ARCTIC
VOL. 60, NO. 2 (JUNE 2007) P. 195–202

Drinking Water and Potential Threats to Human Health in Nunavik: Adaptation Strategies under Climate Change Conditions

DANIEL MARTIN,[1,2] DIANE BÉLANGER,[1] PIERRE GOSSELIN,[1] JOSÉE BRAZEAU,[3] CHRIS FURGAL[4] and SERGE DÉRY[5]

(*Received 5 April 2006; accepted in revised form 12 January 2007*)

ABSTRACT. In Nunavik, chlorine-treated water is delivered daily, by tank truck, to the houses, where it is stored in tanks. A large part of the Inuit population continues to depend on an untreated water supply, however. This traditional activity poses certain risks in a region with an abundant presence of migratory animals. Nunavik has also experienced significant climate warming since the beginning of the last decade. The main goal of this study, which took place in 2003 and 2004, was to evaluate drinking habits that may place Nunavik residents at an increased risk of gastroenteric diseases in the context of climate change. During the *Amundsen* cruise in fall 2004, we observed that raw water from the collection sites most frequently visited (brooks, lakes, rivers) was of good quality in most of the villages. Regular monitoring of these sites is necessary, however, and the public should be warned when the sites become contaminated. Of particular concern was the water from the individual storage containers, which was much more contaminated than the water at the collection sites. To develop or improve the climate change adaptation strategies in this area, we propose 1) establishing an appropriate environmental monitoring system, 2) improving wastewater disposal and municipal water systems, 3) involving nursing staff in microbiological testing of the water at community sites, 4) raising public awareness of the risks related to raw water consumption, and 5) gathering strategic health information during the periods of the year when cases of gastroenteric diseases are most frequent, in order to establish whether there is a link between these disorders and water quality.

Key words: climate change, drinking water, human health, gastroenteric diseases, Inuit, Nunavik

RÉSUMÉ. Au Nunavik, de l'eau traitée par chloration est livrée à domicile tous les jours au moyen d'un camion-citerne, après quoi cette eau est stockée dans des réservoirs. Cependant, une grande partie de la population inuite continue de s'approvisionner en eau non traitée. Cette activité traditionnelle pose certains risques dans une région caractérisée par une abondance d'animaux en migration. Aussi, depuis le début de la dernière décennie, le Nunavik a enregistré un réchauffement climatique considérable. Cette étude, qui s'est déroulée de 2003 à 2004, avait pour but principal d'évaluer les habitudes de consommation d'eau qui sont susceptibles de mettre les habitants du Nunavik davantage à risque de subir des maladies gastro-entériques dans le contexte du changement climatique. Dans le cadre de la croisière de l'*Amundsen* à l'automne 2004, nous avons constaté que l'eau brute des lieux de collecte les plus souvent visités (les ruisseaux, les lacs et les rivières) était de bonne qualité dans la plupart des villages. Cela dit, la surveillance régulière de ces emplacements s'avère nécessaire et le grand public devrait être averti en cas de contamination. L'eau des contenants de stockage individuels représentait une source de préoccupation particulière, car elle était bien plus contaminée que l'eau des lieux de collecte. Afin d'élaborer ou d'améliorer les stratégies d'adaptation au changement climatique dans cette région, nous proposons ce qui suit : 1) établir un système de surveillance environnementale adéquat, 2) améliorer le système d'élimination des eaux usées et le réseau municipal d'alimentation en eau, 3) faire appel au personnel infirmier pour faire les tests microbiologiques de l'eau aux emplacements communautaires, 4) sensibiliser le grand public davantage aux risques liés à la consommation d'eau non traitée, 5) recueillir des renseignements stratégiques sur la santé pendant les périodes de l'année où les maladies gastro-entériques sont plus fréquentes afin de déterminer s'il existe un lien entre ces maladies et la qualité de l'eau.

Mots clés : changement climatique, eau potable, santé humaine, maladies gastro-entériques, Inuit, Nunavik

Révisé pour la revue *Arctic* par Nicole Giguère.

[1] Unité de Recherche en Santé Publique, Centre de recherche du CHUL-CHUQ, 2875, boulevard Laurier, 6e étage, Édifice Delta, bureau 600, Québec, Québec G1V 2M2, Canada
[2] Corresponding author: daniel.martin@crchul.ulaval.ca
[3] Ministère de l'Environnement du Québec, Direction régionale Nord-du-Québec, 180 Boulevard Rideau, Rouyn-Noranda, Québec J9X 1N9, Canada
[4] Departments of Indigenous Studies and Environment and Resource Studies/Science, Trent University, 1600 West Bank Drive, Peterborough, Ontario K9J 7B8, Canada
[5] Régie Régionale de la Santé et des Services Sociaux du Nunavik, C.P. 900, Kuujjuaq, Québec J0M 1C0, Canada
© The Arctic Institute of North America

INTRODUCTION

Nunavik, the northern part of the province of Quebec, is a sparsely populated territory of about 11 000 mostly Inuit residents, living in 14 coastal communities (Fig. 1) (Association touristique du Nunavik et Tourisme Québec, 2003). Their traditional fishing and hunting activities and resulting dietary habits place Inuit among the populations most vulnerable to risks associated with diseases transmitted by food and water. Climate change could magnify the environmental impacts on Inuit health (ACIA, 2005).

