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The Water Series

Safe Drinking Water Policy for Canada –

Turning Hindsight into Foresight

Steve E. Hrudey

In this issue...

A decade after the Walkerton and North Battleford outbreaks, Canada remains out of step with the international leaders in adopting management systems for assuring safe drinking water.

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The Study in Brief

The Walkerton and North Battleford drinking water outbreaks in 2000 and 2001 highlighted major inadequacies in Canada's drinking water system. Yet roughly 10 years later, notwithstanding the major improvements in a system that was demonstrably inadequate before, much of Canada remains out of step with the international leaders in adopting management systems for assuring safe drinking water.

Drinking water is essential to human health and well-being. Currently, throughout much of the developed, industrialized world, including most of urbanized Canada, public drinking water generally poses a negligible health risk to consumers. But the regulation of drinking water in Canada is generally guided and managed in a fragmented, almost ad hoc, manner that leaves us vulnerable to future water-quality failures, most likely in smaller systems. The problem is not that numerical water safety criteria are inadequately stringent; the documented failures have been caused by an inability to operate water systems effectively, pointing to inadequate competence.

Despite some clear progress in individual provinces, Canada, overall, needs a system that better promotes and rewards competence among drinking water providers. Under a "know your own system" water safety plan approach, those assigned to provide drinking water need to be afforded the training, intellectual support and compensation that is commensurate with their taking responsibility, through their actions or inactions, for the health of an entire community. Concurrently, provincial drinking water policies should encourage, where conditions allow effective results, consolidation of smaller systems into larger more viable operations. Much of England and Australia now provide small communities' drinking water via large and competent regional water authorities.

Canadians should expect that they will be provided safe drinking water in any community, not just the larger urban areas. This *Commentary* proposes the universal adoption of a "know your own system" water safety plan approach in Canada that would be based on a tangible demonstration of operator competence for understanding and delivering safe drinking water.

The Author of This Issue

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After serving on the Research Advisory Panel to Justice Dennis O'Connor for the Walkerton Inquiry, I have been asked several times, *"If the Walkerton disaster were not enough to motivate Canadians to manage drinking water safety effectively, what would it take?"* Because clear deficiencies are still evident in Canada's management structure for assuring safe drinking water, this critical question remains unanswered. The following discussion identifies some major deficiencies in contrast with current international best practice for assuring safe drinking water.

Drinking water is essential to human health and well-being. Currently, throughout much of the developed, industrialized world, including most of urbanized Canada, public drinking water generally poses a negligible health risk to consumers. However, Canadians residing in smaller communities and remote settings do not have that assurance (Hrudey 2008).

In Canada, the management of drinking water and assurance of safety is not as universally effective as it can and should be, largely because of a management structure that is ill-suited to the task, complacency, some misunderstanding of key safety issues and an overall lack of leadership.

The reality that we have not detected major drinking water outbreaks in Canada since North Battleford, Sask., in 2001 suggests that we must be doing something right, a point made by federal and provincial health officials in response to early drafts of this *Commentary*. Technical expertise in many Canadian water providers is certainly on par with the best in the world. Most operational personnel in Canada are dedicated to providing safe drinking water. Indeed, Ontario, in particular, and the other provinces to a lesser degree have instituted major changes and improvements to the regulation of drinking water in the intervening years.

Notwithstanding the major improvements in a system that was demonstrably inadequate before the Walkerton and North Battleford outbreaks, I believe much of Canada remains out of step with the international leaders in adopting management systems for assuring safe drinking water. Canadians should ask: why?

Our current system is structured largely to download responsibility for safe drinking water to the lowest level of public authority, municipal government. In contrast, some jurisdictions like England and the Australian states of South Australia, Victoria and Western Australia have organized drinking water services to be provided by large, regional water corporations, even for small communities.

Post-Walkerton, Canadian provinces now generally hold municipal authorities more directly accountable for providing safe drinking water, but the regulatory system remains generally more reactive than preventive. It focuses more on monitoring treated water quality rather than primarily on training and process monitoring aimed at ensuring operators know their own system better. Despite some clear progress in individual provinces, Canada, overall, needs a system that better promotes and rewards competence among drinking water providers. It needs a system that helps providers understand fully the nature of the challenge they have been dealt and better equips them with appropriate and effective support systems to deliver on their responsibility.

Ultimately, Canada needs a more consistent and comprehensive "know your own system" approach, such as is promoted by international best practice requiring water safety plans as a fundamental management approach. Under an effective water safety plan approach, those

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assigned to provide drinking water need to be afforded the training, intellectual support and compensation that is commensurate with their taking responsibility, through their actions or inactions, for the health of an entire community.

Concurrently, provincial drinking water policies should encourage, where conditions allow effective results, consolidation of smaller systems into larger more viable operations. The relevant test of viability should be based on a tangible demonstration of operator competence for understanding and delivering safe drinking water. For their part, Ontario regulators argue that the province has achieved all of these objectives and is now recognized as a world water safety leader. That said, there still remains more of a focus on compliance with complex regulations than there is encouragement and promotion of knowing one's own system, specifically for the smaller systems with limited resources.

Water professionals can judge for themselves whether the critical elements of the water safety plan approach advocated in this *Commentary* are being met in Ontario. However, one critical element of the water safety plan approach is that it requires continuous self-assessment and a commitment to continuous improvement. A blanket conclusion that everything is now under control and improvement is not necessary is wholly inconsistent with that philosophy.

