Protecting Drinking Water Sources and Public Health

Robert J. Patrick

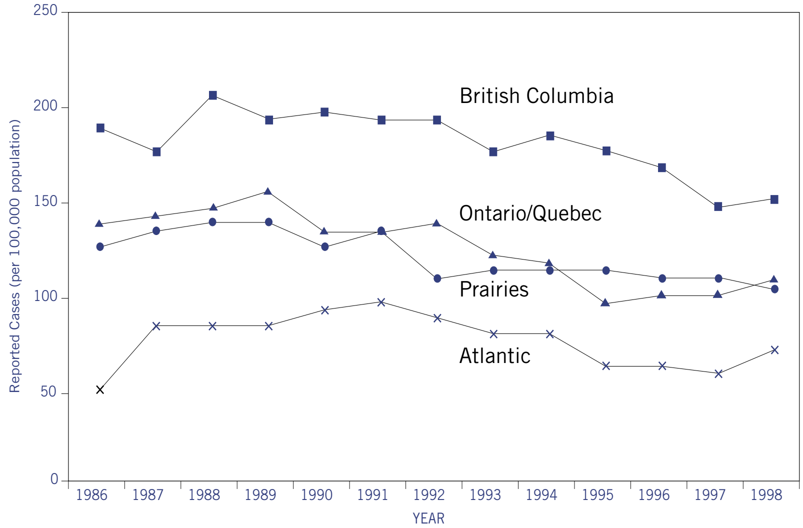
Abstract

Microbial agents of waterborne disease include bacteria, viruses and parasites. Microbes in drinking water have caused at least 29 outbreaks in British Columbia over the last 20 years, 17 of which (59%) were caused by protozoan parasites that are resistant to chlorine. Bacteria, viruses and parasites that can cause waterborne disease all share common characteristics. Most have an animal host and can infect humans through drinking water supplies. Human infection by these microorganisms most commonly appears as gastrointestinal illness; however, some can cause systemic disease, such as hepatitis (viruses) and kidney failure (*E. coli* 0157:H7). Evidence from recent water contamination crises from across Canada suggests that traditional water treatment such as chlorination and filtration may no longer suffice to provide clean water. Source water protection, the first line of defence in the multi-barrier approach to safe drinking water, has rapidly gained favour within the water industry and government regulators. It is now prudent for health professionals to recognize the connection between source water protection and public health.

INTRODUCTION

Since 1980 there have been 29 confirmed waterborne disease outbreaks in British Columbia resulting in tens of thousands of reported illnesses by such microorganisms as *Giardia*, *Cryptosporidium* and *Campylobacter* (Kendall 2001). For many years, British Columbia has had the highest reported rate of human intestinal illness of all the provinces and territories in Canada, the result of contaminated water or food (Figure 1).

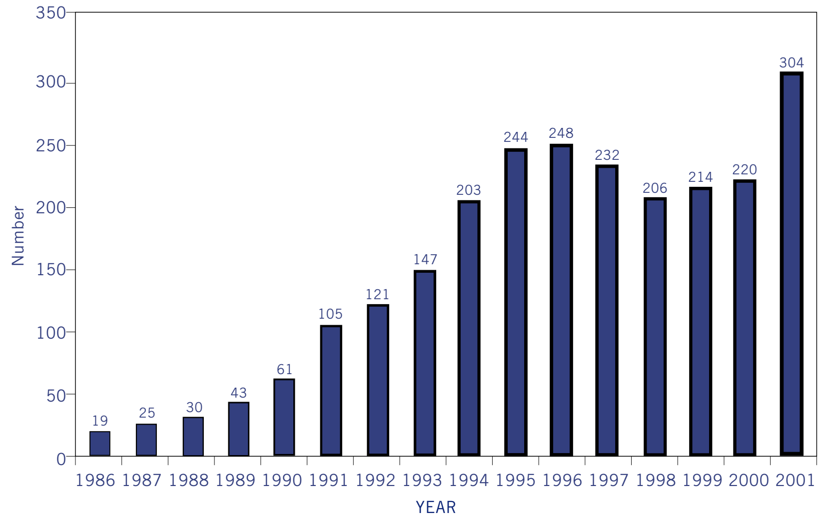
Figure 1. Enteric disease rates, 1986–1998



