Domestic access to water in a decentralized truck-to-cistern system: a case study in the Northern Village of Kangiqsualujjuaq, Nunavik (Canada)

Alexandra Cassivi a,*, Anne Carabin b, Caetano Dorea c, Manuel J. Rodrigueza and Stéphanie Guilherme c

a Chaire de recherche CRSNG en eau potable, École supérieure d’aménagement du territoire et de développement régional, Université Laval, Québec, QC, Canada
b Department of Civil Engineering, Engineering and Computer Science (ECS), University of Victoria, Victoria, BC, Canada
c Department of Civil Engineering, Faculty of Engineering, University of Ottawa, Ottawa, ON, Canada

*Corresponding author. E-mail: alexandra.cassivi.1@ulaval.ca

ABSTRACT

Municipal water supply through truck-to-cistern system is common in northern Canada. Household satisfaction and concerns about water availability, quality, and accessibility likely impact user preferences and practices. This case study explores household perspectives and challenges with regard to domestic access to water in a decentralized truck-to-cistern system. A case study was conducted in the Northern Village of Kangiqsualujjuaq, Nunavik (Quebec, Canada). A paper-based questionnaire was completed by 65 households (one quarter of the population). Many households (37%) reported not drinking tap water from the truck-to-cistern system. Chlorine taste was a frequently reported concern, with those households being significantly less likely to drink water directly from the tap ($p = 0.002$). Similarly, households that reported a water shortage in the previous week (i.e., no water from the tap at least once) (33%) were more likely to express dissatisfaction with delivered water quantity ($r_s = 0.395, p = 0.004$). Interestingly, 77% of households preferred using alternative drinking water sources for drinking purposes, such as public tap at the water treatment plant, natural sources or bottled water. The study underscores the importance of considering household perspectives to mitigate the risks associated with service disruptions and the use of alternative sources for drinking purposes.

Key words: Arctic, domestic access, drinking water, northern, truck-to-cistern

HIGHLIGHTS

- Northern communities served by truck-to-cistern face substantial challenges in accessing safe drinking water.
- Significant proportion of households refrain from using tap water for domestic purposes.
- The taste of chlorine emerges as a prevalent concern among residents regarding water quality and safety.
- Retrieving drinking water from untreated natural sources remains a common cultural practice in Indigenous households.

INTRODUCTION

In 2010, the United Nations General Assembly recognized the right to safe and clean water as a human right in Resolution 64/292 (UN Committee on Economic Social and Cultural Rights 2010). Although generally acknowledged as one of the most water-rich nations, Canada faces substantial drinking water challenges related to marginalized and vulnerable populations such as Indigenous communities (Eggerton 2008; White & Murphy 2012; Bradford et al. 2016; Hanrahan & Mercer 2019; Cassivi et al. 2023). In Canada, the federal and provincial governments are accountable for providing essential public services of reasonable quality to all Canadians, as stated under section 36 of the Constitution Act, 1982. However, governance, responsibilities, and management of drinking water services vary according to Indigenous status and location (e.g., province, territory or on- and off-reserves), leading to regional and geographic disparities and inequalities (Hennessy & Bressler 2016).
The Inuit Nunangat, which consists of four northern Canadian regions, is a unique and distinct geographic, climatic, and cultural region. Homeland of the Inuit people in Canada, the Inuit Nunangat comprises 51 communities and more than 50,000 people.

Municipal water and sanitation services are provided under the jurisdiction of local and provincial–territorial governments (i.e., Inuvialuit Settlement Region, the territory Nunavut, Nunavik in northern Québec, and Nunatsiavut of Newfoundland and Labrador). The geographic isolation, cold climate, and permafrost geology complicate the implementation of conventional piped water supply. As a result, most communities are served through decentralized, trucked water and sewer systems (WHO/UNICEF 2017). A better understanding of overall access can inform efforts for mitigating the risks associated with service disruptions and use of alternative drinking water sources.

