Retrospective Surveillance for Drinking Water-Related Illnesses in Canada, 1993-2008:

Final Report

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EXECUTIVE SUMMARY

Waterborne infections are an important cause of preventable enteric disease in Canada each year. The design of policies and programs for waterborne disease prevention is hampered, in part, by an absence of systematically collected information on the characteristics and causes of waterborne disease events (WBEs). Our objective was to obtain information that would facilitate WBE prevention policies and programs, including: (i) defining the characteristics of WBEs in Canada (ii) describing factors contributing to WBEs (iii) describing current WBE detection and prevention practices and (iv) identifying information needs of front-line public health staff.

Representatives from all public health regions across Canada were contacted to obtain information on WBEs (suspected or confirmed) that had occurred between 1993 and 2008 based on recall and their review of available reports. Voluntary telephone interviews using a standardized questionnaire collected information on the factors described. Of 100 attempted contacts, 71 respondents agreed to be interviewed (71% response rate). Forty-seven WBEs were identified.

The majority of WBEs identified occurred prior to 2001. *Giardia* and *Cryptosporidium* were the most common etiological agents, followed by bacteria and viruses. One half of communities experiencing WBEs had surface water as their water source and the majority of surface water was from unprotected watersheds. In terms of water treatment at the time of WBE identification, no water treatment was available for 39% of the communities, disinfection alone was used in 46%, and filtration combined with disinfection was used in 15%. Communities with larger populations tended to use a multiple barrier approach to water treatment. Most regions issued some form of boil order or advisory in response to the outbreak. The proportion of regions using surface water declined post-outbreak while water treatment practices tended to improve.

The majority of WBEs occurred in communities having small to medium-sized populations with the exception of those caused by *Cryptosporidium* which occurred most commonly in larger communities. For the most part, *Giardia*, bacteria and viruses were the etiologic agents in WBEs that occurred in communities having either no water treatment or disinfection only, while *Cryptosporidium*-related outbreaks generally occurred in communities having some combination of disinfection and filtration. In WBEs caused by *Cryptosporidium* that occurred in association with filtration, filtration systems were either old or were affected by some form of system failure.

Approximately 50% of communities experiencing WBEs did not monitor water quality in the incriminated water system. Regions often cited multiple factors that contributed to WBEs, such as inadequate treatment, lack of source protection, and precipitation. In response to outbreaks, 65% of regions changed the water source while 56% upgraded or changed the treatment system and 30% changed or improved policy, reporting, monitoring, or a combination thereof.

This investigation provides a detailed description of WBE characteristics in Canada. These characteristics suggest several key opportunities to improve drinking water management and mitigate known risks for waterborne disease and WBEs:

1. Improve water treatment effectiveness and water quality monitoring

2. Enhance waterborne disease surveillance and communication between stakeholders
3. Establish WBE prevention plans and policies that include watershed management and which take into account the potential for extreme weather events and the impact of global climate change
4. Seek appropriate expert advice in the event of WBEs
5. In each of the above, place special emphasis on small to medium sized communities

The occurrence of WBEs is an important factor in the motivation to improve drinking water management based on interview responses; collection and dissemination of information on WBEs should be encouraged.

INTRODUCTION

Waterborne infections constitute an important cause of preventable enteric disease in Canada each year. The design of policies and programs for waterborne disease prevention is hampered, in part, by an absence of systematically collected information on the characteristics and causes of waterborne disease events (Schuster *et al*, 2005).

Surveillance for endemic waterborne infections is problematic, in part because it can be difficult to accurately determine the source of individual cases of infection and the pathogens involved in waterborne disease can be acquired from a variety of other sources such as food, person-to-person transmission, and animal exposure. Though perhaps not constituting the majority of waterborne disease cases, outbreaks of waterborne disease (Waterborne Disease Events: WBEs), do provide a window into sources, health impacts, and factors contributing to waterborne illness under conditions where disease can be verified to be due to consumption of contaminated drinking water, through laboratory or epidemiologic evidence (Hrudey and Hrudey, 2004).

Unfortunately there is no national surveillance system in Canada for waterborne disease outbreaks, and approaches to collection of information on such outbreaks are not standardized. Information that is collected is often not published or not distributed beyond the relevant regional public health authorities, and is often incomplete. Schuster *et al* (2005) noted these issues in their review of available published information on waterborne disease outbreaks in Canada between 1974 and 2001.

To address these deficiencies, this investigation was undertaken in order to obtain detailed, standardized information on past waterborne disease outbreaks between 1993 and 2008 through in-depth interviews of relevant front-line environmental health professionals working in each pubic health authority in Canada. Information collected included characteristics of WBE and associated source waters, the nature of water treatment and WBE prevention programs, demographic information and health outcomes related to WBEs, and information needs related to WBE prevention.

Our objective was to obtain information of direct relevance to the design of WBE prevention policies and programs by (i) defining the characteristics of WBEs in Canada including etiologic agents involved, temporal and geographic patterns, demographic characteristics of cases and health outcomes (ii) describing factors contributing to WBEs including the nature of source waters and their treatment and predisposing factors such as weather, water contamination and human error (iii) describing current WBE detection and prevention practices and (iv) identifying information needs related to WBE prevention for front-line public health staff. For the sake of completeness, this investigation included acute illness related to exposure to chemical and radiological agents in addition to infectious organisms.

METHODS

Representatives from all public health regions across Canada were contacted to obtain information on drinking water-related disease events (Waterborne Disease Events: WBEs), suspected and confirmed, that had occurred between 1993-2008. Relevant individuals received an initial email and telephone call and were asked to identify the appropriate person to speak with regarding waterborne disease outbreaks. The appropriate individuals were sent information by email explaining the study and requesting an interview. Those who did not respond were subsequently contacted by telephone.

Telephone interviews were arranged for those willing to participate. Participants were interviewed using a standardized questionnaire to obtain information for all outbreaks experienced in the relevant region over the study period with respect to (i) characteristics of WBEs (ii) water source characteristics at the time of the WBE and at the time of the interview (iii) water treatment and distribution at the time of WBE and at the time of the interview (iv) demographic information and health outcomes related to WBEs (v) factors contributing to and outbreak control measures related to WBEs (vi) WBE prevention programs or policies stemming from the WBE (vii) programs in place to detect or prevent WBEs and (viii) information needs with respect to WBEs. Public health regions reporting no WBE over the study period were interviewed using a condensed questionnaire that focused on current water treatment systems and WBD prevention programs and excluded questions related to specific WBE. Participants were asked to examine and have on hand relevant outbreak reports to assist in their responses. The questionnaires are shown in Appendix I.

For the purposes of this study, WBE was defined as a suspected or confirmed acute illness related to exposure to biological, chemical or radiological agents from drinking water and involving two or more individuals. Also included were such events involving a singe individual where a clear point source (eg a private well) could be identified.

Questionnaire responses were entered into a database and analyzed using SPSS (16.0 SPSS for MAC 1989-2007). The analysis included calculation of descriptive statistics (means, proportions etc) and relevant cross-tabulations.

RESULTS

Compliance

Different provinces had a different structure and approach to their waterborne disease outbreak monitoring, depending on whether it was a provincial, a regional, or a combined responsibility. Also, some provincial authorities requested that we interview a more limited number of individuals (who sometimes had familiarity with outbreaks in more than one regional authority) rather than interviewing a representative from each regional authority. This affected our approach to identifying the appropriate individual to be interviewed. For AB, ON, QC, NL, and SK, we contacted every regional health authority directly. For MB and BC, provincial authorities directed us to the appropriate contacts. For PEI, NS, NB, YK, NU, and NWT, a single interview was arranged that covered the entire province or territory. The result was that individuals were identified who in total, provided coverage of past WBEs across the country. However, it was not possible in every case to determine precisely which regional authorities were covered by each interview. We attempted to contact 100 different individuals that resulted in 71 successful contacts for a 71% success rate.

There were 47 viable WBE interviews by the study end date, although a total of 48 waterborne disease event interviews were conducted (the New Brunswick interview was not complete enough at the deadline to be included). There were 41 shortened interviews with regions that had not had an outbreak. In total there were 88 completed interviews from 100 contacts for 11 of the 12 provinces and territories. Table 1 summarizes the number of contacts made and the number that were successfully interviewed, by province. Note that the number of interviews per province does not necessarily equal the number of successful contacts as some contacts provided interviews for more than one outbreak and some contacts provided information on more than one regional authority. Also note that, in tables of results of single response questions where the total number of WBEs is less than 47, the difference is the result of missing data for the relevant question.

Table 1 Distribution of contacts and interviews by province.