Health statistics such as these will surprise those that hold Canada's west coast province as synonymous with pristine Alpine watersheds and pure running rivers. In fact, the official promotion of "SuperNatural" British Columbia as "the best place on earth to live" regularly depicts (and thus constructs) "nature" using images of clean, healthy running water. The truth is, in August 2001, 304 communities in B.C., or 10% of the community water systems in the province, were under provincial boil-water advisories (Figure 2) as a result of water not meeting minimum B.C. drinking water standards (Kendall 2001).

This paper will describe human health impacts of past waterborne diseases in B.C. as well as the recent response from the regulators to mitigate these impacts. The future prospect of source water protection, an emerging approach in drinking water management, will be assessed. In particular, the relationship between source water protection and public health will be revealed.

Figure 2. Boil-water advisories, B.C., 1986–2001



CONNECTING PUBLIC HEALTH TO DRINKING WATER QUALITY

During the 19th century, overcrowding, social inequity and lax hygiene spurred by the Industrial Revolution caused widespread waterborne disease outbreaks, including typhoid, hepatitis and cholera. By the mid-20th century various forms of drinking water filtration and the use of chlorine and chloramines as a disinfectant in municipal water systems all but eliminated the spread of these diseases. Yet, despite these advances in water treatment, public health today continues to be compromised by a host of new microbial waterborne contaminants. For example, a series of North American outbreaks in the 1990s of the protozoa *Giardia* and *Cryptosporidium* along with the emergence of new toxin-producing strains of soluble bacteria such as *E. coli* 0157:H7 have drawn greater attention to the safety of our water supplies (Kendall 2001). In B.C. alone over

Table 1. Preventable waterborne disease outbreaks in B.C., 1980–2000

Year	Location	Organism	Cases: Lab and clinical confirmed	Cases: Total estimate	Suspected source	Preventability
1982	Kimberley	Giardia			Wildlife	Better source protection
1985	Creston	Giardia	72		Beaver	Better source protection
1986	Penticton	Giardia	362		Beaver	Treatment/source protect.
1986	Penticton	Giardia	606	3,125	Beaver	Treatment/source protect.
1987	Black Mtn.	Giardia	60		Cattle	Treatment/source protect.
1990	Fernie	Giardia	50		Wildlife	Better source protection
1990	Rossland	Giardia	>40		Wildlife	Better source protection
1993	Fernie	Campylobacter	35		Cattle	Better source protection
1995	Victoria	Taxoplasmosis	110	3,000	Cats	Removal of cats
1996	Cranbrook	Cryptosporidium	136	2,097	Calves	Source protection
1996	Kelowna	Cryptosporidium	177	10,000	Human	Uncertainty about origin
1998	Chilliwack	Cryptosporidium	19		Cattle	Source protection

Source: Adapted from Provincial Health Officer's Annual Report 2000, Kendall 2001.

15,000 epidemiological cases of waterborne disease cases were estimated between 1990–1998. During a single event in the spring of 1996, cryptosporidiosis affected 10,000 Kelowna residents, the result of human sewage contaminating the city's filtered and chlorinated drinking water supply. Table 1 provides a 20-year summary of waterborne disease outbreaks in B.C.

Clearly, technological "end-of-pipe" solutions to safe drinking water are not entirely failsafe. Rather than relying solely on treating potentially contaminated water at the point of delivery, source-water protection aims to prevent contamination of raw drinking water at the source of supply. Source water protection is well established in the United States due to amendments to the *Safe Drinking Water Act* (Harrigan-Farrelly 2002). However, progress toward source water protection in Canada has been slow to develop.