The objectives of this case study were two-fold. The first was to assess challenges that relate to domestic water access in a truck-to-cistern water supply system using the case of Kangiqsualujjuaq, Nunavik. The second was to understand household overcrowding, which presents important public health challenges including indoor air quality, water security, and domestic hygiene (Pepin et al. 2018; Perreault et al. 2020; Poulin 2021; Simard et al. 2022). Previous studies revealed that lack of trust in truck-to-cistern water systems (Martin et al. 2007; Ritter et al. 2014; Spicer et al. 2020) combined with traditional views and cultural practices (Martin et al. 2007; Eichelberger 2018) may lead to the use of alternative drinking water sources among Indigenous populations (i.e., substitute to water supplied through trucked water systems). For example, retrieving drinking water from untreated natural sources on the land (e.g., surface water, ice, rivers, and springs) is recognized as a common practice in Inuit and First Nations communities (Canada) (Martin et al. 2007; Goldhar et al. 2014; Bradford et al. 2017; Wright et al. 2018a; Awume et al. 2020; Spicer et al. 2020) as well as communities of Alaska Natives (United States) (Marino et al. 2009; Eichelberger 2018).

Truck-to-cistern systems and the concurrent use of alternative drinking water sources have received insufficient attention from researchers and policymakers (Baird et al. 2013; ITK 2020). The WHO–UNICEF Joint Monitoring Programme for Water Supply and Sanitation recognized that although trucks may be able to deliver safe water, a lack of data prevents the comprehensive analysis of community access (WHO/UNICEF 2017). In a joint submission to the UN Special Rapporteur on the Human Rights to Safe Drinking Water and Sanitation, Inuit Circumpolar Council and Inuit Tapiriit Kanatami called for the prioritization of and investments in improving access to clean water and sanitation in Inuit communities (ICC and ITK 2021). Generating field-based evidence on water challenges and their impacts on people in a decentralized truck-to-cistern water supply system is essential to ensuring universal and equitable access to safe and affordable drinking water for all by 2030, as declared/detailed in the UN Sustainable Development Goals target 6.1 (WHO/UNICEF 2017). A better understanding of overall access can inform efforts for mitigating the risks associated with service disruptions and use of alternative sources of drinking water.

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practices and preferences related to municipal water supply and the consumption of alternative water sources, as well as identify socio-economic factors associated with accessing and using domestic water.

METHODS

Study site

Kangiqsualujjuaq is the easternmost village in Nunavik and is located on the coast of Ungava Bay in the province of Quebec, Canada. The village occupies an area of 35 km² along the George River, with no roads to other communities or the rest of Quebec. According to Statistics Canada, the population of Kangiqsualujjuaq was 956 inhabitants in 2021, over 85% of whom are Inuit. There are 270 households, with an average household size of 3.9 people. Most live in subsidized social housing (Canada 2021). Kangiqsualujjuaq, like other villages in Nunavik, is undergoing large demographic changes. The population is growing and the resulting larger, younger population influences housing needs and community development (Déry & Zoungrana 2009; Rodon & Schott 2014).

In Kangiqsualujjuaq, drinking water is supplied to households through a truck-to-cistern system, similar to most northern villages in Nunavik. Source water is pumped through an intake pipe from a lake located 2 km away to the water treatment plant. There, the water is treated with a primary ultraviolet (UV) disinfection and a secondary chlorine disinfection before being distributed by trucks to the community (Figure 1(a)). Water is delivered using available trucks (i.e., two water trucks at the time of the survey), generally on a daily schedule, to residential and public building water tanks (Figure 1(b)). An outdoor public tap, which was identified as an alternative water source, is also available for household water retrieval beside the water treatment plant (Figure 2(a)). Finally, a natural untreated water source that is located away from the village near a main

Figure 1 | (a) Water truck at the water treatment plant (Photo credit: Alexandra Cassivi). (b) Example of a residential water tank (covered with an insulation layer). (Photo credit: Alexandra Cassivi).

Figure 2 | (a) Public tap at the water treatment plant; (Photo credit: Alexandra Cassivi). (b) Natural water sources are located near the road to the airport (Photo credit: Alexandra Cassivi).
road was also identified by community leaders as an alternative source from which households retrieve drinking water (Figure 2(b)).

**Study design**

This research is based on a case study conducted in the northern village of Kangiqsualujjuaq, Nunavik, as part of a larger collaborative research program with the community. Researchers engaged with the community prior to the commencement of research and received local guidance from local authorities and the community to conduct the study. Members of the northern village office and regional partners, including the Nunavik Regional Board of Health and Social Services (NRBHSS), supported the research program.

The household survey was organized in August and September 2021 and was thus adapted to overcome limitations due to the COVID-19 pandemic. A strict safe research plan was established for in-person research activities following recommendations provided by the community, the health authority of Nunavik (i.e., NRBHSS) and Université Laval. The study was approved by the Human Research Ethics Board at Université Laval (CÉRUL) (2020-216).

