocolate. No pop or other sweetened bottled, canned or boxed drinks. So, I am asking about plain unboiled water or cold drinks made with unboiled water, like frozen juices and crystal drink mixes.

About how much water do you drink each day?

Estimate as a number of 500ml bottles

- Less than 1 bottle
- 1 bottle
- 2 bottles
- 3 bottles
- 4 bottles
- 5 or more bottles
- Other, please specify... __________________________
- Unsure
- Refuse to answer

In the past 2 weeks, what was your MAIN source of drinking water?
I.e. from what source did you drink the most?

- Tap water
- Water from a brook, stream, or river (type actual name of source) __________________________
- Melted snow or ice
- Melted iceberg
- Store bought bottled water (By bottled water, I mean both sparkling water like Perrier and soda water, plain bottled water, and water from Culligan-type water coolers bought from the store)
- Private well
- Water from the ADWS (RIGC Water Dispensing Unit)
- Other, please specify... __________________________
- Unsure
- Refuse to answer

How do you usually store the water from the main source?

- In a container in the fridge
- In a container outside the fridge
- I do not store my water in a container
How do you retrieve water from your main storage container/bucket to drink?
That is, how do you get it into a drinking glass?
- I scoop water with my hands
- I pour the water directly from the container
- I use a dipper to scoop water from the container into a glass
- I get it from a water cooler/dispenser
- Other, please specify... __________________________
- Unsure
- Refuse to answer

Does your household treat the drinking water from this main source? (Ex. Brita filter, boil, etc)
- Yes
- No
- Unsure
- Refuse to answer

Of all the water you consumed yesterday, about how much was from your main source?
I.e. the source you mentioned for your main drinking water
- All of the water (100%)
- Most of the water (about 75%)
- Half of the water (about 50%)
- Less than half of the water (about 25%)
- None of the water (0%)
- Unsure
- Refuse to answer

How would you rate the quality of your main drinking water source?
- Very poor
- Poor
- Fair
- Good
- Very good
- Unsure
- Refuse to answer

In the past 2 weeks, did you drink any water from another source? (q12)
I.e. from a source not mentioned as the main source above
- Yes
- No
- Unsure
- Refuse to answer

What was the secondary source of drinking water? (q12a)
If you used more than one source, pick the one that is the second most common after the main source.
- Tap water
- Water from a brook, river, or stream (type actual name of source) __________________________
- Melted snow or ice
- Melted iceberg
- Store bought bottled water (By bottled water I mean sparkling water like Perrier and soda water, plain bottled water, and water from Culligan-type water coolers bought from the store)
- Private well
- Water from the ADWS (RIGC Water Dispensing Unit)
Other, please specify... __________________________
Unsure
Refuse to answer

How do you store the water from the secondary source mentioned above? (q12b)
- In a container in the fridge
- In a container outside the fridge
- I do not store water from my secondary source
- Other, please specify... __________________________
Unsure
Refuse to answer

How do you retrieve water from your secondary storage container/bucket to drink?
That is, how do you get it into a drinking glass?
- I scoop water with my hands
- I pour the water directly from the container
- I use a dipper to scoop water from the container into a glass
- I get it from a water cooler/dispenser
- Other, please specify... __________________________
Unsure
Refuse to answer

Does your household treat the water from the secondary source? (q12c)
- Yes
- No
- Unsure
- Refuse to answer

Of all the water you drank yesterday, how much was from your secondary source?
I.e. the source you mentioned as the second most common for drinking water.
- All of the water (100%)
- Most of the water (about 75%)
- Half of the water (about 50%)
- Less than half the water (about 25%)
- None of the water (0%)
- Unsure
- Refuse to answer

How would you rate the quality of your secondary drinking water source?
- Very poor
- Poor
- Fair
- Good
- Very good
- Unsure
- Refuse to answer
Branching Information

- If in the past TWO weeks, did you have any vomiting or diarrhea? is one of [1, 2, 3] then Skip to Page 5
- If in the past TWO weeks, did you have any vomiting or diarrhea = Yes then Skip to Page 6

C. Gastrointestinal Illness Questions

I will be asking you about stomach sickness or illness. Some of the questions are very personal. This information will help develop better programs to treat and prevent stomach sickness. All the information we collect is confidential, and your name will not be shared with anyone outside the research team. You don’t have to answer any questions you don’t want to. You are free to skip any question.