	Contact Success			Interview Breakdown		
Province	**Successful Contacts**	**Attempted Contacts**	**Success (%)**	**Outbreak Interview**	**Non-outbreak Interview**	**Total Interviews**
Alberta	9	9	100	2	7	9
British Columbia	13	14	93	12	5	17
Manitoba	2	3	67	2	1	3
New Brunswick	0	1	0	0	0	0
Newfoundland	4	4	100	4	1	5
Northwest Territories	1	1	100	0	1	1
Nova Scotia	1	1	100	0	4	4
Nunavut	1	1	100	0	1	1
Ontario	22	36	61	10	14	24
Prince Edward Island	1	1	100	1	0	1
Quebec	8	17	47	14	0	14
Saskatchewan	8	11	73	1	7	8
Yukon	1	1	100	1	0	1
TOTAL	71	100	71	47	41	88

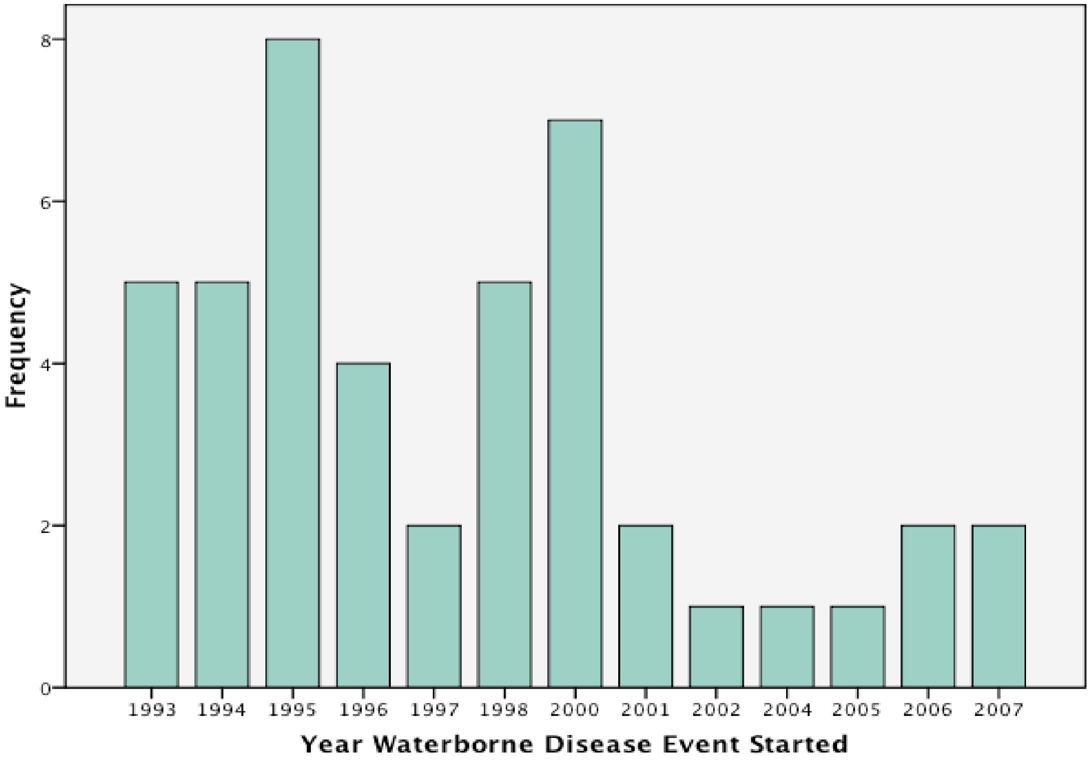
Temporal Characteristics of Waterborne Disease Events

The distribution of outbreaks by year of onset (Table 2 and Figure 1) reveal that the annual number of reported outbreaks was substantially higher up to and including the year 2000, and lower subsequently.

Table 2 Distribution of waterborne disease events (WBE) by year of onset.

Year	Number of WBE (%)	
1993	5	(11)
1994	5	(11)
1995	8	(18)
1996	4	(9)
1997	2	(4)
1998	5	(11)
1999	0	(0)
2000	7	(16)
2001	2	(4)
2002	1	(2)
2003	0	(0)
2004	1	(2)
2005	1	(2)
2006	2	(4)
2007	2	(4)
2008	0	(0)
Total	**45**	**(100)**

Figure 1 Histogram of the distribution of waterborne disease events by year of onset.



The majority of WBEs began in summer (June-August; 54%) and spring (March-May; 21.7%). WBEs lasted an average of 74 days, with a median of 45 days (range 6-671 days). The average number of days between the onset of a WBE and its identification was 18.2 (median 18; range 2 - 120).

Table 3 shows the distribution of WBEs by the mechanism through which they were identified. Participants reported that outbreaks were identified most frequently through patient, (35%), laboratory (33 %) or physician (22%) reports. However, respondents also reported that the identification of WBEs often involved more than one source of information.

Table 3 Method of waterborne disease event (WBE) identification.

Method of WBE Identification	Number (%)	
Patient	16	(35)
Lab Reports	15	(33)
Physician	10	(22)
Complaint Phone Line	3	(7)
Pharmacist	2	(4)
Water Utility / Municipality	2	(4)
Water Regulator	2	(4)
Other Public Health Unit	2	(4)
Surveillance	2	(4)
Other	1	(2)

Table 4 shows the distribution of WBE by etiologic agent. Protozoa (*Giardia* and *Cryptosporidium*) were the most commonly identified agents, followed by bacteria and norovirus. Two waterborne chemical-related outbreaks were identified: one was due to copper poisoning and the other was related to elevated nitrate levels.

Table 4 Distribution of waterborne disease events (WBE) by etiologic agent.

WBE Agent	Frequency (%)	
Giardia	10	(21)
Cryptosporidium	7	(15)
Cryptosporidium & Giardia	2	(4)
Toxoplasma	1	(2)
Campylobacter	3	(6)
E. coli	3	(6)
E. coli & Campylobacter	1	(2)
Legionella	1	(2)
Salmonella	1	(2)
S. aureus	1	(2)
Total coliform	1	(2)
Norovirus	4	(9)
Hepatitis A	3	(6)
Chemical	2	(4)
Not identified	7	(15)
Total	**47**	**(100)**

Drinking Water Orders and Advisories

A drinking water order or advisory was issued in response to WBEs in the majority of the cases (77%). In 19% of WBEs no order or advisory was instituted, and an order or advisory was already in effect when two WBEs had occurred (Table 5). The majority of drinking water restrictions were boil water advisories (BWA; Table 6). Drinking water restrictions or recommendations were most commonly issued by the medical health officer, local health unit staff member, or a private facility (Table 7). The duration of the drinking water restriction or recommendation was determined for 20 WBEs, and the mean was 158.25 days with a median of 48 days (range 2 – 802 days). Very few WBE involved more than one regional authority; the average number of additional regions involved was less than 1.

Table 5 Number of drinking water orders / advisories implemented due to waterborne disease events.

Order or Advisory Instituted	Number (%)	
Yes	33	(77)
No	8	(19)
Order or Advisory already in Place	2	(5)
Total	**43**	**(100)**

Table 6 Type of drinking water restriction and recommendation issued due to waterborne disease events.

Type of Restriction or Recommendation	Number (%)	
Boil Water Advisory	25	(71)
Boil Water Order	5	(14)
Boil Water Advisory & Shut Public Facility	2	(6)
Closed Well / Shut Off Water	2	(6)
Boil Water Notice	1	(3)
Total	**35**	**(100)**

Table 7 Individuals or agencies declaring drinking water restrictions or recommendations due to waterborne disease events.

Individual / Agency Declaring Drinking Water Restrictions or Recommendations	Number (%)	
Public Health Unit Staff or Inspector	9	(32)
Medical Officer	4	(14)
Private Facility	4	(14)
Department of Environment	3	(11)
Department of Health	3	(11)
Town or City Staff	2	(7)
Departments of Environmental & Health	2	(7)
Water purveyor	1	(4)
Total	**28**	**(100)**

Table 8 shows the reasons provided for why no drinking water restriction or recommendation was issued in the face of a WBE. The most common reason was that the implicated facility or water source had been closed in response to the outbreak.

Table 8 Reasons given for not issuing a drinking water restriction or recommendation in the presence of a waterborne disease event (WBE).

Reasons for not issuing a Drinking Water Restriction or Recommendation	Number (%)	
Facility Closed / Source Shut Down	4	(50)
Advisory Already in Place	1	(13)
WBE Already Resolved	1	(13)
Source of WBE not Identified	1	(13)
Water Source Tested Negative	1	(13)
Total	**8**	**(100)**

Water Source

The water source was surface water in 50% of WBEs, and ground water in 39%. A mix of ground and surface water accounted for the remaining 11% of WBEs (Table 13). Protozoal infections were most commonly associated with surface water, while viral and certain bacterial infections (*E. coli, S. aureus* and *Salmonella*) were most commonly associated with ground water sources, although the numbers of WBEs associated with viral and bacterial infections were small (Table 9).

Table 9 Distribution of waterborne disease events (WBEs) by water source type.

WBE Agent	Surface Water (%)		Ground Water (%)		Surface & Ground Water (%)		Total
Giardia	9	(90)	1	(10)	0	(0)	10
Cryptosporidium	4	(57)	1	(14)	2	(29)	7
Cryptosporidium & Giardia	2	(100)	0	(0)	0	(0)	2
Toxoplasma	1	(100)	0	(0)	0	(0)	1
Campylobacter	2	(67)	0	(0)	1	(33)	3
E. coli	1	(33)	2	(67)	0	(0)	3
E. coli & Campylobacter	0	(0)	1	(100)	0	(0)	1
Legionella	0	(0)	0	(0)	1	(100)	1
Salmonella	0	(0)	1	(100)	0	(0)	1
S. aureus	0	(0)	1	(100)	0	(0)	1
Total Coliform	1	(100)	0	(0)	0	(0)	1
Norovirus	1	(25)	3	(75)	0	(0)	4
Hepatitis A	0	(0)	3	(100)	0	(0)	3
Chemical	0	(0)	1	(50)	1	(50)	2
Total	21	(53)	14	(35)	5	(13)	40

*Percentages represent row totals

Surface Water

The most common source of surface water was streams or rivers followed by lakes (Table 10). Eighty-four percent of watersheds in regions with a WBE associated with surface water were unprotected at the time of the outbreak (Table 11). Information on the type of activity at the time of the outbreak was available for only 12 of the 21 unprotected watersheds. Activities included the presence of wildlife (33%), heavy multiple uses (25%) and agriculture (17%). A change in weather at the time of the outbreak was reported by 54% of WBE and it was most often (70%) an increase in rain or spring runoff / thaw or a combination of the two.

Table 10 Distribution of waterborne disease events by surface water type.