Prior to data collection, the arrival of the research team was announced to the community through local radio and posters (no community gathering was possible due to COVID-19 restrictions). A systematic sampling method was used to randomly select participants for the household survey (Etikan & Bala 2017). This sampling approach targets the whole population and offers a good geographical representation of the community. Every second household, starting from the easternmost to the westernmost points of the village, was selected to be part of the sample. For semi-detached homes and multi-family units, the households located on the right side of the buildings were selected. All identified households were first visited on weekday late afternoons or early evenings. If household members were absent, they were revisited a second time on the weekend. Of the total 270 households in the community, 80 households were available either on the first or second visit, and thus invited to participate in the household survey. The researchers (Cassivi and Carabin) provided general information about the survey and its scope and explained the voluntary recruitment and informed consent process. If interested, the adult household member (Age 18+) presents at the time of the visit received an information sheet for informed consent in the language of their choice (i.e., Inuktitut or English), which included details about the research project, participation, and benefits and risks. A structured questionnaire was distributed along with the consent sheet. The paper-based questionnaire was considered the most appropriate approach to limit the risk of COVID-19 exposure during data collection. To further reduce contact between the researcher and the participants, a returned questionnaire was considered an implicit expression of consent to participate, as indicated in the information sheet. Questionnaires could be returned using the secured deposit box available in the village, left in their entrance hall, or handed back to the researchers the next day. Among the questionnaires initially distributed, 12 were not retrieved because the respondent did not return it and/or was absent during subsequent visits. Three questionnaires were returned but not completed by the respondent. The final sample included 65 households.

The household questionnaire was designed by the research team based on UNICEF Multiple Indicator Cluster Surveys, which are readily available and implemented worldwide. The questionnaire (Supplementary Information) relates to access to water for drinking and domestic purposes and contains approximately 50 close-ended and two open-ended questions, covering different dimensions of the water supply such as production, distribution, storage, and household water consumption and use practices. Questions about water supply preferences were also included, such as the use of alternative water sources. As part of the questionnaire, respondents were asked to complete self-identification questions about their gender, Indigenous identity, and legal residence status (permanent resident or non-permanent resident of Nunavik). The questionnaire was initially revised by the local authorities in the community for cultural context and additional questions were thereafter included for their information needs (e.g., perception of the population on received water services). The questionnaire was initially designed in English and translated into Inuktitut, which is, respectively, the first official language and mother tongue spoken in Kangiqsualujjuaq (Canada 2021). The translation of the questionnaire was done by a certified translation service. The questionnaire was offered to participants in the language of their choice. The French questionnaire was also available but not requested.

**Data analysis**

Data from the questionnaire were compiled, coded, and analyzed using StataSE14. Descriptive and analytical statistics were used to assess the impact of different risk factors on access to water and to analyze the degree of association between water-related variables and socio-economic (i.e., respondent gender, age, level of education, identification as Inuit) and household
characteristics (i.e., household size, presence or absence of children). Descriptive statistics included mean (\(\bar{x}\)), median (\(\tilde{x}\)) and ranges (min–max), and appropriate analytical statistics included odds ratios (OR), Chi-square test of independence (\(\chi^2\)), Fischer’s Exact Test, Spearman’s rank correlation (\(r_s\)) and simple logistic regression (logit). Prefer not to answer (PNTA) and do not know (DK) responses were reported when applicable. Non-responses were treated as missing values. Results were considered significant (p-value) at a confidence interval of 95%. Results were also rounded off to the nearest decimal unit after analysis to ease readability and interpretability when necessary.

## RESULTS

### General characteristics

Survey data were collected from 65 households, representing nearly one quarter of the total households in Kangiqsualujjuaq. The majority of respondents (one per household) identified themselves as women (50.8%), permanent residents of Nunavik (73.9%) and Inuit (70.8%). All non-permanent residents of Kangiqsualujjuaq identified themselves as non-Inuit. More than 50% of the respondents reported being between 25 and 44 years old, and having completed at least secondary school. The average household was comprised of 4 people (\(\bar{x} = 5\); range of 1–9 people), including an average of 2.5 adults (\(\bar{x} = 2\); range of 1–5 adults) and 2 children (\(\bar{x} = 2\); range of 1–7 children) per household, consistent with the 2021 Population Census data. At the time of survey, 70% of the households lived in semi-detached (2 units) or multi-family houses (4–6 units), while the remaining households lived in single-family houses. A descriptive table of the socio-economic and household characteristics is available in the Supplementary Information (Table S1).