In the past TWO weeks, did you have any vomiting or diarrhea?

☐ Yes
☐ No
☐ Unsure
☐ Refuse to answer
Branching Information

• If In the past FOUR weeks, did you have any vomiting ... is one of [u'1', u'2', u'3'] then Complete survey

☑ In the past FOUR weeks, did you have any vomiting or diarrhea?
☐ Yes
☐ No
☐ Unsure
☐ Refuse to answer
Branching Information

- If not [q21] Did you vomit? = Yes then Hide q21a
- If not [q21] Did you vomit? = Yes then Hide q21b
- If not [q21] Did you vomit? = Yes then Hide q21c
- If [q21] Did you vomit? is one of [u'1', u'2', u'3'] then Skip to Page 9
- If not = Unsure then Hide If unsure, can you narrow down the day you first g...

What was the date you first got sick?
If you have been sick more than once in the past two weeks, please answer the questions for the most recent illness.

_______/_______/(YYYY/MM/DD)

- Unsure
- Refuse to answer

If unsure, can you narrow down the day you first got ill to a range of a few days?
Ex. It was between June 10th and the 13th when I first got sick.

- Yes (please specify range) __________
- No

C.1 Questions for Cases with Vomiting

Did you vomit? (q21)

- Yes
- No
- Unsure
- Refuse to answer

Are you still vomiting? (q21a)

- Yes
- No
- Unsure
- Refuse to answer

How many days did the vomiting last? (q21b)

- Please specify... __________
- Unsure
- Refuse to answer

When you were the MOST sick, about how many times did you vomit in one day? (q21c)

- Please specify... __________
- Unsure
- Refuse to answer
Have you been DIAGNOSED with an illness or condition that causes vomiting?
Ex. Pregnancy, H.pylori, colitis, diverticulitis, Crohn's disease, Irritable Bowel Syndrom, or other conditions.

- Yes
- No
- Unsure
- Refuse to answer

Do you think that your vomiting was due to that condition or illness?

- Yes
- No
- Unsure
- Refuse to answer
Branching Information

• If not Are you taking any medications, receiving treatments... = Yes then Hide Do you think that your vomiting was due to that me...

Are you taking any medications, receiving treatments, or taking drugs/alcohol that might cause vomiting?

☐ Yes
☐ No
☐ Unsure
☐ Refuse to answer

Do you think that your vomiting was due to that medication, treatment, or drugs/alcohol?

☐ Yes
☐ No
☐ Unsure
☐ Refuse to answer
Branching Information

• If not [q29] When you were sick did you have any diarrhea? = Yes then Hide q29a
• If not [q29] When you were sick did you have any diarrhea? = Yes then Hide q29b
• If not [q29] When you were sick did you have any diarrhea? = Yes then Hide q29c
• If [q29] When you were sick did you have any diarrhea? is one of [u'1', u'2', u'3'] then Skip to Page 12

C.2 Questions for Cases with Diarrhea

Now I would like to ask you some questions about diarrhea.

When you were sick did you have any diarrhea? (q29)

Diarrhea is ANY loose stools within a 24 hour period

☐ Yes
☐ No
☐ Unsure
☐ Refuse to answer

Do you still have diarrhea? (q29a)

☐ Yes
☐ No
☐ Unsure
☐ Refuse to answer

About how many days did the diarrhea last? (q29b)

☐ Please specify: __________________________
☐ Unsure
☐ Refuse to answer

When your diarrhea was the worst, how many times did you have diarrhea in one day? (q29c)

☐ Please specify: __________________________
☐ Unsure
☐ Refuse to answer
Branching Information

• If not Have you been DIAGNOSED with an illness or condition that causes diarrhea? (Ex. Pregnancy, H. pylori, colitis, diverticulitis, Crohn's disease, irritable bowel syndrome, or other chronic conditions)
  - Yes
  - No
  - Unsure
  - Refuse to answer

• If Do you think your diarrhea was due to that illness or condition?
  - Yes
  - No
  - Unsure
  - Refuse to answer
Branching Information

• If not Are you taking any medications, receiving any med... = Yes then Hide Do you think that your diarrhea was due to that me...

