WEATHER, WATER, AND INFECTIOUS GASTROINTESTINAL ILLNESS IN THE CONTEXT OF CLIMATE CHANGE IN NUNATSIAVUT, CANADA

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Climate change is expected to cause changes in precipitation and runoff patterns, likely increasing the risk of waterborne infectious disease in some areas. In this context, the research objectives were to describe links between weather, water quality, and infectious gastrointestinal illnesses (IGI) in Nunatsiavut, Canada, which necessarily involved evaluating the quality and usefulness of data captured by the local health registry system. For this evaluation, IGI was used as a reference syndrome. Community-based meteorological stations captured weather data; trained local personnel conducted water quality testing. Clinic records provided IGI-related data (2005-2008). This study is the first to systematically gather and describe baseline empirical data on weather, water quality, and health in Nunatsiavut. It showed the necessity of improving Inuit health data quality and monitoring environmental health variables consistently and systematically across all Arctic regions. These data are critical to inform adaptation strategies for managing impacts of climate change on health.
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CHAPTER ONE

INTRODUCTION, LITERATURE REVIEW, AND STUDY RATIONALE

INTRODUCTION

Water is essential to life and access to water is often considered to be a basic human right (1). Access to water that does not present any significant health risks to individuals over a lifetime of consumption, or safe water (1), is crucial for consumption and personal hygiene. However, 16-53% of the world’s population currently does not have access to the necessary quantity of safe water (20-50L/person/day) that is required for subsistence and effective hygiene (2, 3). This global shortfall is responsible for many public health problems, including 6% of all deaths annually and 9% of the annual global disease burden (4). A substantial part of this water-related disease burden is due to infectious gastrointestinal illnesses (IGI), illustrating the importance of Health Target 3 of the UN Millennium Development Goals, which aims to reduce by half the proportion of people without access to safe drinking water and sanitation by 2015 (5). Climate change could increase the disease burden associated with infectious waterborne diseases (6-9) especially for vulnerable populations around the world, given the linkages between weather and IGI, as well as changes already experienced in location, timing, intensity, and duration of precipitation and temperature patterns.

LITERATURE REVIEW

The aim of this literature review is to systematically identify, summarize, and integrate literature regarding the global burden of waterborne diseases, climate change...
impacts on waterborne diseases, Aboriginal health data quality, and climate change impacts on waterborne disease in Inuit communities. A list of relevant search terms was generated to include population, exposure, and outcome terms (Table 1.1). Searches for abstracts published in the English language in the last decade (1998-2008) were conducted using the electronic databases Web of Knowledge and PubMed. Titles, abstracts, and keywords were screened and included if they described primary or secondary research, human IGI cases, and an IGI outcome that was self-reported, or was clinically, serologically, or microbiologically confirmed. Abstracts were excluded if they described non-human study populations or the IGI was clearly identified as non-waterborne (e.g. foodborne illnesses). Next, the screened literature deemed relevant to the literature review aims was read and summarized. Article references were reviewed for citations not captured in the original searches.

**Waterborne Pathogen Exposure**

Exposure to waterborne pathogens can occur via ingestion, inhalation, and/or direct contact with contaminated water. Waterborne diseases vary in severity from mild self-limiting gastroenteritis to fatal diarrhoea. The different types of waterborne pathogens identified to-date broadly fit under three categories: bacterial, viral, and protozoal pathogens (Appendix 1). Agents in all three pathogen categories can be introduced to water sources via animal and/or human faeces, and then once ingested, grow and reproduce in the animal or human gastrointestinal tract (1). These pathogens can cause sporadic waterborne disease or outbreaks, depending on a variety of factors,
such as pathogen type, pathogen virulence, infectious dose, geographical distribution, host factors, and ecosystem factors.

To protect public health against waterborne disease, the World Health Organization (WHO) recommends a holistic approach to drinking water supply management, including creation of water safety plans (WSP) to manage all steps from water source to consumption (1), as well as emergency preparedness plans and policies. These WSP should (i) assess the potential hazards that can affect the water system including microbial, non-microbial, and aesthetic aspects; (ii) identify control measures to reduce and then monitor the hazards; and (iii) develop management plans to describe both normal and incident conditions (1). Source water protection, to prevent contamination of water sources, as well as water treatment, is often utilised in the provision of safe drinking water. In Canada, the provision of safe water is a provincial responsibility, except on Aboriginal reserves where it is a federal responsibility. Water treatment can use one or more of the following to control pathogens in water: coagulation, flocculation, sedimentation, filtration, and disinfection.

**Waterborne Disease Risk Factors**

*Exposure to Contaminated Water*

*Untreated Drinking Water:* For decades water treatment systems have been used to treat water to reduce the incidence of waterborne disease in some communities. Decreases in waterborne disease incidence were found when communities switched from untreated to treated water systems (10-13), or when communities improved water treatment standards (14); however, other studies did not produce similar findings (15,
16). While there are numerous treated water distribution systems worldwide, many people still rely on untreated drinking water from private wells or surface water. For example, over 4 million Canadians (20% of the population) rely on private water supplies for drinking water (17). Often this water is treated poorly, if at all, which could increase the risk of exposure to waterborne pathogens (17). Indeed, consumption of contaminated raw water has been associated with diarrhoea in every continent worldwide; examples are listed in Table 1.2. Going further, the World Health Organization estimates that improved water quality would reduce the global burden of IGI by 31% (4).

**Failures in System Design and Water Treatment:** Some pathogens are resistant to certain methods of water treatment. For example, *Giardia* and some viruses are highly resistant to chlorination treatment; however, high quality filtration can reduce the prevalence of these pathogens in water. This resistance might explain why some studies found waterborne disease attributable to treated water that met established standards for safe drinking water (18). For example, a Canadian study found that at least 14% of IGI cases were attributable to drinking treated water that met or exceeded water standards (19).

Inadequate water treatment can be a result of human error or system malfunction. Manual or digital chlorine residual monitoring is a common way to provide rapid indication of microbial water quality. Sudden drops in free-chlorine residual levels can indicate early stages of microbial contamination which requires intervention (e.g. additional chlorination) to protect public health (1). Studies have linked low chlorine residuals levels with cases of self-reported diarrhoea (20, 21). Moreover, other studies
associated malfunctioning water treatment systems with waterborne disease rates in developing (22, 23) and developed countries (24-31).

Recreational Activities: It is possible to contract waterborne diseases via recreational water use, including the use of treated pools and spas, lakes, beaches, hot springs, and fountains. A meta-analysis showed a strong dose-dependent relationship between indicator bacteria levels in recreational water and IGI cases (32). Furthermore, other studies associated recreational water with increased sero-prevalence of antibodies to waterborne pathogens (33), cases of self-reported diarrhoea (34, 35), clinical cases of diarrhoea (36), and outbreaks in both developed (29, 37-41) and developing countries (42).

Travelling: While people can develop immunity to certain local microflora found in the water supplies that they normally drink, they may lack protective immunity to pathogens that they encounter, perhaps for the first time, while travelling. For example, a New Zealand study found that drinking untreated and treated water away from home increased the risk of childhood giardiasis up to 10.4 and 8.6 times, respectively, compared to those who did not drink water away from home, and 57.8% of childhood giardiasis was attributed to drinking water away from home (43). Waterborne illness is also frequently associated with international travel (e.g. traveller’s diarrhoea). The rate of traveller’s diarrhoea has not significantly decreased since the 1970’s despite improvements in vaccination (e.g. Dukoral™ vaccination for E. coli (ETEC) and cholera) and wide-spread educational campaigns about precautionary measures (44, 45).
High Impact Weather Events

Rainfall: Heavy rainfall events include rainy seasons in tropical regions or periods with more rainfall than usual in temperate regions, and can lead to contaminated water due to (i) runoff and/or (ii) channel erosion, both of which can lead to increased turbidity. Both situations can lead to increased risk of waterborne disease (30, 46-53). During periods of heavy rainfall there can be an extension of the channel network and/or flow over the surface or immediate subsurface. Runoff can result from rainfall and/or rapid snowmelts on impermeable surfaces, which can occur as a result of geological conditions, soil saturation, and/or frozen ground. This runoff is capable of transporting pathogens into water sources, increasing the risk of human exposure and infection. In tropical regions, many studies found increased levels of faecal contamination in water sources during rainy seasons (54-56). This contamination might explain increased rates of diarrhoeal diseases (54, 56-61) and waterborne disease outbreaks (62, 63) during this season. Similarly, in temperate regions, periods of heavy rainfall can increase the risk or incidence of waterborne disease. Many studies associated periods of heavy rainfall with increased levels of pathogens in drinking water sources (64-68), as well as increased rates of diarrhoea (69-72) and waterborne disease outbreaks (46, 51, 73). For example, in the United States one study estimated that up to 51% of waterborne disease outbreaks occurred after a period of heavy rainfall (46).

Periods of heavy rainfall are considered to contribute substantially to increased risks and rates of waterborne disease globally. However, other trends have also been observed; some studies reported an increased incidence of diarrhoeal disease during periods of low rainfall or drought (71, 74-76). For example, the incidence of cholera
increased during periods of low rainfall, but also during periods of heavy rainfall, in Vietnam (77) and Indonesia (78). During periods of heavy rainfall the transmission of IGI is likely due to floods flushing faecal contaminants into drinking water sources (78). Conversely, periods of low rainfall might increase risk of diarrhoea through reduced dilution of sewage effluent, stagnation of open water, as well as reduced availability of safe water for proper hygiene and sanitation (78).

Periods of heavy rainfall in both tropical and temperate regions can increase surface water turbidity. High turbidity can stimulate micro-organism growth and various studies found positive correlations between water turbidity and pathogen levels (57, 70, 79). Furthermore, high turbidity levels in treated water can protect pathogens from the effects of disinfection, significantly increasing the required amount of chlorine for adequate disinfection (1) and affecting other disinfection techniques, such as UV treatment (80). Thus, increased turbidity can complicate or overwhelm water treatment approaches (81, 82), thereby increasing the risk of waterborne disease (30, 82-84). In a Russian study, even small increases in pre-treatment water turbidity were significantly associated with the risk of self-reported diarrhoea (85), and similar associations were found in Canada (84) and the United States (86). Therefore, monitoring or controlling turbidity levels in drinking water are important potential strategies to reduce waterborne disease incidence. For example, from 1998 to 2000 in Kamloops, Canada, daily turbidity monitoring and daily turbidity-based public water quality advisories decreased IGI physician visits by as much as 25% (87).

Flooding: Flooding after periods of heavy rainfall, tidal surges, and/or rapid snowmelt can increase the pathogen load in water reservoirs (67, 88) and can overwhelm
water treatment facilities. Numerous studies found evidence linking waterborne disease outbreaks to flooding events in developing countries (72, 89-95); however, this trend is not as apparent in developed countries (96-99). This difference in outbreak trends might be due to differences in emergency preparedness plans and/or water treatment infrastructure.

*Temperature:* Changes in atmospheric and/or water temperatures can also increase the risk of waterborne disease. Generally, pathogen growth is temperature dependent (100, 101). For example, increased water temperature can lead to blooms of various planktonic species (e.g. cyanobacteria) that produce toxins which cause human illnesses (102, 103). Furthermore, in some cases heat can be conducive to overgrowth of bacteria in faecally contaminated material (79) or in water (67, 79, 104), and can result in increased rates of diarrhoeal diseases (93, 104). Increased ambient temperatures were also correlated with various waterborne disease outbreaks in developing (78, 105-109) and developed countries (51, 110). Furthermore, some research shows relationships between warmer seasons and rates of diarrhoeal diseases (111, 112), which might be due to increased recreational water use (14, 113-118).

**Climate Change and Waterborne Disease**

Build-up of greenhouse gases in the atmosphere is warming the Earth (119-121), which will intensify the hydrological cycle (122-124). Generally, it is suggested that climate change will result in changes in temperature (maximum and minimum), precipitation (spatio-temporal patterns, intensity, and duration), evapotranspiration, runoff, and hydrological extremes (e.g. storms, droughts, hurricanes) that will change the
environmental conditions in which we live (119). It has been argued that these ecological changes will very likely increase the risk and incidence of infectious disease (6-9), including waterborne disease (125).

In order to adapt to and prepare for future impacts of climate change on drinking water, it is important to understand the relationships between weather events and waterborne disease (Figure 1.1.). Undoubtedly, the impact of climate change on health could be substantial in some developing countries due to lack of infrastructure, disaster preparedness plans and policies, and resources (6-9); however, it has been suggested that developed countries with good water treatment infrastructure generally have the capacity to manage changes in drinking water quality due to climate change (49, 126). Nevertheless, there were instances in developed countries where adequate water treatment infrastructure combined with inadequate training have led to the occurrence of disease outbreaks (127-129). Furthermore, many people in these countries still rely on private wells or surface water as their primary water source, which tend to be poorly treated, if at all (130-132). While existing water treatment infrastructure in developed countries might be adequate to protect public health, an increased human capacity to manage and monitor public and private water sources and treatment systems is still needed to protect human public health from changes in water quality due to changes in climate, especially in vulnerable populations.
Burden of Infectious Gastrointestinal Illness

Morbidity and Mortality

Globally, the burden of diarrhoeal disease due to all causes translates to an estimated 1.8 million deaths every year, with 88% of these cases attributable to unsafe water (4). It is estimated that developing countries experience diarrhoeal mortalities of 8.0%, while developed countries have much lower mortalities of approximately 0.5% (4, 133). While these mortality rates include diarrhoeal disease due to all causes, it is likely that waterborne diarrhoeal mortality rates show similar disparities between developing and developed countries. Indeed, this trend is reflected in many studies that have estimated the prevalence or incidence rates of potential waterborne IGI and are summarized in Appendix 2 (e.g. (20, 134-139)).

In developed countries IGI is typically mild and self limiting (140), but is still a significant cause of morbidity with considerable economic impacts (137, 141). For example, in Canada in 2001 the incidence of self-reported IGI was estimated to be 1.3 episodes per person-year (137) or an estimated 90,000 cases and 90 deaths per year (142), with up to 35% of cases attributable to waterborne pathogens (143). Furthermore, it is estimated that 10% of cases report symptoms of diarrhoea or vomiting with an average duration of 4 days (137). These illnesses can result in lost work days and medical care costs. When these costs are considered, the economic burden of IGI can be substantial. Studies investigating the economic burden of IGI are displayed in Table 1.3, where the currency used in the original study was converted into 2004 USD by using official exchange rates and GDP deflator (144). The purchasing power parity (PPP) was also calculated using PPP conversion factors (145). This factor takes into account the
different costs of local goods within countries and provides a better representation of the ‘cost’ of lost income due to IGI for comparison between countries (145). Nevertheless, making comparisons between studies is difficult because they often use different measurements of days lost work and medical costs.

**Risk Groups**

Globally, children suffer a proportionally greater burden of IGI than adults, with water related deaths accounting for 25% and 6% of all child and adult deaths, respectively (4). For example, in developing countries, higher rates of waterborne infections were found in children than adults, including infections of *Giardia* (22, 146), *Cryptosporidium* (59, 147), and *Vibrio* (74). Similar trends in children were seen in developed countries for giardiasis (117, 148), cryptosporidiosis (149), and other diarrhoeal diseases (111).

Immuno-compromised groups that tend to be at higher risk of waterborne infection include the elderly (86, 146), malnourished (150, 151), HIV positive patients (146, 152), and cancer patients (146). Moreover, the risk of developing waterborne infections can be associated with gender. Men were observed to have higher risks of giardiasis (117, 146), cryptosporidiosis (152, 153), and viral infections (153) than women; however, other studies found higher rates of IGI in females (137, 154).

**Burden of Illness Estimate Limitations**

The burden of disease can be difficult to estimate given the fragmented nature of health statistics, limitations of surveillance systems, and difficulty comparing and
combining results from studies with differing designs (133). It is particularly difficult to estimate the burden of IGI attributable specifically to waterborne pathogens because they can also be contracted from food or person-person contact. For example, many studies found that drinking water consumption was not associated with infections that are typically transmitted via water, including Cryptosporidium (155-157), Giardia (158), E. coli (159), and other diarrhoeal agents (160, 161). Furthermore, many studies and outbreak investigations fail to identify the source(s) of infection.

Reporting biases present another difficulty in estimating the burden of IGI. Many countries have national or regional disease reporting systems, where specified notifiable diseases with confirmed diagnoses must be reported to authorities. While these systems can provide national or regional estimates of disease burden, they can significantly underestimate the true population incidence and prevalence of IGI because of gaps in reporting. These gaps include few IGI cases consulting a physician, few physicians requesting stool samples, lack of sensitivity of diagnostic procedures, and failure to report laboratory findings (118, 162, 163). For example, in Canada, under-reporting of IGI is considered substantial: for every officially reported case of IGI, an estimated 313 cases actually exist in the community (162). Furthermore, a study in England found that for every officially reported case of IGI, 136 actual IGI cases existed in the community (164). Other reporting biases can result in over-estimates of true IGI incidence and prevalence in populations. For example, studies found that there might be significant recall bias when using self-reported cases of diarrhoea resulting in over-estimates of disease burden (165-167). These under- or over-estimates of true IGI rates can present challenges when studying IGI risk factors, planning health programs, and prioritizing
health promotion. Therefore, prospective or cross-sectional studies that examine stool samples for pathogens or serological indicators of infection might help to better estimate the true incidence or prevalence of IGI in the population that is attributable to waterborne pathogens.

**Capturing Health Data for Epidemiological Research**

*Health Registries and Surveillance Systems*

A health registry systematically collects data related to health events, which can be used to analyse, interpret, and disseminate information regarding the health of a community (168). The extent to which the registry can be utilized for public health monitoring or surveillance depends on the quantity and quality of information that is captured by the system. Health registries often use coding systems to capture patient and disease information and can be systematically used to record, analyze, interpret, and compare the morbidity and mortality from a disease over space and time (169). For example, the International Statistical Classification of Diseases and Related Health Problems (ICD), created by the World Health Organization, provides translation of a diagnosis from words into a standardized numerical (ICD-9) or alphanumerical (ICD-10) code, which allows easy storage, retrieval, and analysis of the data (169).

One or more health registries can provide data for public health surveillance, which is an on-going and systematic collection, analysis, interpretation, and dissemination of data related to a health-event (168). Surveillance of health events can provide estimates of the magnitude of a health problem, enhance understanding of the natural history of a disease, detect epidemics, identify risk factors, examine the
distribution and spread of a disease, facilitate research, evaluate control measures, monitor changes in infectious agents, and prioritize and plan public health programs (168).

Surveillance system structures and operations vary in complexity from a simple paper-based source to multiple electronic sources of data in multiple formats (170). Surveillance systems also range in health data collection methodology, including passive or active data collection. Passive surveillance systems rely on mandatory or voluntary reporting of health-events (e.g. notifiable disease reporting) or on data derived from other primary sources (e.g. health registries), whereas active surveillance systems rely on outreach from authorities, such as telephone calls or visits to laboratories and hospitals to stimulate reporting of specific health-events. Both active and passive surveillance have benefits and limitations. For example, due to the voluntary nature of passive surveillance systems, health-events are often under-reported (171-173). Furthermore, if volunteers that are reporting health information are inadequately trained, the surveillance system might fail to detect the health-event of interest (174), potentially resulting in under-estimates of the health-event. Conversely, if a health-event is stimulating media and public attention, the volunteer nature of passive surveillance might result in over-reporting because of heightened interest in the issue. Thus, due to these potential limitations of passive surveillance, active surveillance is often thought to capture higher quality data; however, active surveillance is often expensive and time consuming (171). Therefore, to help decide which data collection method is most suitable, public health authorities can conduct costs/benefits analyses to determine whether the added expense of an active surveillance system is justified (175-177). For example, in the United States,
active *Hepatitis A* surveillance was more cost-effective than passive surveillance (172), because the health costs of not detecting the spread of infection outweighed the costs of the active surveillance system for detection and control of outbreaks in the population.