### Water quality and safety

Overall, 37% of households reported that no individual in their household consumed water directly from the tap (Table 1). Household preferences with respect to the use of tap water for drinking purposes did not differ from one socio-economic group to another and were not explained by the presence of children in the household. Households that did not drink the tap water were more inclined to report the limitations or restrictive factors related to tap water consumption (\(p < 0.001\)). The taste of chlorine (62.5%) and the fear of germs, contaminants, or chemicals (57.5%) were the most prevalent factors, followed by concerns about plumbing maintenance (i.e., bad smell (22.5%), unpleasant appearance (20%), and warm water temperatures (2.5%)). Households that reported being concerned about the taste of chlorine were significantly less likely to drink water directly from the tap (\(p = 0.002\)), and this was similar across all socio-economic groups. However, younger people 18–34 years old (\(p = 0.04\)) and non-Inuit (\(p = 0.038\)), more frequently reported concerns about germs, contaminants, or chemicals in the tap water.

Using a three-point Likert scale, nearly half of the households perceived water as safe or neutral at every stage of the water supply (before, during, and after delivery). Other households identified at least one stage being perceived as unsafe. Spearman rank correlations revealed a strong positive relationship with the perception of water safety during different stages of the truck-to-cistern water supply system: from the water treatment plant to water trucks (\(r_s = 0.5114, p = 0.002\)), from water trucks to residential water cisterns (\(r_s = 0.6149, p < 0.001\)), and from the water treatment plant to residential water tanks (\(r_s = 0.8239, p < 0.001\)) (Table 2). Although the taste of chlorine was frequently reported as a limiting factor for drinking tap water, the level of satisfaction regarding the use of chlorine at the water treatment plant varied. Overall, the use of chlorine was considered favorable by 45% of the households, while 45% reported being neutral and 10% considered it unfavorable. Household members were initially more likely to perceive water as safe at the treatment plant when they were in favor of the use of chlorine (\(r_s = 0.3942, p = 0.005\)), but this was not significant at the other stages of the water supply (i.e., water truck and residential water tank). In addition, the level of satisfaction regarding the use of chlorine did not significantly differ by socio-economic factors.

Households that consumed tap water reported being more likely to run the tap before using the water (\(p < 0.05\)). The use of on-site point-of-use (POU) water treatment devices or procedures was also found to be common among households (Table S2). Independently of the source of water, most households reported boiling water before consumption (80%) and/or using home water filtration systems (e.g., Brita® Filtration) (63%). POU water treatment systems were widely used in the community and did not differ significantly from one household to another. Using on-site POU water treatment devices was not related to the perception of water safety at different stages of the water supply.
Water quantity and availability

Nearly half of households reported that the trucks typically delivered water at a frequency of 5 or 6 times per week ($\bar{x} = 5$; range of 1–7 times), although water delivery service is scheduled daily by the municipality. The level of satisfaction on the frequency of water delivery reported by households was moderately associated with reports that the quantity of water provided was enough to meet their households needs ($r_s = 0.5667$, $p < 0.001$) (Table 3). Overall, most households (94%) reported being satisfied or neutral when it came to trucked water delivery frequency. This did not significantly differ between households or socio-economic groups.