For 40 years (1949–88), Nunavik cooled slightly, while the Western Canadian Arctic warmed. A linear trend showing a 0.7˚C decline in the mean temperature of ambient air from 1949 to 1988, for a cooling rate of 0.02˚C per year, was found for Kuujjuaq. However, from 1990 to 2003, this trend reversed, and the Inukjuak, Kuujjuaq, and Kuujjuarapik weather stations observed sustained warming of nearly 0.37˚C per year (Fortier and Allard, 2003).

Climate warming will have several probable consequences for the environment of northern communities, and these changes may also affect population health (Furgal et al., 2002; Martin et al., 2005). The rise in temperature may degrade vast expanses of permafrost. In Nunavik, wastewater is frequently deposited in small ponds or even on the ground near the village. Permafrost melting may cause pathogens to migrate to the sub-permafrost aquifers or, via runoff, to the neighbouring watercourses and lakes. Temperature increases may also lead to a resurgence in wastewater deposit areas of bacteria and parasites, which can be carried by the humans and animals who visit these sites. The increase in sunny periods in summer may increase evaporation and reduce the supply of water available from lakes and watercourses. A future drop in summer and winter precipitation could also contribute to a decline in the levels and flow of surface water: some communities might be led to use sources of supply much more distant than those currently used. Temperature increases may also limit winter and spring access to the usual sources of supply. Particularly in spring, the lack of snow could make it harder to travel by snowmobile, and the thinning of the ice could make trips on lakes and rivers more hazardous. In summer, permafrost melting may limit or impede access to the sources of supply by deforming the roads. The rising sea level could lead to salt water intrusions into the aquifers and thus to possible contamination by chemicals or pathogens. Most of the Nunavik villages are located in a continuous permafrost zone, and the municipalities use surface water for their supply. In discontinuous permafrost zones, some residents are beginning to have artesian wells installed, which may also be sensitive to salt water intrusions. Harsh winters or increasing frequency of extreme occurrences (such as violent winter storms) may contribute to prolonging the residential heating periods and lead to degradation of the quality of water stored in the domestic tanks, which in most cases are located near the heating systems. It is impossible to maintain residual chlorine in the tank water if its temperature is too high, which can contribute to the proliferation of bacteria (Ministère de l'Environnement du Québec, 2000). The increased frequency of extreme events can also affect the collective systems, for example, by causing freezing in the water supply pipes to the treatment stations or breakdown of heating systems.

FIG. 1. Map of Nunavik showing the communities visited during the cruise of the *Amundsen* in autumn 2004. Arrows indicate communities involved in this study.

Water quality is particularly sensitive to environmental changes, and its degradation can lead to many human health problems. Climate change, for most of the reasons we have just mentioned, can have a major impact on the incidence of gastroenteric diseases, and even on the reappearance or emergence of certain other infectious diseases. Table 1 shows the different diseases likely to be linked to water quality in Nunavik. The published statistics (Santé Publique – Nunavik, 1990–2002) correspond only to reportable diseases (*maladies à déclaration obligatoire,* or MADOs). *Giardia* and *Cryptosporidium*, two parasites of animal and human origin, are associated with several waterborne epidemics (Ministère de l'Environnement du Québec, 2000). The presence of *Giardia* is associated with the release into the environment of animal or human feces, which, via runoff, reach the watercourses that supply the villages with drinking water. Ingestion of contaminated water causes severe gastroenteric diseases. Periodic mammal and bird migrations in Nunavik can greatly increase the risks of raw water contamination: for example, approximately one million caribou cross the region. The cysts of *Giardia* and *Cryptosporidium* are not eliminated effectively by chlorination of water (Ministère de l'Environnement du Québec, 2000).