**System Evaluation**

Periodic evaluations are important to ensure that surveillance systems are efficiently and effectively meeting their objectives. With advances in technologies that capture, monitor, and integrate data regarding health-events, these evaluations are becoming increasingly important in order to ensure patient privacy, data confidentiality, and system security (170). A widely used framework for evaluating health surveillance systems is the Centers for Disease Control and Prevention’s (CDC) *Guideline for Evaluating Public Health Surveillance Systems* (170). This framework involves five tasks: (i) engaging stakeholders; (ii) describing the system; (iii) focusing the evaluation design; (iv) evaluating system usefulness and attributes; and (v) stating recommendations and sharing lessons learned ((170); Appendix 3). To assist in data quality analysis in system evaluations, it can be useful to analyse a subset of the data captured by the system (e.g. using random sampling) or data captured about a specific health-event (e.g. using a reference disease/syndrome (178)).

In published academic literature, there are several examples of evaluations of surveillance systems that capture data on chronic illnesses, infectious diseases, notifiable diseases, and other health-events. Many evaluations found the systems to be useful and meeting their goals (175, 176, 179-184); however, some evaluations found major flaws (173, 178, 185, 186), resulting in significant recommendations for improvement,
including implementing new information technologies (178, 186), increasing funding (186), increasing human resources (178, 187), creating new laws (173), and reducing surveillance regimes (188).

**Health Record Systems in Aboriginal Communities**

In developed countries with Aboriginal populations, ethnicity/cultural \(^i\) data are not captured in some national health databases (189, 190), resulting in gaps in Aboriginal health statistics and research. For example, cancer registries are often considered to capture high quality epidemiological data (191-193). When these registries do collect ethnic/cultural data (e.g. *North West Territory Cancer Registry*, *Nunavut Cancer Registry*, and *Alaska Native Tumour Registry* (194)), this high quality data capture is indeed the case; however, when these data are not captured (e.g. *Quebec Tumour File* and the *Danish Cancer Registry*), it is difficult to study Aboriginal-specific cancer trends (194, 195). Even when ethnic/culture information is collected in national registries or local clinic records, the quality of health data can be comprised due to lack of uniform reporting (189, 190, 196), low levels of completeness (197), high monetary cost of patient follow-up (198), and lack of validity (199, 200). Data quality and representation can be limited further due nomadic cultures and/or the remote geographical location of some Aboriginal communities. For example, in Canada, 30-50% of Aboriginal communities are only accessible by air (201). The remote location of these communities might limit access to health care, influence care-seeking behaviour, and impact health

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\(^i\) Past literature examining Aboriginal health data often use the term ‘ethnicity’; however, here the term ‘ethnicity/cultural’ is used to recognize that the term “Aboriginal Peoples refers to organic political and cultural entities that stem historically from the original people of North America, rather than collections of individuals united by so-called ‘racial’ characteristics” (257).
care capacity and resources, potentially compromising the ability to collect adequate data on community health (189, 190, 196, 202). Thus, some health information captured by national databases and registries is thought to substantially under-estimate true rates of Aboriginal disease (189, 190). Consequently, in countries such as Australia, annual national reports of disease sometimes exclude Aboriginal data, leaving unfortunate gaps in Aboriginal health statistics and research (197).

In Canada, some surveillance systems are designed to increase data capture in remote Aboriginal populations. For example, the *International Circumpolar Surveillance* is a population-based system that captures invasive bacterial disease information from Inuit populations. This system increases data quantity and quality via heightened surveillance and routine data audits (203), but still faces challenges. For example, successful transportation of viable medical specimens to suitable laboratories is difficult due to travel times and extreme temperatures of circumpolar communities.

**Waterborne Disease in the Canadian Context**

In Canada, public concerns about drinking water quality were recently elevated by a major waterborne outbreak of two pathogens (*E. coli* O157:H7 and *Campylobacter*) that occurred in Walkerton, Ontario in 2000. There are few published studies that focus on safe drinking water in Aboriginal communities even though there are anecdotal reports that they have experienced more water problems than others in Canada (204, 205). These problems include perceived concerns regarding treated water quality and availability. For example, Aboriginals are 90 times less likely to have access to piped water than non-Aboriginal Canadians (9.4% and 0.10% respectively, (206)); however, access to safe
piped water can still be problematic in some Aboriginal communities. For example, one review reported that over 25% of available drinking water in Inuit communities was not considered suitable for drinking (206). Another study conducted in the fall of 2004 in Nunavik, point-tested raw water as well as treated water within storage containers for faecal indicator bacteria (207). While no raw water sources were deemed unsuitable for drinking, all water samples from 64 storage containers were considered unsafe for drinking (207); however, this study did not report community rates of IGI, making it difficult to determine the impact of the contaminated water on public health. Another example of drinking water quality concerns in Aboriginal communities are reported high frequency and long durations of boil water advisories (BWA, (208)). When publically supplied water does not meet established water quality standards in Canada, BWA are issued to protect public health temporarily until the water problem has been resolved. One study found a total of 127 boil water advisories were issued and the median duration of un-revoked BWAs was three years on Northwest Ontario Aboriginal reserves, between 2002 and 2007 (208). Furthermore, three communities had un-revoked BWAs that were over six years old and these lengthy BWAs led to some residents consuming un-boiled water despite the advisory (208). While BWAs are meant to be temporary measures to protect the public’s health against waterborne illnesses, BWAs are not always temporary in these communities, and therefore might not adequately protect public health and indicate that underlying problems are not being resolved in a timely manner.

These water-related public health concerns in Aboriginal communities might reflect other disparities in health between Aboriginal and non-Aboriginal Canadians. For example, in Canada, Aboriginal disease mortality and morbidity rates from all causes are
substantially higher than those of non-Aboriginal citizens (201, 209), Inuit infant mortality rates are more than twice as high (201), Aboriginal post-neonatal mortality rates are up to 5 times higher (202, 210), and Inuit life expectancies are the shortest of all Canadians (206). Similar trends in disease mortality and morbidity (211, 212), as well as life expectancy (213, 214), are seen in other developed countries with Aboriginal populations. While there are very few published data on rates of waterborne diseases in Aboriginal communities, the data available do suggest that some Canadian First Nations may experience high rates of infectious gastrointestinal illnesses (208) and some studies suggest this is partly due to limited access to safe water, resulting in inadequate sanitation and hygiene. For example, on First Nations reserves the incidence of giardiasis and shigellosis in Alberta (215), as well as Hepatitis A in British Columbia (216) was twice that of non-Aboriginal communities in the province, and was linked to inadequate water supply; in Manitoba, the incidence of shigellosis was 29 times higher on First Nations reserves than other areas in the province (130).

While there are a few studies on IGI rates in Aboriginal communities, published studies investigating linkages between water quality and IGI in Aboriginal communities are rare, and often lack high quality empirical evidence. One study in Nunavut in 1997 did examine a community indicator of IGI and water quality: this study found *H. Pylori* in drinking water supplies and a *H. Pylori* sero-prevalence of over 50% in the community (217), suggesting a potential waterborne transmission route. In general, research that investigates water quality should also consider human health measures (217) in the community to determine what impact, if any, the contaminated water is having on public health. While research conducted to-date does suggest that water quality issues might
impact IGI public health in some Aboriginal communities, more empirical evidence is needed.

**Conclusion**

Canadian Inuit continue to live an indigenous lifestyle that is closely tied to and reliant upon the natural environment, therefore, they find themselves especially vulnerable to any variation in the local ecosystem (218). Given climate change, the resulting environmental changes predicted might increase Inuit risk of waterborne disease. Therefore, the impacts of climate change on drinking water quality and human health could be substantial in some Inuit communities considering (i) existing disparities in Aboriginal health, (ii) reported water quality issues in Aboriginal communities, and (iii) reported climate change impacts already occurring in some Inuit communities. Despite these concerns, there are very few published empirical studies investigating the relationships between weather, water quality, and public health in Arctic regions, thus, further research is warranted. This research is needed to inform the development of adaptation strategies to manage and become resilient to the impacts of climate change on drinking water and health.

**STUDY RATIONALE**

Based on the synthesis of background information on climate change, water quality, and Aboriginal health, the results of a pilot study investigating weather and water in Nunatsiavut (219), as well as discussions with community members and other stakeholders, the overall goal of this research project is to investigate associations
between weather patterns, drinking water quality, and infectious gastrointestinal illness (IGI) outcomes in Nunatsiavut, Canada. The specific research objectives are:

1) To evaluate a health registry’s utility and system attributes using modified CDC guidelines for evaluating surveillance systems and use IGI as an example syndrome to provide insight on the quality of data captured by the system (Chapter Two); and

2) To gather, describe, and analyse comparisons of temporal weather patterns, water quality, and IGI-related health data in two Nunatsiavut communities (Chapter Three).

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Table 1.1. Search terms used to identify relevant literature on the burden of waterborne illnesses, water relationships with climate change, Aboriginal health data collection, and climate change impacts on water in Aboriginal populations.

<table>
<thead>
<tr>
<th>Research question</th>
<th>Population terms</th>
<th>Exposure terms</th>
<th>Outcome terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) What is the burden of waterborne diseases?</td>
<td>human OR people</td>
<td>(water) AND (waterborne OR gastrointestinal illness OR diarrhea OR diarrhoea OR vomiting OR water-borne)</td>
<td>incidence OR prevalence OR rate</td>
</tr>
<tr>
<td>2) Will/does climate change influence waterborne diseases?</td>
<td>human OR people</td>
<td>climate change OR rain OR heat OR rainfall OR snow melt OR weather OR temperature</td>
<td>waterborne OR gastrointestinal illness OR diarrhea OR vomiting OR water-borne</td>
</tr>
<tr>
<td>3) Is the quality of Aboriginal health data collected of high quality?</td>
<td>health surveillance evaluation OR health surveillance assessment</td>
<td>health registry evaluation OR health registry assessment</td>
<td>human OR person</td>
</tr>
<tr>
<td>4) Will/does climate change influence waterborne diseases in Canadian Aboriginal communities?</td>
<td>Aboriginal OR Indigenous OR Native OR Inuit OR First Nation OR Indian</td>
<td>water</td>
<td>disease OR illness</td>
</tr>
</tbody>
</table>
Table 1.2. Examples of published academic studies reporting waterborne disease associated with drinking raw water by country or region.

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Study Year</th>
<th>Studies associating IGI with raw drinking water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>Uganda, Tanzania, Kenya</td>
<td>1967, 1997</td>
<td>(134)</td>
</tr>
<tr>
<td></td>
<td>Kenya</td>
<td>1995</td>
<td>(220)</td>
</tr>
<tr>
<td></td>
<td>Kenya</td>
<td>1997-1998</td>
<td>(221)</td>
</tr>
<tr>
<td></td>
<td>South Africa</td>
<td>1998</td>
<td>(222)</td>
</tr>
<tr>
<td></td>
<td>Swaziland</td>
<td>1990-1992</td>
<td>(63)</td>
</tr>
<tr>
<td>Asia</td>
<td>China</td>
<td>1994</td>
<td>(42)</td>
</tr>
<tr>
<td></td>
<td>Indonesia</td>
<td>1999</td>
<td>(224)</td>
</tr>
<tr>
<td></td>
<td>Vietnam</td>
<td>2001-2002</td>
<td>(225)</td>
</tr>
<tr>
<td>Australia</td>
<td>Australia</td>
<td>2001-2002</td>
<td>(226)</td>
</tr>
<tr>
<td></td>
<td>Albania</td>
<td>-</td>
<td>(227)</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>2002</td>
<td>(228)</td>
</tr>
<tr>
<td></td>
<td>Kazakhstan</td>
<td>1999</td>
<td>(229)</td>
</tr>
<tr>
<td>India</td>
<td>India</td>
<td>1993-2004</td>
<td>(135)</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>(230)</td>
</tr>
<tr>
<td>Middle</td>
<td>Bangladesh</td>
<td>1998</td>
<td>(231)</td>
</tr>
<tr>
<td>East</td>
<td>Jordan</td>
<td>1999-2001</td>
<td>(232)</td>
</tr>
<tr>
<td></td>
<td>Bangladesh</td>
<td>2001</td>
<td>(233)</td>
</tr>
<tr>
<td></td>
<td>Israel</td>
<td>1988</td>
<td>(234)</td>
</tr>
<tr>
<td>North</td>
<td>Canada</td>
<td>1974-2001</td>
<td>(30)</td>
</tr>
<tr>
<td>America</td>
<td>United States</td>
<td>1999-2000</td>
<td>(235)</td>
</tr>
<tr>
<td></td>
<td>United States</td>
<td>2004</td>
<td>(236)</td>
</tr>
<tr>
<td></td>
<td>United States</td>
<td>1995-1996</td>
<td>(237)</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>2002</td>
<td>(238)</td>
</tr>
<tr>
<td>Russia</td>
<td>Russia</td>
<td>1998-2000</td>
<td>(20)</td>
</tr>
<tr>
<td></td>
<td>Russia</td>
<td>1999</td>
<td>(33)</td>
</tr>
<tr>
<td>South</td>
<td>Peru</td>
<td>1995-1998</td>
<td>(150)</td>
</tr>
<tr>
<td>America</td>
<td>Brazil</td>
<td>2002</td>
<td>(239)</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>1997-1998; 2003-2004</td>
<td>(240)</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>1997-1999</td>
<td>(241)</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>-</td>
<td>(242)</td>
</tr>
<tr>
<td></td>
<td>Peru</td>
<td>1995-1997</td>
<td>(243)</td>
</tr>
</tbody>
</table>
Table 1.1. A summary of estimates of the economic burden of IGI in various countries in 2005 USD and in 2004 international dollars (ID). The variables used to calculate economic burden of IGI vary by study.

<table>
<thead>
<tr>
<th>Source</th>
<th>Country</th>
<th>Location</th>
<th>Study Period</th>
<th>Population</th>
<th>Currency in Study</th>
<th>Official Exchange Rate to 2004 USD</th>
<th>Cost per Illness</th>
<th>Total Cost of IGI*</th>
<th>Cost per Illness†</th>
<th>Total Cost of IGI‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>(244)</td>
<td>Australia</td>
<td>South Australia</td>
<td>Feb 1999–May 1999</td>
<td>Children with diarrhoea</td>
<td>AU</td>
<td>1.36</td>
<td>93</td>
<td>27.03</td>
<td>1.4</td>
<td>95</td>
</tr>
<tr>
<td>(245)</td>
<td>Australia</td>
<td>Melbourne</td>
<td>Sep 1997 – Feb 1999</td>
<td>Individuals with IGI</td>
<td>AU</td>
<td>1.36</td>
<td>40</td>
<td>607.43</td>
<td>1.4</td>
<td>41</td>
</tr>
<tr>
<td>(246)</td>
<td>Austria</td>
<td>Innsbruck and Leoben</td>
<td>Dec 1997–May 1998</td>
<td>Children with Rotavirus</td>
<td>EURO†</td>
<td>0.81</td>
<td>211-2,064</td>
<td>6.09</td>
<td>0.9</td>
<td>234-2,293</td>
</tr>
<tr>
<td>(247)</td>
<td>Canada</td>
<td>British Columbia</td>
<td>Jun 2002- Jun 2003</td>
<td>Individuals with IGI</td>
<td>CAN</td>
<td>1.30</td>
<td>540-1,973</td>
<td>668.46</td>
<td>1.3</td>
<td>540-18,372</td>
</tr>
<tr>
<td>(249)</td>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(250)</td>
<td>Malaysia</td>
<td>Kuala Lumpur</td>
<td>2002</td>
<td>Children hospitalized with diarrhoea</td>
<td>2002 EURO</td>
<td>3.80</td>
<td>916</td>
<td>7.78</td>
<td>1.8</td>
<td>434</td>
</tr>
<tr>
<td>(251)</td>
<td>South Africa</td>
<td>South Africa</td>
<td>1995</td>
<td>Children hospitalized with Rotavirus</td>
<td>1995 USD R</td>
<td>6.46</td>
<td>1,482</td>
<td>35,579.72</td>
<td>2.7</td>
<td>620</td>
</tr>
<tr>
<td>(252)</td>
<td>Taiwan</td>
<td></td>
<td>2001-2003</td>
<td>Children hospitalized with diarrhoea</td>
<td>2002 USD</td>
<td>1.00</td>
<td>920</td>
<td>32.92</td>
<td>1.9</td>
<td>1,747</td>
</tr>
<tr>
<td>(253)</td>
<td>USA</td>
<td>Orange County, CA</td>
<td>2001</td>
<td>Adult waterborne IGI (recreational water)</td>
<td>2001 USD</td>
<td>1.00</td>
<td>39</td>
<td>1.44</td>
<td>1.0</td>
<td>39</td>
</tr>
<tr>
<td>(254)</td>
<td>USA</td>
<td></td>
<td>1979-1983</td>
<td>Individuals with IGI</td>
<td>1985 USD</td>
<td>1.00</td>
<td>325</td>
<td>32,142.25</td>
<td>1.0</td>
<td>325</td>
</tr>
<tr>
<td>(255)</td>
<td>USA</td>
<td>Houston, TX</td>
<td>1989-1991</td>
<td>Children with diarrhoea at Day-Care</td>
<td>1990 USD</td>
<td>1.00</td>
<td>220</td>
<td>255.74</td>
<td>1.0</td>
<td>220</td>
</tr>
<tr>
<td>(256)</td>
<td>USA</td>
<td>1998</td>
<td></td>
<td>Children with diarrhoea at Day-Care</td>
<td>2000 USD</td>
<td>1.00</td>
<td>n/a</td>
<td>1,224.88</td>
<td>1.0</td>
<td>n/a</td>
</tr>
</tbody>
</table>

* In 1,000,000 USD (2004)
† In 1,000,000 International Dollars (ID; 2004)
‡ Year of currency assumed to be year of study publication
Figure 1.1. A flowchart showing potential climate change impacts on waterborne diseases in Nunatsiavut, Canada. a Moderating influences include non-climate factors that affect climate-related health outcome, such as household practices. b Finished drinking water must meet higher regulatory standards than recreational water or water used for irrigation. c Adaptation measures include actions to reduce risks of water contamination, such as watershed management and enhanced surveillance of waterborne disease outbreaks (adapted from (49)).
ABSTRACT

Background: Currently, there is a lack of high-quality health information available to accurately estimate burdens of disease in some Aboriginal populations, creating gaps in Aboriginal health research.

Objectives: As part of a broader initiative investigating weather, water quality, and human health in Inuit communities of northern Labrador, Canada, this study evaluated a paper-based health registry system that captures data on patient consultations provided by Labrador Grenfell Health (LGH). The main objectives of this study were to (1) evaluate an existing health registry’s utility and system attributes using modified CDC guidelines for evaluating surveillance systems and (2) use infectious gastrointestinal illness (IGI) as a reference syndrome to provide insight on the quality of data captured by the system.

Methods: The CDC’s guidelines for evaluating surveillance systems (2001) were adapted to evaluate a patient visit data system. Qualitative data were gathered from semi-structured interviews with key system stakeholders to examine system utility and system
attributes. Data quality was examined by extracting and analysing IGI data from the registries of two Nunatsiavut communities (2005-2008).

**Results:** The evaluation uncovered limitations in both data quality (e.g. poor coding of patient visit events) and data accessibility. These findings resulted in recommendations for LGH to improve Inuit health data capture in the region, including the conversion to an electronic system.

**Conclusions:** The CDC’s guidelines for evaluating surveillance systems provided a useful framework to evaluate the health registry system. Use of IGI as a reference syndrome provided information on the data quality captured by the system that was useful to the broader environmental health project, as well as LGH. Evaluations of existing Aboriginal health registry systems involving a variety of stakeholders are necessary to identify system weaknesses and strengths in order to improve the quality of health data captured.

**INTRODUCTION**

Health registries systematically collect data related to health-events and often provide data to public health surveillance systems for on-going and systematic collection, analysis, interpretation, and dissemination of data related to health-events (1). Monitoring health-events is critical to public health practice because it allows for estimating the magnitude of a health problem, understanding the natural history of a disease, detecting epidemics, examining disease distribution and spread, and evaluating control measures (1). In turn, this information informs the prioritisation of public health
actions, program planning, interventions, and research for disease prevention and health promotion (1).

Periodic evaluations of health registry systems are important to ensure that the registry is meeting its objectives efficiently and effectively. A widely used framework is the Centers for Disease Control and Prevention’s (CDC) Guidelines for Evaluating Public Health Surveillance Systems (2). While these guidelines are intended for evaluating health surveillance systems, this framework could be adapted to evaluate registry systems. Moreover, to evaluate the quality of data captured by the system, it can be useful to examine all data related to a pre-determined, reference syndrome (3).