Households indicated that a full tank, of which the capacity varied depending on the type of unit, could generally provide water for a maximum of 2.5 days ($\bar{x} = 2$; ranges 1–5 days). Nearly one quarter of households reported that their water tank
<table>
<thead>
<tr>
<th>Table 2</th>
<th>Satisfaction with water delivery and preferences based on household drinking-water practices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drink water from the tap</strong></td>
<td><strong>Use alternative water sources</strong></td>
</tr>
<tr>
<td>Frequency</td>
<td>Percentage</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Use POU water treatment</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>20</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
<tr>
<td>Water shortage in the last week</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9</td>
</tr>
<tr>
<td>No</td>
<td>13</td>
</tr>
<tr>
<td>Full water tank duration (days)</td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>6</td>
</tr>
<tr>
<td>2 days</td>
<td>10</td>
</tr>
<tr>
<td>3 days</td>
<td>3</td>
</tr>
<tr>
<td>4 days</td>
<td>1</td>
</tr>
<tr>
<td>5 days</td>
<td>4</td>
</tr>
<tr>
<td>Level of satisfaction – water delivery frequency</td>
<td></td>
</tr>
<tr>
<td>Very favorable</td>
<td>0</td>
</tr>
<tr>
<td>Favorable</td>
<td>15</td>
</tr>
<tr>
<td>Neutral</td>
<td>9</td>
</tr>
<tr>
<td>Unfavorable</td>
<td>0</td>
</tr>
<tr>
<td>Very unfavorable</td>
<td>0</td>
</tr>
<tr>
<td>Perception water safety – water treatment plant</td>
<td></td>
</tr>
<tr>
<td>Unsafe</td>
<td>0</td>
</tr>
<tr>
<td>Neutral</td>
<td>10</td>
</tr>
<tr>
<td>Safe</td>
<td>10</td>
</tr>
<tr>
<td>Perception water safety – water truck</td>
<td></td>
</tr>
<tr>
<td>Unsafe</td>
<td>2</td>
</tr>
<tr>
<td>Neutral</td>
<td>14</td>
</tr>
<tr>
<td>Safe</td>
<td>6</td>
</tr>
<tr>
<td>Perception water safety – water tank</td>
<td></td>
</tr>
<tr>
<td>Unsafe</td>
<td>3</td>
</tr>
<tr>
<td>Neutral</td>
<td>12</td>
</tr>
<tr>
<td>Safe</td>
<td>6</td>
</tr>
<tr>
<td>Adverse factors – taste of chlorine</td>
<td></td>
</tr>
<tr>
<td>Yes, concerned</td>
<td>15</td>
</tr>
<tr>
<td>No</td>
<td>9</td>
</tr>
<tr>
<td>Adverse factors – contaminants</td>
<td></td>
</tr>
<tr>
<td>Yes, concerned</td>
<td>13</td>
</tr>
<tr>
<td>No</td>
<td>8</td>
</tr>
</tbody>
</table>

*pSignificant at p < 0.05.
**Significant at p < 0.01.
***Significant at p < 0.001.
would not last more than one day without being refilled. The total length of time a water tank could last was negatively correlated to the water delivery frequency reported by the respondents ($r_s = -0.4736$, $p < 0.001$). More than 10% of households reported that the quantity of water provided by their tanks wasn’t enough to meet daily households needs.

Overall, 33% of households reported that they experienced a water shortage at least once during the previous week when they could not access water from the tap (Table S2). These households were more likely to report being unsatisfied or very unsatisfied with the quantity of water delivered, contrary to households that reported no shortages ($r_s = 0.395$, $p = 0.0038$).

Water tanks that provided water for longer periods of time significantly decreased the likelihood of the household reporting a water shortage in the last week ($r_s = 0.4601$, $p < 0.001$) and being unsatisfied with the quantity of water ($r_s = -0.2783$, $p = 0.026$). The length of time a tank could provide water depended on the size of the tank and the frequency of water delivery. None of the studied socio-economic and household factors were associated with water availability.

In response to factors that may affect water service, 85% of households reported using various coping strategies to limit water use (Table S3). Among households reporting one or more strategies, reduced laundry frequency (77%) and shower length (72%) were the most common. Half the households also reported collecting water from additional sources to cope with the lack of water. Other less frequently used strategies included washing their hands in the same basin and/or taking multiple baths with the same water (9%). The use of coping strategies did not vary between socio-economic groups or households, or by whether a water shortage was reported in the previous week.

Repeated occurrences of broken water and/or sewage trucks were reported by 83% of respondents as the reason for insufficient water delivery and lack of water availability. Delays in scheduled water delivery and/or sewage collection were also reported as a main factor affecting water availability in 57% of the households. Community issues such as problems with water and sewage trucks, including the repairability of trucks (71%), population growth and overcrowded dwellings (67%) are perceived as the most probable factors affecting water and/or sewage services. Difficulty obtaining mechanical assistance and supplies and absenteeism in the public service (e.g., drivers and operators are absent) were also reported in 40% of the households (Figure 3).

When asked what could be done to improve water quantity for their households (open-ended question), the need for extra trucks and higher delivery frequency was mentioned by nearly three quarters of the respondents. Some examples of responses included ‘get more water trucks and sewage trucks’, ‘proper maintenance of service trucks’, and ‘increase number of service trucks in the community’, echoing similar responses provided by other participants. Water and sewage tanks with higher capacities were also commonly suggested by household members (e.g., ‘bigger water/sewage tanks and more trucks and employer[s] working or pipe system if possible’ or ‘have one water tank per room [unit] instead of one big tank shared by all rooms [units]’). The implementation of a piped water system was also reported as a preferred solution to improve the availability of water (e.g., ‘get running water underground like [in the] south... if not, get more water trucks’). Results show that more than half of the households would feel very favorable toward the implementation of a piped water supply in their community. Among households that reported not being in favor for the implementation of a piped water supply, the loss of work for truck drivers was a commonly cited reason.