☐ Yes ☐ No ☐ Unsure ☐ Refuse to answer

Do you think that your diarrhea was due to that medication, treatment, or drugs/alcohol?

☐ Yes ☐ No ☐ Unsure ☐ Refuse to answer
### C.3 Questions for All Cases

#### When you were sick, did you telephone a doctor, nurse, or other health care provider?
- Yes
- No
- Unsure
- Refuse to answer

#### When you were sick, did you SEE a doctor, nurse, or other health care provider?
- Yes
- No
- Unsure
- Refuse to answer

#### When you were sick, did you take any...

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
<th>Refuse answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicine prescribed by a nurse or doctor?</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Over-the-counter medicine (ex. Advil, Tylenol, Pepto-Bismol, Gravol, Imodium etc)?</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Traditional medicines?</td>
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</table>
General Instructions
This survey is to be filled out once per water storage container/bucket in the household. Please answer the following questions to the best of your ability. You may skip any question you are not comfortable answering. Your answers will help in understanding water storage and stomach illness in your community. All data collected from this survey will be strictly confidential, and there will be no way to link any names to the results. The survey should take about 10 minutes.

Part 1: Household Questions | Filled out once per household container
A. Demographic Questions
Date and Time
_____/_____/______ ___:___ ___(YYYY/MM/DD HH:MM AM/PM)
Interviewer Name

Household ID

Gender of respondent
☐ Male
☐ Female
☐ Refuse to answer

How old is respondent?

Branching Information
• If Do you have any water stored in containers/buckets... is one of [u'1', u'2', u'3'] then Complete survey

B. Water Storage Questions | Filled out once per container/bucket
The following questions are about water stored in your home. This includes water in Brita jugs, buckets, blue jugs, pitchers, bottles, or any other type of container. This does not include water that you drink directly from the tap. Please answer the following questions to the best of your ability.

The next questions are about the water CONTAINER/BUCKET.

Do you have any water stored in containers/buckets in your home?
☐ Yes
☐ No
☐ Unsure
Branching Information

- If not [q3] Does the container/bucket have a lid? = Yes then Hide q3a
- If not [q7] Have you ever cleaned this container/bucket? = Yes then Hide q7a
- If not [q7] Have you ever cleaned this container/bucket? = Yes then Hide q7b
- If not [q8] Do you ever store anything other than water in you... = Yes then Hide What did you store in this container/bucket before...

What is the source of the water in this container/bucket?
- Creek, brooke, or stream (specify location) __________________________
- Lake
- Surface water (i.e. still, shallow water)
- Melted snow or ice
- Tap
- Store bought water
- Private well
- RICG water station
- Store-filtered water
- Other, please specify... __________________________
- Unsure
- Refuse to answer

Can I take a sample of this water?
- The test takes at least 24 hours to complete. We will call you with the results within 48 hours.
- Yes
- No

Water Sample Information
- Please record sample name, number and other observations

Water Temperature 1
- Degrees Celsius

Water Temperature 2
- Degrees Celsius

Water Temperature 3
- Degrees Celsius
What type of container/bucket is the water stored in?
- Plastic water bottle (Ex. a 500ml or 1L bottle)
- Clear plastic
- Opaque plastic (cannot see through)
- Metal
- Glass
- Bucket, specify material... __________________________
- Other, please specify... __________________________
- Unsure
- Refuse to answer

Does the container/bucket have a lid? (q3)
- Yes
- No
- Unsure
- Refuse to answer

Do you keep the lid on the container/bucket when you are not using it? (q3a)
- Yes
- No
- Unsure
- Refuse to answer

What is the approximate size of the container/bucket?
- 500 ml
- 1 gallon
- 2.5 gallons
- 3 gallons
- 5 gallons
- 10 gallons
- Other, please specify... __________________________
- Unsure
- Refuse to answer

Where is the container/bucket usually stored?
- In the refrigerator
- In a dark place (ex. a cabinet or closet)
- In the open (ex. on a counter)
- Outside
- Other, please specify... __________________________
- Unsure
Typically, how often do you fill this water container/bucket?
- More than once per week
- About once per week
- About once every 2 weeks
- About once per month
- Other, please specify... __________________________
- Unsure
- Refuse to answer

Have you ever cleaned this container/bucket? (q7)
- Yes
- No
- Unsure
- Refuse to answer