Evaluations of Aboriginal health registries, surveillance systems, and associated databases are especially critical due to a recognised lack of good quality health data (4-6). Aboriginal populations often live in substandard conditions and do not have access to the same quantity and quality of resources as other non-Aboriginal citizens, which contributes to disparities in health (5, 6). For example, in Canada, compared to non-Aboriginal citizens, Aboriginal disease mortality and morbidity rates from all causes are substantially higher (7, 8), Inuit infant mortality rates are more than twice as high (8), Aboriginal post-neonatal mortality rates are up to five times higher (9), and Inuit life expectancies are the shortest of all Canadians (10). These increased rates need to be better understood by investigating disease and environmental risk factors; however, relevant health data of adequate quality are extremely limited resulting in inaccurate and generally under-estimated Aboriginal disease rates (11, 12). This lack in available data is partly due to gaps in Aboriginal health data collection, as well as poor quality of data captured. For example, in Canada, the United States and Australia, some health
databases and registries do not capture ethnicity/cultural** data that would allow
investigations of Aboriginal health (11-15). Furthermore, even when ethnicity/cultural
information is collected in population health databases, the following can considerably
compromise the quality of the Aboriginal health data that are captured: lack of uniform
reporting (11, 12, 16), low levels of completeness (17), high monetary costs of patient
follow-up (18), and lack of validity (4, 19). Furthermore, the remote location of many
Aboriginal communities can limit access to health care, resulting in limited human
resources to provide high quality health care, as well as reduce care-seeking behaviour,
which can further compromise the quality and accuracy of health data captured (9, 11, 12,
16). Consequently, in some countries, national reports of annual disease burden exclude
Aboriginal-specific data leaving unfortunate gaps in Aboriginal health statistics and
research (17).

In the northern Inuit communities of Labrador, Canada, primary healthcare is
provided by the Labrador Grenfell Regional Health Authority. Labrador Grenfell Health
(LGH) has community health clinics in each of Labrador’s seven northern coastal
communities (Figure 2.1) where patients are provided primary care by resident nurses
and visiting physicians; when necessary, patients are medically evacuated by air to the
Labrador Health Center (LHC) in Goose Bay. All seven northern clinics use the paper-
based “E-Book” health registry system to record information regarding patient visits,
including patient name, date of birth, sex, ethnic/cultural origin, medical insurance

** Past literature examining Aboriginal health data often use the term ‘ethnicity’; however, here the term ‘ethnicity/cultural’ is used to recognize that the term “Aboriginal Peoples refers to organic political and cultural entities that stem historically from the original people of North America, rather than collections of individuals united by so-called ‘racial’ characteristics” (15).
number, date of clinic visit, diagnosis description, disease codes (ICD-9), who examined the patient, along with other relevant information.

The E-Book health registry was suggested as a source of data on infectious gastrointestinal illness (IGI) clinic visits for a companion study investigating potential associations between weather, water quality, and human health (see Chapter Three). First however, it was necessary to evaluate and understand the patient health data capture system from which the IGI health data were drawn. This study presents the methodology developed and outcomes of that evaluation process using IGI as a reference syndrome. The main objectives of the evaluation were to: (1) evaluate the health registry’s usefulness and system attributes using modified CDC guidelines for evaluating surveillance systems, and (2) use IGI as a reference syndrome to provide insight on data quality captured by the E-Book system in two Inuit communities.

METHODS

Study Communities

E-Book health registries in two northern community clinics, Nain and Rigolet, were used for the evaluation. Nain (56°N, 61°W) is the most northern community in Labrador with a population of 1,034, mainly Inuit residents (91.8%), with approximately equal numbers of men and women, and 73% of the population over 15 years of age (20). The clinic is staffed by six regional nurses, five personal care attendants (PCAs), one laboratory attendant, four maintenance repairers, one clerk typist, and a visiting physician (monthly). The clinic has four holding beds, an incubator, basic trauma and resuscitation equipment, and a defibrillator.
Rigolet (54°N, 58°W) has a population of 269, approximately equal numbers of men and women; most residents identify as Inuit (94.3%), and 81.5% of the population are over 15 years of age (20). Rigolet’s Groswater Bay Clinic is staffed by two regional nurses, one PCA, and a visiting physician (once every 6 weeks). The clinic has one holding bed, basic trauma and resuscitation equipment, and a defibrillator.

E-Book Evaluation

The CDC’s Guidelines for Evaluating Public Health Surveillance Systems provided the framework for the E-Book health registry evaluation (2, 21). Briefly, this framework involves five tasks: (i) engaging stakeholders; (ii) describing the system; (iii) focusing the evaluation design; (iv) evaluating system usefulness and attributes; and (v) stating recommendations and sharing lessons learned (2). The CDC guidelines recommend examining nine system attributes ((Table 2.1) (2)). Two of these system attributes, sensitivity and positive predictive value, were not evaluated because there was no other appropriate source of IGI data in northern Labrador with which to compare the IGI data captured by the E-Book health registry.

Qualitative methods were used to evaluate simplicity, flexibility, acceptability, timeliness, and stability attributes of the E-Book system. Analyses of registry attributes were based on the registry’s design, documents related to the E-Book registry, and information obtained from key informant interviews. Seven key E-Book stakeholders (health officials) from community and regional levels were invited for confidential in-person, on-site, semi-structured interviews that were audio-recorded (with permission) in February 2008 (Appendix 4).
To evaluate system representativeness and data quality, IGI was used as a reference syndrome. To examine IGI data captured by the system, de-identified E-Book health registry entries for Nain and Rigolet (January 1, 2005 to October 31, 2008) were reviewed and entries related to IGI were manually extracted into an electronic database (Excel, Microsoft Office 2007). A broad case definition was used to increase sensitivity and case capture, and included vomiting and/or diarrhoea not due to chronic conditions such as colitis, diverticulitis, Crohn's disease, and irritable bowel syndrome, as well as illness from pregnancy, medication use, and alcohol/drug use (22). Transcription accuracy was assessed using a random systematic sample of 10% of the extracted IGI entries, with an acceptable error rate of less than 5%. Using systematic random sampling, age and sex proportions were extracted from records of clinic visits for all causes from January 1 - October 31, 2008 for Nain (n=598) and Rigolet (n=166). These proportions were then compared to 2006 Canadian Census data (20) to determine if certain segments of the population (by age and sex) used the clinic more often than others. Ethics approval was obtained from the University of Guelph Research Ethics Board and LGH.

RESULTS

For the period January 1, 2005 to October 31, 2008, the E-Books contained a total of 48,620 clinic records in Nain, and 16,656 clinic records in Rigolet; 541 and 175 records were related to IGI, respectively. The overall proportion of IGI consultations out of all clinic visits from January 1, 2005 to October 31, 2008 was 1.1% in Nain and 1.0%
in Rigolet (Table 2.2). A detailed description of IGI clinic visit trends by season, sex, and age are presented elsewhere (see Chapter Three).

**System Evaluation**

Seven LGH employees that regularly worked with the E-Book system at regional and community levels were interviewed (response rate = 100%). Each system attribute was qualitatively ranked as being a major strength, strength, limitation, or severe limitation of the system based on stakeholder interviews, document review, and data quality analysis (Table 2.1). Interview responses are summarised by system attribute below.

*i) Purpose and Objectives of the System:* Based on E-Book documents and interviews, no record could be found, nor could interviewees remember the original purpose of the E-Book health registry. All respondents reported that the detailed data requested for this system should be utilised for health statistics and feedback on the overall health of each community.

*ii) System Design and Scope:* Figure 2.2 illustrates the patient visit data capture system. The attending nurse entered patient information on a patient chart. From this chart, the PCA or clerk copies patient visit records into the E-Book, ascribing ICD-9 codes associated with the diagnosis or complaint. Month-end summaries of total patient counts were sent to LHC where count data were transferred from paper to an electronic file. These data eventually contributed to annual reports that were disseminated to community clinics and senior LGH management to inform decision making processes, including clinic workload and budget requirements.
iii) **Simplicity:** The structure of the E-Book health registry system was described as relatively simple (Figure 2.2); however, some stakeholders reported that registry operation was not easy due to disease coding procedures. Most reported that the ICD-9 coding scheme could be unclear, confusing, inconsistent, outdated, and a burden on time. Furthermore, some PCAs and clerks who coded data often had little or no healthcare or ICD training, making coding even more difficult.

iv) **Flexibility:** Some respondents expressed concern regarding the flexibility of the system to capture new or emerging diseases and new case definitions due to the limitations of, and dependency on, the available short-list of ICD-9 codes. Furthermore, while the system had few supply costs, personnel costs were considered high because of the time-consuming transcription, making the system vulnerable to personnel funding cuts. All stakeholders agreed that converting to an electronic system could bring more flexibility to the system.

v) **Data Quality:** With regard to IGI clinic visits in both communities, excluding ICD-9 entries, over 99% of fields were complete; however, one community did not fill in ICD-9 codes. Examining validity of IGI data captured by one community’s E-Book health registry (2005-2007) revealed that 18.31% of IGI diagnosis descriptions did not match the assigned ICD-9 code. With regard to all entries in the E-Books (e.g. all diagnoses), 6.2% of out-patient department numbers were incorrect, some entries were illegible (0.23-11.70% per month), and others were out of chronological order (11.00-42.22% per month).

vi) **Acceptability:** It was reported by respondents that all northern community clinics participated in the E-Book health registry system; however, the level of
participation was reported to vary by community. System components that were reported by stakeholders to have low acceptability included security, usefulness, time burden, and data dissemination to stakeholders. In particular, most community level respondents felt that the frequency and type of data analysis was not acceptable, and that the time required to record the extensive data into the registry did not seem justified considering its use and minimal feedback.

vii) Representativeness. In one community, comparisons between sex proportions in the population and clinic visitors revealed that females were over-represented in clinic visits. In both communities, the proportion of people under age 20 visiting the clinic was slightly lower, and the proportions of those over 75 visiting the clinic were much higher, than the age proportions in the actual community.

viii) Timeliness: The data collected by the system were analysed annually to inform year-end hiring and budget decisions. For these purposes, the time from data capture to data analyses was considered acceptable. However, for data to be used for other purposes, such as disease surveillance, the current system timeliness was considered unacceptable by stakeholders.

ix) Stability: Overall, the stakeholders reported that due to the paper-based nature of the system, it operated with few interruptions. The availability of E-Book information for use by its stakeholders was also examined: monthly statistical counts were considered by regional stakeholders as easy to access to inform annual hiring and budgeting decisions. Conversely, the availability and accessibility of data for other uses by registry stakeholders was considered quite poor by all community stakeholders and some regional stakeholders.
DISCUSSION

The CDC’s *Guidelines for Evaluating Public Health Surveillance Systems* (2) provided a useful framework for evaluating a patient visit registry system. In this study, this framework was used to engage system stakeholders and examine data quality, thus making it possible to provide informed recommendations to LGH related to specific attributes of their health registry system in Nunatsiavut (Appendix 5). Therefore, although the CDC’s guidelines are intended to evaluate health surveillance systems, this study demonstrated how this framework can be successfully adapted to evaluate health registry systems in general.

This study highlighted the need to understand how data are being collected and subsequently how they can be utilised in other research studies. For instance, descriptive analyses on the reference syndrome (IGI) provided insight on data quality and informed decisions regarding the use of health data for a comprehensive study linking weather, water, and human health in Nunatsiavut. Furthermore, similar to other evaluations using a reference syndrome (23-25), these descriptive analyses provided LGH with new and useful information regarding IGI clinic visit trends in Nunatsiavut. The findings of this study also have broader implications in Canada and abroad, especially when considering the gaps in Aboriginal health statistics. This step of descriptive data analysis is critical (17) in all evaluations because it increases understanding of Aboriginal health, and this information would be useful to health care providers, policy makers, and health researchers for improving public health.

The original purpose of the E-Book system was apparently lost or forgotten, and the current understanding of the objectives was particularly unclear and vague to all
stakeholders. To improve the registry, the system goal should be clarified because the most critical component of any system is a clearly defined, well understood, and widely accepted purpose and objective(s) (21). In general, periodic system evaluations, or initial evaluations in the case of many Aboriginal health registries, are needed to ensure that the system is meeting the stakeholders’ needs and allow monitoring of the system’s ability to meet its goals. These evaluations could also be used to strengthen or clarify the system’s purpose and objectives.

Similar ICD-9 coding frustrations to those identified here have been reported elsewhere (26-28), and might explain the poor quality of coded data in the E-Book system and in other systems (29, 30). Updating to ICD-10 codes might alleviate some coding frustrations in Nunatsiavut because other studies have reported that ICD-10 codes provide clearer disease definitions (31), result in higher quality data capture (31, 32), and allow more detailed diagnoses (33) than ICD-9 codes. Moreover, clerks with little healthcare training in Nunatsiavut were often responsible for coding, which can result in coding errors and compromised data quality (27, 28). Thus, in these communities and potentially other remote communities, providing ICD training to nurses, PCAs, and clerks could make coding easier to understand and more efficient (28, 34). Training courses in any Aboriginal context should be designed to be accessible and appropriate for remote locations. For example, training modules should be designed with the involvement of multiple stakeholders to ensure cultural respect, local relevance, appropriate language(s), suitable learning platform and pedagogy (e.g. in-person vs. online training), and accessibility and affordability to all appropriate stakeholders.
The E-Book registry evaluation uncovered poor quality and accessibility of coded data. Paper-based systems, such as the E-Book registry, tend to be prone to human error, resulting in illegible, missing, and incomplete entries (29). For example, the E-Book registry had some entries in which descriptions did not match the assigned ICD-9, outpatient department numbers were incorrect, entries were illegible, and visits recorded out of chronological order. Thus, converting existing paper-based registries to electronic registries for capture of Aboriginal health data could increase data quality (35-38) because software could be programmed to employ data validity checks during data entry, allow improvement via data editing, consolidate health information into one entry (39), and facilitate the effective and efficient assignment of disease codes (26, 27). Moreover, conversion to electronic systems would also improve the accessibility and usability of captured data (26, 35, 36, 40-42) and allow more timely responses to health-events in a community (35, 37, 38). In general, considering the remote locations of many Aboriginal communities and the successes of electronic health registries, developing an electronic data collection system that would provide an excellent patient visit registry, as well as serve to provide community level health statistics in near real time, would enhance Aboriginal public health surveillance.

In summary, adapting the CDC’s framework for evaluating surveillance systems to evaluate a health registry system was useful and resulted in recommendations to improve the quality and usefulness of Inuit health data captured in Nunatsiavut. A reference syndrome was used to aid in analyses, which provided LGH with new and useful information on IGI clinic visit trends and community IGI health. Evaluations of Aboriginal databases could indicate ways to improve existing registries, or indicate that
new registry systems need to be implemented, creating opportunities to develop new methodologies and techniques to collect health data that are socially, culturally, and geographically relevant. A standardised evaluative process, perhaps such as the one presented here, should be conducted on all existing Aboriginal health data collection systems because it provides a quick, effective, and simple starting point in addressing the necessity to improve the quality of available Aboriginal health data. Higher quality health data are essential to improve our understanding of the magnitude of Aboriginal health problems and will allow for the prioritisation of actions, program planning, and research for disease prevention and health promotion in these populations (1).

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LITERATURE CITED


Table 2.1. Attributes used to evaluate the E-Book health registry used by Labrador Grenfell Health (LGH), Newfoundland and Labrador, Canada (2, 43).

<table>
<thead>
<tr>
<th>Surveillance Attribute</th>
<th>Definition</th>
<th>Method of Evaluation</th>
<th>Qualitative Judgment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplicity</td>
<td>System design</td>
<td>Qualitative</td>
<td>Major strength</td>
</tr>
<tr>
<td></td>
<td>System ease of operation</td>
<td></td>
<td>Limitation</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Ability to adapt to changing information needs or operating conditions</td>
<td>Qualitative</td>
<td>Strength</td>
</tr>
<tr>
<td>Data quality</td>
<td>Completeness of data recorded</td>
<td>Quantitative</td>
<td>Limitation</td>
</tr>
<tr>
<td></td>
<td>Validity of data recorded</td>
<td></td>
<td>Limitation</td>
</tr>
<tr>
<td>Acceptability</td>
<td>Willingness to participate in the system</td>
<td>Qualitative</td>
<td>Strength</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>The proportion of true cases detected by the system</td>
<td>Not evaluated</td>
<td>-</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>The proportion of reported true cases</td>
<td>Not evaluated</td>
<td>-</td>
</tr>
<tr>
<td>Representativeness</td>
<td>The ability to describe a health-event’s distribution in the population by place and time</td>
<td>Quantitative</td>
<td>Strength</td>
</tr>
<tr>
<td>Timeliness</td>
<td>Speed between steps in the system</td>
<td>Qualitative</td>
<td>Strength</td>
</tr>
<tr>
<td>Stability</td>
<td>Reliability to operate without failure</td>
<td>Qualitative</td>
<td>Strength</td>
</tr>
<tr>
<td></td>
<td>Availability of information to be used by system stakeholders</td>
<td></td>
<td>Severe limitation</td>
</tr>
</tbody>
</table>
Table 2.2. Annual counts of the number of infectious gastrointestinal illness (IGI) related patient visits and total patient visits to the clinics in Nain and Rigolet (Labrador, Canada) from January 1, 2005 to October 31, 2008.

<table>
<thead>
<tr>
<th>Year</th>
<th>Nain</th>
<th></th>
<th></th>
<th>Rigolet</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IGI Clinic Visits</td>
<td>Total Clinic Visits</td>
<td>Proportion IGI (%)</td>
<td>IGI Clinic Visits</td>
<td>Total Clinic Visits</td>
</tr>
<tr>
<td>2005</td>
<td>130</td>
<td>16,370</td>
<td>0.8</td>
<td>33</td>
<td>5,202</td>
</tr>
<tr>
<td>2006</td>
<td>107</td>
<td>12,697</td>
<td>0.8</td>
<td>47</td>
<td>4,280</td>
</tr>
<tr>
<td>2007</td>
<td>188</td>
<td>11,921</td>
<td>1.6</td>
<td>41</td>
<td>4,365</td>
</tr>
<tr>
<td>2008</td>
<td>116</td>
<td>10,500</td>
<td>1.1</td>
<td>54</td>
<td>3,510</td>
</tr>
<tr>
<td>Overall</td>
<td>541</td>
<td>51,488</td>
<td>1.1</td>
<td>175</td>
<td>17,357</td>
</tr>
</tbody>
</table>

* Statistics Canada, 2006 (20)
† Infectious gastrointestinal illness
‡ Clinic records from January 1 – October 31, 2008

Nain population = 1034
Rigolet population = 269
Figure 2.1. A map of Labrador’s seven northern coastal communities where Labrador Grenfell Health (LGH) has community health clinics (Newfoundland and Labrador, Canada).
Figure 2.1. A flowchart displaying the flow of data captured by the E-Book health registry used by Labrador Grenfell Health (LGH), Newfoundland and Labrador, Canada.
CHAPTER THREE

COMPARISON OF TRENDS IN WEATHER, WATER QUALITY, AND INFECTIOUS GASTROINTESTINAL ILLNESS IN TWO INUIT COMMUNITIES IN NUNATSIAVUT, CANADA: POTENTIAL IMPLICATIONS OF CLIMATE CHANGE

ABSTRACT

Background: Climate change is expected to cause changes in precipitation, runoff, and hydrological extremes that will alter environmental conditions. It has been argued that these ecological changes are very likely to increase the risk and incidence of infectious disease (1-4), including waterborne disease (5-9).

Objectives: The overall objective of this study was to gather, describe, and analyse comparisons of weather, water quality, and IGI-related health data in two Nunatsiavut communities.

Methods: Weather data were obtained from meteorological stations in Nain (2005-2008) and Rigolet (2008). Free-chlorine residual levels in drinking water were extracted from municipal records (2005-2008). Raw surface water was tested weekly for total coliforms and E. coli counts using Colilert© kits; these data were obtained retrospectively from the Nunatsiavut Government (2007) and prospectively by trained local personnel (2008). Aggregate daily counts of all patient visits and those related specifically to IGI complaints were obtained from de-identified E-Book Health Registry entries (2005-
Temporal patterns of weather, water quality, and health variables were analysed and compared using seasonal-trend decomposition procedures based on Loess, Loess smoothers, and linear regression.