In a 1999 report to the B.C. legislature, the B.C. Auditor General cautioned that "the [human and financial] cost of not protecting our drinking water sources in B.C. would be unacceptably high" (Morfitt 1999). Citing the numerous small- and medium- sized community water systems in the province, the Auditor General concluded that the capital cost of installing filtration treatment for the 100 larger municipalities outside Vancouver and Victoria could approach $700 million, with an additional $30 million a year in combined financing, operating and maintenance costs (Morfitt 1999). These costs would overwhelm the budgets of most municipalities and would require provincial and federal subsidy, creating competition between municipalities for limited water treatment funding.

The Auditor General's report drew attention to the important, but often neglected, practice of protecting drinking water sources against potential contamination. After decades of technological advances in water treatment and emphasis on securing adequate quantities of supply, the protection of those supplies and thus the quality of drinking water was often overlooked and taken for granted (Morfitt 1999).

For many Canadians this all changed in May 2000, in the Ontario town of Walkerton, a community of 4,800 residents, located 175 km northeast of Toronto, where more than 2,300 individuals experienced gastroenteritis, 65 were hospitalized, 27 developed long-term kidney ailments and seven died (Hrudey et al. 2003). Beyond the human tragedy, the economic cost of Walkerton has been estimated at $65 million (O'Connor 2002). The lack of source protection combined with a poorly sited well, a heavy rainfall event, farm runoff, provincial funding cutbacks and local managerial ineptitude set the stage for tragedy in Walkerton. The Walkerton Inquiry that followed the tragedy produced 93 recommendations, 14 of which directly reference the importance of the multi-barrier approach, including source water protection (O'Connor 2002). See Glouberman (2001) for a more detailed account of Walkerton with a perspective from complex adaptive systems. A similar public inquiry into the water contamination event in North Battleford, Saskatchewan, produced a similar call for the multi-barrier approach, with strong emphasis on source water protection (Laing 2002).

THE MULTI-BARRIER APPROACH

The term "multi-barrier approach" is commonly used in the drinking-water resources literature. The multi-barrier approach involves a series of both physical and non-physical "barriers" to protect, and enhance, drinking-water quality. Based on the literature from industry and academia, the components of the multi-barrier approach broadly include the following:

- source water protection
- treatment of drinking water
- distribution system upgrades/maintenance
- monitoring and reporting water quality results
- response to water quality problems

Although not using the term multi-barrier, the 1999 B.C. Auditor General's report espouses the benefits of "a layered approach to drinking water provision, combining an appropriate mix of protection and treatment" (Morfitt 1999). In response to documented evidence of deteriorating drinking water quality in B.C. (Morfitt 1999; Christensen and Parfitt 2001) and in the aftermath of the Walkerton tragedy, the B.C. provincial government undertook to develop a Drinking Water Protection Plan (DWPP) in 2001 that incorporated the multi-barrier approach. In the same year the DWPP evolved into legislation as the Drinking Water Protection Act, the first such legislation in B.C. dedicated to drinking water quality.

Time will tell whether the multi-barrier approach is effective at reducing the high incidence of waterborne illness in BC. As well, there is some uncertainty whether all components of the multi-barrier approach will be given equal attention (Christensen and Parfitt 2004). In a province that depends on revenue from watershed resource activities such as forestry, mining, agriculture, grazing, recreation and tourism there is concern that the technological "treatment of water" component within the multi-barrier approach will continue to dominate over source water protection.

WHAT IS SOURCE WATER PROTECTION?

The first of the multi-barriers, source water protection, is based on the adage an ounce of protection is worth a pound of cure. Source water protection has become a centrepiece in the drinking water resources literature and involves implementing programs and activities aimed at preventing contaminants from entering drinking water sources (Ontario Ministry of the Environment 2004). These sources may either be surface water (i.e., lakes, rivers, streams) or groundwater (aquifers).

Source water protection refers to the management of watersheds and aquifer recharge areas that are the source of public drinking water supply for water quality (Shrubsole 2004). The practice of source water protection can be broken down into four main components:

- delineation of a watershed or groundwater recharge area;
- an inventory of potential sources of contamination;
- assessment of vulnerability of water supply to contamination; and
- implementation of a management plan.