### Table 3 | Correlation between household level of satisfaction and reported water delivery information using Spearman’s rank coefficient

<table>
<thead>
<tr>
<th></th>
<th>Reported delivery frequency</th>
<th>Delivery frequency</th>
<th>Quantity of water delivered met needs (level of satisfaction)</th>
<th>Reported full water tank duration</th>
<th>Reported water shortage in the previous week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported delivery frequency</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivery frequency (level of satisfaction)</td>
<td>$-0.2110$ ($p = 0.1295$)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity of water delivered met needs (level of satisfaction)</td>
<td>$-0.0718$ ($p = 0.6096$)</td>
<td>0.5667 ($s = 0.001$)</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Reported full water tank duration (days)</td>
<td>$-0.4736$ ($s &lt; 0.001$)</td>
<td>$-0.2201$ ($p = 0.0806$)</td>
<td>$-0.2783$ ($s = 0.0259$)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Reported water shortage in the previous week</td>
<td>$0.2296$ ($p = 0.1247$)</td>
<td>0.3142 ($s = 0.038$)</td>
<td>$0.3949$ ($s = 0.0038$)</td>
<td>$-0.4601$ ($s &lt; 0.001$)</td>
<td>1</td>
</tr>
</tbody>
</table>

$r = 0.0038$
Water accessibility and alternatives sources

Retrieving drinking water from alternative sources was found to be reported a common practice among households in the community. Responses to the survey show that 77% of the households use alternative drinking water sources, whether that is the public tap available at the water treatment plant, natural sources on the land, and/or purchased bottled water. The remaining households reported using no alternative sources to tap water (Table 1). Regardless of the type of source, a single alternative source was used by 25% of the households, while a combination of two or three alternative sources was used in the remaining households.

Preferences for alternative water sources varied within the population. Households with Inuit permanent residents of Nunavik were more likely than those with non-permanent or non-Indigenous residents to use water from alternative water sources ($p < 0.001$) (Table 1). An increase in household size also increased the likelihood of using alternative sources (OR = 1.70, $p = 0.011$), as did the presence of children in the household ($p = 0.021$). However, the presence of children likely reflects results based on cultural identification, as Inuit household had significantly more children than non-Indigenous households. Non-permanent and/or non-Indigenous residents were often temporary workers, and very few had dependents.

The approximate duration for which a full tank could provide water was also found to be significantly correlated to the use of alternative sources. The shorter the duration, the more likely the households were to retrieve water from alternative sources. No differences were observed in households that reported water shortages in the previous week, indicating that using alternative sources is a sustained practice. Other factors, including gender, age or education of the respondent, level of satisfaction of water supply, and limiting the use of/not drinking tap water were not associated with the use of additional sources.

Households generally reported using various sources of water as an alternative to tap water. Water collected using plastic jugs was mainly used for drinking purposes. Overall, 71% of the households retrieved water either from the community public tap located beside the water treatment plant or from untreated natural sources located near the community in summer, winter, or throughout the year. The public tap beside the water treatment plant was used by 56% of households, whereas
60% collected water from natural sources, including surface water or springs, rainwater or snow/ice melt in winter. Results show that households that retrieved water from one alternative source were more likely to use other ones ($p < 0.001$). The combined use of both public tap and natural sources was reported in 45% of the households. Overall, 60% of households reported that collection time (i.e., time to retrieve water and come back home) was less than 10 min, while the rest reported a collection time between 10 and 30 min. Cars and/or quads were widely used for water retrieval (90% of the households) from either the water treatment plant or the natural sources within or outside the community limits. Bottled water, as a single additional source for drinking water, was used by 6% of households. No significant association was found between the common retrieval of water and the purchase of bottled water, meaning households either used alternative water sources or purchased bottled water. The use of bottled water did not differ between socio-economic groups or other household factors.

DISCUSSION

This study identifies challenges associated with domestic water access in a decentralized truck-to-cistern system in Nunavik. Various factors that relate to water quality and availability influence household preferences and practices, as well as the overall access to drinking water in Kangiqsualujjuaq, Nunavik.