How do you clean it? (q7a)
- Rinse with tap water
- Soap and water
- Rinse with hot water
- Bleach or chemical solution
- RICG Water Station (ADWS) bottle cleaning sprayer
- Other, please specify... __________________________
- Unsure
- Refuse to answer

How often do you clean it? (q7b)
- Each time before I fill it
- About once per week
- About once every 2 weeks
- About once per month
- Less than once per month
- Once per year or less
- Other, please specify... __________________________
- Unsure
- Refuse to answer

Do you ever store anything other than water in your containers/buckets? (q8)
- Yes
- No
- Refuse to answer

What did you store in this container/bucket before?
_____________________________________________________________
_____________________________________________________________
_____________________________________________________________

Can I take a few photos of the container/bucket?
- Yes
- No

Photo Information
Record photo number and any other observations
Branching Information

• If not [q13] Do you do anything to treat the water from this container/bucket before you drink it? [q13a]
  - Nothing is done to the water before drinking
  - The water is boiled
  - The water is filtered by a product like a Brita filter
  - The water is filtered through a cloth, mesh, etc to remove debris
  - The water is treated with purifying tablet or drops
  - Other, please specify... __________________________
  - Refuse to answer

• If not In the past month, have you ever filled this container/bucket to contain water? [q13a]
  - Yes, contains one of [u'0', u'1', u'2', u'3', u'4', u'5', u'6', u'7', u'8'] then Hide

  Did you clean the container/bucket before filling...

The next questions are about the WATER stored in the container/bucket.

When collecting water or snow from the source, how did you get the water into your container/bucket? [q10a]
  - I scooped it in with my hands
  - I used the container to collect it straight from the source
  - I used a smaller jug or dipper to transfer source water into the container
  - I used a pipe to refill the container
  - ADWS water dispensing unit
  - Other, please specify... __________________________
  - Refuse to answer

When was the last time water was collected in this container/bucket?
  - Within 24 hours
  - Less than 1 week ago
  - Between 1 and 2 weeks ago
  - Between 2 weeks and 1 month ago
  - More than one month ago
  - Unsure
  - Refuse to answer

Who collected this water?

Age

Gender
  • Male
  • Female

Refuse to answer

Do you do anything to treat the water from this container/bucket before you drink it? [q13a]
I have never changed the filter
About once per year
About once every 6 months
About once every 2 months or sooner
Other, please specify... __________________________
Unsure
Refuse to answer

How do you retrieve water from the container/bucket to drink?
That is, how do you get it into a drinking glass?
I scoop it with my hands
I pour the water straight from the container
I use a dipper to scoop water from the container
I use a water cooler/dispenser
Other, please specify... __________________________
Unsure
Refuse to answer

In the past month, have you ever filled this container/bucket with a different type or source of water? If so, check all sources that apply.
I.e. a source not mentioned as the water in the container now.
Creek, brook, or stream water
Lake water
Surface water
Melted snow or ice
Tap water
Store bought water
Private well water
RICG water station
Other, please specify... __________________________
I have not put other sources of water in this container in the past 2 months
Unsure
Refuse to answer

Did you clean the container/bucket before filling it with a different source of water?
Yes
No
Unsure
Refuse to answer
Appendix B. Chapter Two Supplementary Tables

Supplementary Table B.1 Results of univariable analyses examining associations between explanatory variables and the odds of using potable water dispensing unit (PWDU), tap, purchased, and brook water, as well as the odds of consuming > 2L water/day in Rigolet, Canada (2014). Table includes crude univariable results for all variables considered, which had p-values ≤0.2.