In the first-ever survey of how Canadian provinces and territories are doing in protecting their drinking water sources, B.C. received barely a passing grade (Christensen and Parfitt 2001).

CONSTRAINTS TO SOURCE PROTECTION IN B.C.

While the economic and human health benefits of source protection are well documented in the literature (Job 1996; O'Connor 2002; Davies and Mazumder 2003) there are many constraints facing its practice in the field. One of these constraints has to do with land tenure. Approximately 92% of the province's land base is owned and administered by the provincial Crown. It is over this land base that legal resource tenures allow activities such as forestry, mining, agriculture, grazing, recreation and tourism. The vast majority of watersheds are designated for integrated uses, meaning that forestry, backcountry recreation, mining, even cattle grazing, are permitted and often encouraged within community watersheds that are the source areas for public drinking water. Therein lies the conundrum. There is ongoing controversy in B.C. over the compatibility of integrated-use watersheds and drinking water source protection (Cameron 1998). To understand this controversy it is important to recognize that two watershed models exist in B.C. The first of these is the protected watershed model of Vancouver and Victoria, which stand as anomalies among the province's community watersheds. Both Vancouver and Victoria own or hold long-term leases over most of their watershed areas. Ownership allows control, and entry to these watersheds is by permission only, through locked gates. The second watershed model applies to the remainder, and thus vast majority, of the province's community watersheds. These watersheds are under Crown provincial ownership and are administered as integrated-use watersheds by provincial agencies.

While some argue that the Vancouver-Victoria model provides the only effective means of providing pristine, safe drinking water (Christensen and Parfitt 2001, 2003) others suggest that such an approach unnecessarily restricts access to important and vital natural resources that provide provincial revenue and other economic opportunities (Cameron 1998; Kendall 2001). In a recent unpublished survey (August–October 2004) conducted in the Okanagan Basin, none of the local water authorities interviewed stated a preference for the Vancouver-Victoria model of watershed management despite their continuing efforts to provide clean drinking water. Instead, the local water authorities in this region of the province cited the importance of community employment and economic opportunity in primary resource activities. Within these watersheds, methods other than land ownership must be considered to advance source protection. These methods will be described in the following section in relation to human health risks.

CONNECTING MICROBIAL INFECTION TO SOURCE WATER PROTECTION

This section will detail specific microbial agents of waterborne disease that have the potential for eradication through source water protection initiatives.

Pathogenic Bacteria

E. coli: Enterohemorrhagic *E. coli* can cause severe illness such as bloody diarrhea and serious complications including kidney failure and potential death from hemolytic uremic syndrome. This was the tragic case in Walkerton, Ontario, where heavy rains during the week of May 17, 2000, washed fresh cattle manure into a shallow well (Walkerton's infamous Well # 5). By May 22, over 1,300 patients had been identified as carriers of the bacteria that would eventually kill seven residents and leave many others with long-term symptoms. The bacteria are known to be carried harmlessly in the gut of cattle and may enter drinking water supplies when cattle manure contaminates raw water sources. Source protection measures to reduce potential for drinking water contamination requires coordinated range management between cattle owner licensees, provincial forestry personnel (licensor) and the local water provider. In the past, coordinated management often excluded participation by the local water providers, who lack jurisdiction over provincial Crown land. Recent range management in the Okanagan region of B.C. has required forestry companies to restrict cattle access away from stream and lake areas that are the source of drinking water by use of fence construction. Cattle owner licensees are then required to maintain the fencing. Ongoing monitoring of the fencing is the responsibility of the local water provider.