Most Nunavik communities are now equipped with a water plant. Permafrost makes it difficult to install aqueducts, so water is delivered by truck to houses, where it is kept in large tanks. Many Nunavimmiut continue to supply themselves with untreated water, which they draw from lakes, creeks, and rivers in the summer or obtain by melting ice or snow in winter and spring. In Nunavik, one person in

TABLE 1. Diseases likely to be waterborne in Nunavik.[1]

Type of disease (French)	Agent[2]	MADO[3] (x)	Cases: 1990–2002[4]
Giardiasis (Giardiase)	*Giardia duodenalis* (P)	x	52 cases (1999:9; 2002:9)
Salmonellosis (Salmonellose)	*Salmonella* spp. (B)	x	18 cases (1993:5)
Amebiasis (Amibiase)	*Entamoeba histolytica* (P)	x	2 cases (1993:1; 1999:1)
Campylobacteriosis (Campylobactériose)	*Campylobacter* spp. (B)	x	14 cases (2000:4)
Enterovirus meningitis (Méningite à entérovirus)	Several enteroviruses (V)	x	12 cases (2001:11)
Gastroenteritis *E. coli* (Gastro-entérites à E-Coli)	Enterotoxigenic *E. coli* (B) Enterohaemorrhagic *E.coli* (B)	x	2 cases (2000)
Hepatitis A (Hépatite A)	*Hepatitis A* (V)	x	1 case (2000)
Shigellosis (Shigellose)	*Shigella* spp. (B)	x	240 cases (2000:190; 2001:50)
Typhoid fever (Fièvre typhoïde)	*Salmonella typhi* (B)	x	1 case (1997)
Norwalk virus infection (Infection par le norovirus de Norwalk)	Norwalk virus (V)		
Cryptosporidiosis (Cryptosporidiose)	*Cryptosporidium parvum* (P)		
Helicobacter gastritis (Gastrite à hélicobacter)	*Helicobacter pylori* (B)		
Toxoplasmosis (Toxoplasmose)	*Toxoplasma gondii* (P)		

[1] Sources: Santé Publique–Nunavik, 1990–2002; J.F. Proulx, pers. comm. 2003
[2] P: Protozoan, B: Bacteria, V: Virus.
[3] MADO = Maladie à déclaration obligatoire (Reportable Disease).
[4] The years mentioned are those with the largest number of cases.

five is under five years of age. The human immune system is still fragile at that young age, placing this group at high risk for gastrointestinal diseases (WHO, 2002).

The main goal of our study in 2003 and 2004 was to evaluate drinking habits that may increase the risk of disease for Nunavik residents in a climate change context. Our objectives were 1) to verify what science and traditional knowledge can teach us about climate and environmental changes in Nunavik; 2) to document the existing drinking water and wastewater management initiatives in each village; 3) to specify and validate the information we have on the water consumption habits of this region's residents; 4) to verify the bacteriological quality of water in domestic tanks, raw water supply sites, and storage containers for this raw water, and use the bacteriological analyses as a baseline for future studies; 5) to identify courses of action that will develop or improve climate change adaptation strategies related to impacts on Inuit health.

METHODS

Four Nunavik communities were selected for this study. Two of them, Ivujivik and Puvirnituq, had already implemented technological and community strategies to improve the quality of drinking water. The other two, Umiujaq and Kangiqsujuaq, were still distributing untreated water to residents in 2003, when our study began.

We use the following definitions for water in this study (ITK, 2005): *Potable water*: water that is safe for drinking and cooking; *Surface water*: all water naturally open to the atmosphere (rivers, lakes, ponds, reservoirs) and all springs, creeks, and wells; and *Raw water*: any intake water from a lake or river before it is used or treated—in the text, the terms "raw water" and "outdoor water" are equivalent.

We conducted semi-structured key informant interviews with water resource managers, public health officials, elected representatives, and an Inuit population sample in the four communities. Topics discussed were related to climate change trends and the resulting impacts on drinking water resources and human health. We used a discussion format, posing open-ended questions followed by probes or more specific suggestions (Creswell, 1994). Interviews were conducted face to face, with the aid of a translator when required. Interview data were analyzed by methods of qualitative content analysis (Marshall and Rossman, 1989; Creswell, 1994), in which common responses are grouped into categories that are then reviewed and, if necessary, subdivided into smaller categories of more specific related information.

Preliminary contacts had been made with the mayors of the different communities. We left it up to the interpreters to recruit the individuals from the "Inuit population" category. Thus, this was a convenience sample. Interview guides for questioning the different categories of individuals had been prepared, and these provided information on all the aspects of the study. These guides were reviewed by several representatives from the Public Health Research Unit and the Quebec Ministry of the Environment. The consultation process received the approval of the Centre Hospitalier Universitaire de Québec (CHUQ) Ethics Committee (project 65.05.01).

Investigators gathered information at drinking water treatment stations, at individual and collective water supply sites, and at wastewater disposal sites. Preliminary information on these sites was found in Quebec Government reports (Ministère de l'Environnement du Québec, 2002).