Univariable results

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<th>Variables considered</th>
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<th>OR</th>
<th>p-value</th>
<th>95% CI</th>
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<td>Outcome: Tap water as 1° water source (J14)</td>
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<td>Survey period</td>
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<tr>
<td>Sep 2012</td>
<td>91</td>
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<tr>
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<td>42</td>
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<td>&lt;0.001</td>
<td>0.09 - 0.28</td>
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<td>Survey period</td>
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<td>Survey period</td>
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<td>Felt that chlorine had negative health impacts (M13)</td>
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<td>Rated smell of tap water as poor or very poor (M13)</td>
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<td>0.004</td>
<td>0.11 - 0.66</td>
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<td>Rated colour of tap water as poor or very poor (M13)</td>
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### Table 1. Prevalent Risk Factors for Water Consumption $>2$L/day

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<td>Female</td>
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<td>125</td>
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<td>Male</td>
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<td>175</td>
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<td>3.08</td>
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<td>Someone in household had full-time employment (M13)</td>
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<td>93</td>
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<tr>
<td>Felt that chlorine had both positive and negative health impacts (M13)</td>
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**Outcome: Water consumption $>2$L/day (J14)**

Total number of explanatory variables considered: 16

### Table 2. Additional Risk Factors for Water Consumption $>2$L/day

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<th>Odds Ratio</th>
<th>95% CI</th>
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<td>Drank brook water as 1$^{st}$ or 2$^{nd}$ water source (J14)</td>
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<td>Someone in household had full-time employment (M13)</td>
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<td>0.16 - 0.74</td>
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<td>Age (J14)</td>
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<td>0.86 - 3.95</td>
</tr>
<tr>
<td>Primary drinking water was from PWDU (J14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>82</td>
<td>162</td>
<td>Ref.</td>
<td></td>
<td>1.84</td>
<td>0.86 - 3.95</td>
</tr>
<tr>
<td>No</td>
<td>162</td>
<td>173</td>
<td>Ref.</td>
<td></td>
<td>1.06</td>
<td>3.08</td>
</tr>
<tr>
<td>Drank tap water as 1$^{st}$ or 2$^{nd}$ water source (J14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>73</td>
<td>173</td>
<td>Ref.</td>
<td></td>
<td>0.49</td>
<td>0.21 - 1.10</td>
</tr>
<tr>
<td>No</td>
<td>173</td>
<td>173</td>
<td>Ref.</td>
<td></td>
<td>1.06</td>
<td>3.08</td>
</tr>
<tr>
<td>Drank purchased water as primary water source (J14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>34</td>
<td>207</td>
<td>Ref.</td>
<td></td>
<td>0.40</td>
<td>0.12 - 1.39</td>
</tr>
<tr>
<td>No</td>
<td>207</td>
<td>173</td>
<td>Ref.</td>
<td></td>
<td>1.06</td>
<td>3.08</td>
</tr>
</tbody>
</table>

* S12 = September 2012; M13 = May 2013; J14 = June 2014

† Exact logistic regression

Variables in shaded area were included in principal component analysis.

Note: some contingency tables do not add to the total number of survey observations, as individuals who responded “unsure” or “refuse” were excluded from analysis of that question.
**Supplementary Table B.2** Crude univariable results of regressions examining associations between explanatory variables and the odds of using tap, purchased, and brook water, as well as the odds of consuming > 2L water/day in Rigolet, Canada.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>OR</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome: Tap water as 1° water source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep 2012</td>
<td>91</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 2013</td>
<td>93</td>
<td>1.21</td>
<td>0.648</td>
<td>0.69 - 1.83</td>
</tr>
<tr>
<td>Jun 2014</td>
<td>42</td>
<td>0.16</td>
<td>&lt;0.001</td>
<td>0.09 - 0.28</td>
</tr>
<tr>
<td><strong>Outcome: Purchased water as 1° water source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep 2012</td>
<td>113</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 2013</td>
<td>124</td>
<td>1.15</td>
<td>0.560</td>
<td>0.72 - 1.86</td>
</tr>
<tr>
<td>Jun 2014</td>
<td>34</td>
<td>0.06</td>
<td>&lt;0.001</td>
<td>0.03 - 0.12</td>
</tr>
<tr>
<td><strong>Outcome: Brook water as 1° water source</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sep 2012</td>
<td>16</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>May 2013</td>
<td>13</td>
<td>0.42</td>
<td>0.123</td>
<td>0.14 - 1.26</td>
</tr>
<tr>
<td>Jun 2014</td>
<td>3</td>
<td>0.04</td>
<td>&lt;0.001</td>
<td>0.01 - 0.25</td>
</tr>
<tr>
<td><strong>Outcome: Consumption of tap water as 1° or 2° water source in June 2014</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concerned or extremely concerned about chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>76</td>
<td>0.30</td>
<td>0.008</td>
<td>0.12 - 0.73</td>
</tr>
<tr>
<td>No</td>
<td>39</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rated quality of tap water for drinking as fair, poor, or very poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>94</td>
<td>0.31</td>
<td>0.009</td>
<td>0.13 - 0.74</td>
</tr>
<tr>
<td>No</td>
<td>31</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PCA: component one†</td>
<td>103</td>
<td>0.76</td>
<td>0.040</td>
<td>0.58 - 0.99</td>
</tr>
<tr>
<td>PCA: component two†</td>
<td>103</td>
<td>0.66</td>
<td>0.009</td>
<td>0.48 - 0.90</td>
</tr>
<tr>
<td><strong>Outcome: Consumption of purchased water as 1° or 2° water source in June 2014</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>121</td>
<td>1.81</td>
<td>0.029</td>
<td>1.06 - 3.08</td>
</tr>
<tr>
<td>Male</td>
<td>125</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Someone in household had full-time employment in May 2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>99</td>
<td>5.52</td>
<td>&lt;0.001</td>
<td>2.80 - 10.89</td>
</tr>
<tr>
<td>No</td>
<td>93</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Outcome: Water consumption &gt;2L/day in June 2014</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drank brook water as 1° or 2° water source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>42</td>
<td>2.60</td>
<td>0.014</td>
<td>1.22 - 5.56</td>
</tr>
<tr>
<td>No</td>
<td>204</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Someone in household had full-time employment in May 2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>93</td>
<td>0.34</td>
<td>0.006</td>
<td>0.16 - 0.74</td>
</tr>
<tr>
<td>No</td>
<td>99</td>
<td>Ref.</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