Campylobacter: At least four waterborne outbreaks of the bacteria have occurred in BC in the last 10 years. *Campylobacter* may be carried by puppies, kittens, chickens, pigs, wildlife and cattle. The bacteria enter water through fecal contamination of the water supply. The resulting human illness, campylobacteriosis, is typically diarrhea, abdominal pain, fever, nausea and vomiting. Prevention for campylobacter includes avoidance of animal feces washing into water supplies. Cattle grazing activities are common within the province's community watersheds. Measures such as restricting cattle access away from stream and lake areas that are the source of drinking water supply as well as timing of grazing activities, are now in practice in some areas of the Okanagan Basin, B.C. Timing and location of grazing activity requires cooperation between cattle licensee and the water purveyor. Finally, recovering forestry cut block areas tend to attract cattle to new vegetative growth. Fencing such areas where drinking water sources are proximate is another source protection measure requiring interagency cooperation.

Viral Agents

Hepatitus A and E; Norwalk-like Viruses: Viruses are the smallest microbes to contaminate a water supply. Viruses differ from bacteria in that they tend to be hardier and persist longer. A number of viruses have been identified that cause gastroenteritis, which can be transported through contaminated water supplies (Kendall 2001). Viral agents such as hepatitis A and E and Norwalk-like viruses may infect healthy adults, children and immune-compromised adults causing symptoms such as diarrhea, nausea and vomiting for 24–48 hours. Without human contamination of the water supply there is little chance of viruses entering water supplies. Source protection activities would therefore seek to limit human access to riparian areas, provide outhouse facilities well away from shoreline areas and require minimum setback areas for cottages and recreational lodges where appropriate.

Parasites

Giardia Lamblia: Carried by humans and wild and domesticated animals this parasite (erroneously called 'beaver fever') is found throughout rural and wilderness areas. The parasite infects the intestinal tract of warmblooded animals and is excreted in feces. The cyst cycle is particularly a threat, as durable cysts may survive many months in lakes, reservoirs and streams. Symptoms of giardiasis include abdominal cramping, bloating, fatigue and weight loss. Testing for *Giardia* in water is expensive and unreliable. Source protection measures include avoidance of animal grazing near water sources, fencing of riparian areas, limiting wildlife corridors near water sources, avoiding excessive surface runoff into water sources and removing beavers from watersheds (Kendall 2001).

Cryptosporidium: Like *Giardia*, this waterborne enteric parasite has been found in a large percent of surface water studies in North America. In 1996, four consecutive community outbreaks of cryptosporidiosis occurred in B.C., three of which were confirmed to be caused by contaminated water (Ong et al. 1999). The strain believed to cause most of the infection to humans is *Cryptosporidium parvum*, a hard-shell parasite called oocysts that live in the intestinal tract of young cattle and other domesticated animals. Oocysts can be introduced into the drinking water supply through animals defecating in lakes and streams that feed water reservoirs (Kendall 2001). Ong et al. (1996) note that peak concentrations of both *Giardia* cysts and *Cryptosporidium* oocysts in two adjacent B.C. Okanagan watersheds coincided with calving activity. Contamination of water supplies is not, however, specific to animal waste. Human waste contamination may also be an agent for waterborne disease. Such was the case in 1993 in Milwaukee, when the municipal water supply became contaminated with *Cryptosporidium,* killing 70 people and infecting 400,000 (Kendall 2001). Outbreaks in B.C. include Kelowna and Cranbrook (1996) and Chilliwack (1998). Symptoms include watery diarrhea, abdominal cramps, nausea, vomiting, fever and loss of appetite. At present there is no effective treatment for *Cryptosporidium*. While healthy adults may clear the infection within two weeks, young children, the elderly and those with weakened immune systems (people with HIV, AIDS, undergoing cancer treatment, recent transplants) can have "severe and long lasting infections that may lead to death" (Kendall 2001). For this reason, the B.C. Provincial Health Officer issued a public boil-water advisory in 1996 (re-issued in 2001) to immuno-compromised individuals. Source protection measures to prevent *Cryptosporidium* oocysts from contaminating drinking water include avoiding animal grazing near water supplies through fencing or regulatory means, limiting (fence) wildlife corridors near water supplies and directing surface water runoff away from water supplies. Water treatment by chlorination is not effective in inactivating the oocysts.

The discussion of the microbial waterborne pathogens listed here is not intended to be definitive, nor are the source protection measures exhaustive. What is intended is an illustration of the linkage between waterborne illness and watershed land-use practices. Source water protection offers a viable bridge between public health safety and land-use practices.