Water samples were collected during the Nunavik Health Survey (called *Qanuippitaa*? 'How are we?') in fall 2004 (Dewailly et al., in press). They were analyzed onboard the *Amundsen*, using Colilert™ for total coliforms (TC) and E. coli (EC) and Enterolert™ for enterococci (EI). These techniques are similar to those used in Nunavik communities to check the water quality at water plant and water tank outlets. The samples, taken in the morning, were prepared for incubation that same afternoon in one of the shipboard modules. The results were read after 24 hours of incubation at 35˚C for total coliforms and *E. coli* and at 41˚C for enterococci. Additionally, we tested for presence or absence of *Cryptosporidium parvum*, *C. hominis*, and *Giardia duodenalis* using Polymerase Chain Reaction (PCR) methods on a limited number of samples (about six per community, from individual containers and raw water sources). Samples collected for PCR tests were treated on the ship, but analyzed at the Infectious Diseases Research Center (CRI) in Quebec City.

We considered that the water collected was unfit for consumption when it equaled or exceeded the following thresholds: 1) ten total coliforms (TC)/100 ml, 2) one *E. coli* (EC)/100 ml, 3) one enterococcus (EI)/100 ml (Ministère de l'Environnement du Québec, 2000). When the samples exceeded these standards, the health centres promptly notified residents.

In February 2005, a workshop for drinking water managers and public health officials was held in Kuujjuaq to formulate appropriate adaptation strategies.

RESULTS

Local Observations on Climate Change

> …last summer was so hot—meat was drying very fast—it is hotter in summer than before…
> (female elder, Ivujivik)

> …snow was abundant in the 1940s and the 1950s—we were able to build igloos—not anymore…
> (female elder, Ivujivik)

> …when I was young, the hill behind the town had snow all summer—not anymore…
> (female elder, Ivujivik)

The main climate change impacts reported by Nunavik residents are earlier springs, longer and hotter summers than before (30 to 40 years ago) with less precipitation, colder and shorter winters with less snow, thinner ice covering on lakes and rivers, lower lake levels, decreased river flows, and the drying up of small rivers and small lakes (Table 2). Nunavik residents have also noticed major shoreline erosion on certain rivers, higher turbidity of running water, and a deterioration of raw water quality.

Drinking Water Consumption Habits

The origin of water consumed, by village, is represented on Figure 2. In the four villages visited, 69% of the people consumed water from their domestic tanks and 31% got their water from lakes, creeks, and rivers in the summer and from melt ice or snow in winter and spring. The proportions for our four study communities were similar to those for Nunavik as a whole. In all 14 Nunavik communities, 71% of residents drank treated water and and 29% drank raw water.

TABLE 2. Summary table of climate change observations by Nunavik residents.

Topic	Observed Change
Spring/Summer	• Longer and hotter summers than before • Drought (more dust and fewer berries) • Earlier spring • Insects that lived in the ponds can now be found in certain lakes • Great variability over time • Less precipitation during the summer—fewer storms than before • Pollution brought by precipitation ("the rain blackens the tents")
Fall/Winter	• Colder and shorter winters • Rapid changes in weather conditions • Less snow • Thinner ice on lakes and rivers • Softer and dirtier snow (pollution) • Early melting of snow and ice • Later freeze: one month later than before (previously November—now end of December: reported in Kangiqsujuaq and Ivujivik)
Lakes and Rivers	• Falling lake levels (drop estimated at 2.5 feet [ca. 75 cm] in Kangiqsujuaq) • Decrease in river flows • Deterioration of water quality • Higher turbidity of running water • More insects in the ponds and lakes • Drying up of small rivers and small lakes • Major shoreline erosion on certain rivers (Kangiqsujuaq)

Domestic Tank Water Quality

During the *Amundsen* cruise, water samples from 64 domestic tanks in the four municipalities were analyzed. Out of the 64 tanks analyzed, 21 contained more than 10 TC/100 ml, none exceeded 1 EC/100 ml, and only one exceeded 1 EI/100 ml. Figure 3 shows the proportion of home water tanks tested in each village, with acceptable levels (white) and unacceptable levels (black) of TC per 100 ml. The water coming from the tanks was tested with SenSafe™ tapes. None of the tanks analyzed contained free chlorine at the time of sampling.