† 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.
Appendix C. Chapter Three Supplementary Tables

Supplementary Table C.1 All variables considered in statistical models as potential exposure variables for the outcomes of interest in Rigolet, Canada in the June 2014 survey.

<table>
<thead>
<tr>
<th>Model One: Total coliforms</th>
<th>Model Two: Acute gastrointestinal illness (AGI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
<td><strong>Outcome</strong></td>
</tr>
<tr>
<td>Presence of total coliforms in personal stored water containers (dichotomous variable: present/absent)</td>
<td>Self-reported AGI in past 28 days (dichotomous variable: yes/no)</td>
</tr>
<tr>
<td><strong>Exposure variables considered</strong></td>
<td><strong>Exposure variables considered</strong></td>
</tr>
<tr>
<td>• Age and sex of individual who collected the water</td>
<td>• Demographic information (age, sex, household ID)</td>
</tr>
<tr>
<td>• Water source currently in container</td>
<td>• Main &amp; secondary sources of drinking water</td>
</tr>
<tr>
<td>• Container size &amp; material</td>
<td>• Storage of main or secondary water sources</td>
</tr>
<tr>
<td>• How often container is refilled</td>
<td>• Ratings of main &amp; secondary water sources</td>
</tr>
<tr>
<td>• Last date of water collection</td>
<td>• Daily volume of water consumption</td>
</tr>
<tr>
<td>• Frequency of container cleaning and cleaning method</td>
<td>• Household water treatments used</td>
</tr>
<tr>
<td>• Storage location</td>
<td>• individual water retrieval methods</td>
</tr>
<tr>
<td>• Other substances previously stored in container</td>
<td>• Severity of vomiting and diarrhea</td>
</tr>
<tr>
<td>• Other water sources previously stored in container</td>
<td>• Diagnosed chronic conditions that cause vomiting or diarrhea</td>
</tr>
<tr>
<td>• Treatment methods applied to stored water</td>
<td>• How water is retrieved from container for drinking</td>
</tr>
<tr>
<td>• How water is collected into container from source water</td>
<td>• How water is collected into container from source water</td>
</tr>
</tbody>
</table>
Supplementary Table C.2 Results of univariable and multivariable analyses assessing the impact of exposure variables on odds of (1) self-reported AGI and (2) presence of total coliforms in stored water containers in Rigolet, Canada (2014). Table includes results for liberally significant variables (p ≤ 0.2).