Based on recent evidence from B.C., the vast majority of waterborne illnesses are due to the microbial pathogens previously discussed and not from chemical contaminants. This evidence supports the call from the Provincial Health Officer for increased attention to microbial pathogens, for which there are no existing provincial or federal standards nor reliable tests. Source water protection offers not a solution but a path toward reducing the potential for waterborne contamination.

CONCLUSION

Health professionals in Canada have long recognized the connection between public health and drinking water quality. This recognition has traditionally focused on the need for raw water treatment, such as disinfecting with chlorine and more recently, the benefits of advanced treatment, including membrane filtration.

High profile water contamination events such as Walkerton (2000) and North Battleford (2001) captured the attention of the Canadian public and the international water research community. As often happens, crisis events spur policy innovation. In the case of Canadian drinking water management there has been a sudden movement toward the multi-barrier approach, particularly source water protection.

Source water protection provides many potential benefits both fiscal and health related. Using the high incidence of waterborne disease outbreaks in B.C., this paper links medical evidence to land-use policy practices and suggests that health professionals need to speak out not only for clean drinking water in B.C. and Canada but also for source water protection in integrated, multi-use watersheds. As local and provincial governments increasingly look to public health agencies to lead the way on drinking water policy in Canada, there has never been a better time for health practitioners, medical health officers and health administrators to be a voice for the protection of raw water supplies.

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About the Author

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COMMENTARY

Perspective on Protecting Drinking Water Sources and Public Health

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Source water protection is indeed a necessary component of a multi-barrier strategy for delivering safe and potable drinking water to the public. However, it is far from being a sufficient strategy and the experience of two of British Columbia's largest water systems provides a useful perspective on the expectations of what can reasonably be delivered through protecting water sheds.

Both the Greater Vancouver and the Greater Victoria areas, which provide water for over two million of the province's total population of approximately four million, have protected watersheds, with virtually no anthropogenic activities occurring within them. Despite this, and despite good disinfection practices, both of the authorities responsible for delivering safe water have over the past few years and at the urging of local medical health officers (who also support watershed protection) committed to improved treatment including water filtration and additional state-of-the-art ultra-violet disinfection.

WHY HAVE THEY DONE THIS?

Quite simply, while human activity can severely compromise raw water quality in a variety of ways, the lack of human activity in no way guarantees pristine water. The watersheds of B.C. are home to a variety of mammalian species that are capable of harbouring and shedding disease, producing organisms such as *Giardia, Cryptosporidium and Toxoplasma gondii*, all of which have been implicated in human illness and waterborne outbreaks in B.C. and all of which are resistant to standard disinfection practices (see Provincial Health Officers Annual Report 2000: *Drinking Water Quality in British Columbia: The Pubic Health Perspective*). (While wild mammals and birds can also contaminate water sources with *Campylobacter* and *Salmonella*, these pathogens would normally be removed through standard disinfection practices.)

For example, in 1995, a screening program showed that of 3,800 exposed pregnant or newly delivered women, at least 100 were infected during a waterborne *Toxoplasmosis* outbreak in Victoria that was subsequently linked to cougars or feral house cats in the watershed. *Giardia* cysts are regularly detected in Vancouver's water supply, especially during periods of turbidity following heavy rains.

Since the elimination of wildlife from B.C.'s watersheds is neither feasible nor desirable, we should temper our expectations as to the benefits that watershed protection measures can reasonably deliver. Watershed protection will likely not remove requirements for additional measures such as filtration, ozonation and UV disinfection. Watershed protection will, however, contribute to the sustainability of certain watersheds. Watershed protection can be helpful in reducing the risk of chemical contamination from human activity, and preventing the degradation of raw water will assist in keeping treatment costs from escalating. In addition, the challenges around balancing the many and competing uses to which a substantial proportion of B.C.'s watersheds are presently put, has great potential for public discourse around and clarification of, potentially different underlying community value systems.

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