Type of Surface Water	Number (%)	
Stream / River	12	(43)
Lake	7	(25)
Pond / Reservoir	4	(14)
River to Reservoir	2	(7)
Lake & River	2	(7)
Spring	1	(4)
Total	**28**	**(100)**

Table 11 Type of watershed protection present at time of waterborne disease events associated with surface water.

Watershed Protection	Number (%)	
Unprotected	21	(84)
Partially Protected	3	(12)
Fully Protected	1	(4)
Total	**25**	**(100)**

Ground water

Ground water source at the time of WBEs was primarily drilled (55%) or artesian wells (18.%; Table 12). In 53% of WBEs involving ground water the ground water was reported to be under the direct influence of surface water. The well-head was protected in 67% of WBEs involving ground water, and a few WBEs (36%) involved a change in the integrity of the well or aquifer prior to the outbreak.

Table 12 Distribution of waterborne disease events by type of ground water.

Type of Ground Water Source	Number (%)	
Drilled Well	12	(55)
Artesian Well	4	(18)
Dug Well	2	(9)
Mixed Ground Source	2	(9)
Shallow Well	2	(9)
Total	**22**	**(100)**

Source water post-outbreak

There were changes in water source from the time of WBEs to the time of the respective interviews. Surface water was the water source in 50% of WBEs but only 35% for the same populations at the time of interview. Conversely, ground water was the water source in 39% of WBEs but 50% for the same populations at the time of interview (Table 13).

In addition to a change from surface to ground water, regions having experienced WBEs also made changes in the type of surface and ground water they used subsequent to the outbreak, for the same populations. At the time of the interview, populations having experienced WBEs were served less by river and stream surface water and more by reservoirs and lakes than at the time of the outbreaks. There was also an increase in the use of drilled wells, a decrease in artesian wells and a reduction in the number of ground water sources under the direct influence of surface water.

Table 13 Type of water source during waterborne disease events (WBE) and at the time of interview for the same populations.

Water Source During WBE	Number	(%)
Surface Water	23	(50)
Ground Water	18	(39)
Mix of Surface & Ground	5	(11)
Total	46	(100)
Water Source at Time of Interview	**Number**	**(%)**
Surface Water	16	(35)
Ground Water	23	(50)
Mix of Surface & Ground	5	(11)
Closed Facility	2	(4)
Total	**46**	**(100)**

Water Treatment and Distribution

The most common water treatment in effect during WBEs was disinfection (46%); in 39% of WBEs there was no treatment in effect at all. Filtration was in effect in only 15% of WBEs (Table 14). Of the 28 WBEs in which disinfection was in place, chlorine was used in 75%.

Table 14 Method of water treatment in place at time of waterborne disease event (WBE).

Water Treatment at time of WBE	Number	(%)
Disinfection	21	(46)
No Treatment	18	(40)
Disinfection & Filtration	3	(7)
Disinfection, Coagulation, & Filtration	3	(7)
Disinfection, Coagulation, Filtration & Reverse Osmosis	1	(2)
Total	**46**	**(100)**

Interviewees were asked to specify any events related to water treatment that occurred around the time of the WBE. The most commonly reported deficiency was a lack of or inadequate filtration followed by inadequate chlorination.

Water treatment practices also changed between the time of WBEs and the time of the interview for the same populations. There was an increase in the use of disinfection, filtration, coagulation and reverse osmosis and a decrease in the absence of water treatment (Table 14 vs. Table 15). Water distribution was by pipe in 80% of regions before a WBE event and 79% of regions after a WBE.

Table 15 Method of water treatment in place at time of interview for populations having experienced a waterborne disease event (WBE).

Current Water Treatment	Number (%)	
Disinfection	18	(43)
No Treatment	7	(17)
Disinfection & Filtration	9	(21)
Disinfection, Coagulation, & Filtration	6	(14)
Disinfection, Coagulation, Filtration & Reverse Osmosis	2	(5)
Total	**42**	**(100)**

Table 16 shows the distribution of water treatment practices by etiologic agent for reported WBEs. Generally speaking, bacterial, viral and *Giardia* outbreaks tended to occur in systems having either no treatment or disinfection only. *Cryptosporidium* outbreaks, on the other hand, tended to occur in association with systems having some combination of disinfection and filtration.

Table 16 Method of water treatment in place at the time of waterborne disease event (WBE) by agent identified

	No Treatment	Disinfection	Disinfection & filtration	Disinfection, coagulation & filtration	Disinfection, coagulation, filtration & reverse osmosis
Giardia	4 (40%)*	5 (50%)	1 (10%)	0	0
Cryptosporidium	0	3 (43%)	0	3 (43%)	1 (14%)
Cryptosporidium & Giardia	1 (50%)	1 (50%)	0	0	0
Toxoplasma	0	1 (100%)	0	0	0
Campylobacter	2 (67%)	1 (33%)	0	0	0
E. coli	2 (67%)	1 (33%)	0	0	0
E. coli & Campylobacter	0	1 (100%)	0	0	0
Legionella	0	0	1 (100%)	0	0
Salmonella	1 (100%)	0	0	0	0
S. aureus	1 (100%)	0	0	0	0
Total Coliform	0	1 (100%)	0	0	0
Norovirus	2 (50%)	2 (50%)	0	0	0
Hepatitis A	3 (100%)	0	0	0	0
Chemical	0	1 (50%)	1 (50%)	0	0
Total	16	17	3	3	1

*Values in parentheses represent row percentages

Water Quality Monitoring

Table 17 shows the distribution of water quality monitoring activities for reported WBEs. There was no routine testing at all for chlorine in 48% of regions that had a WBE, for turbidity in 57%, for coliforms / *E. coli* in 34% and for *Giardia / Cryptosporidium* in 55%.

Table 17 Type and frequency of water quality monitoring at time of waterborne disease event (WBE).

	Chlorine		Turbidity		Coliform / *E. coli* / Chemicals		*Giardia* / *Cryptosporidium*	
	Number	(%)	Number	(%)	Number	(%)	Number	(%)
Daily	1	(4)	1	(5)	1	(3)		
Weekly					4	(11)		
Biweekly	1	(4)	1	(5)				
Monthly					3	(9)	2	(9)
Sometimes	4	(16)			7	(20)	1	(5)
Yearly	2	(8)	2	(10)	2	(6)	2	(9)
According to Standards	5	(20)	5	(24)	6	(17)	5	(23)
Not at all	12	(48)	12	(57)	12	(34)	12	(55)
Total	**25**	**(100)**	**21**	**(100)**	**35**	**(100)**	**22**	**(100)**

*Values in parentheses represent row percentages

Demographic Information and Health Outcomes

Population Size

WBEs occurred in communities with an average population of 26,969 (median 438; range 4-390,000). The mean number of cases per WBE was 654 (median 20; range 0-15,000). The mean number of laboratory-confirmed cases was 40.6 (median 13; range 0-283) (Table 18).

Table 18 Demographic characteristics of waterborne disease events (WBE)..

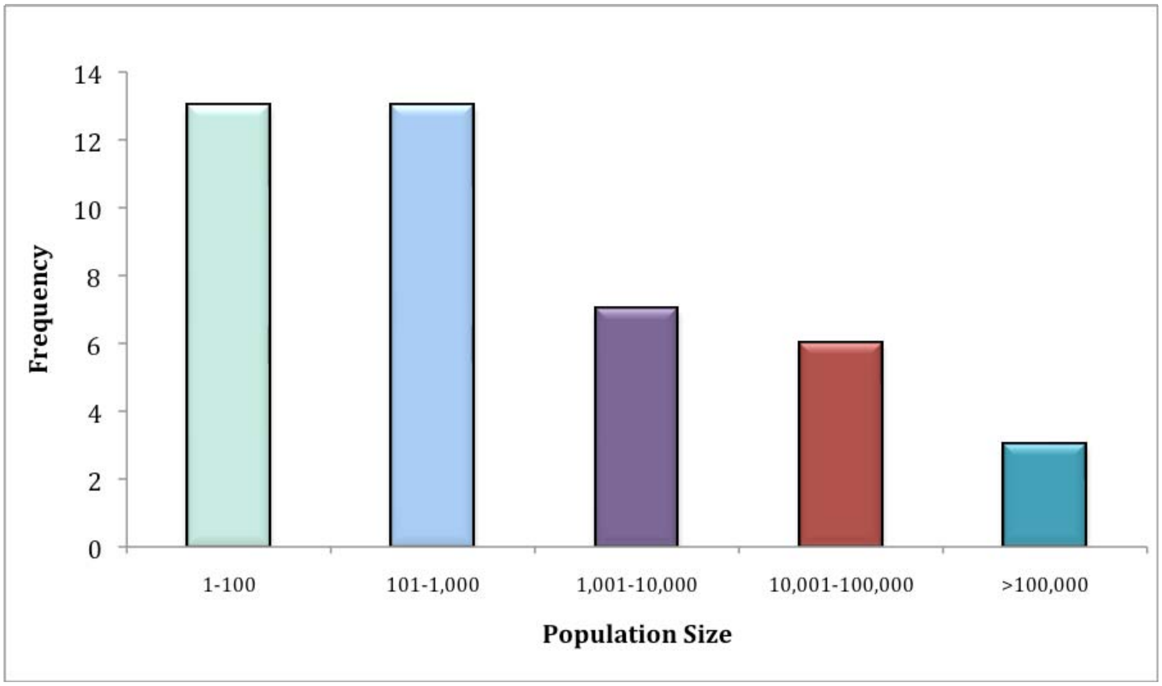
	Number of People Served by Water Supply	Number of People Who Became Ill	Number of Lab-Confirmed Cases
Mean	26,969	654	41
Median	438	20.	13.
Standard Deviation	75,501	2,578	73
Minimum	4	0	0
Maximum	390,000	15,000	283
Number of WBE	42	39	37
Missing	5	8	10

The frequency distribution of community population category size is shown in Table 19 and Figure 2. The results indicated that the majority of WBEs occurred in systems serving less than 1000 people.