Use of River or Lake Water in Summer

> ... the old people want the best things in life …
> (elder, Puvirnituq)

Collection of untreated water is a traditional activity among Inuit, particularly elders, who have spent a large part of their lives outdoors. Figure 4 shows a raw water supply site at Umiujaq (Hudson Bay region). From interviews, we found that the frequency of supply depended on the number of people living under the same roof. In Ivujivik, we were told that some homes consumed 25 litres

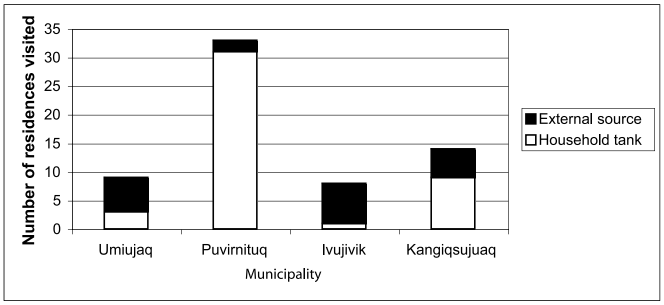

FIG. 2. Origin of water consumed in the four communities studied.

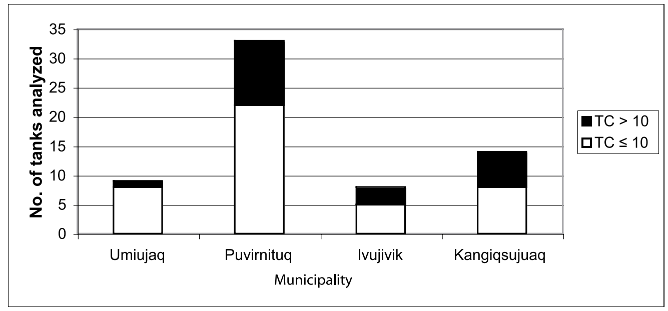

FIG. 3. Total coliforms per 100 ml in household tank water: proportions of water tanks tested with acceptable (white) and unacceptable (black) levels in the four communities.

of water daily, while in others, this same quantity accounted for the weekly consumption. Thus, households replenished their supply of water from creeks, lakes, and rivers from one to three times a week. The main reasons given by the participants for obtaining their water supply in this manner were essentially the same from one village to another. According to the participants, the raw water was clearer and less contaminated than water from the household tanks (fewer bacteria), and in some villages, many notices to boil water had been issued. They said raw water is fresher because it has not been sitting in a truck or domestic tank, and it tastes better than tap water: people do not like the taste of chlorine. In Kangiqsujuaq, residents reported to us that there was rust in the pipes. Several times it was mentioned that tap water, and even the bottled water purchased at the "Coop" (local grocery), turned black when tea was added, which never happened with the water taken from the watercourses and lakes.

For most of the people interviewed, gastrointestinal symptoms were usually associated with tap water. When they started having problems with the tap water, they would look for water outdoors. However, they mentioned that in spring, when the ice was starting to break up (March), the water obtained outdoors tasted different, and cases of diarrhea were more frequent. In Puvirnituq, some people affirmed they had gastrointestinal problems that they attributed to drinking water during the caribou migration period (in fall). However, the people mentioned that they avoided this kind of problem by boiling the river water they collect. Some people used a container with a "Brita" filter and stored the collected river water in their refrigerator. In September 2004 during the *Amundsen* cruise, we visited the principal water resource sources used by the residents and analyzed water samples from six outdoor sites. At several sites, we found a large quantity of total coliforms (TC) (118.4 TC/100 ml at Puvirnituq - site 1), which is normal in the case of surface water, but few *E. coli* or enterococci (2 EC/100 ml at Puvirnituq-site 2, and 1 EI/100 ml at Ivujivik) (Table 3).

We also analyzed the water stored in 20 individual containers (7 at Ivujivik, 2 at Puvirnituq, 6 at Umiujaq, and 5 at Kangiqsujuaq). In most cases, these were plastic containers with a five-gallon capacity. The water had been taken from one of the six sites mentioned above, and the containers were not refrigerated. We performed the same analyses as on the samples taken from the domestic tanks and at the raw water sources (TC, EC, EI/100 ml). Of the 20 receptacles analyzed, 16 contained more than 10 total coliforms/100 ml (several readings were higher than 200.5 TC/100 ml), four exceeded one *E. coli*/100 ml (the highest: 12.4 EC/100 ml), and four contained at least one enterococcus/100 ml (the highest: 12.4 EI/100 ml) (Fig. 5). The water contamination level in these containers appeared to be higher than that of raw water. However, it must be noted that in two cases (raw water and container), this was a spot analysis of the samples. Quite often, the water in the container had been collected several days before our visit, and the contamination at the source could be different from what we measured. However, the degree of contamination of water in containers leaves a persistent doubt regarding the quality of cleaning of the receptacles. Absence of cleaning or ineffective cleaning between fillings could contribute to the increase in the number of bacteria present in the container. The external appearance of most of the containers supported these hypotheses.

FIG. 4. The raw water supply site in Umiujaq. (Photo by Daniel Martin.)