**Results:** Seasonal water volume input (rainfall + snowmelt) peaked in the spring and summer in Nain. Bacteriological variables for raw water had a significant positive association with water volume input in Nain. Seasonal patient visits related to IGI peaked in the winter, summer, and fall. Missing observations in weather (Rigolet) and water quality (Nain and Rigolet) data precluded certain analyses.

**Conclusion:** This study is the first to gather, analyse and compare baseline data on weather, water quality, and health systematically in Nunatsiavut. Such empirical data on weather, water quality, and health are unfortunately rare in Inuit regions. This study illustrates the need for systematic gathering of high quality temporal baseline information against which any future impacts of climate change on Inuit human and environmental health can be detected in Nunatsiavut and other Arctic regions.

**INTRODUCTION**

Build-up of greenhouse gases in the atmosphere is warming the Earth (10, 11) and there is evidence that the Canadian North is already experiencing changes in climate at an alarming rate (12-15). Thus, many consider climate change to be the most pressing ecological issue facing Canadian Inuit today (15-17). Generally it is suggested that climate change will result in changes in temperature, precipitation, evapotranspiration, runoff, and hydrological extremes, which will change environmental conditions (10). It has been argued that these ecological changes will very likely increase the risk and
incidence of infectious disease (1-4), including waterborne diseases (5-9). These predictions are based on studies that investigated associations between weather events and waterborne disease, but are discussed in the context of climate change and focus on rainfall events, rapid snowmelt, flood events, and increased temperature. For example, during periods of heavy rainfall and rapid snowmelt, the channel system expands, the water velocity increases, and overland flow and shallow subsurface flow can occur. This runoff is capable of transporting pathogens and contaminating drinking water sources. Heavy rainfall and flooding can increase surface water turbidity through overland flow and/or channel erosion, and high turbidity levels can protect pathogens from disinfection and increase the required amount of chlorine for adequate disinfection (18), as well as hinder other disinfection techniques (19). As a result of this run-off and increased turbidity, the risk of exposure to waterborne pathogens might be increased (20-24).

While these types of relationships between weather events, water quality, and health have been documented in Canada, little research has specifically investigated these relationships in the Canadian North. Due to limited availability of empirical data, research investigating the impacts of climate change on public health in the North has so far relied on Indigenous knowledge and stories (15-17, 25). This research has provided valuable information for risk assessments and informing future research directions; however, there is a need to greatly improve the quality of systematic monitoring of empirical environmental and human health data in Arctic regions, including water-related diseases. Indeed, few published studies have focused specifically on issues with safe drinking water in Aboriginal communities, although anecdotally these communities have experienced more water problems than other areas in Canada (26, 27). Perceived water
quality concerns have been reported in Inuit regions, where 34% of Canadian Inuit reported that they believed there were times during the year when their water was contaminated and 18% reported that the water available to their homes was not safe (28). In other studies, water sampling in Inuit regions uncovered water quality problems (29-31); however, these empirical studies are rare. Problems regarding accessibility to safe drinking water have also been reported, and include reports that 90 times more Aboriginal households were without access to piped water than other Canadian households (29).

The reported water quality and accessibility issues in these Aboriginal communities could increase the risk of waterborne disease, including infectious gastrointestinal illnesses (IGI). While few studies investigated Aboriginal water-related IGI public health, enteric illnesses are suspected to be endemic or high in Canadian Aboriginal populations (31-35). While research conducted to date does suggest that existing water quality issues could impact IGI public health in some Aboriginal communities, more empirical evidence is needed to investigate the impact of water quality and accessibility on community health. Because Inuit culture and practices are closely tied to and reliant upon the natural environment, they may be especially vulnerable to even small variations in the local ecosystem (15). Thus, even subtle environmental changes caused by climatic changes could increase the risk of waterborne disease to Inuit and compound existing concerns with current drinking water quality and availability.

In Inuit communities of Labrador, now collectively called Nunatsiavut, reports from scientists and residents alike indicate that recent years have been characterised by
higher temperatures, increased intensity and frequency of storms, and changes in rainfall patterns (15-17, 36). Labrador Inuit have expressed concern about the quality of their drinking water. For example, in 2001 33% of Labrador Inuit reported that they believed their water was contaminated at certain times of the year, and 12% reported that they believe water available at their homes was unsafe (28). In the community of Rigolet in 2001, 100% of Inuit reported that during certain times of the year, they believe their water is not safe (28). A pilot study conducted in 2006 investigated drinking water quality and weather patterns in Nain and Rigolet, Nunatsiavut (37). This study reported that some residents collect and drink untreated surface water, especially when out on the land hunting or at their cabins; a practice that exists in other Inuit regions and probably stems from traditional drinking water habits and personal preferences (30). Drinking from raw water sources without treatment could present increased risks of waterborne disease under climate change scenarios (30). Recommendations from the pilot study included further investigation into the risk of waterborne illness and the related potential human and environmental health impacts of climate change in Inuit communities (37). Therefore, the overall objective of this study was to gather, describe, and analyse temporal relationships between weather, water quality, and IGI-related health data in two Nunatsiavut communities.

METHODS

Study Communities

This study was conducted in collaboration with two Inuit communities in Nunatsiavut, Canada: Nain and Rigolet (Figure 3.1). Nain (56º N, 61º W) is the most
northern community in Nunatsiavut with a population of 1,034; most residents identify as Inuit (91.8%), with approximately equal numbers of men and women, and 27.1% of the population under the age of 15 years (38). Rigolet (54° N, 58° W) is the most southern Inuit community in Nunatsiavut, with a population of 269. Most residents identify as Inuit (94.3%), with approximately equal numbers of men and women; 18.5% of the population are under the age of 15 years (38). Both communities have a Labrador Grenfell Health Authority health clinic staffed by resident nurses and a visiting physician. In 2007, there were 11,921 patient consultations (approximately 11.5 visits/person) in Nain and 4,365 patient consultations (approximately 16.2 visits/person) in Rigolet (see Chapter Two).

An ecosystem approach to health research (39) was adopted for this study, in which local and regional stakeholders participated in all phases of research design, planning, data collection, data analyses, and conclusions to ensure cultural sensitivity and respect, as well as research relevance and suitability. The project was formally approved by the Nunatsiavut Government, Nain Inuit Community Government, Rigolet Inuit Community Government, Labrador Grenfell Health Authority, and the University of Guelph Research Ethics Board.

Weather Data

In Nain, daily average temperature (°C), total daily rainfall (mm), and daily snow depth (cm) data were obtained from an Environment Canada meteorological station located at the community airport (January 1, 2005 - October 31, 2008; (40)). Water volume input in mm water equivalent (mm w.e.) was calculated as follows:
\textit{Water Volume Input (mm w.e.)} = \textit{Rain (mm)} + \textit{Snowmelt (mm w.e.)};

where snowmelt (mm w.e.) equals the negative change in snow depth ($d_2 - d_1$, where $d_1 > d_2$ cm)*snow density(0.25 g cm$^{-3}$)*10. Prior to this study, Rigolet did not have a community meteorological station, thus, a new community meteorological station (HOBO® Weather Station) was placed at the community’s water reservoir in November 2007. Hourly temperature ($^\circ$C; May 15, 2008 - October 31, 2008) and rainfall (mm; August 22 - October 31, 2008) data were captured.

\textbf{Water Data}

In both communities, surface water from small man-made reservoirs was chlorinated and piped underground via gravity to the communities. In Nain, free-chlorine residual levels (mg/L) at start, end, and intermediate (the public school) points in the distribution system were obtained from available daily municipal records (May 24, 2007 - October 31, 2008). In Rigolet, available bi-weekly municipal records of free-chlorine residual levels (mg/L) at an intermediate point in the system (the public school) were obtained (July 7, 2005 - October 2008).

In each community, local personnel were hired and trained to collect water samples (100 mL) in sterile bottles for testing using IDEXX Colilert® QuantiTray®/2000 following the manufacturer’s instructions (41) to detect the most probable number (MPN) of total coliforms and \textit{Escherichia coli} (\textit{E. coli}) per 100 mL. In Nain, retrospective data for Anainak’s Brook (56° 31’ 914” N, 61° 41’ 644” W) were obtained from the Nunatsiavut Government (January 21, 2005 - November 2, 2006). Prospective water samples in Nain (May 5, 2008 - October 31, 2008) and Rigolet (May 15, 2008 -
October 31, 2008) were collected on a weekly basis and for each of three days following a high impact weather event (e.g. heavy rainfall or rapid snow melt) at two locations per community: at the pre-treatment water reservoir (Nain: 56° 32' 225'' N, 61° 42' 740'' W; Rigolet: 54° 10' 985'' N, 58° 28' 315'' W) and at one location where some residents obtained untreated water for drinking (Nain: Anainak’s Brook; Rigolet: Old Graveyard Brook 54° 10' 981'' N, 58° 26' 023'' W). Turbidity measures were attempted in both communities: Nain collected samples from both locations and tested them using a handheld turbidity monitor (LaMotte 2020e, version 1.5), while in Rigolet an online turbidity probe (Turner Designs CYCLOPS-7 Submersible Turbidimeter) was integrated into the meteorological station.

**Health Data**

Daily counts of de-identified IGI-related cases presenting to Labrador Grenfell Health clinics in Nain and Rigolet were obtained from historic E-Book Health Registries which logged descriptions of all patient visits to the clinic (Appendix 5). De-identified entries from January 1, 2005 to October 31, 2008 were examined; all visits related to IGI, along with date of visit, age, sex, and ethnicity/culture, were extracted manually into an electronic database (Excel, Microsoft Office 2007) on Labrador Health Centre premises. Cases of IGI were defined as patients with vomiting and/or diarrhoea not attributed to pregnancy, medication use, alcohol/drug use, colitis, diverticulitis, Crohn's disease, irritable bowel syndrome, or other chronic conditions (42). Recorded IGI-related entries were checked for accuracy by review of a systematic random sample of 10% of the entries, with an acceptable error rate of less than 5%.
**Statistical Analyses**

Due to community differences in geography, demography, and data captured, statistical analyses were performed separately for each community. Furthermore, limitations due to missing observations for weather (in Rigolet) and water quality (in Rigolet and Nain) variables influenced the scope of trend analyses.

Seasonal-trend decomposition procedures based on Loess (STL) were conducted, which is a filtering procedure used to decompose time-series data into seasonal, trend, and remainder components. This procedure was chosen because it provides robust estimates of trend and seasonal components and is capable of handling aberrant behaviour in the data and missing observations (43). The procedure produces four plots: a time-series data plot, seasonal component plot, trend component plot, and remainder component plot. The seasonal plot shows the variation in the data at or near the seasonal frequency. The trend component is calculated using Loess smoothers and shows low frequency variation in the data with long-term changes. Finally, the remainder component shows the remaining variation beyond the variation in seasonal or trend components. This procedure was run for daily, weekly, and monthly aggregated data. The daily, weekly, and monthly aggregated data STL plots were examined to determine which explained the most variation by observing seasonal, trend, and remainder components.

In Nain, STL were run for daily, weekly, and monthly aggregated average temperature (°C) and total water volume input (mm w.e.). Missing data precluded these weather analyses for Rigolet. Because *E. coli* is one type of coliform captured in total coliform tests, associations between total coliform MPN and *E. coli* MPN were
investigated using linear regression in Nain and Rigolet. Water quality variables available for Nain and Rigolet were examined for trends using Loess smoothers with a bandwidth of 67%, which is a weighted linear regression conducted on a point of interest using 67% of the surrounding points to obtain a predicted value and are joined to create a smoothed curve (44). In Nain and Rigolet, free-chlorine residual levels in treated water were compared to Canadian averages, provincial standards, World Health Organization (WHO) recommendations, and Public Health Agency of Canada (PHAC) suggestions (45, 46). Finally, a series of univariable linear regressions were conducted to examine potential associations between water volume input and water quality variables in Nain; missing weather observations precluded these analyses for Rigolet.

Patient visit data and the population at risk (2006 Canadian Census data (38)) were used to calculate the incidence rate of IGI-related patient visits, three-year cumulative incidence risk of visiting the clinic with IGI, and the proportion of IGI-related patient visits out of all clinic visits (due to all causes). Distributions of IGI clinic visitors in 2006 were compared to the population at risk for 2006 (38) for each community by sex (using Pearson chi-squared tests) and age (Fisher’s exact test). Ages were categorized by IGI risk groups as reported by Majowicz et al. ((2007), (42)); in the Canadian census data those over the age of 75 were not categorized by age and sex to ensure anonymity (due to small numbers) and thus were not included in the age and sex analyses. In Nain and Rigolet, STL were run for daily, weekly, and monthly aggregated IGI patient visit data. Statistical software included R (version 2.7.2) for STL and Intercooled Stata© 10 (College Station, Texas, USA) for all other analyses; the significance level of all statistical tests was $P < 0.05$. 
RESULTS

Summary statistics for all weather, water quality, and health variables are presented in Table 3.1 and Table 3.2. Plots from STL that were produced using monthly aggregate data were smoother and explained more variation than daily and weekly aggregated data plots (Appendix 6-9). Thus, monthly aggregate data for weather and IGI variables were used to investigate seasonal and trend components (Figure 3.2, Figure 3.3). In Nain, the seasonal component of monthly total water volume input (Figure 3.2) showed the top four seasonal peaks in the spring (March, April, and May) and summer (July) months. In Rigolet, meteorological trends were not assessed due to missing observations (Appendix 10). The trend components of weather variables did not show any clear long term trend.

Free-chlorine residual level records and untreated water bacteriological records were more complete in Nain; however, both communities had too few data to thoroughly investigate temporal trends. Therefore, potential temporal trends in water quality variables collected in Nain and Rigolet were investigated using Loess smoothers. In Nain, free-chlorine residual levels at the start and end points of the distribution system remained somewhat consistent from 2007-2008 (Appendix 11). In both communities, the free-chlorine residual level at intermediate points in the distribution system increased slightly from 2005-2008 (Figure 3.4). In Nain, the mean free-chlorine residual level at the start of the distribution system was 1.34 mg/L (Table 3.1, Table 3.2), which falls within the average Canadian range of 0.4 to 2.0 mg/L; the mean free-chlorine residual level at the end of the distribution system was 0.30 mg/L in Nain, which also falls within the typical Canadian range of 0.04 to 0.8 mg/L (46). Missing data in Rigolet precluded
free-chlorine residual level analysis at the start and end points of the distribution system. The free-chlorine residual level at intermediate points in the system was 0.24 mg/L in Nain and 0.10 mg/L in Rigolet, both of which are below the typical Canadian range of 0.4 to 0.8 mg/L (46). In Nain, the free-chlorine residual levels at intermediate and end points rarely dropped below the provincial guideline levels, and 13% and 11% of dates sampled at end and intermediate distribution points, respectively, dropped below the PHAC and WHO 0.2 mg/L suggested level (45, 46). In Rigolet, the free-chlorine residual levels at the school (an intermediate distribution point) rarely dropped below provincial guidelines, and 85% of dates sampled did drop below the PHAC and WHO 0.2 mg/L suggested guideline (45, 46).

A series of univariable linear regressions between total coliform MPN and E. coli MPN for untreated water in Nain and Rigolet uncovered a significant positive relationship at each sampling location ($P<0.05$). Missing observations in the water bacteriology datasets made it difficult to identify potential temporal trends (Appendix 12-13); however, based on available data, there appears to be an increase in E. coli and total coliform counts in untreated surface water during summer and fall in both communities. Water turbidity variables were not analysed due to equipment malfunctions in both communities.

Univariable linear regression was used to investigate potential relationships between water volume input and water quality variables in Nain (Table 3.3). No significant associations were found between water volume input and free-chlorine residual levels at start ($P=0.17$), end ($P=0.81$), and intermediate ($P=0.82$) points in the distribution system. However, there were significant positive associations between water
volume input and untreated water coliform levels at the pre-treatment water reservoir (P<0.01), as well as Anainak's Brook (P<0.01) in Nain. Similarly, significant positive relationships were found between water volume input and untreated water *E. coli* levels at the pre-treatment water reservoir (P<0.01), as well as Anainak's Brook (P<0.01). Due to missing weather observations in Rigolet, these weather and water analyses were not conducted for this community.

Between January 1, 2005 and October 31, 2008, the incidence rate of IGI-related visits was 0.13 and 0.16 patient visits per person-year, in Nain and Rigolet, respectively; or a 41% and 45% three-year (2005-2007) cumulative incidence risk of visiting the clinic with IGI complaints in Nain and Rigolet, respectively (Table 3.4). The overall proportions of IGI-related consultations out of all patient visits during the study period were 1.1% in Nain and 1.0% in Rigolet (Table 3.4). In both communities, the proportion of females in the population visiting the clinic for IGI symptoms were significantly different than males (Nain: Pearson chi-square test, $x^2$=33.61, df=1, P<0.001; Rigolet: Pearson chi-square test, $x^2$= 6.59, df=1, P=0.010; Figure 3.5). Furthermore, in both communities the proportion of the population visiting the clinic for IGI symptoms were significantly different between age groups (Nain: Pearson chi-square test, $x^2$=180.09, df=7, P<0.001; Rigolet: Fisher’s exact test, P<0.001; Figure 3.5). The proportions of the population in Nain and Rigolet visiting the clinic with IGI complaints by age and sex are displayed in Figure 3.5. From this figure, it appears that generally, the proportions of females, those under 9 years of age, and those over 65 years of age visiting the clinic with IGI symptoms are higher than others. The seasonal component of the STL for monthly IGI-related patient visits showed the top four seasonal peaks of increased IGI-related
patient visits in the summer (June and August) and fall (September and October) months in Nain, and in the winter (January), summer (June and July), and fall (September) months in Rigolet. The data related to IGI patient visits in both communities were complete; however, due to small population sizes and thus low case counts, analyses investigating associations between IGI and other variables, such as water volume input and water quality measures were precluded.

**DISCUSSION**

In Nain, distinct seasonal peaks in total water volume input occurred in the spring and summer. The peaks in the spring months (March to May) are most likely due to snowmelt, whereas the peaks in the summer (July) and fall (September) months are likely due to rainfall. Furthermore, we observed significant positive associations between water volume input and total coliform counts and *E. coli* counts in untreated water sources. These findings could be explained by overland flow transporting pathogens into water sources, as has been described in other studies showing similar results after rainfall (47-51) and flooding (50, 52). This relationship suggests that Nunatsiavut residents who drink untreated brook water might be at an increased risk of exposure to pathogens, especially after periods of heavy rainfall and rapid snowmelt. Furthermore, since increased numbers of bacteria in the pre-treatment water reservoir were observed after these weather events, this also suggests an increased challenge to municipal water treatment. The potential risk could be compounded if these weather events also increase surface water turbidity (18). Increased turbidity can complicate or overwhelm water treatment systems (53, 54), thereby increasing the risk of waterborne disease (20, 54-56).
We found no significant relationships between water volume input and free-chlorine residuals at start, end, or intermediate points of the water distribution system in Nain. This finding suggests that the free-chlorine residual levels in Nain remained relatively consistent regardless of water volume input and that Nain’s current water treatment infrastructure was capable of handling the trends and surges in rainfall or flooding experienced during the study period; however, monitoring should be continued especially considering potential environmental impacts of climate change. Limited availability of weather and water quality data in Rigolet precluded any conclusions on weather and water quality residual associations; further research is suggested to investigate these associations.

The Government of Newfoundland and Labrador requires minimum disinfectant residuals of 0.3 mg/L for water entering the distribution system, and that detectable levels be maintained at intermediate points of the distribution system (57). Conversely, studies suggest a need for a minimum free chlorine residual level of 0.2 mg/L at all points in the system (e.g. start and intermediate points) to control bacterial re-growth in the distribution system and protect human health against waterborne pathogens (58). Therefore, PHAC and WHO both suggest maintenance of a minimum free chlorine residual level of 0.2 mg/L at all points in the system (45, 46). In Nain, the mean free-chlorine residuals at the start of the distribution system were within the typical ranges in Canadian systems (46), and rarely dropped below the PHAC and WHO 0.2 mg/L suggested guideline. However, in both communities, the mean free-chlorine residual levels at intermediate points within the system were lower than typical Canadian systems.
and at times did drop below PHAC and WHO 0.2 mg/L suggested levels (45, 46, 58), especially in Rigolet.