Table 19 Frequency and percentage of waterborne disease events (WBE) by community population.

Population Size	Frequency (%)	
1-100	13	(31)
101-1,000	13	(31)
1,001-10,000	7	(17)
10,001-100,000	6	(14)
>100,000	3	(7)
Total	42	(100)

Figure 2 Histogram of frequency of waterborne disease events (WBE) by community population size.



Population size and year of outbreak

WBEs were more frequent prior to 2001 although there was no clear change in the distribution of WBEs as a function of community size over time (Table 20).

Table 20 Frequency distribution of waterborne disease events (WBE) by population size and year

Year	Population size				
	1-100	**101-1,000**	**1,001-10,000**	**10,001-100,000**	**>100,000**
1993	0	3 (75%)*	0	0	1 (25%)
1994	2 (40%)	2 (40%)	1 (20%)	0	0
1995	3 (43%)	1 (14%)	2 (29%)	1 (14%)	0
1996	0	0	1 (33%)	1 (33%)	1 (33%)
1997	0	2 (100%)	0	0	0
1998	2 (40%)	2 (40%)	0	1 (20%)	0
2000	3 (50%)	1 (17%)	2 (33%)	0	0
2001	0	0	0	0	0
2002	1 (100%)	0	0	0	0
2004	0	1 (100%)	0	0	0
2005	1 (100%)	0	0	0	0
2006	0	0	0	1 (50%)	1 (50%)
2007	0	1 (50%)	1 (50%)		0
Total	12	13	7	6	3

*Values in parentheses represent row percentages

Population size, illness, and WBE agent

Giardia outbreaks on average tended to affect communities of smaller population size and to cause fewer cases than all outbreaks combined. In contrast, *Cryptosporidium* outbreaks tended to affect larger communities and to cause more cases (Tables 21-23).

Table 21 Size of population affected by waterborne disease events (WBE) as a function of the agent involved.

	Population Served by Water Supply During WBE			
Agent	**Mean**	**Median**	**Minimum**	**Maximum**
Giardia	2,213	800	6	8,000
Cryptosporidium	138,643	90,000	15,500	390,000
E.coli	295	80	4	800
Hepatitis A	23	23	15	30

Table 22 Number of individuals who became ill during waterborne disease events (WBE) as a function of the agent involved.

	People Who Became Ill During WBE			
Agent	**Mean**	**Median**	**Minimum**	**Maximum**
Giardia	21	16	2	54
Cryptosporidium	3,173	200	20	15,000
E.coli	3.	3	1	6
Hepatitis A	16	16	15	16

Table 23 Number of laboratory-confirmed cases during waterborne disease events as a function of the agent involved.

	Lab-Confirmed Clinical Cases			
Agent	**Mean**	**Median**	**Minimum**	**Maximum**
Giardia	10	9	1	26
Cryptosporidium	97	29	17	275
E.coli	3	2		6
Hepatitis A	16	16	15	16

The distribution of community size by agent was examined (Tables 24-25). *Cryptosporidium* outbreaks tended to occur in larger communities, while *Giardia*, bacterial and viral outbreaks tended to occur in smaller communities.

Table 24 Frequency distribution of waterborne disease events (WBE) by population size category and agent.

	Population size				
Agent	**1-100**	**101-1,000**	**1,001-10,000**	**10,001-100,000**	**>100,000**
Giardia	2 (25%)*	3 (38%)	3 (38%)	0	0
Cryptosporidium	0	0	0	4 (57%)	3 (43%)
Cryptosporidium & Giardia	0	0	2 (100%)	0	0
Toxoplasmosis	0	0	0	1 (100%)	0
Campylobacter	0	3 (100%)	0	0	0
E. coli	2 (67%)	1 (33%)	0	0	0
Legionella	0	1 (100%)	0	0	0
Salmonella	0	1 (100%)	0	0	0
S. aureus	1 (100%)	0	0	0	0
Total coliform	0	0	0	1 (100%)	0
Norovirus	2 (50%)	1 (25%)	1 (25%)	0	0
Hepatitis A	2 (100%)	0	0	0	0
Chemical	0	1 (50%)	1 (50%)	0	0
Not identified	4 (67%)	2 (33%)	0	0	0
Total	13	13	7	6	3

*Values in parentheses represent row percentages

Table 25 Summary of population size and year for each waterborne disease event (WBE).

Agent	Population	Year	Agent	Population	Year
Giardia	6	1994	***Cryptosporidium***	15500	2001
Giardia	12	2000	***Cryptosporidium***	20000	1996
Giardia	170	1998	***Cryptosporidium***	35000	1998
Giardia	800	1993	***Cryptosporidium***	90000	2006
Giardia	1000	1993	***Cryptosporidium***	170000	2006
Giardia	3000	2000	***Cryptosporidium***	250000	1996
Giardia	3500	1994	***Cryptosporidium***	390000	1993
Giardia	8000	1996			
Giardia	unknown	1996	***Cryptosporidium & Giardia***	5000	2000
Giardia	unknown	1993	***Cryptosporidium & Giardia***	7200	1995
E. coli	4		**Toxoplasmosis**	100000	1995
E. coli	80	1998			
E. coli	800	2007	***Campylobacter***	400	1993
			Campylobacter	475	1998
Legionella	300	1997	***Campylobacter***	600	2004
Salmonella	200	1995	***E. coli & Campylobacter***	unknown	2000
S. aureus	55	1998	**Total coliform**	25000	2001
Norovirus	90	1994	**Hepatitis A**	15	1995
Norovirus	90	2005	**Hepatitis A**	30	1995
Norovirus	160	1994	**Hepatitis A**	unknown	1995
Norovirus	1805	1995			
			Chemical	350	1997
Unidentified	8	1995	**Chemical**	2500	2007
Unidentified	27	2000			
Unidentified	60	2002			
Unidentified	100	2000			
Unidentified	200	1994			
Unidentified	200	2000			
Unidentified	Unknown				

Population size, water source, and frequency of illness.

WBEs associated with surface water involved larger populations and larger numbers of cases than those associated with ground water (Tables 26-27). The average number of people who became ill was highest in communities served by surface water and lowest when served by ground water (Table 28-29)

Table 26 Size of population affected by waterborne disease events (WBE) as a function of water source.

	Population Served by Water Supply During WBE			
Source Type	Mean	Median	Minimum	Maximum
Surface Water	58,291	5,750	8	390,00
Ground Water	7,627	73	4	90,000
Surface & Ground Water	41,210	400	300	170,000

Table 27 Frequency distribution of WBEs by community population size category and water source.

	Population size				
Source Type	**1-100**	**101-1,000**	**1,001-10,000**	**10,001-100,000**	**>100,000**
Surface water	4 (19%)*	6 (29%)	5 (24%)	4 (19%)	2 (10%)
Ground water	9 (56%)	4 (25%)	2 (13%)	1 (6%)	0
Surface & Ground water	0	3 (60%)	0	1 (20%)	1 (20%)
Total	13	13	7	6	3

*Values in parentheses represent row percentages

Table 28 Number of individuals who became ill during waterborne disease events (WBE) as a function water source.

	People who Became Ill During WBE			
Source Type	**Mean**	**Median**	**Minimum**	**Maximum**
Surface Water	1,565	29		15,000
Ground Water	37	18	1	200
Surface & Ground Water	97	20	1	350

Table 29 Number of laboratory-confirmed cases during waterborne disease events (WBE) as a function water source.

	Lab-Confirmed Clinical Cases			
Source Type	**Mean**	**Median**	**Minimum**	**Maximum**
Surface Water	58	15		275
Ground Water	8	6		21
Surface & Ground Water	17	18	1	44

Population size, water treatment, watershed protection and water quality monitoring

Communities that had no treatment in place at the time of WBE tended to be small, while disinfection alone tended to be utilized in small to medium sized ones. Filtration in effect was in larger populations (Table 30). There was no relationship between watershed protection and population size (Table 31). WBE in which there was no water quality monitoring occurred in small communities only (Table 32).

Table 30 Frequency distribution of waterborne disease events (WBE) by population size category and water treatment.

	Population size				
Treatment type	**1-100**	**101-1,000**	**1,001-10,000**	**10,001-100,000**	**>100,000**
None	8 (50%)*	6 (38%)	2 (13%)	0	0
Disinfection	5 (26%)	4 (21%)	5 (26%)	4 (21%)	1 (5%)
Disinfection & filtration	0	3 (100%)	0	0	0
Disinfection, coagulation, & filtration	0	0	0	1 (33%)	2 (67%)
Disinfection, coagulation, filtration, & reverse osmosis	0	0	0	1 (100%)	0
Total	13	13	7	6	3

*Values in parentheses represent row percentages

Table 31 Frequency distribution of waterborne disease events (WBE) by watershed protection and population size category.

	Population size				
Watershed protection	**1-100**	**101-1,000**	**1,001-10,000**	**10,001-100,000**	**>100,000**
Fully	0	0	1 (100%)*	0	0
Partially	0	1 (33%)	1 (33%)	1 (33%)	0
Unprotected	4 (20%)	6 (30%)	3 (15%)	4 (20%)	3 (15%)
Unknown	0	2 (100%)	0	0	0
Total	4	9	5	5	3

*Values in parentheses represent row percentages

Table 32 Frequency distribution of waterborne disease events (WBE) by water quality monitoring and population size category

	Population Size				
Water Quality Monitoring	**1-100**	**101-1,000**	**1,001-10,000**	**10,001-100,000**	**>100,000**
Yes	4 (17%)*	6 (25%)	6 (25%)	5 (21%)	3 (13%)
No	8 (67%)	4 (33%)	0	0	0
Unknown	1 (25%)	3 (75%)	0	0	0
Total	13	13	6	5	3

*Values in parentheses represent row percentages

Age and sex of waterborne illness cases

There were only seven WBEs in which information on average age of cases was provided, and this was an estimate by the interviewees in some cases (Table 33). The mean of the average age per WBE was 38 years (median 34; range 29-65). The range of case ages was 0.2 to 97 years. Approximately 50% of the cases were women.