Our sampling did not detect any *Cryptosporidium parvum* or *C. hominis* oocysts or Giardia *duodenalis* cysts in samples from raw water (for supply sites, see Table 3) or from plastic containers in any of the four communities studied. However, the Nunavik Health Survey (*Qanuippitaa*?) did detect these protozoa in other communities: *Giardia duodenalis* cysts were found in

TABLE 3. Bacteriological quality of raw water from six outdoor sites, indicating the number of colony-forming units (CFU) per 100 ml of total coliforms (TC), *E. coli* (EC), and enterococci (EI).

Municipality	Supply Site	TC CFU/100 ml[1]	EC CFU/100 ml	EI CFU/100 ml
Umiujaq	Pipe (Guillaume-Delisle Lake road)	94.5	< 1	< 1
Puvirnituq 1	River 1 (foot of the rapids)	118.4	< 1	< 1
Puvirnituq 2	River 2 (near the pumping station)	78.2	2	< 1
Ivujivik	Lake (near the pumping station)	5.3	< 1	1
Kangiqsujuaq 1	River (waterfall – summer site)	27.1	< 1	< 1
Kangiqsujuaq 2	Lake (used in winter by the municipality)	13.7	< 1	< 1

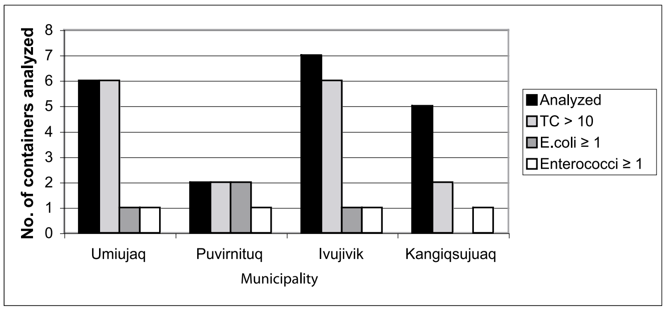

FIG. 5. Bacteriological quality of the water in individual containers.

Kangiqsualujjuaq and Kuujjuarapik, in plastic containers, and in Kuujjuarapik, in a raw water site.

Use of Meltwater in Winter and Spring

In winter and spring, when lakes and watercourses are frozen, some Inuit melt snow and ice (from lakes, rivers, and icebergs) to obtain drinking water. An example of a snow supply site near the village of Ivujivik is seen in Figure 6. In the four villages visited, residents obtained water from such sites from one to three times a week. The reasons participants gave for obtaining water in this way were essentially the same as those given for obtaining water from lakes and rivers: it tastes better than tap water (which contains chlorine). For elders, water harvest is an ancestral practice. Also, meltwater is considered cleaner than tap water because it does not run through the pipes or sit in a domestic tank. Moreover, it eliminates stomach cramps related to the use of tap water.

Most of the people consulted indicated that they never had gastrointestinal problems after consuming meltwater (snow or ice). According to them, this is a healthy practice if clean snow or ice is used. However, some people did say that they had stomachaches after consuming meltwater.

DISCUSSION

Environmental monitoring is a key factor in maintaining water quality, especially in the context of climate change. Community members can participate at the local level in monitoring of river levels, liquid precipitation, quantities of snow on the ground, and availability of the resource at certain periods of the year. The same people could also apply simple analytic methods (e.g., Colilert™, Enterolert™) at the water sources, especially during the caribou migration period or at other times of year when raw water sources are prone to contamination. The microbiological analyses performed in 2004 are only a baseline: water quality at natural sources should be followed over the long term. Finally, we envision specific training in environmental observation for young people interested in this field.

The water treatment facilities are vulnerable both to climatic extremes and to mechanical failure. They require proactive maintenance, since expertise available to repair them is limited, and delivery of equipment parts depends on seasonally available means of transportation. Currently, health professionals (nursing staff from the nursing stations) have only limited involvement with drinking water quality. They should be trained to perform certain bacteriological tests for community facilities such as nursing stations, daycare centres, and schools. In some communities, such as Puvirnituq, a study of the bacteriological and parasitic impacts of caribou migrations on raw water quality is needed to determine whether these migrations are linked to a seasonal increase in the occurrence of gastroenteric diseases in the villages.

The installation of outdoor faucets with chlorine-free purification systems (UV lamps, ozone system, charcoal filters) for the use of elders and people with limited mobility would be an interesting option. The operators of the drinking water treatment stations could maintain these systems and test the water for bacteria. Health professionals and municipal officers should inform the population about the existence of these alternative systems and their advantages.