Distinct seasonal peaks in the number of IGI patient visits occurred in winter, summer, and fall months, compared with spring, summer, and fall water volume input peaks. Past Canadian studies have suggested that peaks of IGI in winter months are usually viral infections (59), and most likely explain the winter IGI-related patient visits peak in Rigolet. The seasonal increase in IGI-related patient visits in the summer (20, 22) and fall (59-62) reported here are similar to past findings elsewhere in Canada. Due to missing observations, relationships between IGI patient visits and water volume input were not statistically examined and further research is warranted. Indeed, other studies have found that periods of heavy rainfall were associated with increased rates of diarrhoea (63-66) and waterborne disease outbreaks (9, 21, 22). For example, one study in the United States estimated that up to 51% of waterborne disease outbreaks occurred after a period of heavy rainfall (21). While this might also be the case in Nunatsiavut, further longer-term studies are needed to confirm this hypothesis.

The proportion of patient visits related to IGI relative to total clinic visits (due to all causes) was lower in Nain and Rigolet (approximately 1% of all visits) compared to those reported in another study conducted in three regions in British Columbia, Canada (2.5% of all visits; (67)). The incidence rate of IGI-related visits reported here (0.13-0.16 patient visits per person-year) were higher than reported in Ontario, Canada (0.056 patient visits per person-year; (68)). It is difficult to make inferences regarding the apparent differences between the IGI patient visits reported here compared to other regions due to study design and regional differences. For example, the British Columbia
and Ontario studies captured physician-reported IGI related patient visits, whereas this study used clinic registry data. Furthermore, the differences in IGI-related patient visit trends could be due to differences in health care settings. For example, Nunatsiavut communities are only accessible by air and have no resident physicians, which might limit access to health care and result in differences in care-seeking behaviour (69-72), making patient visit trends difficult to compare to those in other southern regions in Canada. While it would be more useful to compare patient visit trends in Nunatsiavut with other northern Inuit regions, published data from these regions are not available and warrants further research. Furthermore, considering that most Canadian studies use self-reported cases of IGI to estimate disease rates, a future study that investigates the magnitude, distribution, and environmental risk factors of self-reported IGI in Nunatsiavut in comparison to the rates elsewhere in the province, other northern remote communities, and other regions in Canada is needed.

In both communities there were significant differences between sex and age proportions of the population visiting the clinic for IGI-related reasons. When viewing the proportion of the population visiting the clinic by age and sex, there appeared to have been more females, youth (under age 9), and seniors (over age 65) visiting the clinic with IGI complaints than others. Past studies have also reported higher rates of IGI in females than males (59) and suggest that this trend could be attributable to a higher prevalence of gastrointestinal disorders in women (73) or increased exposure to pathogens via food preparation (59) and collecting untreated drinking water from brooks; however, other studies have found opposite sex trends (60, 62). Similarly, higher rates of IGI in youth have also been reported elsewhere (59, 60, 62, 74, 75) and could be attributable to
decreased immunity to pathogens or age-specific behaviours, such as more hand-to-mouth contact (faecal-oral) and decreased hygiene practices. Moreover, past studies found disproportionately high hospitalization and case-fatality rates in the elderly, which could be attributable to decreased immunity to pathogens (76, 77). In this study, however, it was not possible to investigate IGI-related patient visit trends for those over 75 years of age due to low population counts in this age category (to ensure anonymity). These low counts probably reflect a significantly shorter life expectancy in Canadian Inuit compared to other Canadians (29). Thus, it might be appropriate to compare the seniors (or community elders) in Nunatsiavut to the elderly in other Canadian regions. In this situation, the higher proportions of elders visiting the clinic with IGI symptoms are similar to results reported in other studies (76, 77). When investigating age and sex trends of IGI-related patient visits, it is important to note that it is difficult to determine whether the age and sex trends reported here indicate that females and certain age groups actually do experience higher rates of IGI in the community, or whether these groups tend to visit the clinic more often in general. This question could form the basis for future studies.

**Study Limitations**

Some of the weather and water quality variables in this study had many missing observations. Monitoring of turbidity variables was discontinued in both communities due to technological problems that could not be resolved during the study period. The data related to IGI patient visits in both communities were complete; however, due to small population sizes and thus low case counts, longer study periods are required to
investigate associations between IGI and other variables, such as water volume input and water quality measures. More complete and longer term datasets would allow for multivariable modeling to investigate magnitude, distribution, and environmental risk factors for IGI occurrence in Nunatsiavut. These missing observations and small population sizes highlight the difficulties in empirically examining potential human and environmental health impacts of climate change in many Canadian Arctic regions.

The IGI case definition used was very broad to ensure high sensitivity and is assumed to have also captured non-waterborne related IGI cases. The challenge with this, and in other enteric illness studies (42, 59, 68, 78), is determining what proportion of these cases are derived from contaminated water, food, or other sources of infection. Furthermore, because the health registries were de-identified, it was not possible to exclude patients that visited the clinic more than once for the same case of IGI. Therefore, it was not possible to calculate the community rate of IGI based on patient visit data (rather it was the rate of IGI-related visits). The IGI-related patient visit rate is likely an inflated estimate of true population IGI rates, but might be offset somewhat by high under-reporting (60, 68, 79). For example, under-reporting of IGI is considered substantial in Ontario: for every officially reported case of IGI, 73 cases consult a physician, and an estimated 313 cases actually exist in the community (68); similar trends are seen in England (80).

**Conclusions**

It is important to understand the relationships between weather events and waterborne disease in the Arctic in order to adapt to and prepare for future pressures and
impacts of climate change. While existing water treatment infrastructure helps to protect public health, enhanced human capacity to manage and monitor public and private water sources and treatment systems is still needed to protect communities from adverse changes in water quality due to changes in climate. To inform this type of action, there is a need for systematic collection of high quality baseline empirical data that will improve understanding of local relationships between weather events, water quality, and human health in Inuit communities. Community participation and/or direction of this data collection and results dissemination within and across communities in a culturally appropriate and locally-relevant manner is critical, and further research investigating effective knowledge translation methods in Inuit regions is needed. Promoting and supporting enhanced understanding and monitoring of local environment and human health relationships will increase locally developed solutions that are relevant, culturally acceptable, and sustainable, and will help communities to prepare, adapt, manage, and become resilient to changes in water quality due to changes in local climate.

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Table 3.1. Summary of weather, water quality, and infectious gastrointestinal (IGI) data in Nain and Rigolet, Labrador, Canada (January 1, 2005 - October 31, 2008).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAIN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IGI Patient Visit Count</td>
<td>Daily</td>
<td>Jan 1, 2005-Oct 31, 2008</td>
<td>0</td>
<td>0.39</td>
<td>0.00 - 7.00</td>
</tr>
<tr>
<td>Water Volume Input (mm w.e.)</td>
<td>Daily</td>
<td>Jan 1, 2005-Oct 31, 2008</td>
<td>0</td>
<td>1.43</td>
<td>0.00 - 41.20</td>
</tr>
<tr>
<td>Average Temperature (°C)</td>
<td>Daily</td>
<td>Jan 1, 2005-Oct 31, 2008</td>
<td>0</td>
<td>-1.44</td>
<td>-29.80 - 21.70</td>
</tr>
</tbody>
</table>

*Untreated Water total coliform Levels (MPN/100ml)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment Reservoir</td>
<td>Weekly</td>
<td>Jan 21, 2005-Oct 31, 2008</td>
<td>83</td>
<td>15.99</td>
<td>0.00 - 97.80</td>
</tr>
<tr>
<td>Anainak's Brook</td>
<td>Weekly</td>
<td>Jan 21, 2005-Oct 31, 2008</td>
<td>57</td>
<td>21.84</td>
<td>0.00 - 218.70</td>
</tr>
</tbody>
</table>

*Untreated Water E. coli (MPN/100ml)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment Reservoir</td>
<td>Weekly</td>
<td>Jan 21, 2005-Oct 31, 2008</td>
<td>84</td>
<td>7.08</td>
<td>0.00 - 79.10</td>
</tr>
<tr>
<td>Anainak's Brook</td>
<td>Weekly</td>
<td>Jan 21, 2005-Oct 31, 2008</td>
<td>57</td>
<td>0.64</td>
<td>0.00 - 11.60</td>
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*Municipal Treated Water Free-chlorine residual level (mg/L)*

<table>
<thead>
<tr>
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<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of Distribution</td>
<td>Daily</td>
<td>May 24, 2007-Oct 31, 2008</td>
<td>66</td>
<td>1.34</td>
<td>0.00 - 3.84</td>
</tr>
<tr>
<td>End of Distribution</td>
<td>Daily</td>
<td>May 24, 2007-Oct 31, 2008</td>
<td>77</td>
<td>0.30</td>
<td>0.00 - 2.20</td>
</tr>
<tr>
<td>School</td>
<td>Daily</td>
<td>Feb 8, 2005-Oct 31, 2008</td>
<td>85</td>
<td>0.24</td>
<td>0.00 - 3.70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIGOLET</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IGI Patient Visit Count</td>
<td>Daily</td>
<td>Jan 1, 2005-Oct 31, 2008</td>
<td>0</td>
<td>0.12</td>
<td>0.00 - 2.00</td>
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</table>

*Untreated Water total coliform Levels (MPN/100ml)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment Reservoir</td>
<td>Weekly</td>
<td>May 15, 2008-Oct 31, 2008</td>
<td>86</td>
<td>754.96</td>
<td>0.00 - 2419.60</td>
</tr>
<tr>
<td>Brook</td>
<td>Weekly</td>
<td>May 15, 2008-Oct 31, 2008</td>
<td>87</td>
<td>167.27</td>
<td>3.10 - 1046.20</td>
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</table>

*Untreated Water E. coli (MPN/100ml)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment Reservoir</td>
<td>Weekly</td>
<td>May 15, 2008-Oct 31, 2008</td>
<td>86</td>
<td>7.67</td>
<td>0.00 - 42.00</td>
</tr>
<tr>
<td>Brook</td>
<td>Weekly</td>
<td>May 15, 2008-Oct 31, 2008</td>
<td>87</td>
<td>10.63</td>
<td>0.00 - 178.50</td>
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*Municipal Treated Water Free-chlorine residual level (mg/L)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sampling Frequency</th>
<th>Dates</th>
<th>Missing Observations during study period: 2005-2008 (%)</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>School</td>
<td>Bi-Weekly</td>
<td>Jul 2005-Oct 2008</td>
<td>38</td>
<td>0.10</td>
<td>0.01 - 0.60</td>
</tr>
</tbody>
</table>

*2007 data are missing
Table 3.2. A summary of daily weather variables in Nain, Labrador, Canada (January 1, 2005 - October 31, 2008)

<table>
<thead>
<tr>
<th>Variable</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Temperature ($^\circ$C)</td>
<td>27.9</td>
<td>30</td>
<td>26</td>
<td>31.2</td>
</tr>
<tr>
<td>Minimum Temperature ($^\circ$C)</td>
<td>-31</td>
<td>-28</td>
<td>-30.5</td>
<td>-31.4</td>
</tr>
<tr>
<td>Maximum Daily Rainfall (mm)</td>
<td>31</td>
<td>41.2</td>
<td>36.8</td>
<td>37.2</td>
</tr>
<tr>
<td>Maximum Snow on ground (cm)</td>
<td>113</td>
<td>107</td>
<td>138</td>
<td>77</td>
</tr>
<tr>
<td>Maximum Daily Water Volume Input (mm w.e.)</td>
<td>47.5</td>
<td>53.1</td>
<td>62.5</td>
<td>45</td>
</tr>
</tbody>
</table>

* Data from January 1, 2008 to October 31, 2008
Table 3.3. Summary results of univariable linear regression investigating water volume input (mm water equivalent) and water quality in Nain, Labrador, Canada from January 1, 2005 - October 31, 2008.

<table>
<thead>
<tr>
<th>Untreated Water and Water Volume Input</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t</th>
<th>P</th>
<th>95% Confidence Interval</th>
<th>R²</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliform Levels (MPN/100ml)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment Reservoir</td>
<td>1.38</td>
<td>0.50</td>
<td>2.75</td>
<td>0.010</td>
<td>0.36- 2.40</td>
<td>0.192</td>
<td>34</td>
</tr>
<tr>
<td>Anainak's Brook</td>
<td>1.55</td>
<td>0.65</td>
<td>2.40</td>
<td>0.019</td>
<td>0.27 - 2.84</td>
<td>0.064</td>
<td>86</td>
</tr>
<tr>
<td>E. coli (MPN/100ml)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment Reservoir</td>
<td>1.23</td>
<td>0.36</td>
<td>3.43</td>
<td>0.002</td>
<td>0.50 - 2.84</td>
<td>0.275</td>
<td>33</td>
</tr>
<tr>
<td>Anainak's Brook</td>
<td>0.09</td>
<td>0.03</td>
<td>3.54</td>
<td>0.001</td>
<td>0.04 - 0.15</td>
<td>0.130</td>
<td>86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treated Municipal Water and Water Volume Input</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t</th>
<th>P</th>
<th>95% Confidence Interval</th>
<th>R²</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free-chlorine residual level (mg/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of Distribution</td>
<td>0.007</td>
<td>0.005</td>
<td>1.39</td>
<td>0.17</td>
<td>-0.01 - 0.02</td>
<td>0.004</td>
<td>321</td>
</tr>
<tr>
<td>End of Distribution</td>
<td>0.001</td>
<td>0.003</td>
<td>0.25</td>
<td>0.81</td>
<td>-0.01 - 0.01</td>
<td>0.001</td>
<td>467</td>
</tr>
<tr>
<td>School</td>
<td>-0.001</td>
<td>0.005</td>
<td>-0.23</td>
<td>0.82</td>
<td>-0.01 - 0.01</td>
<td>0.001</td>
<td>217</td>
</tr>
</tbody>
</table>
Table 3.4. A summary of the yearly total infectious gastrointestinal illness (IGI) related patient visits to the community clinic compared to total patient visits for all reasons in Nain and Rigolet from January 1, 2005 to October 31, 2008 (Labrador, Canada).

<table>
<thead>
<tr>
<th>Year</th>
<th>Nain IGI Clinic Visits</th>
<th>Total Clinic Visits</th>
<th>Proportion IGI (%)</th>
<th>Rigolet IGI Clinic Visits</th>
<th>Total Clinic Visits</th>
<th>Proportion IGI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>130</td>
<td>16,370</td>
<td>0.8</td>
<td>33</td>
<td>5,202</td>
<td>0.6</td>
</tr>
<tr>
<td>2006</td>
<td>107</td>
<td>12,697</td>
<td>0.8</td>
<td>47</td>
<td>4,280</td>
<td>1.1</td>
</tr>
<tr>
<td>2007</td>
<td>188</td>
<td>11,921</td>
<td>1.6</td>
<td>41</td>
<td>4,365</td>
<td>0.9</td>
</tr>
<tr>
<td>2008</td>
<td>116</td>
<td>10,500</td>
<td>1.1</td>
<td>54</td>
<td>3,510</td>
<td>1.5</td>
</tr>
<tr>
<td>Overall</td>
<td>541</td>
<td>51,488</td>
<td>1.1</td>
<td>175</td>
<td>17,357</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Statistics Canada, 2006 (20)
† Infectious gastrointestinal illness
‡ Clinic records from January 1 – October 31, 2008
Figure 3.1. A map of the study communities (Nain and Rigolet, Nunatsiavut, Labrador, Canada).
Figure 3.1. Plots of seasonal-trend decomposition procedure based on Loess plotting the data, as well as seasonal, trend, and remainder components of data for (A) average monthly temperature (°C) and (B) water volume input (mm w.e.) in Nain, Labrador, Canada from January 1, 2005 - October 31, 2008. In the seasonal plots, dashed boxes highlight winter, spring, summer, and fall seasons.
Figure 3.2. Plot of seasonal-trend decomposition procedure based on Loess plotting the data, as well as seasonal, trend, and remainder components of data for monthly infectious gastrointestinal illness (IGI) patient visits in Nain (A) and Rigolet (B), Labrador, Canada from January 1, 2005 - October 31, 2008. In the seasonal plots, dashed boxes highlight winter, spring, summer, and fall seasons.
Figure 3.4. Plots for free-chlorine residuals (mg/L) at the school in Nain (A) and Rigolet (B), Labrador, Canada. The solid line is a Loess smoother with a bandwidth of 67% to help identify potential trends in the data.
Figure 3.5. The proportion of the Nain (A) and Rigolet (B) population visiting the clinic with infectious gastrointestinal illnesses (IGI) complaints in 2006 by age and sex (Labrador, Canada).
CHAPTER FOUR

SUMMARY DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

DISCUSSION AND CONCLUSIONS

This thesis presented the results of a study investigating the impacts of weather and water quality on the health of two Inuit communities in northern Labrador. The process by which this study took place highlighted and addressed gaps that are recognisable for many Aboriginal communities in Canada: the need for quality health data, the necessity of an excellent health data capture mechanism, a standardised way to evaluate that system, participation of community, health and environmental health stakeholders in maintaining the health of the community, and foresight and planning for long term capacity and adaptability in the face of climate change.

In addressing the question of how weather and water quality might impact human health (using infectious gastrointestinal illness or IGI occurrence in the communities as a reference), this study proceeded in a stepwise fashion to consider health and environmental data (capture, quality, analysis, and interpretation) with generous input and consultation from community stakeholders and regional health and environmental authorities.

As a result, the evaluation of the Labrador Grenfell Health (LGH) E-Book health registry system used to capture patient visit data in Nunatsiavut was systematically evaluated by adapting the Centers for Disease Control and Prevention’s (CDC) Guidelines for Evaluating Public Health Surveillance Systems (1), providing LGH with
recommendations on improving quality and usefulness of Inuit health data captured by
the system. The emphasis on stakeholder participation throughout every step of the
evaluation and results dissemination was crucial. This evaluation uncovered limitations
in both data quality and data accessibility, and illustrates concerns regarding the poor
quality of Aboriginal health data in general. The impact of this study has been
recognised in that since the results and recommendations from Chapter Two were
presented to LGH, converting this paper-based system to an electronic system has
become a LGH priority. When funds become available, LGH would like to implement
the MEDITECH™ system in LGH’s northern coastal clinics, which is currently used in
southern Labrador clinics (2). In the meantime, LGH implemented an electronic registry
immediately after the evaluation report (November 2008), where patient visit data are
entered into an electronic spreadsheet (Excel, Microsoft Office 2007). While this interim
spreadsheet system might not provide as many benefits as the sophisticated
MEDITECH™ system, it should immediately improve the quality and accessibility, and
thus usability, of Inuit health data captured in the region.

In general, higher quality health data across Inuit regions are essential to
improving our understanding of the magnitude of Aboriginal health problems and will
allow for the prioritisation of actions, program planning, and research for disease
prevention and health promotion in these populations (3). Thus, a standardised
evaluative process, as seen in this research, should be conducted on all existing
Aboriginal health data collection systems because it provides a quick, effective,
systematic, and simple starting point for improving the quality of available Aboriginal
health data.
The second stage of the study focussed on conducting an investigation of temporal trends in weather, water quality, and IGI data in the Nunatsiavut Inuit communities of Nain and Rigolet. In Nain, distinct seasonal peaks in total water volume input occurred in the spring and summer months, and water volume input and bacteriological quality of untreated were positively associated, which might suggest that bacteriological water quality has a similar seasonal trend; however, longer-term water quality data are needed to test this hypothesis. In both communities the number of IGI patient visits also peaked in summer and fall months. Due to missing observations, relationships between IGI patient visits and water volume input were not statistically examined and further research is warranted. However, considering that associations between weather events, water quality, and IGI health have been documented and described elsewhere (4-6), it raises the possibility that weather and untreated water quality are risk factors for IGI occurrence in Nunatsiavut; however, this hypothesis could not be tested due to data limitations. Therefore, longer-term spatio-temporal research to test this hypothesis is especially warranted because the consumption of untreated water in these communities is not uncommon, especially when community members are out on the land. Seasonal variations in water volume input and bacteriological water quality could have important public health implications in Nunatsiavut, which could be magnified in the context of climate change. Trends in climate change indicate increasing frequency and magnitude of heavy rainfall and rapid snowmelt events; the impact on raw water quality and IGI health could be substantial. Chapter Three also illustrated the importance and necessity of systematically gathering reliable temporal data in order to establish a sound baseline context for the detection of future changes in trends,
potentially due to climatic impacts on Inuit and environment health. Numerous missing observations in weather and water quality data precluded certain analyses, such as multivariable modeling to examine environmental risk factors of IGI, highlighting the difficulties in empirically examining possible human and environmental health impacts of climate change in many Canadian Arctic regions.