Table 33 Age and sex of cases in waterborne disease events (WBE).

Age & Sex of Cases	Mean	Median	Std. Deviation	Minimum	Maximum	n	Missing
Average Age	38	34	13	29	65	7	40
Minimum Age	17	16	16	0	60	15	32
Maximum Age	59	56	22	19.0	97	15	32
Percent Female	50	52	27	0	100	18	29

Case definition, hospitalizations, and fatalities.

The case definition used for WBEs varied among regions and outbreaks, but consisted of a combination of symptoms, laboratory confirmation, water use, and relevant time frame and geographic area (Table 34). Hospitalizations were required in 38% of WBEs (Table 35), and the mean duration of hospitalization was 12 days (median 2 days; range 1-65 days). Fatalities were reported in one WBE (Table 36). There was only 1 WBE in which extra-GI clinical syndromes were reported; the identified syndromes included retinochoroditis and lymphadenopathy.

Table 34 Case definition utilized during waterborne disease events (WBE).

Case Definition for WBE	Frequency (%)	
GI Symptoms	8	(25)
Severe Symptoms	1	(3)
Lab Confirmation	9	(28)
CDC Guidelines	1	(3)
Symptomatic & Used Suspect Water	2	(6)
Symptomatic in WBE Timeframe & Area	4	(13)
Symptomatic & Lab Confirmation	7	(2
Total	32	(100)

Table 35 Frequency of waterborne disease events in which hospitalization was reported:.

Hospitalizations	Frequency (%)	
Yes	9	(38)
No	13	(54)
In seniors home	2	(8)
Total	24	(100)

Table 36 Frequency of waterborne disease events in which fatalities were reported.

Deaths	Frequency (%)	
Yes	1	(3)
No	30	(97)
Total	31	100

Factors contributing to waterborne disease events

Interviewees identified factors that may have contributed to waterborne events, and multiple factors were often indicated (Table 37). Inadequate treatment was cited as the most common contributing factor (64%), followed by lack of source water protection (39%), animals in the watershed (36%), and precipitation (32%).

Table 37 Frequency of responses regarding contributing factors to waterborne disease events.

Contributing Factors*		Frequency (%)	
Contamination at Water Source	Precipitation	14	(32)
	Spring thaw / run-off	7	(16)
	Flooding	3	(7)
	Lack of source water protection	17	(39)
	Animals in the watershed	16	(37)
	Other	7	(16)
Water Treatment Deficiencies	Treatment failure	7	(16)
	Inadequate treatment	28	(64)
	Other	5	(11)
Cross Contamination in Water Distribution	Broken pipe(s)	3	(7)
	Post-treatment contamination	5	(11)
	Cross connection	0	(0)
Other	Turbidity	10	(23)
	Human error	5	(11)
	No contributing factors identified	1	(2)

*Multiple responses possible

The study requested additional information on factors believed to have contributed to WBEs listed in Table 37. Wildlife accounted for the majority of animals identified as contributing to WBEs. “Other” sources of contamination of source water was principally septic and / or sewage. Causes of treatment failure were usually unspecified. Cause of inadequate treatment was most often not specified, although no treatment and no filter were cited frequently (Table 38).

Table 38 Frequency of responses that specified contributing factors* in waterborne disease events from Table 37.

Type of Animals in the Watershed*	Frequency	(%)
Wildlife	10	(6
Yes-Unspecified	3	(19)
Cattle / Agriculture	2	(13)
Wildlife & Agriculture	1	(6)
“Other” Contamination at Water Source	**Frequency**	**(%)**
Septic / Sewage too Close	4	(57)
Human Activity	1	(14)
Upstream Water Contamination	1	(14)
Heat & Septic / Sewage	1	(14)
Treatment Failure	**Frequency**	**(%)**
Yes-Unspecified	4	(57)
Chlorine Turned Off	1	(14)
Inadequate Chlorination	1	(14)
No Flocculation Blanket & Crack in Plant	1	(14)
Inadequate Treatment	**Frequency**	**(%)**
Yes-Unspecified	9	(32)
No Treatment	8	(29)
No Filter	6	(21)
Chlorination Inadequate	3	(11)
Recycled Filter	1	(4)
No Retention Pond	1	(4)
“Other” Water Treatment Deficiencies	**Frequency**	**(%)**
Backflow Minnow Tank	1	(20)
Sewage Upstream	1	(20)
No Treatment	1	(20)
No Water Monitoring	1	(20)
Yes-Unspecified	1	(20)

***Multiple responses possible**

Table 39 shows the relationship between contributing factors and community population size category.

Table 39 The frequency of waterborne disease events (WBE) by population size categories and contributing factors.

		Population size									
Contributing factors*		1-100		101-1,000		1,001-10,000		10,001-100,000		>100,000	
		Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Contamination at Water Source	**Precipitation**	6	46%	2	15%	1	17%	1	17%	2	67%
	Spring thaw/run-off	1	8%	2	15%	1	17%	1	17%	2	67%
	Flooding	0	0%	2	15%	0	0%	0	0%	0	0%
	Lack of source protection	5	39%	4	31%	4	67%	2	33%	1	33%
	Animals in the watershed	2	15.	4	31%	5	83%	3	50%	1	33%
	Other	2	15%	2	15%	2	33%	0	0%	1	33%
Water Treatment Deficiencies	**Treatment failure**	4	31%	1	8%	0	0%	1	17%	0	0%
	Inadequate treatment	7	54%	9	69%	4	67%	3	50%	3	100%
	Other	2	15%	2	15%	0	0%	1	17%	0	0%
Cross Contamination in Water Distribution	**Broken pipe(s)**	1	8%	1	8%	0	0%	0	0%	1	33%
	Post-treatment contamination	2	15%	2	15%	0	0%	0	0%	1	33%
	Cross connection	0	0%	0	0%	0	0%	0	0%	0	0%
Other	**Turbidity**	3	23%	2	15%	1	17%	1	17%	1	33%
	Human error	0	0%	3	23%	0	0%	0	0%	1	33%
	No factors	0	0%	0	0%	0	0%	1	17%	0	0%

***Multiple responses possible**

Additional Resources Used During Waterborne Disease Events

Additional expert resources relied on by local public health personnel during WBE are listed in Table 40. Most frequently consulted were various local experts, the provincial epidemiologist and water treatment experts. Twenty percent of respondents said no additional resources were consulted as part of WBE investigations. Details of local experts and "other" resources consulted during WBEs are shown in Table 41.

Table 40 Additional resources brought in to assist with waterborne disease event investigations.

Additional Resources	Frequency (%)	
Local Expert	21	(50)
Provincial Epidemiologist	20	(486)
Water Treatment Personnel	14	(33)
No Additional Resources	9	(21)
Other	9	(21)
Field epidemiologist	8	(19)

***Multiple responses possible**

Table 41 Details of types of local experts and "Other" resources brought in to assist in waterborne disease event investigations.

"Other" Resources	Frequency (%)	
Public Health Staff	3	(33)
Municipal Affairs Staff	2	(22)
Conservation Staff	1	(11)
Engineers	1	(11)
Federal Epidemiologist	1	(11)
Engineers & Other Consultants	1	(11)
Local Experts	**Frequency (%)**	
Provincial Health / Environment Staff	10	(48)
Yes-Unspecified	7	(33)
Chief Environmental Health Officer	2	(10)
Physicians	1	(5)
Staff from Other Public Health Units	1	(5)

***Multiple responses possible**

Evidence for Drinking Water as Source of Outbreaks

The type of evidence used to determine that WBEs were waterborne is shown in Table 42. The evidence frequently included identification of the same pathogen in water as in clinical cases (63%), a failure in water quality (42%), and epidemiologic evidence (46%).

Table 42 Type of evidence that suggested that WBEs were waterborne.

Type of Evidence	Count (%)	
Pathogen Identified in Cases and Water	26	(63)
Water Quality Failure	17	(42)
Descriptive Epidemiology	17	(42)
Water Treatment Problem But No Pathogen Found	4	(10)
Analytical Epidemiologic Study	2	(5)

***Multiple responses possible**

Prevention of Future WBEs

A series of questions, both closed- and open-ended, addressed WBE prevention.

Actions to prevent future waterborne events

Participants were asked to describe actions that were taken to prevent future waterborne events. Some regions took multiple steps to prevent waterborne events. Many of the participants reported that they changed their water source or upgraded their treatment system (Table 43).

Table 43 Actions taken to prevent future waterborne events (WBEs).

Actions Taken to Prevent Future WBE	Frequency (%)	
Upgrade / change treatment system	24	(56%)
Education / study / assessment	12	(28%)
Changed water source	28	(65%)
Changed / improved policy, reporting, monitoring	13	(30%)

***Multiple responses possible**

Following are examples of the type of open-ended responses provided:

1. Upgraded, added, or altered water treatment systems
    a. Added UV, filtration,
    b. Turbidity monitoring system
    c. Shock treated well or disinfected system.
2. Education / study / examination / assessment
    a. Public and staff training
    b. Conducted a study of WBE prevention approaches
    c. Assessed / evaluated their system
3. Changed water source or added protection to water source
    a. New well
    b. Changed source of water
    c. Stopped use (closed facility)
    d. Maintained boil water advisory until safe
    e. Covered / protected reservoir
4. Change / improve policy, reporting, monitoring
    a. Increased monitoring of water quality / pathogens
    b. Changed inspection of water systems

Effectiveness of actions

In addition, participants were asked about the effectiveness of their actions to prevent WBEs. The majority found the actions they took to prevent future waterborne events to be effective (Table 44).