Raising residents' awareness of the risks associated with raw water consumption is of primary importance. In none of the villages visited did we see any posters mentioning the disorders (such as coliforms, giardia, and cryptosporidium) that can result from raw water contamination. The health professionals could be associated with this awareness campaign. An important objective would be to establish routine water quality testing at the individual supply sites; alerts could then be issued when the analyses show contamination. It is important to raise awareness of the need for frequent and adequate cleaning of the containers used to store untreated water. Pamphlets with cleaning instructions should be provided to everybody.

It would be necessary to gather more detailed information on cases of gastroenteric diseases, supported by statistics,

FIG. 6. The snow supply site near the village of Ivujivik. (Photo by Daniel Martin.)

from the nursing stations, to establish whether there is a link between these disorders and water quality. In-depth documentation of the bacteriological impact of cleaning of domestic tanks still needs to be done.

CONCLUSION

Through visits in June 2003 and June 2004 and the consultation process conducted in the four subject communities in 2003, we were able to document and update the information we possessed about existing drinking water management initiatives. We were also able to note the changes meant to improve the water quality situation in the communities visited: reopening of former systems, construction of new drinking water treatment facilities, and innovative wastewater treatment initiatives. However, all these initiatives, which stem from the good will of the provincial, regional, and municipal authorities, are very sensitive to climatic extremes. If a major snowstorm or an intense cold spell causes the water supply systems to break down, it can disrupt the life of a village not just for a few days, but for months. These extreme occurrences are bound to increase in the coming decades.

Beyond the technical information gathered during the visits, we were able to get an overview of how the population, elected representatives, technicians, and managers perceive the existing or future drinking water treatment structures. During the consultation process, we were able to pinpoint water consumption habits that stem from ancestral customs, but which can present human health risks, especially in a context of climate warming. Our proposals for community environmental monitoring, maintaining water treatment facilities, involving health care workers in water quality testing, providing alternatives to chlorine treatment, raising awareness of water risks, cleaning water storage tanks, and documenting gastroenteric diseases are, above all, designed to prevent potential health problems that can arise from consumption of untreated water. During the *Amundsen* cruise in fall 2004, we observed that in most villages, the raw water from the collection sites most frequently visited is of good quality. Regular monitoring of these sites is necessary, however, and the public should be warned when the sites become contaminated, especially during animal migration periods. Of particular concern was the fact that the water from individual home storage containers was much more contaminated than the water at the collection sites. Residents should be made aware of the importance of cleaning these containers adequately between fillings.

While it is difficult to anticipate future climate changes, it is impossible to deny what is currently happening. This region is going through major warming, which is already upsetting the water supply of the communities: science and traditional knowledge both attest to this. A high level of uncertainty persists regarding precipitation (liquid and solid): the residents affirm that these forms of precipitation have declined over the past decades, while some models forecast a considerable increase over the next 50 years. We can now affirm that the anticipated changes show the urgency of setting up both an effective environmental monitoring system and an effective health monitoring system to detect and deal rapidly with health problems related to water quality.

ACKNOWLEDGEMENTS

We thank mayors Abelie Napartuk (Umiujaq), Paulusie Novalinga (Puvirnituq), Peter Iyaituk (Ivujivik) and Charlie Alaku (Kangiqsujuaq) for their welcome; our interpreters, Frances Weetaltuk (Umiujaq), Patsy Tulugak (Puvirnituq), Sara Mark (Ivujivik), Ulaayu Qisiiq (Kangiqsujuaq), who made the study possible; the health care personnel: Jean-François Proulx, for statistics on Nunavik; Serge Auclair, hospital administrator, for lodging, food, and office space in Puvirnituq; and the community nurses who facilitated our work. We thank Michael Barrett, Minnie Abraham, Christopher Davies, Stéphane Ferrero, Simon Ricard, and Nathalie Girard of the Kativik Regional Government for their cooperation, and Alain Bourque, Luc Vescovi, Marie-Claude Simard, and Philippe Gachon of the Ouranos consortium for their commitment and efforts. Many helped during the *Amundsen* cruise: Jean-Sébastien Maguire, Jean-Luc Bernier, Pauline Brindel, and Andrée Maheux collected and analyzed samples; nurses Suzanne Côté, Louise Billon, Véronique Doutreloux, Karine Lemay, Alain Paré, and Michel Poulin facilitated sample collection; Suzanne Bruneau, mission leader, organized ship-community trips; several driver-interpreters took us to raw water supply sites; and the two crews of the NGCC *Amundsen* were remarkably efficient and unfailingly kind. External partners Éléna Labranche, (Nunavik Regional Health and Social Services Board) and Scot Nickels (Inuit Tapiriit Kanatami) supported this initiative, and the Climate Change Action Fund (Natural Resources Canada), ArcticNet (Réseau des Centres d'Excellence) and the Nasivvik Centre (Aboriginal Capacity and Developmental Research Environments program) provided funding. Carole Vézina organized our trips to Nunavik (2003 and

2004), Yolande Lapierre participated in consultations (2003), Susie Bernier translated the interview guides, Suzanne Gingras processed statistical data, and Lise Côté provided secretarial support. We thank them all.