Chapter Three recommended further research investigating knowledge translation methodologies in Inuit regions. The impact of this study recommendation was the development of a new knowledge translation pilot project to share the results of the environmental health project with the community. Interactive workshops for local high school students in Rigolet, Nunatsiavut were co-designed and implemented with local teachers, local research assistants, and local and regional government. The workshops demonstrated how weather and water quality data are collected and analysed, and encouraged students to develop educational media for communicating the weather-water-health study results to the larger community. Currently, research is being conducted to examine the program process and outcomes, and to evaluate the efficacy of the pilot school program and school-researcher partnership as a knowledge translation method.

Chapter Three also called for communities to actively participate in and/or direct environmental health data collection and results dissemination to effectively communicate environmental health relationships within and among Inuit communities. As a result of this recommendation and the local interest that the project generated, a community-driven and directed project entitled *Changing Climate, Changing Health, Changing Stories* successfully obtained Federal funding for community research on climate change and adaptation. This project builds on past research and critically
recognizes the importance of gathering first-hand stories and experiences documenting the impact of climate change on human health. The community will use digital storytelling and storymapping (7, 8) to not only gather data, but also to create accessible and transferrable educational health media in the community of Rigolet, Nunatsiavut. This endeavour is expected to have far-reaching effect, both nationally and internationally.

In summary, this research describes the first study to systematically gather, analyse, and compare baseline data on weather, water quality, and health in Nunatsiavut. Such empirical data on weather, water quality, and health are unfortunately rare in Inuit regions. What became evident in this research process was that community and stakeholder engagement was critical. Further to this was the empowerment that good quality data imparts on the ability to understand and inform locally-driven development of adaptation strategies for managing future changes and challenges to healthy environments and communities in Nunatsiavut and other Arctic regions.

**Recommendations from the Research**

Based on the reviewed literature (Chapter One), the E-Book evaluation (Chapter Two), and the weather, water quality, and health study (Chapter Three), the following recommendations are made:

- *Improve Aboriginal Health Data Capture*: Evaluations of Aboriginal databases could indicate ways to improve existing registries, or indicate that new registry systems need to be implemented, creating opportunities to develop new health data collection methodologies and techniques that are socially, culturally, and geographically
relevant. Ultimately, improved health data capture will assist in estimating the magnitude of health problems, prioritize immediate action, program planning, and research in Aboriginal communities.

- **Improve Waterborne Disease Surveillance:** Monitoring enteric illnesses is difficult; identifying the source of enteric illnesses more so. Improved waterborne disease surveillance would contribute to better estimates of burden of disease, monitoring disease trends, identification of local risk factors of disease, and the use of this generated information to improve Inuit public health. In general, researchers need to continue to develop methodologies to allow easier and more efficient methods of enteric illness surveillance, such as improved reporting systems in Inuit regions (e.g. *International Circumpolar Surveillance* (9)), or innovative methods, such as syndromic surveillance of over-the-counter diarrhoeal-related products (10). Improving enteric illness monitoring and surveillance is particularly important when considering the potential impacts of climate change on water quality in Arctic regions (11). Moreover, a future study that investigates the magnitude, distribution, and environmental risk factors of self-reported IGI in Nunatsiavut in comparison to the rates in the province, other northern remote communities, and other regions in Canada is recommended.

- **Enhance Environmental Health Monitoring Across Arctic Regions:** Due to limited availability of empirical data, investigating the impacts of climate change on public health in the Canadian North has thus far relied heavily on Indigenous knowledge and stories (12-15). While this research has been valuable, researchers and communities need to improve the quality of systematic monitoring of empirical baseline
environmental health data across Arctic regions. By engaging communities in this type of research and data collection, local adaptation strategies can be developed that are relevant and culturally acceptable in order to successfully adapt and become resilient to the health impacts of environmental changes resultant from climate change.

- **Use Respectful Research Methodologies:** Historically, Canadian Inuit communities have had a long history of marginalization and mistreatment by colonial powers (e.g. issuance of Eskimo-numbers, RCMP slaughter of sled-dogs, High Arctic relocations, and coercive movement of Inuit to maintain Canadian sovereignty (16, 17)). Partly due to this colonial influence, Inuit communities can understandably be resistant and distrustful towards ‘Southern’ research projects occurring in their communities (17). Inuit communities report that researchers do not consider Inuit perspectives in research design, do not adequately involve Inuit throughout the research process, do not properly recognize or compensate important Inuit contributions, are using inappropriate research methodologies that are sometimes perceived as biased, provide no tangible benefits for communities, and do not share study results in a timely manner or in an appropriate format (18). Thus, research in Inuit regions must move towards cooperative and respectful research that engages communities in all stages of research design, implementation, and application. Furthermore, these respectful methodologies must be continually developed and documented.

- **Ensure Knowledge Translation and Transfer of all Research Findings:** Knowledge translation is the process of turning research into action, as well as accelerating the practical application of knowledge uncovered by research (19). This process not only includes publishing research in academic journals and presenting at conferences, but
also widespread dissemination of information to stakeholders outside of scientific audiences to further encourage the sustainable application of research results. This process should be considered a critical aspect in any research project, but it is essential in Inuit health research, particularly in the context of climate change. When considering the close relationship that Inuit have with the land, Inuit communities have an ethical right to full disclosure of research results that impact them so profoundly. This access to environmental health research results will help inform the development of climate change adaptation strategies that are locally created, developed, appropriate, relevant, and effective.

‘The true measure of any society is not what it knows but what it does with what it knows.’

- W. Bennis

LITERATURE CITED


(15) Nickels S, Furgal C, Buell M, Moquin H. *Unikkaaqatigiit – Putting the Human Face on Climate Change: Perspectives from Inuit in Canada*. Ottawa: Joint publication of Inuit Tapiriit Kanatami, Nasivvik Centre for Inuit Health and Changing Environments at Université Laval and the Ajunnginiq Centre at the National Aboriginal Health Organization, 2005.


(19) CIHR. *Knowledge to Action: A Knowledge Translation Casebook*. Ottawa, Canada: Canadian Institutes of Health Research, 2008.
Appendix 1. An overview of examples of common waterborne bacterial, viral, and protozoan pathogens, with symptoms, incubation period, symptom duration, chronic sequelae, transmission routes, relative infectivity, and example literature reviews for each pathogen listed.

<table>
<thead>
<tr>
<th>Species</th>
<th>Waterborne Disease</th>
<th>General Symptoms</th>
<th>Incubation Period (days)</th>
<th>Symptom Duration (days)</th>
<th>Chronic Sequelae</th>
<th>Infective Dose (50)</th>
<th>Transmission</th>
<th>Relative Infectivity</th>
<th>Literature Reviews</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacterial</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Campylobacter</em></td>
<td>Campylobacteriosis</td>
<td>Abdominal pain Bloody diarrhea Cramping Fever Vomiting</td>
<td>2-5</td>
<td>7</td>
<td>Guillain-Barré syndrome</td>
<td>&lt; 500</td>
<td>Foodborne Waterborne Person-person contact</td>
<td>Moderate</td>
<td>(1)</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>E. coli (ETEC; EHEC)</td>
<td>Abdominal pain Bloody diarrhea Vomiting</td>
<td>3-4</td>
<td>5-7</td>
<td>Hemolytic uremic syndrome</td>
<td>10^7</td>
<td>Foodborne Waterborne Person-person contact</td>
<td>Low</td>
<td>(2-6)</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>Salmonellosis Typhoid</td>
<td>Abdominal pain Diarrhea Fever</td>
<td>0.5-3</td>
<td>4 days-several months</td>
<td>Reiter’s syndrome</td>
<td>10^7</td>
<td>Foodborne Waterborne Person-person contact</td>
<td>Low</td>
<td>(7)</td>
</tr>
<tr>
<td><em>Shigella</em></td>
<td>Shigellosis</td>
<td>Abdominal pain Diarrhea Fever</td>
<td>1-2</td>
<td>5 days-several months</td>
<td>Post-infectious arthritis</td>
<td>10-10^2</td>
<td>Foodborne Waterborne Person-person contact</td>
<td>Moderate</td>
<td>(8)</td>
</tr>
<tr>
<td><em>Vibrio cholerae</em></td>
<td>Cholera</td>
<td>Death Leg cramps Vomiting Watery diarrhea</td>
<td>0.25-5</td>
<td>Death may occur in hours</td>
<td>–</td>
<td>10^2-10^6</td>
<td>Foodborne Waterborne Person-person contact</td>
<td>Low</td>
<td>(9)</td>
</tr>
<tr>
<td><em>Yersinia enterocolitica</em></td>
<td>Yesiniosis</td>
<td>Abdominal pain Bloody diarrhea Fever</td>
<td>4-7</td>
<td>7-21</td>
<td>Erythema nodosum</td>
<td>10^6</td>
<td>Foodborne Waterborne Person-person contact</td>
<td>Low</td>
<td>(10)</td>
</tr>
<tr>
<td><em>Helicobacter pylori</em></td>
<td>Helicobacter pylori</td>
<td>Gastritis</td>
<td>–</td>
<td>–</td>
<td>Peptic ulcers Duodenal ulcers Chronic gastritis</td>
<td>–</td>
<td>Foodborne Waterborne Person-person contact</td>
<td>–</td>
<td>(11)</td>
</tr>
<tr>
<td>Pathogen</td>
<td>Disease</td>
<td>Contact</td>
<td>Gastric cancer</td>
<td>Modality</td>
<td>Duration</td>
<td>Symptoms</td>
<td>Incubation</td>
<td>Recovery</td>
<td>Relapse</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>---------</td>
<td>---------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>------------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td><em>Legionella</em></td>
<td>Legionnaires' disease</td>
<td>Oral-oral</td>
<td>2-14</td>
<td>2-5</td>
<td>–</td>
<td>Thought to be low</td>
<td>Aerosol inhalation and aspiration</td>
<td>Moderate</td>
<td>(12)</td>
</tr>
<tr>
<td><em>Protozoan</em></td>
<td>Cryptosporidium</td>
<td>Foodborne</td>
<td>2-10</td>
<td>7-14, relapses might occur</td>
<td>–</td>
<td>&gt;1</td>
<td>Waterborne Person-person contact</td>
<td>High</td>
<td>(13-15)</td>
</tr>
<tr>
<td></td>
<td>Cyclospora cayetanensis</td>
<td>Foodborne</td>
<td>7</td>
<td>2 days-months, relapses might occur</td>
<td>–</td>
<td>Thought to be low</td>
<td>Waterborne Person-person contact</td>
<td>High</td>
<td>(16-18)</td>
</tr>
<tr>
<td></td>
<td>Giardia</td>
<td>Foodborne</td>
<td>7-14</td>
<td>14-42</td>
<td>–</td>
<td>10 cysts</td>
<td>Waterborne Person-person contact</td>
<td>High</td>
<td>(19, 20)</td>
</tr>
<tr>
<td><em>Viral</em></td>
<td>Calicivirus</td>
<td>Foodborne</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Thought to be low</td>
<td>Waterborne Person-person contact</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Symptoms: Abdominal pain, Chills, Cough, Diarrhea, Fever, Headaches, Muscle aches, Nausea, Vomiting, Weight loss, etc.
<table>
<thead>
<tr>
<th>Hepatitis</th>
<th>Hepatitis A</th>
<th>Abdominal pain</th>
<th>Appetite loss</th>
<th>Clay-colored stools</th>
<th>Dark urine</th>
<th>Fatigue</th>
<th>Fever</th>
<th>Jaundice</th>
<th>Joint pain</th>
<th>Nausea</th>
<th>Vomiting</th>
<th>Infective Dose (50)</th>
<th>Relative Infectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>14-42</td>
<td>60-180</td>
<td>–</td>
<td>–</td>
<td>Foodborne</td>
<td>Waterborne</td>
<td>Person-person contact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(21)</td>
<td></td>
</tr>
<tr>
<td>Hepatitis</td>
<td>Hepatitis E</td>
<td>Abdominal pain</td>
<td>Fever</td>
<td>Jaundice Appetite loss</td>
<td>Nausea</td>
<td>Vomiting</td>
<td>Infective Dose (50)</td>
<td>Relative Infectivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-56</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Foodborne</td>
<td>Waterborne</td>
<td>Person-person contact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(22)</td>
<td></td>
</tr>
<tr>
<td>Rotavirus</td>
<td>Rotavirus</td>
<td>Abdominal pain</td>
<td>Fever</td>
<td>Vomiting</td>
<td>Watery diarrhea</td>
<td>Infective Dose (50)</td>
<td>Relative Infectivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>3-8</td>
<td>–</td>
<td>5-6</td>
<td>Foodborne</td>
<td>Waterborne</td>
<td>Person-person contact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(23)</td>
<td></td>
</tr>
</tbody>
</table>

*Infective Dose (50) is the number of pathogens required for infection in 50 per cent of the test subjects
† Relative Infectivity as defined by the World Health Organization
REFERENCES


Appendix 1. Examples of studies investigating potential waterborne disease incidence or prevalence, country, study period, study design, and IGI data type.