Table 44 Effectiveness of actions taken to prevent future waterborne events (WBEs).

Effectiveness of Actions to Prevent WBE	Frequency (%)	
Yes	29	(91)
No - had BWA since	2	(6)
No - had outbreak since	1	(3)
Total	32	(100)

Modification or creation of policy to prevent waterborne disease events

The majority of regions (88%) created or modified policies and procedures to prevent additional waterborne disease events as a result of the reported outbreak. These usually involved multiple agencies, with the most frequently reported being the Provincial Department of Health or Environment and the public health unit or regional health authority (Table 45).

Table 45. Policies and procedures developed to prevent future waterborne events (WBEs), the departments involved in the process, and the policies and procedures that were developed.

Policies & Procedures to Prevent WBE	Frequency (%)	
Yes	30	(88)
No	4	(12)
Total	34	100
Departments / Agencies Involved in Process	**Frequency (%)**	
Municipality / city	5	(20)
Public health office / regional health authorities	10	(40)
Provincial agency (health / environment)	23	(92)
Water purveyor	1	(4)
Policies & Procedures Developed	**Frequency (%)**	
Water source	5	(19)
Boil water advisory/order	2	(7)
Surveillance	2	(7)
Inspection / water quality monitoring	7	(26)
Treatment	11	(41)
Response to outbreak	2	(7)
Other initiative	5	(19)

***Multiple responses possible**

The policies and procedures that were created to prevent future waterborne events are elaborated below. The most common policies and procedures developed were for treatment (41%) and inspection or water quality monitoring (26%).

1) Water Source
    a. Protection
    b. Alter source and maintain surface water for emergency use
    c. Restrictions related to potential contamination
    d. Address ground water under influence of surface water
2) Boil water policy / restrictions
3) Surveillance
4) Inspection / water quality monitoring of drinking water and sewage
    a. Municipal inspection – modify / invoke
    b. Privately held publicly utilized facilities (camps) - address
5) Drinking Water Regulations or Treatment Policy
6) Response to outbreak
7) Other initiatives

Creation and modification of policies for waterborne event investigation

Policies and procedures created to modify or address investigation or management of future waterborne events were reported by 71% of respondents (Table 46).

Table 46 Policies and procedures developed to investigate or manage future waterborne events (WBEs).

Policies and Procedures for WBE Investigation	Frequency (%)	
Yes	20	(71)
No	8	(29)
Total	28	(100)

The policies and procedures developed to address investigation or management of future waterborne events included:

1) Increased sampling
2) Restructured investigation approach
3) Changed approach
    a. Spend more time understanding water quality and treatment
    b. Use resources more appropriately
4) Specialized health inspectors
5) Upgraded groundwater protocols
6) Education
    a. Supplied fact sheets for education of private well owners
    b. Ensured up-to-date contact list

Were actions taken to prevent future WBE congruent with contributing factors?

Table 47 shows the relationship between contributing factors and the actions taken to prevent future WBE. For each contributing factor a range of actions were taken, reflecting that appropriate action is multifaceted and depends on the specifics of each situation. When examining this table, one must keep in mind that contributing factors and actions to prevent future WBE were both multiple response answers. So, for example a region that cited animals in the watershed as a contributing factor may have also cited treatment failure, and hence actions relevant to both would be appropriate.

Table 47 Frequency of waterborne disease events (WBE) as a function of contributing factors and actions taken to prevent future outbreaks.

		Actions Taken to Prevent Future WBE			
		Upgrade/ change treatment	**Education/ study/ assessment**	**Changed water source**	**Changed/ improved policy, reporting, monitoring**
Contributing factors		**Frequency (%)**	**Frequency (%)**	**Frequency (%)**	**Frequency (%)**
Contamination at Water Source	**Precipitation**	8 (62%)	5 (39%)	9 (69%)	4 (31%)
	Spring thaw/run-off	6 (86%)	3 (43%)	2 (29%)	3 (43%)
	Flooding	2 (67%)	1 (33%)	2 (67%)	1 (33%)
	Lack of source protection	10 (63%)	5 (31%)	12 (75%)	6 (38%)
	Animals in the watershed	10 (67%)	4 (27%)	11 (73%)	3 (20%)
	Other	5 (71%)	1 (14%)	5 (71%)	2 (29%)
Water Treatment Deficiencies	**Treatment failure**	3 (43%)	2 (29%)	6 (86%)	3 (43%)
	Inadequate treatment	17 (63%)	8 (30%)	18 (67%)	8 (30%)
	Other	1 (33%)	3 (100%)	1 (33%)	2 (67%)
Cross Contamination in Water Distribution	**Broken pipe(s)**	2 (67%)	2 (67%)	1 (33%)	2 (67%)
	Post-treatment contamination	2 (67%)	1 (33%)	2 (67%)	1 (33%)
	Cross connection	0	0	0	0
Other	**Turbidity**	8 (89%)	4 (44%)	6 (67%)	4 (44%)
	Human error	3 (60%)	4 (80%)	3 (60%)	4 (80%)
	No contributing factors	0	0	0	0

***Multiple responses possible**

Risks Predisposing to WBEs

An overwhelming majority of respondents (88%) reported that there were risks that predisposed their region to waterborne events (Table 48).

Table 48 Risks that predisposed regions to waterborne events (WBEs).

Risks that Predispose Area to WBE	Frequency (%)	
Yes	37	(88)
No	5	(12)
Total	42	(100)

The risks were varied and included the following:

1) Environmental & Cultural
    a. Human activity
    b. Agricultural activity
    c. Wildlife activity
    d. Industry
    e. Spring run-off
    f. Cultural disbelief in safety of treatment
2) Monitoring
    a. Lots of small systems
    b. Large geographic area with small population to monitor
    c. Budgets inadequate
3) Source
    a. Surface water
    b. Turbidity
    c. Shallow wells
    d. Old or damaged wells
    e. Poorly located wells (i.e. in barnyard)
    f. Chemical naturally present in water
4) Treatment facilities
    a. Water treatment
    b. Sewage treatment
    c. Placement of septic systems close to source
    d. Old treatment facilities / equipment
    e. Inexperienced operators

Drinking Water Programs in Place

Almost all the respondents (98%) answered that programs to reduce the risk of a WBE had been in place prior to the interview (Table 49). Of those that responded, 74% said that the program was currently in place.

Table 49 Programs in place to reduce the risk of waterborne disease events (WBE).

Programs to Reduce Risk of WBE	Frequency (%)	
Yes	40	(98)
No	1	(2)
Total	41	(100)

Examples of relevant programs were as follows:

1) Surveillance & water quality monitoring
    i. Increased frequency of water monitoring
    ii. Camp surveillance program in place
2) Regulation
    i. BWA in provincial camps
    ii. Development of 'watershed authority' with focus on protection plans
    iii. Program to train operators for small water systems
    iv. Drinking water regulations for large systems and bulk tank delivery
3) Communication initiatives
    i. Communication protocol
4) Source protection
    i. Water source ownership addressed
    ii. Restricting public access
    iii. Restricting industry
    iv. Restricting waste contamination of water source
5) Education
    i. Well Aware program (Ontario), well education
    ii. Education program for all water operators
    iii. Information sheets for private well owners
    iv. Public education programs

Evidence offered for the effectiveness of these programs included the following:

1) No further outbreaks
2) Improved public awareness and private well owner compliance
3) Issuing more BWA's demonstrating a proactive approach
4) Have identified population at greatest risk and target resources to those areas
5) Increased communication

Information, Tools & Training

Participants were asked what kind of information related to the prevention and management of WBEs they required and what format would be most beneficial. The majority (65%) stated an interest in information on water treatment and technologies while 48% indicated an interest in the range of educational options and opportunities available and 43% requested information on waterborne event investigation (Table 50). Respondents were interested in a multiple information formats with online being the most popular followed by training sessions, on or off-site.

Table 50 Information needs related to waterborne disease events (WBE).

Type of Information, Tools, or Training	Frequency (%)	
WBE investigation	17	(43)
WBE illness	11	(28)
Water treatment, technologies	26	(65)
Water quality monitoring	11	(28)
Education availability and options	19	(48)
Legal process	1	(3)
No further information	4	(10)
Information Format	**Frequency (%)**	
Training sessions, on- or off-site	22	(58)
Online	25	(66)
Fact sheet / written information	18	(47)
NCCEH retrospective WBE report	11	(29)

Examples of the type of information participants felt they would find useful included the following:

1. Waterborne illness
2. Waterborne event Investigation
3. Training on water treatment
    a. Meaning of log values
    b. Multi-barrier treatment
    c. New equipment and technologies
    d. Chemicals in water and how to remove
    e. Information on small water systems and application to commercial operations
    f. Information on byproducts of water treatment
4. Education options
    a. Research updates and best practices
    b. Education for public health inspectors
    c. Tools to link surveillance systems to operations
    d. Education tools for the public, on waterborne illness
    e. Treatment operations and technologies
5. Legal process
    a. Legal process of enforcing treatment of public water systems

DISCUSSION AND CONCLUSIONS

To our knowledge, this is the first in-depth, comprehensive and systematic examination of waterborne disease outbreaks in Canada, summarizing detailed, standardized information on past waterborne disease outbreaks. Although previous work (Schuster *et al*, 2005) summarized Canadian WBEs from 1974 to 2001, it relied on documented outbreak summary reports accessed from the province of Quebec and Health Canada, as well as from the literature. In contrast, this investigation obtained data via in-depth interviews of relevant front-line environmental health professionals in public health authorities across Canada using a standardized data collection tool.