Preferences

Kangiqsualujjuaq is serviced by a conventional small-scale water treatment plant supplied by high-quality surface water. The water at the plant is treated using both UV disinfection and chlorination, suggesting that the finished drinking water is in accordance with Quebec regulations for drinking water quality. However, the use of tap water for drinking purposes was varied. General dissatisfaction with tap water in a truck-to-cistern system has been previously highlighted in other Indigenous communities in Canada (Bernier et al. 2009; Waldner et al. 2017). In Kangiqsualujjuaq, while more than half of the households reported using tap water for drinking purposes, results show that many were concerned by the taste, odor, and other organoleptic characteristics (e.g., general appearance). These households were also concerned about the quality of the water provided at the tap. Findings from other contexts show that negative perceptions of tap water increased risk perception of water quality and safety, and decreased the likelihood of consuming tap water (McLeod et al. 2015; Wright et al. 2018a). Results from a study conducted in an urban center suggest that the perception of water quality would be closely related to residual chlorine levels in the distribution systems (Turgeon et al. 2004). In Kangiqsualujjuaq, households that reported being concerned with the taste of chlorine in the water were less likely to drink water from the tap. Similar findings were reported in other studies conducted in the Arctic region, where the taste of chlorine was commonly reported as a limiting factor for drinking tap water (Doria 2006; Goldhar et al. 2013; Dupont et al. 2014; Ritter et al. 2014; Eichelberger 2018; Ratelle et al. 2022). Concerns about the negative health outcomes of drinking tap water identified in the community were shown to be reinforced by the intermittent service and frequent boil water advisories (Anadu & Harding 2000). Similar issues have also been reported in other contexts (Awume et al. 2020; Eichelberger 2018; Goldhar et al. 2013). Regardless, households in Kangiqsualujjuaq reported being generally satisfied with the use of chlorine for drinking water treatment. Considering that multiple households also reported not drinking tap water because of the taste, it can be argued that the reported satisfaction of many households may have been due to levels of residual chlorine being undetectable by taste or smell (Garcia 2022). Indeed, in a recent field research, very low levels of free residual chlorine were observed in domestic storage tanks in Kangiqsualujjuaq (Garcia 2022). In piped systems, maintaining a sufficient level of residual chlorine from the water treatment plant to the point of use is a common measure to prevent microbial growth, but maintaining a comparable level in non-piped systems is reported to be more challenging. However, it is also critical to determine whether the population finds the use of chlorine acceptable. Lack of trust in the distribution system as well as long storage times and concerns about the cleanliness of water trucks and household tanks may discourage households from using tap water for drinking purposes, as similarly reported for other First Nations communities in Canada (Waldner et al. 2017). A comprehensive understanding of safety perceptions can better inform decision-making and different approaches to provide culturally appropriate water services to Indigenous communities (Goldhar et al. 2013; Kot et al. 2014).

Practices

Water delivery frequency inevitably influences the quantity of water available at the point of use and plays an important role on household practices. The household water tanks have a capacity of approximately 1,200 L per household, although this
varies depending on the type of house (i.e., detached or semi-detached) (SHQ 2018). In Inuit Nunangat, more than half of households live in overcrowded conditions, increasing their vulnerability to water shortages (ITK 2020). The number of people sharing a house and the approximate length of time a water tank can fulfill household needs impact the average daily water usage per household member. Lack of in-home water may affect the amount of water used. Intermittent water supply led to various household coping strategies, such as reusing water for bathing and reducing the frequency of showers and laundry. Uncertainties sustaining daily water needs were shown to compromise the quantity of water allocated to basic personal and domestic hygiene. Lack of access to water increases the transmission of disease within the community and continues to be a leading factor for the prevalence of gastrointestinal and respiratory illnesses in remote communities in USA and Canada (Martin et al. 2007; Gessner 2008; Daley et al. 2014; Miernyk et al. 2018; Wright et al. 2018c). Additionally, results show that when experiencing water shortages, households were more likely to report dissatisfaction with the municipal water supply systems. Many households were shown to rely on alternative water sources (e.g., natural sources, public tap) to meet their water needs, including for purposes other than drinking. This has also been reported elsewhere in Nunavik (Martin et al. 2006; NRBHSS 2020). Operational measures such as increasing water delivery frequency (e.g., more water trucks) and storage capacity (i.e., water tanks with greater capacity) as well as improving water conservation strategies would reduce water shortage frequencies and help communities overcome the lack of available water. This is particularly important for households that are large or above-average, as insufficient water is more likely to affect the health and hygiene of these members. Other measures such as rainwater harvesting during summer months (Elliott et al. 2017; Mercer & Hanrahan 2017) should also be considered to increase the available water for domestic purposes, particularly where conventional piped water is not available. It is essential to reevaluate the water supply system and its ability to provide acceptable, accessible, and sufficient drinking water.