REFERENCES

ACIA (ARCTIC CLIMATE IMPACT ASSESSMENT). Arctic climate impact assessment: Scientific report. 2005. Cambridge: Cambridge University Press.

ASSOCIATION TOURISTIQUE DU NUNAVIK ET TOURISME QUÉBEC. 2003. Guide touristique officiel 2003–2004. (Available in English as Nunavik: Official tourist guide).

CRESWELL, J.W. 1994. Research design: Qualitative and quantitative approaches. Thousand Oaks, California: Sage Publications. 227 p.

DEWAILLY, E., CHATEAU-DEGAT, M.L., ÉKOÉ, J., and LADOUCEUR, R. In press. Health survey of the Inuit of Nunavik; "Qanuippitaa 2004": Status of cardiovascular disease and diabetes in Nunavik. Québec: Nunavik Regional Board Health and Social Services and Institut National de Santé Publique du Québec.

FORTIER, R., and ALLARD, M. 2003. Les impacts d'un réchauffement récent sur le pergélisol au Nunavik. Présentation faite au 24ième colloque annuel du Centre d'Études Nordiques, December 2003. Available at Centre d'études nordiques, Université Laval, Pavillon Abitibi-Price, Québec, Québec G1K 7P4.

FURGAL, C.M., MARTIN, D., GOSSELIN, P, VIAU, A., NUNAVIK REGIONAL BOARD OF HEALTH AND SOCIAL SERVICES/NUNAVIK NUTRITION AND HEALTH COMMITTEE, LABRADOR INUIT ASSOCIATION, and LABRADOR INUIT HEALTH COMMISSION. 2002. Climate change and health in Nunavik and Labrador: What we know from science and Inuit knowledge. Final scientific report. Available at Unité de Recherche en Santé Publique, 2875, boulevard Laurier, 6e étage, Édifice Delta 2, bureau 600, Québec, Québec G1V 2M2. 139 p.

INUIT TAPIRIIT KANATAMI. 2005. Freshwater in Inuit communities. Environment Bulletin 3:22–23.

MARSHALL, C., and ROSSMAN, G.B. 1989. Designing qualitative research. Newbury Park, California: Sage Publications.

MARTIN, D., LEVESQUE, B., MAGUIRE, J.S., MAHEUX, A., FURGAL, C.M., BERNIER, J.L., and DEWAILLY, E. 2005. Drinking water quality in Nunavik: Health impacts in a climate change context. Final report. Available at Unité de Recherche en Santé Publique, 2875, boulevard Laurier, 6e étage, Édifice Delta 2, bureau 600, Québec, Québec G1V 2M2. 87 p.

MINISTÈRE DE L'ENVIRONNEMENT DU QUÉBEC. 2000. Étude d'impact du projet de modification réglementaire sur l'eau potable en regard des communautés autochtones. Direction des politiques du secteur municipal, Service de l'expertise technique en eau, May 2000. Available at Ministère de l'Environnement du Québec, Direction régionale Nord-du-Québec, 180 Boulevard Rideau, Rouyn-Noranda, Québec J9X 1N9. 29 p.

———. 2002. Rapports d'inspection sur l'eau potable et les eaux usées de 14 villages du Nunavik, Nord du Québec, Directions régionales de l'Abitibi-Témiscamingue et du Nord-du-Québec, Rouyn-Noranda, September 2002. Available at Ministère de l'Environnement du Québec, Direction régionale Nord-du-Québec, 180 Boulevard Rideau, Rouyn-Noranda, Québec J9X 1N9.

ROSE, J.B., DAESCHNER, S., EASTERLING, D.R., CURRIERO, F.C., LELE, S., and PATZ, J.A. 2000. Climate and waterborne disease outbreaks. Journal of the American Water Works Association 92(9):77–87.

SANTE PUBLIQUE–NUNAVIK. 1990–2002. Sommaire des maladies à déclaration obligatoire, Transmission MADO. Available at Régie Régionale de la Santé et des Services Sociaux du Nunavik, C.P. 900, Kuujjuaq, Québec J0M 1C0.

WHO REGIONAL OFFICE FOR EUROPE. 2002. Children's health and environment: A review of evidence. Edited by G. Tamburlini, O.S. von Ehrenstein, and R. Bertollini. Environmental Issue Report 29. Luxembourg: Office for Official Publications of the European Communities.