The study period for this investigation (1993-2001) overlapped partially with the Schuster study. In the current investigation, the number of WBEs identified (n=47) was lower than that reported by Schuster *et al* for this time period (n~150). However, this was not unexpected, since approximately half of the outbreaks in Schuster *et al* were of unknown cause and not confirmed as waterborne, and thus may not have been actual WBEs. For the period of 1993 to 2001, 40 WBEs were identified in the current study; of these, 31 (78%) WBEs were also identified by Schuster *et al* and 9 (23%) were identified only in the present study. As shown in Table 2, seven WBEs included in the current investigation, occurred between 2002 and 2008.

Another possible reason for the lower number of WBEs observed here may have been recall bias (Rothman and Greenland, 1998). In our study, interviewees may have been more likely to provide information on larger, more significant outbreaks that had more substantial evidence of a waterborne source. As well, interviewees may have not been aware of some WBEs that occurred, either due to personnel turnover over the study period or incomplete reporting and documentation. However, our investigation had a very high compliance rate for interviews. This combined with the high completion rate for individual question responses meant that there were relatively little missing data on the WBEs identified. Thus, the current investigation represents a rich and nearly complete set of information for those WBEs identified, and has a high specificity for capturing events that were truly waterborne (i.e. all events included here are most likely waterborne, but some WBEs may not have been captured due to reasons above). In contrast, the Schuster *et al* study has a higher sensitivity (i.e. it included a broader list of events, though many events included may not have been truly waterborne), but captured only minimal information that was not systematically collected.

Both this investigation and the prior study by Schuster *et al* are subject to under-reporting bias, which is likely significant. Under-reporting of enteric illness in Canada is substantial, with 313 to 347 cases of acute gastroenteritis occurring in the community for every case of reportable enteric illness at the provincial level (Majowicz *et al*, 2005; MacDougall *et al*, 2008). On a per pathogen basis, for every case captured within the national surveillance system, there are an estimated 10-47 community cases of VTEC infection, 13-37 cases of salmonellosis, and 23-49 cases community cases of campylobacteriosis (Thomas *et al,* 2006). Since detection of WBEs depends largely on case ascertainment via passive surveillance channels, it is likely that the number of WBEs which come to the attention of public health personnel, and thus reported here, was an under-estimate of the true number of events that occurred in Canada during the study period. Thus this study highlights the need for effective surveillance for WBE. However, since the purpose of this investigation was to describe characteristics of WBEs and provide information to support policy decisions, under-reporting of WBEs likely has minimal impact on the conclusions drawn here.

Interestingly, the number of WBEs per year decreased from the early 1990’s to 2008, with the exception of 2000. This decrease is consistent with Schuster *et al*, who found that the number of WBEs was consistently low from 1974 to 1988, peaked in the early 1990’s, and then declined over the remainder of the study period (1974 to 2001). It is possible that this increase in recognized WBEs in the 1990’s represents a true increase, or possibly improvements in case ascertainment and outbreak detection. The subsequent decrease from the 1990’s to 2008 observed here is likely due in part to improvement in water quality management, resulting from the increased awareness and subsequent efforts to control waterborne disease in Canada. Such effort is likely having a true impact on decreasing the number of WBEs that occur. As well, it may be possible that the decreasing trend in WBEs observed is due in part to a shift in the risk exposures in the population. For example, a 2001 / 2002 study of community residents in three health unit areas of BC found that bottled water was the primary source of drinking water (i.e. >or=75% of the total daily water intake) for 23% of respondents and 47% of households used in-home water treatment methods (Jones *et al*, 2007). Under the assumption that alternative water sources such as bottled water represent an equal risk for waterborne illness, the shift from a common point source for community cases to multiple, geographically diffuse sources will decrease the ability for public health practitioners to identify WBEs using current detection methods. This sort of shift in risk exposure patterns has been seen with foodborne illness, with an increasing number of outbreaks now comprising cases over multiple public heath jurisdictions, rather than the traditional “church basement” type foodborne outbreak. It should also be noted that the rate of WBEs in small systems might not be decreasing as significantly as suggested by the current investigation, as these WBEs are significantly under-reported.

In this investigation, the majority of WBEs occurred in the spring (22%) and summer (54%). This is consistent with the literature, including Schuster *et al*, and with the known seasonality of many protozoal and bacterial infections. The observed seasonality may relate to the survival and multiplication of pathogens in their hosts or the environment, weather variables such as snow melt and rainfall, or increased human and animal activity in watershed areas.

The majority of WBEs identified here were reported to be protozoal in origin (43%), followed by bacterial (23%), viral (15%), and chemical (4%). Of the 38 WBEs caused by infectious agents, the vast majority (~80%) were potentially zoonotic. The high proportion of protozoal disease WBEs highlights the importance of filtration as a preventive measure. The high proportion of WBEs attributable to potentially zoonotic agents highlights the importance of control measures that focus on watershed management, including exposure of water sources to domestic and wild animals, as well as to human waste. Viral outbreaks were probably significantly under-reported as routine surveillance for viral infections is not widespread in Canada.

In this investigation, WBEs were often protracted, with an average duration of 74 days, and a maximum 1.8 years (671 days). Lengthy events such as these represent a significant public health burden, both to the individuals and communities involved, as well as to provincial health systems. Unfortunately, the data collected here did not allow for the burden and costs associated with WBEs to be assessed.

The average time from the onset of a WBE to its detection was 18.2 days, with a maximum of 120 days. This lag may reflect deficiencies in current surveillance systems or outbreak investigation capacity. The majority of WBEs were detected through case identification at the relevant public health authority, through combination of patient inquires, laboratory surveillance and physician reports, highlighting the importance of these as surveillance approaches for WBEs. This also suggests potential opportunities for improved WBE surveillance in jurisdictions where detection is currently not optimal. For example, public health authorities could improve their ability to detect future WBEs by maintaining close relationships with local physicians and the community, in addition to routine examination of laboratory reports to identify elevated incidences of specific pathogens.

For the majority of WBEs identified here, a public health advisory was put in place as a result of the WBE. Generally, this consisted of a ‘Boil Water Advisory’ (71%) or a ‘Boil Water Order’ (14%). WBEs almost always occurred in a single regional health authority area, with advisories most commonly put in place by the responsible local or provincial public health authority.

Advisories were often kept in place for extended periods (mean 158 days; median 48 days; max 802 days). The length of these advisories contributes to the protracted and disruptive impact that a WBE has on the affected communities. Boil water notices incur direct costs, including costs to residents to obtain alternate water sources, and costs to the water system operators. Additionally, indirect impacts may also result, such as the potential desensitization of community residents as boil water notices become considered the norm. For those WBEs where no advisory was instituted, the reasons given were that the facility closed, the event had already resolved, the source had not been determined, or source testing was negative.

Overall, the majority of WBEs (60%) were associated with surface water or a combination of surface and ground water sources, and the majority of surface water sources were rivers / streams and lakes. As expected, WBEs with protozoal causes were particularly related to surface water sources. In contrast, WBEs with viral (norovirus, Hepatitis A) or bacterial (*E. coli*, *S. aureus*, *Salmonella* spp., *Legionella* spp.) were often associated with ground water, although the number of these WBEs was generally small.

The majority of watersheds containing the surface water sources were unprotected. Information on nature of land use was available for just over half of these watersheds, and land use included wildlife and agricultural activity, or heavily used, multiuse watersheds. Such types of land uses are known to predispose communities to WBEs, for example as seen in the 2000 Walkerton outbreak (Bruce Grey Owen Sound Health Unit, 2000). Current practices to controlling waterborne illness recommend a source-to-tap approach, including management of watersheds to reduce the potential for surface water contamination with known pathogens (Canadian Council of the Ministers of the Environment, 2004). However, the results of this investigation suggest that watershed protection was not widely practiced.

Changes in weather at the time of the WBE was identified as a predisposing factor in about half of WBEs captured here, and most frequently consisted of an increase in rainfall or spring runoff. Climate factors such as heavy precipitation in the weeks prior to the event have been shown to increase the risk of WBEs (Thomas *et al*, 2006), and are expected to increase under scenarios of global climate change (Valcour, 2009). The lack of ability to change many of these risk factors, such as weather, directly highlights the need for vigilant water system management, particularly during known times of high risk (e.g. heavy precipitation). Waterborne disease prevention plans and policies should take into account the potential for such weather events and mitigation plans for potential impacts of climate change should be developed for use by local public health authorities and water utilities operators.

For those WBEs associated with ground water sources, the majority were drilled or artesian wells. However, of WBEs associated with ground water sources, 53% reported that the ground water source was under the direct influence of surface water during the WBE, and 36% reported a change in the integrity of the well or aquifer during the WBE, both of which are known risks for ground water contamination. Additionally, 18% of WBEs were associated with dug or shallow wells, also a known risk factor for waterborne disease. The wellhead was protected 67% of the time.

The occurrence of WBEs prompted a number of regions to change their water source to one less likely to be associated with WBE. The use of surface water sources declined, from 50% pre-WBE to 35% post-WBE, and the use of ground water sources increased, from 39% pre-WBE to 50% post-WBE. Two facilities were reported as being closed. In addition, the types of surface and ground water sources also changed post-WBE, to include more sources with reduced risks of waterborne illness. This included a decrease in river and stream sources, and an increase in the use of reservoirs and lakes, and perhaps relates to issues of better quality and a greater opportunity for management. The number of drilled wells also increased, and there was a reduction in the number of wells considered under the influence of surface water. The advent of these changes suggests that WBEs may be significant factors which motivate local authorities to improve drinking water quality, highlighting that publicizing WBEs (either via media or scientific or professional journals or venues) may help to motivate further enhancements.