<table>
<thead>
<tr>
<th>Model One: Total coliforms</th>
<th>Univariable model results</th>
<th>Multivariable model results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>n</td>
<td>OR</td>
</tr>
<tr>
<td>Used dipper to retrieve water from container</td>
<td>Yes</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>88</td>
</tr>
<tr>
<td>Used transfer device when filling container</td>
<td>Yes</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>85</td>
</tr>
<tr>
<td>Water was stored in a bucket</td>
<td>Yes</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>91</td>
</tr>
<tr>
<td>Water was collected directly from PWDU</td>
<td>Yes</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>32</td>
</tr>
<tr>
<td>Container was 3 gallons or larger</td>
<td>Yes</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>72</td>
</tr>
<tr>
<td>Water was poured directly from container to drink</td>
<td>Yes</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>89</td>
</tr>
<tr>
<td>Container was opaque (vs. clear)</td>
<td>Yes</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>56</td>
</tr>
</tbody>
</table>

Model Two: AGI

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariable results</th>
<th>Adjusted univariable results*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drank any purchased water in past 2 weeks</td>
<td>Yes</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>161</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>121</td>
</tr>
<tr>
<td>Drank any tap water in past 2 weeks</td>
<td>Yes</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>173</td>
</tr>
<tr>
<td>Stored secondary drinking water</td>
<td>Yes</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>85</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval

*Adjusted OR, controlling for age and sex
† Mixed logistic regression model controlling for clustering of the outcome (AGI) at the household level.
†† Exact logistic regression
Appendix D. Equations used in Chapter Three

Eq. (D.1) Annual incidence rate
\[
\frac{\# \text{ cases}}{\frac{1}{2}(\text{number at risk})+(\text{number at risk}\text{– cases})} \times \frac{365}{28\text{–day recall period}}
\]

Eq. (D.2) Standard error (rate)
\[
\sqrt{\frac{\text{cases}}{\text{person years}^2}}
\]

Eq. (D.3) 95% confidence interval
\[p \pm 1.96(\text{SE})\]

Eq. (D.4) Annual incidence proportion
\[1 - (1 - X)^{\frac{365}{28}}, \text{ where } X = \frac{\# \text{ cases}}{\text{Number at risk}\text{–} \frac{1}{2}\text{withdrawals}}\]
Appendix E. Chapter Two results sharing materials

Infographic

COLLECTING & STORING YOUR WATER SAFELY

DO YOU STORE WATER AT HOME?

Many people have switched to using the ADWS for their drinking water. People are using less tap, brook, and bottled water, and storing more ADWS water.

It is important to be careful when storing water at home, as germs can accidentally get into clean water containers.

WHAT CAN YOU DO TO KEEP YOUR WATER CLEAN?

CLEAN DIPPERS OFTEN.

Dippers can collect germs from your hands. Make sure to wash them regularly.

COLLECT DRINKING WATER DIRECTLY INTO STORAGE CONTAINERS.

This makes it less likely that germs will get into the water containers.

CLEAN YOUR STORAGE CONTAINERS

Large storage containers, water coolers, Brita jugs, & dippers should be cleaned often. Rinse containers at the ADWS rinse station each time before filling. Wash & sanitize at least once per month:

1. Wash with dish soap & water; rinse well.
2. Use bleach solution to rinse all surfaces that come into contact with drinking water for 30 seconds.
3. After bleeding, rinse well with clean water. Refill with drinking water or let air dry.

HAVE INQUIRIES? Call Inez Shiwik 709-947-3313
CHARLIE FLOWERS 709-947-3465
CAROLE WRIGHT 905-717-6559

HOW TO MAKE A BLEACH SOLUTION:
Add 1 tablespoon of bleach per gallon of water, or 1 teaspoon per litre.
RINSE WATER CONTAINERS AT THE ADWS RINSING STATION EACH TIME BEFORE REFILLING.

CLEAN & SANITIZE CONTAINERS AT LEAST ONCE A MONTH:

1. WASH WITH DISH SOAP & WATER; RINSE WELL.
2. USE BLEACH SOLUTION TO RINSE ALL SURFACES THAT COME IN CONTACT WITH WATER FOR AT LEAST 30 SECONDS.
3. AFTER BLEACHING, RINSE WELL WITH CLEAN WATER. REFILL WITH DRINKING WATER OR LET AIR DRY.

BLEACH SOLUTION: 1 TABLESPOON BLEACH PER GALLON OF WATER, OR 1 TEASPOON PER LITRE