<table>
<thead>
<tr>
<th>Region</th>
<th>Region</th>
<th>Pathogen/Illness</th>
<th>Study Period</th>
<th>Study Design</th>
<th>IGI Data</th>
<th>Sample Size</th>
<th>Prevalence</th>
<th>Incidence (Episode per person-year)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Uganda: 21%*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tanzania: 8%*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghana</td>
<td></td>
<td><em>Cryptosporidium</em></td>
<td>Oct 2001-Jun 2007</td>
<td>Prospective Childhood Survey</td>
<td>Stool Samples</td>
<td>304 Children</td>
<td>24.70%‡</td>
<td>–</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>Pathogenic</td>
<td>Diarrhoea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pathogenic: 51%‡</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>Diarrhoea</td>
<td></td>
<td>2003</td>
<td>Prospective Childhood Intervention Study</td>
<td>Self-reported</td>
<td>176 Households</td>
<td>–</td>
<td>1.38</td>
<td>(4)</td>
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<td>Diarrhoea</td>
<td>Jun 1999-Sep 2002</td>
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<td>401 Diarrheic Individuals</td>
<td>E. coli: 20%‡</td>
<td>–</td>
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<td></td>
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<td>Campylobacter: 20%‡</td>
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<td>Salmonella: 14.5%‡</td>
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<td>Cholera: 3.7%‡</td>
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<td>Rotavirus: 27%‡</td>
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<td>Campylobacter: 1.9%‡</td>
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<td>Prospective</td>
<td>Stool</td>
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<td>–</td>
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</tr>
<tr>
<td>Country</td>
<td>Region</td>
<td>Diarrhoea Type</td>
<td>Study Duration</td>
<td>Study Design</td>
<td>Sampled Group</td>
<td>Sample Size</td>
<td>Prevalence</td>
<td>Notes</td>
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<td>Asia</td>
<td>Gaza Strip</td>
<td>Diarrhoea</td>
<td>1999-2003</td>
<td>Cross-sectional Population Survey</td>
<td>Self-reported</td>
<td>150 Individuals</td>
<td>61.30%</td>
<td>–</td>
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<tr>
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<td>Sep 2002-Aug 2004</td>
<td>Prospective Hospital Patients Survey</td>
<td>Stool Samples</td>
<td>534 HIV Patients</td>
<td>5.20%</td>
<td>–</td>
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<td>India</td>
<td></td>
<td>Diarrhoea</td>
<td></td>
<td>Prospective Population Survey</td>
<td>Self-reported</td>
<td>1070 Households</td>
<td>–</td>
<td>0.61</td>
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<td>India</td>
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<td>Diarrhoea</td>
<td></td>
<td>Cross-sectional Population Survey</td>
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<td>1254 Individuals</td>
<td>34.84%</td>
<td>–</td>
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<tr>
<td>India</td>
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<td>Hepatitis A</td>
<td>1982-1998</td>
<td>Cross-sectional Population Survey</td>
<td>Stool Samples</td>
<td>4091 Individuals</td>
<td>89%</td>
<td>–</td>
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<td>India</td>
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<td>Waterborne Diseases</td>
<td>Mar 2004-Apr 2004</td>
<td>Prospective Population Survey</td>
<td>Self-reported</td>
<td>636 Individuals</td>
<td>66%</td>
<td>–</td>
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<tr>
<td>Japan</td>
<td></td>
<td>H. pylori</td>
<td></td>
<td>Prospective Childhood Survey</td>
<td>Stool Samples</td>
<td>224 Children</td>
<td>13%</td>
<td>–</td>
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<tr>
<td>Jordan</td>
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<td>Sep 1999-Sep 2001</td>
<td>Prospective Childhood Diarrhoeal Patient Survey</td>
<td>Stool Samples</td>
<td>220 Children</td>
<td>65%</td>
<td>–</td>
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<tr>
<td>Kazakhstan</td>
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<td>H. pylori</td>
<td>May 1999-Aug 1999</td>
<td>Cross-sectional Population Survey</td>
<td>Serological Samples</td>
<td>288 Individuals</td>
<td>80%</td>
<td>–</td>
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<td>Oman</td>
<td></td>
<td>Diarrhoea</td>
<td>2002</td>
<td>Prospective Population Survey</td>
<td>Self-reported</td>
<td>380 Children</td>
<td>–</td>
<td>2.6</td>
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<tr>
<td>Country</td>
<td>Pathogen</td>
<td>Period</td>
<td>Study Type</td>
<td>Method</td>
<td>Samples</td>
<td>Symptomatic Patients:</td>
<td>Asymptomatic Patients:</td>
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<td>-------------</td>
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</tr>
<tr>
<td>Pakistan</td>
<td>Cryptosporidium parvum</td>
<td>Mar 1996-Sep 1996</td>
<td>Population Survey Prospective Childhood Patient Survey</td>
<td>Stool Samples</td>
<td>475</td>
<td>10.3%‡</td>
<td>3.3%‡</td>
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<tr>
<td>Pakistan</td>
<td>Diarrhoea</td>
<td>1998</td>
<td>Self-reported</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Pakistan</td>
<td>Diarrhoea</td>
<td>May 1998-Apr 1999</td>
<td>Self-reported</td>
<td></td>
<td>176</td>
<td>6.59%§</td>
<td>3.9</td>
<td></td>
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</tr>
<tr>
<td>Russia</td>
<td>Pathogenic Diarrhoea</td>
<td>1998-2000</td>
<td>Prospective Hospital Diarrhoeal Patients Survey</td>
<td>Stool Samples</td>
<td>528</td>
<td>C. parvum: 6.9%‡</td>
<td>G. lamblia 9.4%‡</td>
<td></td>
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</tr>
<tr>
<td>Russia</td>
<td>Cryptosporidium</td>
<td>Jun 1999-Dec 1999</td>
<td>Prospective Population Survey Serological Samples</td>
<td>100 Individuals</td>
<td>459</td>
<td>68–88%‡</td>
<td>–</td>
<td></td>
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<tr>
<td>Russia</td>
<td>Diarrhoea</td>
<td>Jun 1999-Nov 1999</td>
<td>Self-reported</td>
<td></td>
<td>367</td>
<td>–</td>
<td>1.47</td>
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<td>Turkey</td>
<td>Diarrhoea</td>
<td>Sep 2003-</td>
<td>Self-reported</td>
<td></td>
<td>543</td>
<td>31.70%††</td>
<td>–</td>
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<tr>
<td>Vietnam</td>
<td>Pathogenic Diarrhoea</td>
<td>Mar 2001-Apr 2002</td>
<td>Prospective Childhood Diarrhoeal Patient Survey</td>
<td>Stool Samples</td>
<td>587</td>
<td>67.30%‡</td>
<td>–</td>
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<td>Country</td>
<td>Pathogen</td>
<td>Date/Year</td>
<td>Study Type</td>
<td>Methodology</td>
<td>Sample Size</td>
<td>Confidence Interval</td>
<td>p-Value</td>
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<tr>
<td>Albania</td>
<td>Rotavirus</td>
<td></td>
<td>Prospective Children with Diarrhea</td>
<td>Stool Samples</td>
<td>313 Children</td>
<td>33%†</td>
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<td>England</td>
<td>Pathogenic Diarrhoea</td>
<td>1993-1996</td>
<td>Prospective Population Survey</td>
<td>Self-reported</td>
<td>9776 Individuals</td>
<td>6.5%†</td>
<td>0.194</td>
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<td>Nordic</td>
<td>Pathogenic Diarrhoea</td>
<td>Studies published before 2004</td>
<td>Retrospective Meta-analysis</td>
<td>–</td>
<td>13 Studies</td>
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<tr>
<td>North America</td>
<td>Gastroenteritis</td>
<td>Mar 1988-Jun 1989</td>
<td>Prospective Intervention Trial</td>
<td>Self-reported</td>
<td>1202 Individuals</td>
<td>–</td>
<td>0.76</td>
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<td>Canada</td>
<td>Gastroenteritis</td>
<td>Feb 2001-Feb 2002</td>
<td>Retrospective, Cross-sectional Survey</td>
<td>Self-reported</td>
<td>3500 Individuals</td>
<td>10%†</td>
<td>1.3</td>
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<td>United States</td>
<td>Cryptosporidium</td>
<td>May 1996-Dec 1996</td>
<td>Prospective Population Survey</td>
<td>Serological Samples</td>
<td>462 Individuals</td>
<td>54%†</td>
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<td>United States</td>
<td>Diarrhoea</td>
<td>Jul 1996-Jun 1997</td>
<td>Retrospective Population Survey</td>
<td>Self-reported</td>
<td>8624 Individuals</td>
<td>11%†</td>
<td>1.4</td>
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<tr>
<td>United States</td>
<td>Diarrhoea</td>
<td>1996-2003</td>
<td>Retrospective Population Survey</td>
<td>Self-reported</td>
<td>52840 Individuals</td>
<td>5.1%†</td>
<td>0.6</td>
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<td>Australia</td>
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<td>1999</td>
<td>Prospective Childhood Cohort</td>
<td>Self-reported</td>
<td>1016 Children</td>
<td>–</td>
<td>3.8–5.3</td>
<td></td>
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<td>Australia</td>
<td>Diarrhoea</td>
<td>Sep 1997-Feb 1999</td>
<td>Prospective Population Survey</td>
<td>Self-reported</td>
<td>2811 Individuals</td>
<td>–</td>
<td>0.8</td>
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<tr>
<td>New</td>
<td>Cryptosporidium</td>
<td>Jun 1996-Aug</td>
<td>Retrospective Reported</td>
<td>–</td>
<td>–</td>
<td>0.000112</td>
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Note: † signifies significance at 0.05 level.
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<tr>
<th>Country</th>
<th>Study Description</th>
<th>Year</th>
<th>Cases</th>
<th>Serological Samples</th>
<th>Stool Samples</th>
<th>Sero-Prevalence:</th>
<th>Stool Sample:</th>
<th>Reference</th>
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<tr>
<td>Zealand</td>
<td>Study of Reported Cases</td>
<td>1998</td>
<td></td>
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<td>South America</td>
<td>Brazil Cryptosporidium</td>
<td>–</td>
<td>Cross-sectional Population Survey</td>
<td>Serological and Stool Samples</td>
<td>322 Individual’s Serological Samples</td>
<td>709 Children’s Stool Samples</td>
<td>4.2%‡</td>
<td>(40)</td>
</tr>
<tr>
<td></td>
<td>Brazil Giardia</td>
<td>1998</td>
<td>Cross-sectional Childhood Survey</td>
<td>Stool Samples</td>
<td>694 Children</td>
<td>13.70%‡</td>
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<td>(41)</td>
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<td>Brazil Toxoplasma</td>
<td>1997-1999</td>
<td>Cross-sectional Population Survey</td>
<td>Serological Samples</td>
<td>1436 Individuals</td>
<td>58.70%‡</td>
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<td>(42)</td>
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<td>Brazil Toxoplasma</td>
<td>May 2002-Oct 2002</td>
<td>Cross-sectional Population Survey</td>
<td>Serological Samples</td>
<td>266 Individuals</td>
<td>73.30%‡</td>
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<td>(43)</td>
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<td>Ecuador Pathogenic Diarrhoea</td>
<td>Aug–05</td>
<td>Cross-sectional Childhood Survey</td>
<td>Stool Samples</td>
<td>293 Individuals</td>
<td>Giardia: 21.2%‡</td>
<td>Cryptosporidium: 8.9%‡</td>
<td>(44)</td>
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<tr>
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<td>Ecuador Diarrhoea</td>
<td>Jul 2003-May 2005</td>
<td>Prospective Population Survey</td>
<td>Self-reported</td>
<td>2053 Individuals</td>
<td>–</td>
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<td>(45)</td>
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<td>Ecuador Pathogenic Diarrhoea</td>
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<td>Prospective Population Case–control</td>
<td>Stool Samples</td>
<td>1143 Remote Individuals</td>
<td>–</td>
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<tr>
<td>Country</td>
<td>Type of Diarrhea</td>
<td>Study Period</td>
<td>Study Type</td>
<td>Sample Type</td>
<td>Sample Size</td>
<td>Organism(s)</td>
<td>Prevalence</td>
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<td>Guatemala</td>
<td>Pathogenic Diarrhoea</td>
<td>Sep 30-Dec 1 1999</td>
<td>Cross-sectional Childhood Survey</td>
<td>Serological Samples</td>
<td>522 Children</td>
<td>E. coli: 45.4%&lt;sup&gt;‡&lt;/sup&gt; H. pylori: 22.1%&lt;sup&gt;‡&lt;/sup&gt; C. parvum: 8.7%&lt;sup&gt;‡&lt;/sup&gt;</td>
<td>– (47)</td>
<td></td>
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<tr>
<td>Guatemala</td>
<td>Traveller’s Diarrhoea</td>
<td>1991</td>
<td>Prospective Travellers Longitudinal Survey</td>
<td>Self-reported</td>
<td>36 Travellers</td>
<td>–</td>
<td>4.7 (48)</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>Diarrhoea</td>
<td>Jun 2002-Oct 2002</td>
<td>Cross-sectional Population Survey</td>
<td>Self-reported</td>
<td>950 Children</td>
<td>10.40%&lt;sup&gt;**&lt;/sup&gt;</td>
<td>– (49)</td>
<td></td>
</tr>
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<td>Peru</td>
<td>Diarrhoea</td>
<td>Apr 1995-Dec 1998</td>
<td>Prospective Childhood Survey</td>
<td>Stool Samples</td>
<td>224 Children</td>
<td>–</td>
<td>3.2 (50)</td>
<td></td>
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<td>Peru</td>
<td>Pathogenic Diarrhoea</td>
<td>Feb 1995-Feb 1997</td>
<td>Cross-sectional Hospital Patients Survey</td>
<td>Stool Samples</td>
<td>762 Diarrheic Children</td>
<td>72.70%&lt;sup&gt;‡&lt;/sup&gt;</td>
<td>– (51)</td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td>Traveller’s Diarrhoea</td>
<td>Aug 2002-Nov 2002</td>
<td>Retrospective Travellers Survey</td>
<td>Self-reported</td>
<td>5988 Individuals</td>
<td>24%&lt;sup&gt;§§&lt;/sup&gt;</td>
<td>– (52)</td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>Cryptosporidium</td>
<td>–</td>
<td>Cross-sectional Population Survey</td>
<td>Stool Samples</td>
<td>515 Individuals</td>
<td>13%&lt;sup&gt;‡&lt;/sup&gt;</td>
<td>– (53)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>‡</sup>Weekly Prevalence  
<sup>**</sup>Bi-Weekly Prevalence  
<sup>†</sup>Monthly Prevalence  
<sup>††</sup>Tri-Monthly Prevalence  
<sup>§</sup>Yearly Prevalence  
<sup>§§</sup>Prevalence Unit Not Reported  
<sup>‡</sup>Proportion of Positive Samples
REFERENCES


(22) van der Hoek W, Konradsen F, Ensink JHJ, Mudasser M, Jensen PK. Irrigation water as a source of drinking water: is safe use possible? *Tropical Medicine & International Health.* 2001; 6:46-54.


(30) Horman A, Korpela H, Sutinen J, Wedel H, Hanninen ML. Meta-analysis in assessment of the prevalence and annual incidence of *Giardia* spp. and


(53) Chacin-Bonilla L, Barrios F, Sanchez Y. Environmental risk factors for *Cryptosporidium* infection in an island from Western Venezuela. *Memorias do Instituto Oswaldo Cruz*. 2008; 103:45-49.
Appendix 3. A summary of the tasks for evaluating surveillance systems suggested by the Centers for Disease Control and Prevention (2001).\(^1\)

<table>
<thead>
<tr>
<th>Tasks for Evaluating Surveillance Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>I) Engage the Stakeholders in the Evaluation</td>
</tr>
<tr>
<td>Consultations with those who use the data for health promotion or prevention ensure that the evaluation addresses appropriate questions so that the results can be useful.</td>
</tr>
<tr>
<td>II) Describe the surveillance system</td>
</tr>
<tr>
<td>1. Describe the public health importance of the health-event under surveillance</td>
</tr>
<tr>
<td>a. Indices of frequency and severity</td>
</tr>
<tr>
<td>b. Disparities or inequities associated with the health event</td>
</tr>
<tr>
<td>c. Costs associated with the health event</td>
</tr>
<tr>
<td>d. Preventability</td>
</tr>
<tr>
<td>e. Potential clinical course in the absence of an intervention</td>
</tr>
<tr>
<td>f. Public interest</td>
</tr>
<tr>
<td>2. Describe the purpose and operation of the system</td>
</tr>
<tr>
<td>a. Purpose and objectives of the system</td>
</tr>
<tr>
<td>b. Planned uses of the data from the system</td>
</tr>
<tr>
<td>c. Health-related event under surveillance</td>
</tr>
<tr>
<td>d. Legal authority for the data collection</td>
</tr>
<tr>
<td>e. Where in the organization(s) the system resides (including the context)</td>
</tr>
<tr>
<td>f. Level of integration with other systems</td>
</tr>
<tr>
<td>g. System components (e.g. population, data sources, system security etc.)</td>
</tr>
<tr>
<td>3. Describe the resources needed to operate the system</td>
</tr>
<tr>
<td>a. Funding sources</td>
</tr>
<tr>
<td>b. Personnel requirements</td>
</tr>
<tr>
<td>c. Other resources</td>
</tr>
<tr>
<td>III) Focus the Evaluation Design</td>
</tr>
<tr>
<td>1. Determine the specific purpose of the evaluation</td>
</tr>
<tr>
<td>2. Identify and engage all stakeholders</td>
</tr>
<tr>
<td>3. Consider what will be done with evaluation results</td>
</tr>
<tr>
<td>4. Identify evaluation questions to be answered</td>
</tr>
<tr>
<td>5. Determine standards for assessing system performance</td>
</tr>
<tr>
<td>IV) Gather credible evidence to evaluate system performance</td>
</tr>
<tr>
<td>1. Indicate level of usefulness</td>
</tr>
<tr>
<td>2. Describe system attributes:</td>
</tr>
<tr>
<td>a. Acceptability</td>
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<td>b. Data quality</td>
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<td>c. Flexibility</td>
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<td>d. Positive predictive value</td>
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<tr>
<td>e. Representativeness</td>
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<td>f. Sensitivity</td>
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<td>g. Simplicity</td>
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<tr>
<td>h. Stability</td>
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<tr>
<td>i. Timeliness</td>
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<tr>
<td>V) State and justify conclusions, and make recommendations</td>
</tr>
<tr>
<td>VI) Ensure use of evaluation findings and share lessons learned</td>
</tr>
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</table>


E-BOOK EVALUATION INTERVIEW QUESTIONNAIRE

Participant ID Code:

First, I wanted to thank you for taking the time to meet with me today and answer questions about the E-book health registry system in Nunatsiavut. I am involved in a study that will look at the impacts of climate change on waterborne illness in Inuit communities. A pilot period (December 2007 through March 2008) will be used to help define the project’s methodologies, and local involvement by community representatives to collect weather data, to collect and test water samples on a weekly basis, and following high impact (extreme rainfall or snow melt) weather events, and to do preliminary analysis of each community’s retrospective IGI patient visit data. To do this study, records of local clinic visits will be reviewed to investigate any relationships to the weather and water data collected. Thus, this proposed data quality evaluation will assess the completeness and accuracy of infectious gastrointestinal illness (IGI) data captured by the E-book health registry prior to the Climate Change, Water Quality, and Health study.

The main goals of this E-book system evaluation are (1) evaluate the E-book system based on a number of properties such as data quality, simplicity, flexibility, acceptability, sensitivity, representativeness, timeliness, and stability and (2) to analyze a subset of the data (e.g. IGI as a reference syndrome) from the E-book system to help in the evaluation.

The survey consists of two major parts: (1) a longer section with questions relating to the E-book system and (2) a shorter section with only a few questions about IGI, which is our ‘reference’ syndrome in this evaluation.

The survey will take no longer than one hour to complete. I would like just double check that it is okay that I record this interview.

Your answers will be considered private and confidential, and will only be reported in aggregate form. At any point in this interview, feel free to not answer any question for any reason. Please note that there may be questions that you may not be able to answer because they are not relevant to your work.
1. GENERAL QUESTIONS

First, I would like to ask you some very general and very broad questions about the E-Book system.

1.1 What is the E-book health registry system intended for?

1.2 In your opinion, does it do the job? Explain.

Answer:

Explanation:

1.3 How long have you personally worked with the E-book system?

2. E-BOOK SYSTEM DESCRIPTION

Now I would like to ask you some questions that will describe how the E-book system works.

2.1 What are data collected by the E-book system currently used for?

For example, is the data used to link into surveillance programs, for insurance purposes, for research projects, etc?

2.2 Are there any other uses for the data collected by the E-book system?

For example, could the data be used for disease surveillance, to identify common diseases in communities, etc.

i) If ‘yes’, what might they be?

For example, an electronic system, easier to understand codes, etc.
2.3 What do you do to ensure data accuracy and quality? For example, are there steps to ensure proper codes are used, that codes match definitions, and so on?

2.4 Is any information from the E-books disseminated?

*For example, how does the information captured by the E-book get to you? Is it shared between public health, health care workers, and government?*

i) If ‘yes’, please explain to whom and how they are disseminated.

2.5 Please explain how the E-book is stored and secured in your location.

*For example, is it stored in a room, filing cabinet, etc?*

2.6 Please explain how the E-book is managed in your location.

*For example, who is responsible for maintaining the E-books?*

2.7 Please explain how the data collected by the E-book system is backed-up.

*For example, are duplicate copies of the E-books kept in different locations?*

Now, I would like to ask you some questions about the confidentiality of the data collected by the E-book system.

2.8 Patient confidentiality:

i) What policies and procedures ensure patient confidentiality?

*For example, are there any measures taken to ensure that patient’s personal information collected by the*
E-book system is kept private?

ii) In your opinion, are these policies and procedures sufficient to ensure patient confidentiality? Please explain.

For example, are there other more appropriate policies and procedures that could be put in place to ensure patient confidentiality?

2.9 E-book system security:

i) What policies and procedures ensure E-book system security?

For example, are there steps taken (e.g. locks, passwords, etc) to ensure that the E-book system is protected from security breaches and only available to authorized personnel?

ii) In your opinion, are these policies and procedures sufficient to ensure E-book security?

Now, I would like to ask you some questions about the coding schemes used by the E-book system.

2.10 Is the coding scheme for diagnoses and treatments clear?

For example, do you have access to codes and definition for different types of patient visits?

2.11 In a normal month, what number of commonly used codes would you use?

[If cannot estimate number] Would you use ...

  a. Less than 10 different codes
  b. Between 11 and 20 codes
  c. Between 21 and 30 codes
  d. Between 31 and 40 codes
  e. More than 41 codes
2.12 In general, how many times a week would you have to look up an uncommon code?

For example, how many times a week would you have a patient visit where you did not know the ICD code and had to look the code up for the E-book records?

[If cannot estimate number] Would you look up a code …

a. 1-2 times a week
b. 3-5 times a week
c. 6-9 times a week
d. 10-15 times a week
e. More than 16 times a week

2.13 Is there anything you can think of that would make using the ICD coding system easier to use?

For example, would having greater access to code books or using an electronic system make using the ICD coding system easier to use?

3. DATA ANALYSIS

Now, I would like to ask you some questions about how the data collected by the E-book system is analysed.

3.1 Do you or a member of your staff analyse the data collected by the E-Book system in any way?

➢ If **YES**, please answer i) – iv)

➢ If **no**, please answer v)
i) Who analyses the data and briefly describe what type of analysis?

**Answer:**

**Explain:**

*For example, do you use the information collected by the E-book registry to identify community trends in diseases or illnesses?*

ii) What is done with the results of the analyses?

*For example, who would be supplied with information based on the E-book data?*

iii) How often is the data collected by the E-book system analysed?

*For example, is it analyzed weekly, monthly, yearly, etc?*

iv) Would you or any member of your staff be interested in receiving further training or support for these analyses?

*For example, would you or any member of your staff be interested in learning how to do simple analyses such as frequency counts of disease or monitoring disease trends?*

➤ If **no**, please answer v):

v) Would you or any member of your staff be interested in receiving training or support to conduct analyses on the data captured by the E-book system?

*For example, would you or any member of your staff be interested in learning how to do simple analyses such as frequency counts of disease or monitoring disease trends?*
Now, I would like to ask you some questions about the how the information collected from the E-book registry is used in reports, bulletins, or other media.

3.2 Are E-book community level data used in reports or bulletins and disseminated to local communities?

For example, are the data collected from E-books used in community reports that communicate community trends, outbreaks, etc.?

→ If YES, please answer i – iii):
   i) How are they disseminated?

   For example, are the disseminated by email? By newsletter? By radio? Public use data-files? The internet? Public in scientific, peer-reviewed journals?

   ii) How often are these reports or bulletins disseminated?

   For example, are they distributed weekly? Monthly? Yearly? During outbreaks?

   iii) Who are they disseminated to?

   For example, are they disseminated to public health practitioners? Health-care providers? Members of affected communities? Professional and voluntary organizations? Policymakers? The press? The general public?

3.3 Are E-book regional level data used in reports and disseminated regionally (e.g. to all Nunatsiavut communities)?

For example, are the data collected from E-books used in regional reports that communicate disease trends, outbreaks, etc. and sent to all communities in Nunatsiavut?

→ If YES, please answer i – iii):
   i) How are they disseminated regionally?
For example, are the disseminated by email? By newsletter? By radio? Public use data-files? The internet? Publication in scientific, peer-reviewed journals?

ii) How often are these reports disseminated?

For example, are they distributed weekly? Monthly? Yearly? During outbreaks?

iii) Who are they disseminated to?

For example, are they disseminated to public health practitioners? Health-care providers? Members of affected communities? Professional and voluntary organizations? Policymakers? The press? The general public?

4. USEFULNESS:

Now, I would like to ask you questions about the usefulness of the E-book system.

4.1 Can you describe any actions taken by you as a result of the community level data from the E-book system?

For example, did you take actions (such as identify outbreaks, implement policy, etc) after observing data from the E-book registry?

4.2 Can you describe any actions taken by you as a result of regional level data captured by the E-book system? Please explain.

For example, did you take actions (such as identify outbreaks, implement policy, etc) after observing data from the E-book registry?

4.3 Does anyone else use the data collected by the E-book system to take actions or make decisions at the local or regional level? Who?

Answer:
Explain:

For example, does someone else use the data collected by the E-book system to take action or make policy decisions?

4.4 Are these data useful for providing information at the community level? If yes, how?

For example, could the communities use the data collected by the system for surveillance? For identifying trends? Etc.

4.5 Are these data useful for providing information at the regional level? If yes, how?

For example, could the region use the data collected by the system for surveillance? For identifying trends? Etc.