In 39% of the WBEs captured in this investigation, there was no water treatment reported to be in place. Filtration was only reported to be in place in 15% of the WBEs. Considering the number of WBEs in which surface water was the water source, the proportion of communities with filtration (15%) is low (Hrudey and Hrudey, 2004). With filtration known to be an important measure for the control of protozoal diseases, it was not unexpected that the majority of G*iardia*-associated WBEs and about half of the C*ryptosporidium*-associated WBEs occurred in regions without filtration. Regions that had filtration and a *Cryptosporidium*-associated outbreak had some forma of treatment inadequacy or error (eg older treatment plant downstream from a sewage treatment plant or recycling of filter backwash water) or cited extreme weather conditions as a contributing factor. The most commonly identified deficiency in water treatments related to WBEs was an absence of or inadequate filtration, followed by inadequate chlorination. It is important to note that chlorination is effective in the prevention of bacterial and viral disease but not protozoa (Canadian Council of the Ministers of the Environment, 2004). On a positive note, the proportion of regional authorities reporting filtration post-WBE rose to 41% compared to 15% pre-WBE. As well, the proportion of regional authorities having no treatment declined to 17% post-WBE, compared to 39% pre-WBE. Again, the occurrence of WBEs appears to be a motivating factor that prompts regional authorities to institute approaches to improve water treatment and reduce the risks of waterborne disease.

In a substantial proportion of WBEs, routine water quality monitoring was not undertaken. In 48% of WBEs, there was no chlorine monitoring, in 57% of WBEs there was no turbidity testing, and in 34% of WBEs there was no total coliform or *E. coli* testing. Water quality monitoring is an important component in the prevention of waterborne illness (Hrudey and Hrudey, 2004). The significant lack of monitoring parameters such as these highlights another potential area for improvement and subsequent future reduction in the number of WBEs. The importance of water quality monitoring should be considered a key finding of this investigation (Canadian Council of the Ministers of the Environment, 2004).

WBEs affected primarily small- to medium-sized communities (mean population served: 26,970; median: 438). This highlights the need for emphasis on enhanced drinking water quality targeted to small- and medium-sized communities and small water systems. *Giardia* WBEs tended to affect smaller communities, and have a smaller number of associated cases than the average WBE, while C*ryptosporidium* WBEs affected larger communities than average and caused on average a larger number of associated cases. The reasons for this are likely multi-factorial. For example, it is likely that the water treatment in larger water systems, and their associated larger community and thus larger potential number of cases, are more comprehensive, removing bacterial and viral pathogens. Additionally, it is possible that filtration, employed more frequently by larger water systems, is more effective in removing G*iardia* than C*ryptosporidium*, such that larger systems are better protected against G*iardia*. Hence, larger systems, if affected, will tend to be susceptible to C*ryptosporidium* WBEs.

Generally, the estimated size of the WBEs captured here was small to medium, with a mean number of cases of 654 and a median 20. The largest WBE had an estimated 15,000 cases. Case definitions used within WBEs varied, and included gastrointestinal symptoms of varying severities, lab confirmation, use of specific drinking water sources, and occurrence within a specified time frame or geographic area. The validity and comparability of the different case definitions based on the information gathered by this investigation is hard to assess, particularly since different case definitions are appropriate under different circumstances, sometimes even within the same WBE. Hospitalization was required in 38% of the WBEs, and death was reported in only one WBE. These health outcomes reflect the clinical syndromes normally caused in any circumstance by the agents involved in waterborne disease. Again, this investigation did not collect information on the associated economic costs of the WBE. However, previously published Canadian estimates of the cost of community cases of acute gastroenteritis range from $1,089 (in Hamilton, Ontario; Majowicz *et al*, 2006) to $1,342 (in BC; Henson *et al*, 2008). Applying these estimates to the average number of cases (654.4) yields a crude estimation of the average cost of a WBE, approximately $713,000 to $878,000 per WBE. Since the original estimates did not include outbreak-specific costs, these crude values are likely under-estimates.

The age (mean 38.1 years) and gender distribution (50% female) in the WBEs captured here reflects the underlying populations demographics of exposed communities, water consumption patterns and the age distribution of enteric infections, which tend to affect younger individuals.

In terms of contributing causes to WBEs, interviewees identified inadequate treatment or treatment failure as the most common contributing cause, followed by a lack of watershed protection, animals in the watershed and precipitation. All these factors are known predisposing conditions for WBEs, highlighting the utility of enhanced water treatment, watershed protection plans, and plans to mitigate impact of extreme precipitation events as mechanisms for decreasing the occurrence and magnitude of WBEs in the future (Hrudey and Hrudey, 2004; Thomas *et a*l, 2006).

Although treatment failure was commonly cited as a contributing factor, the nature of failure was unspecified in 43% of WBEs with treatment failure. No treatment or inadequate treatment for unspecified reasons was also commonly cited. Again, preventing treatment failures and ensuring adequate treatment are both amenable to improvement, and thus represent key opportunities to reducing the future occurrence and magnitude of WBEs. Wildlife constituted the main type of animals perceived to increase the risk of WBEs within the source watershed. Unfortunately, control of wildlife to mitigate such risks poses significant challenges. Proximity of human septic systems and sewage to water sources was identified as a contributing cause in 57% of WBE; this risk is amenable to mitigation and represents another key opportunity for reducing the future occurrence and magnitude of WBEs.

During WBEs, public health personnel in the regional authorities relied on a variety of expert resources and sources of information, including a variety of local experts, provincial epidemiologists, and water treatment experts. However, in 21% of WBEs, public health personnel consulted no additional expert resources. Access to expertise is important for both WBE investigation and prevention. Access to specific experts should be supported, and local authorities should be encouraged to seek appropriate advice either during a WBE or during prevention and planning.

A key strength of this investigation was the high specificity for capturing WBEs. Overall, the WBEs included in this investigation had strong evidence of a waterborne source of infection. In 63% of the WBEs, evidence for water as the source of the event included laboratory-confirmed identification of the same pathogen in both the water and cases. Additionally, epidemiological evidence of a waterborne source existed for 42% of WBEs, and water quality failure was part of the evidence of a waterborne source for more than 40% of the WBEs. This weight of evidence suggests that most of the WBEs captured here were truly waterborne, and thus that the information obtained on these events is a relatively accurate reflection of recognized WBEs in Canada (Tillet *et al*, 1998).

Subsequent to WBEs, regional authorities undertook a wide variety of actions, policies and procedures affecting various components of the source-to-tap continuum to prevent future outbreaks - and to manage those WBEs that do occur more effectively. They considered these actions to have been effective in many cases. This highlights again the impact that WBEs have in motivating improvements to future WBE prevention and control. Nonetheless, participants identified a wide variety of potential risks which might precipitate future WBEs. These included a variety of watershed management issues, source water and well characteristics, treatment facilities/methods and water quality monitoring issues.

This investigation took a novel approach to summarizing outbreaks, and accessed information generally not included in traditional reviews. Although there is a move for systematic and other reviews to include as much as possible the grey literature (e.g. government or internal reports), even this level of documentation is often missing key information, for example good information on source (Sargeant *et al*, 2006). The approach used in this investigation (i.e. interview of front-line staff versus review of published or written documents) could also be useful for summarizing other public health events such as foodborne or institutional outbreaks, as it captures richness in data not usually available through traditional review techniques.

Another strength of this investigation is the extent of its Canadian coverage. With the exception of New Brunswick for which no data were captured, compliance was high (71% of interviews covering all regional public health authorities in the country) and there was at minimum a good representation of each province. Thus, the results of this investigation provide an accurate picture of WBEs across Canada during the study period. Although the status of the regions that were either unable to be interviewed, or who refused to be interviewed was mostly unknown, initial contacts revealed that the non-responding public health authorities did have WBEs that were thus not captured here (three WBEs in ON, one in SK, one in NB, and an unknown number in First Nations communities in MB).

Despite its advantages, the approach used in this investigation is subject to several limitations. Information was provided by recollection or reference to internal reports or records (either unavailable or available), or available provincial, federal, or academic reports. There was also a degree of non-response (29%) that could have biased our results. The potential impacts of recall bias (Rothman and Greenland, 1998) are discussed in detail above, as are the other limitations of this design. However, even given these limitations, the rich information generated from this study highlights the wealth of public health data at the front-line level in Canada that is not accessible via traditional search strategies.

This investigation identified several areas and key opportunities to improve drinking water management and mitigate known risks for waterborne disease and WBEs. Results highlight the importance of improving existing or implementing new source-to-tap control measures including a focus on watershed management, such as decreasing where possible the exposure of water sources to domestic and wild animals, and to human waste (septic and sewage sources). As well, improved water treatment and quality monitoring should be supported in areas where these are currently sub-optimal. This study has shown that the lack of treatment and water quality monitoring is more prevalent in water systems serving smaller populations. Based on the findings of this study, future investigations should target small water systems. Waterborne disease prevention plans and policies should also take into account the potential for extreme weather events, and mitigation plans for potential impacts of climate change should be developed for use by local public health authorities and water utilities operators. Surveillance for WBEs should be enhanced at the local, provincial, and national levels.

Maintained and improved communication between stakeholders also is an area of opportunity. WBE detection and response can be improved by public health authorities, through close relationships with local physicians and the community, in addition to routine examination of laboratory reports to identify elevated incidences of specific pathogens. WBE prevention, detection and response can be improved by facilitating and encouraging local authorities to seek and access appropriate expert advice, either from epidemiologists, water treatment experts, or others. Interestingly, WBEs appear to be significant motivating factor for improve drinking water management within a given public health authority area. Thus, publicizing WBEs more systematically and consistently, particularly to public health authorities, may be a key, effective way to motivate further enhancements.

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APPENDIX I

Questionnaires used in interviews regarding waterborne disease events