Results from this study also confirm that more than 75% of the households rely on alternative sources for drinking water. Interestingly, households that retrieve water from one alternative source were more likely to use multiple alternative water sources, e.g., retrieving water from natural sources and purchasing bottled water. The use of alternative water sources might indicate general apprehension about the water supplied through truck-to-cistern systems. This also reveals the predisposition toward long-established practices for using other untreated sources that might be seen as more trustworthy and/or the use of readily available bottled water. Organoleptic properties that were perceived to indicate poor quality of water as well as frequent water shortages are community concerns that affect household perceptions and overall satisfaction of drinking water services. However, the lack of a clear association between such factors and household practices suggests that intrinsic motivations (e.g., cultural, social, historical) might inform the reliance on alternative drinking water sources. Results show that Inuit residents were more likely to rely on alternative sources compared to other non-permanent residents, as is consistent with other studies (Hanrahan et al. 2014; Wright et al. 2018b). Indigenous Peoples have historically collected water from their land for drinking purposes. Deeply held spiritual and cultural attachments to freshwater (i.e., untreated natural water sources) may perpetuate such practices in the Arctic region (Marino et al. 2009; Eichelberger 2018; Cassivi et al. 2023). However, with the changing climate, the Arctic Indigenous territory is facing unprecedented challenges in maintaining their cultural practices (Ford 2009). Decision-making in water management that clearly recognizes and integrates local traditions is necessary to ensure water security (Goldhar et al. 2013; Eichelberger 2018). It should not be assumed that water from the tap is the main source of drinking water for households, even if households have access to in-house water through truck-to-cistern systems. Although our findings might not extend to all northern communities, it is likely that the information provided here is applicable to other communities that rely on truck-to-cistern systems in Inuit Nunangat or other similar communities.

**Limitations of the study**

Results from this study are based on survey data collected in one northern village in Nunavik, Quebec, Canada. Because our study was conducted during the COVID-19 pandemic, a paper-based questionnaire was used instead of the interview-based survey initially planned. The use of self-reported data may involve various biases that relate to social desirability as well as systematic errors caused by recall bias (Van de Mortel 2008). Although the questionnaire was designed to avoid leading questions, the availability of sets of answers might have induced forced choice or affected the perceptions reported by the respondents. Similarly, the responses provided might have been influenced by various historical, cultural and social experiences, which may not have been captured at this stage of the study. Our case study uses cross-sectional data that cannot be used to infer causality. However, our findings can be used for priority-setting for local public utility services, as well as for social and health programs in Nunavik. The results from this survey can also be expanded to a larger research program.
that focuses on water quality monitoring (e.g., characterization and protection of alternative natural water sources) and health risk assessment (domestic hygiene and impact of tank storage on water quality). Future research should also consider seasonal and regional variations in household practices and the preferences among remote northern communities.

CONCLUSIONS

Results from this case study reveal the importance of considering household practices and preferences when accessing domestic water, particularly in the context of remote Indigenous communities. The high relative proportion of respondents that regularly use alternative sources of water suggests that these sources should be characterized, and the related risks should be assessed. Interventions for water safety and water quality monitoring should take a more global approach by not only focusing on the main truck-to-cistern water supply, but by also considering the use of alternative water sources as a cultural practice. Understanding household preferences is essential to designing sustainable and culturally appropriate water supply systems. Promoting safe water quality at the point of consumption, regardless of the source of water used, is important to mitigate the risks associated with water supply and collection chain contamination.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Canada, S. 2021 Census Profile Kangiqsualujjuaq.


ITK 2020 Access to Drinking Water in Inuit Nunangat.


Mercer, N. & Hannaham, M. 2017 Straight from the heavens into your bucket’: Domestic rainwater harvesting as a measure to improve water security in a subarctic indigenous community. *International Journal of Circumpolar Health* 76 (1), 1312223.


Poulin, P. 2021 Amélioration de la Qualité de L’Air Intérieur par L’optimisation de la Ventilation.


SHQ 2018 *Housing Construction in Nunavik. Guide to Good Practices*, Gouvernement du Québec, Quebec, QC.


WHO/UNICEF 2017 Safely managed drinking water.


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