4.6 Do you think that patient visit data are utilized differentially in Nunatsiavut than Newfoundland and Labrador? If yes, how?

Answer:

Explain:

For example, do you think that the data collected is used differently (e.g. for surveillance, policy decisions, community reports, etc) between Nunatsiavut and Newfoundland and Labrador?

4.7 Is there a separate system(s) for data collection related to specific diseases of concern (e.g. TB, HIV/AIDS, STI, Diabetes, etc.)?
5. SYSTEM ATTRIBUTES

[Break?]

Now I would like to make various statements about system attributes and I would like you to rate them as Strongly Agree, Agree, Neither Agree or Disagree, Disagree, Strongly disagree, not applicable or don’t know. Please feel free to provide any comments to accompany your rating.

If you have already filled this section out ahead of time, I would like to go through each section to make sure that you do not have any questions about each attribute, or additional comments regarding the attribute.

First, I would like to ask you about the simplicity of the system. This refers to both the structure and ease of operation of the E-book system. It refers to whether the E-book system is easy to use and understand.

5.1 How would you rank simplicity of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Simplicity</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The training system is simple for the trainer.</td>
<td></td>
<td></td>
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<tr>
<td>The training system is simple for the trainee.</td>
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<tr>
<td>The coding system is easy to use and understand.</td>
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<tr>
<td>Data entry is easy to use and understand. (e.g. recording information to the paper E-book)</td>
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</tr>
<tr>
<td>Data transfer is easy to do and understand. (e.g. transferring data from the paper E-book to other paper or electronic versions)</td>
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<td>Data analysis is easy to do and understand.</td>
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<td>Data storage is easy to do and understand. (e.g. filing cabinets etc.)</td>
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<tr>
<td>Preparing reports based on E-book data is easy to do and understand.</td>
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<tr>
<td>Understanding written reports (from E-book data) is easy to understand.</td>
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<tr>
<td>System maintenance is easy to do and understand.</td>
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</table>

Comments:

Next, I would like to ask you about the flexibility of the system. This refers to the E-book system’s ability to adapt to changing information needs or operating conditions with little additional time, personnel, or allocated funds. For example, flexible systems can accommodate new health-related events, changes in case definitions or technology, and variations in funding or reporting sources.
5.2 How would you rank flexibility of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The codes for patient visits are flexible.</td>
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<td><em>(e.g. are the codes flexible enough for the different types of patient visits?)</em></td>
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<td>The E-book system can adapt to new diseases.</td>
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<td><em>(e.g. could the e-book system record a new emerging chronic or infectious disease?)</em></td>
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<td>The E-book system can adapt to a revised case definition.</td>
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<td><em>(e.g. could a new more specific case definition easily be added to the E-book registry?)</em></td>
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<td>The E-book system can adapt to additional data sources.</td>
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<td><em>(e.g. could the e-book system be used for additional data sources, like home visits?)</em></td>
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<tr>
<td>The E-book system can adapt to new information technology.</td>
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<tr>
<td><em>(e.g. could the E-book system easily change to an electronic registry?)</em></td>
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<tr>
<td>The E-book system can adapt to changes in weather.</td>
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<td>*(e.g. if there was a severe storm, could the E-book system manage?)</td>
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<tr>
<td>The E-book system can adapt to changes in funding.</td>
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<td>*(e.g. if there was a personnel or equipment funding cut, could the E-book system manage?)</td>
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</table>

Comments:

Now, what about the acceptability of the E-book system? This refers to the willingness of persons and organizations to participate in the E-book system. This includes whether personnel use the system, if they like or dislike the system.

5.3 How would you rank acceptability of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Acceptability</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The data entry system is acceptable. * <em>(e.g. is the method of entering information into the paper E-book acceptable?)</em></td>
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</tr>
<tr>
<td>The data transfer is acceptable. * <em>(e.g. is the method of transferring data from the paper E-book to other paper or electronic versions acceptable?)</em></td>
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<tr>
<td>The data analysis is acceptable. * <em>(e.g. is the method, type, and frequency of data analysis acceptable?)</em></td>
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</tr>
<tr>
<td>The data storage is acceptable. * <em>(e.g. is the current method of E-book storage acceptable?)</em></td>
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<tr>
<td>The feedback on community health (resulting from E-book data) is acceptable. * <em>(e.g. do you get acceptable information back about the data that is collected?)</em></td>
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<tr>
<td>Communities fully participate in the E-book system. * <em>(e.g. do all required personnel use the system?)</em></td>
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<tr>
<td>The records in the E-book are complete. * <em>(e.g. are all fields filled out in the E-book?)</em></td>
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</tbody>
</table>
The E-book system responds to suggestions.  
(e.g. does the system incorporate suggestions from various stakeholders?)

There is no burden on time relative to available time.  
(e.g. is the system worth the time it takes?)

It is easy and cost effective to report data.  
(e.g. is the ease and cost of data reporting acceptable?)

The system is able to sufficiently protect privacy and confidentiality.  
(e.g. is the method of protecting patient privacy and confidentiality acceptable?)

Comments:

Now, what about the sensitivity of the E-book system? At the level of case reporting, sensitivity refers to the proportion of cases of a disease (or other health-related event) recorded by the system. Sensitivity can also refer to the ability to detect outbreaks, including the ability to monitor changes in the number of cases over time. In other words, it assesses how good the system is at getting the information it is suppose to get.

5.4 How would you rank sensitivity of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don’t Know</th>
</tr>
</thead>
</table>
| The data entry system is sensitive.  
(e.g. are the codes sensitive? Do they match the visit descriptions?)      |                   |          |                           |       |                |     |            |
| The system is sensitive enough to capture important diseases. 
(e.g. able capture diseases that you consider important)                  |                   |          |                           |       |                |     |            |
| The system tracks the number of cases of suspected disease that are reported, investigated, and ruled out as cases. |                   |          |                           |       |                |     |            |
| The system monitors the diagnostic effort 
(e.g. tracking submission of laboratory requests for diagnostic testing)    |                   |          |                           |       |                |     |            |
| The system monitors the circulation of the agent (e.g. virus or bacterium) that causes the disease |                   |          |                           |       |                |     |            |
| The system produces sensitive reports.  
(e.g. do reports accurately reflect the reality of the community’s health?) |                   |          |                           |       |                |     |            |

Comments:

Now, what about the representativeness of the E-book system? A public health system that is representative accurately describes the occurrence of a health-related event over time and its distribution in the population by place and person. In other words, it assesses whether the data collected reflect the true community health status.
5.5 How would you rank representativeness of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Representativeness</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The system captures all age groups equally. (e.g. are all age groups represented in the data, or are certain age groups over- or under-reported? Are certain age groups not using the clinic services?)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The system captures patients from all geographical locations equally. (e.g. are all geographical locations represented in the data, or are certain communities over- or under-reported? Are certain areas not using the clinic services?)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The system captures the clinical course of the disease or other health-related event (e.g. is the latency period, mode of transmission, and outcome [e.g., death, hospitalization, or disability] included in the data)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The system captures all ethnicities equally. (e.g. are all ethnicities represented in the data or are certain ethnicities over- or under-reported? Are certain ethnic groups not using the clinic services?)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Comments:

Now, what about the timeliness of the E-book system? Timeliness reflects the speed between steps in the E-book system.

5.6 How would you rank timeliness of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Timeliness</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The method of data entry is timely. (e.g. is the method of entering data into the paper E-book time efficient?)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The method of data transfer is timely. (e.g. is the method of transferring data from the paper E-book to other paper or electronic versions time efficient?)</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
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</tr>
<tr>
<td>The method, type, and frequency of data analysis are timely.</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
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<tr>
<td>The method of data storage is time efficient.</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Community health feedback (as a result of the E-book system data) is timely. (e.g. the time it takes for community nurses to get information on trends, outbreaks, etc. from E-book system back)</td>
<td>☐</td>
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</tr>
</tbody>
</table>

Comments:

Now, what about the data quality of the E-book system? Data quality reflects the completeness and validity of the data recorded in the E-book system.
5.7 How would you rank data quality of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Data Quality</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don't Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The data that the E-book captures is accurate. (e.g. are the codes and visit descriptions accurate?)</td>
<td>[ ]</td>
<td>[ ]</td>
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<tr>
<td>The data that the E-book captures is complete. (e.g. the number of “blank” entries or fields)</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>The data that the E-book captures locally is of high quality. (e.g. are all important information recorded?)</td>
<td>[ ]</td>
<td>[ ]</td>
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<td>[ ]</td>
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</tr>
<tr>
<td>The data that the E-book captures regionally is of high quality. (e.g. are all important information recorded?)</td>
<td>[ ]</td>
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</tr>
<tr>
<td>The data transfer does not compromise the quality of the data collected. (e.g. does transferring data from the paper E-book to other paper or electronic versions reduce data quality?)</td>
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<tr>
<td>The data analysis is of high quality. (e.g. is the data analyzed properly?)</td>
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<td>[ ]</td>
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</tr>
<tr>
<td>The feedback of community health (resulting from E-book analyses) is of high quality. (e.g. is the information given back to the community clinics of high quality?)</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Comments:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Now, what about the stability of the E-book system? Stability refers to the reliability (i.e., the ability to collect, manage, and provide data properly without failure) and availability (the ability to be operational when it is needed) of the E-book system.

5.8 How would you rank the stability of the E-book system in terms of the following:

<table>
<thead>
<tr>
<th>Stability</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don't Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>The E-book is always able to record data reliably. (e.g. can you provide data properly without failure due to high personnel turnover rates, improper training, etc.?)</td>
<td>[ ]</td>
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<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>The E-book is always available to record data when needed. (e.g. do you run out of supplies?)</td>
<td>[ ]</td>
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</tr>
<tr>
<td>The E-book is always able to transfer data from the paper E-book to other paper or electronic versions reliably. (e.g. can you transfer data properly without failure due to high turnover rates, improper training, etc.?)</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>The E-book is always available to transfer data from the paper E-book to other paper or electronic versions when needed. (e.g. can you transfer data whenever needed or are there often delays?)</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
The E-book is always able to analyze data reliably.  
(e.g. can you analyze data properly without failure due to high turnover rates, improper training, staffing shortages etc.?)

The E-book is always available to analyze data when needed.  
(e.g. can you transfer data whenever needed or are there often delays?)

The E-book is always able to store data reliably.  
(e.g. are there reliable methods to storing data or is there lack of space, security, etc.?)

The E-book is always able to produce reports from E-book data reliably.  
(e.g. can you produce reports with data properly without failure due to high turnover rates, improper training, staffing shortages etc.?)

The E-book is always available to produce reports with data when needed.  
(e.g. can you produce reports in a timely manner?)

The desired and actual amount of time required for the system to collect or receive data is equal.  
(e.g. the amount of time that the system is running with all required supplies and personnel without any problems)

Comments:

Finally, what about the E-book system overall considering all attributes?

5.9 How would you rank the E-book system overall in terms of the following:

<table>
<thead>
<tr>
<th>E-book System Overall</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
<th>Don’t Know</th>
</tr>
</thead>
</table>
| I am completely satisfied with the E-book **data entry.**  
(e.g. entering data into the E-book) |                   |         |                          |       |                |     |            |
| I am completely satisfied with the E-book **data transfer.**  
(e.g. transferring data from the paper E-book to other paper or electronic versions) |                   |         |                          |       |                |     |            |
| I am completely satisfied with the E-book **data analysis.**  
(e.g. analyzing data captured from E-books) |                   |         |                          |       |                |     |            |
| I am completely satisfied with the E-book **data storage.**  
(e.g. storing the data collected by the E-book system) |                   |         |                          |       |                |     |            |
| I am completely satisfied with the E-book **feedback.**  
(e.g. receiving information about community health as a result of data captured by the E-book) |                   |         |                          |       |                |     |            |

Comments:
6. RESOURCES FOR E-BOOK OPERATION

Now we are moving on to the resources required for the E-book system.

6.1 In your opinion, is the E-book system cost effective in monetary terms? Explain.

Answer:

Explanation:

For example, does the system cost more money than it is worth? Would there be a cheaper more effective method?

6.2 In your opinion, is the E-book system cost effective in terms of personnel and training? Explain.

Answer:

Explanation:

For example, does the system require a lot of costs in terms of training and health care workers time? Would there be a more effective method?

6.3 Now I am going to ask you about 7 aspects of the E-book system, and I would like you to estimate the total staff hours it takes per month (for example, how many hours does it take a staff member to do the following):

a. Data entry
   (e.g. entering data into the E-book):

b. Data editing

c. Data transfer
   e.g. transferring data from the paper E-book to other paper or electronic versions
6.4 Are there any other resources required to maintain the E-book system?

For example, travel, training, supplies, computers, equipment, mail, telephone, computer support, etc.

7. CONCLUSIONS AND RECOMMENDATIONS

We are now almost finished the survey about the E-book system. I would like to finish by asking you to provide any recommendations that you may have for the E-book system and for the health registry system of patient visits.

7.1 List 3 of your top recommendations, if any, for improving the E-book system of patient visits.

7.2 List 3 of your top recommendations, if any, for improving the health registry system of patient visits (e.g. if the E-book system was no longer used).

That is the end of the questions regarding the E-book system.
8. PUBLIC HEALTH IMPORTANCE OF IGI

Now I would like to move on to 6 quick specific questions about the public health importance of infectious gastrointestinal illness (IGI). We are using IGI as a referent syndrome to aid and give context to the E-book evaluation. For this survey, IGI refers to patient visits with vomiting and/or diarrhea, excluding vomiting or diarrhea due to pregnancy, medication use, alcohol or drug use, or chronic conditions such as colitis, diverticulitis, Crohn's disease, and irritable bowel syndrome.

I would like to ask you some questions about the number of yearly patient visits related to GI.

8.1 Do you think that IGI is of public health importance? Why or why not?
Answer:

Why or why not?

For example, do you think that IGI affects many persons, requires large expenditures of resources, or affects few persons?

8.2 Do you think that community residents perceive IGI as an important public health issue? Why/why not?

Answer:

Why or why not?

For example, is the public concerned or worried about IGI? Why or why not?
8.3 Please estimate the **total** number of IGI related patient visits per year in Nain.

*If cannot estimate number* Do you think that there are …

- a. 0-5 patient visits per year
- b. 6-10 patient visits per year
- c. 11-20 patient visits per year
- d. 21-30 patient visits per year
- e. 31-40 patient visits per year
- f. 41-50 patient visits per year
- g. More than 51 patient visits per year

8.4 Please estimate the total number of IGI related patient visits per year in Rigolet.

*If cannot estimate number* Do you think that there are …

- a. 0-5 patient visits per year
- b. 6-10 patient visits per year
- c. 11-20 patient visits per year
- d. 21-30 patient visits per year
- e. 31-40 patient visits per year
- f. 41-50 patient visits per year
- g. More than 51 patient visits per year

8.5 Please list what you feel are the top 3 risk factors for IGI in Nunatsiavut.

For example, what are the most likely things to cause IGI in Nunatsiavut?

*Now, I would like to ask you some questions about the preventability of IGI in Nunatsiavut.*
8.6 Are there any IGI prevention interventions currently in place in Nunatsiavut?

For example, are there any educational programs in place to reduce the burden of IGI in Nunatsiavut?

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8.7 How could incidence of IGI be reduced in Nunatsiavut communities? Explain.

Answer:

Explain:

For example, are there prevention measures such as hand washing that could reduce the number of GI related cases in Nain?

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8.8 Does this vary by community? Explain.

Answer:

Explain:

For example, do you think that the prevention measures (such as hand washing) would be different in Nain compared to Rigolet.
9. COMMENTS

9.1 We are now at the end of the survey. Please feel free to make any additional comments on the Health Registry system.

Thank you very much for your time. This information will aid in our E-book evaluation. When we finish the evaluation, we will provide you with a copy of the formal report. I would like to leave you my contact information, and please feel free to contact me at any time.

Thanks again!
Appendix 5. The executive summary from the E-Book Health Registry Evaluation provided for the Labrador Grenfell Health Authority in 2009 (Labrador, Canada).

E-BOOK HEALTH REGISTRY EVALUATION USING INFECTIOUS GASTROINTESTINAL ILLNESS AS A REFERENT SYNDROME IN NORTHERN LABRADOR, CANADA

Sherilee L. Harper¹, Victoria Edge¹,², Corinne Schuster-Wallace³, Scott McEwen¹

February 2009

¹ Department of Population Medicine, University of Guelph, Guelph ON
² Office of Public Health Practice, Public Health Agency of Canada, Guelph ON
³ International Network on Water, Environment and Health, United Nations University, Hamilton ON

SUMMARY

The northern coastal communities in Labrador are provided with primary healthcare from Labrador Grenfell Health Authority (LGH). In these communities the paper-based E-Book Health Registry is used to capture detailed data on patients that have been consulted in person, over the phone, or at home by a LGH employee. The main goals of this E-Book Health Registry evaluation are (1) to evaluate the E-Book system based on a number of properties such as data quality, simplicity, flexibility, acceptability, sensitivity, representativeness, timeliness, and stability, and (2) to analyze a subset of the data by using infectious gastrointestinal illness (IGI) as a reference syndrome from the E-Book system to aid in the evaluation. The results of this evaluation have led to the following recommendations:

1) **Define Registry Purpose:** (Re)Define the E-Book Health Registry’s purpose and objective(s).
2) **Include Stakeholder Input:** Receive input from community and regional stakeholders as to what community statistics derived from the captured data would be useful to them.
3) **Enhance Communication:** Enhance communication between all stakeholders on the registry’s purpose, objectives, procedures, outputs, and recommendations for improvement.
4) **Implement Standardized Training:** Improve the disease classification coding by updating to ICD-10 codes and providing standardized system training.
5) **Improve Registry Security:** LGH should investigate ways to improve registry security policies to protect patient confidentiality.
6) **Consider an Electronic Registry:** LGH should explore opportunities to convert from a paper-based system to an electronic system to improve data quality and access (e.g. speed and availability), thereby increasing the ability to provide feedback to clinics about community health status (e.g. make data available to a broader group of stakeholders). Also, create/plan an electronic system that will promote enhanced surveillance and public health capacity.
Appendix 1. Plots of seasonal-trend decomposition procedure based on Loess plotting the data, as well as seasonal, trend, and remainder components of data for daily (A), weekly (B), and monthly (C) infectious gastrointestinal illness (IGI) related patient visits in Nain from January 1, 2005 - October 31, 2008 (Labrador, Canada).
C) Monthly data

- Data
- Seasonal
- Trend
- Remainder

Time: 2005-2008
Appendix 2. Plots of seasonal-trend decomposition procedure based on Loess plotting the data, as well as seasonal, trend, and remainder components of data for infectious gastrointestinal illness (IGI) related patient visits in Rigolet from January 1, 2005 - October 31, 2008 (Labrador, Canada).

A) Daily data

B) Weekly data
C) Monthly data
Appendix 3. Plots of seasonal-trend decomposition procedure based on Loess plotting the data, as well as seasonal, trend, and remainder components of data for temperature (°C) in Nain from January 1, 2005 - October 31, 2008 (Labrador, Canada).

A) Daily data

B) Weekly data
C) Monthly data
Appendix 4. Plots of seasonal-trend decomposition procedure based on Loess plotting the data, as well as seasonal, trend, and remainder components of data for water volume input (mm water equivalent) in Nain from January 1, 2005 - October 31, 2008 (Labrador, Canada).

A) Daily data

B) Weekly data
Appendix 10. Plots with Loess smoothers of average daily temperature (°C) and total daily rainfall (mm) from January 1, 2005 - October 31, 2008 in Rigolet, Labrador, Canada.
Appendix 11. Plots with Loess smoothers of the free-chlorine residuals (MPN/100mL) at the start of the distribution system, the end of the system, and at the school from January 1, 2005 - October 31, 2008 in Nain, Labrador, Canada.
Appendix 12. Plots of untreated water quality (total coliforms and *E. coli*) at the pre-treatment reservoir and Anainak’s Brook from January 1, 2005 - October 31, 2008 in Nain, Labrador, Canada.
Appendix 13. Plots with Loess smoothers of untreated water quality (total coliforms and \textit{E. coli}) at the pre-treatment reservoir and the Brook from January 1, 2005 - October 31, 2008 in Rigolet, Labrador, Canada.