Over the past five years, while giving outbreak case-study presentations to water operators in Alberta, Saskatchewan, Ontario and the Atlantic provinces and speaking directly with many front-line personnel in British Columbia, I have heard too many concerns expressed for me to dismiss them as irrelevant outliers. Canadians should expect that they will be provided safe drinking water in any community, not just the larger urban areas.

The challenge for regulators is to bring these smaller communities up to a best-practice standard. A number of small communities persist in providing the minimum financial compensation and training support they can get away with. Such communities are complacent about promoting the level of competence required for assuring safe drinking water. The extent of this problem has been evident in the large number (over 1,700 reported in a national survey in 2008) of ongoing boil-water advisories in Canada, many of which have been in place for months or even years (Eggertson 2008). Boil-water advisories are intended to be emergency measures to protect consumers from imminent but temporary threats to drinking water safety. Long-term continuing or recurring advisories, regardless of their underlying rationale, are a frank admission that the affected systems are otherwise failing to assure safe drinking water.

Given that Canadian provinces are unlikely to undertake a massive regulatory and structural overhaul to relieve municipalities of responsibility for producing safe drinking water, the Federal/Provincial/Territorial Committee on Drinking Water (CDW) provides the only forum that has the potential to show the necessary national leadership to improve the current system. Primarily, the CDW could encourage the meaningful and universal adoption of the "know your own system" water safety plan approach in Canada.

Currently, Health Canada, on behalf of the CDW, believes that its publications (CDW 2001, CDW/CCME 2002, CDW/CCME 2004, IWGDW 2005) on implementing a source-to-tap, multiple-barrier approach are sufficient to assure a water safety plan approach. For its part, Ontario believes it has fully implemented that approach, so it should be willing to show leadership in documenting and sharing its experience with other CDW jurisdictions to achieve national adoption. Ongoing critical self-examination is essential for fully implementing the philosophy underpinning the water safety plan approach advocated in this *Commentary*.

Distant Hindsight

Throughout much of human history, the quality and safety of drinking water has been suspect, notably where humans have gathered in close proximity, allowing human wastes to contaminate drinking water. The ability of drinking water to transmit disease was only established by scientific evidence in the mid- to late 1800s. Cholera attracted particular attention at this time because of its devastating epidemics, such as one in 1849 causing more than 53,000 deaths in England and Wales – more than 12 percent of all deaths that year (Morris 1976). English physician John Snow was the first to publish a rational scientific hypothesis about how cholera was spread by sewage-contaminated drinking water (Snow 1849).

Remarkably, Snow was able to develop the correct explanation of disease causation 33 years before the bacterial pathogen responsible for cholera was isolated by a German microbiologist. Snow's theory ultimately proved correct because of his meticulous and exhaustive efforts to challenge his own findings by disproving alternative explanations (Vinten-Johansen et al. 2003).

Understanding the true cause of waterborne disease allowed for development of effective water treatment and distribution, mainly by filtration and disinfection (chlorination). The resulting public health benefits have been enormous. Cutler and Miller (2004) estimate that in the early 20th century clean water was responsible for nearly half of the total mortality reduction, three-quarters of the infant mortality reduction and nearly two-thirds of the child mortality reduction observed in major US cities.

This remarkable advance was only achieved because the underlying causes of the problem were understood and accepted thereby allowing focused measures to be developed to deal with the root cause – pathogens in human fecal wastes contaminating drinking water supplies. Based on an accurate understanding of the problem, effective measures to reduce fecal contamination and to treat and disinfect drinking water were implemented.

Modern History of Unsafe Drinking Water in Developed, Industrialized Countries[1]

The foregoing advances have not been achieved universally, with much of the world still exposed to unsafe drinking water (Appendix A). That reality should serve as a constant reminder that the primary causes of unsafe water (microbial pathogens) are a pervasive threat to drinking water safety. As a consequence of participating on the Research Advisory Panel to the Walkerton Inquiry, I initiated a review of recent waterborne disease outbreaks in developed countries that was later published as a book (Hrudey and Hrudey 2004). Ultimately, we presented over 70 case studies of outbreaks since 1974 from 15 different affluent nations. These included seven outbreaks where fatalities arose, causing a total of 24 deaths during or shortly after the outbreak, and the Milwaukee outbreak that was followed by an estimated 50 deaths over two years. These findings are summarized in Appendix B, Table B1, which also includes two more recent fatal outbreaks – Nokia, Finland, in 2007, and Alamosa, Colorado, in 2008.

I discuss the Canadian outbreaks below, as well as summarizing some US cases, in Box 1. The latter are particularly relevant to Canada because the United States suffers from the same structural flaw of placing responsibility for drinking water upon municipalities. Despite having the most detailed and onerous regulatory regime for drinking water in the world, the US accounted for 23 of the 70 disease outbreak case studies mentioned above. Canada, with a population just 10 percent that of the United States, provided half as many of the case studies (12). For its part, England, with a population 60 percent larger than Canada's, provided only eight case studies.

Schuster et al. (2005) reported that a total of 99 waterborne disease outbreaks occurred in Canada over a similar period (1974-2001). Taken together with the fact that Canada had over 1,700 boil-water advisories in place in March 2008 (Eggertson 2008) as the last line of defense to protect consumers, Canada clearly has a tangible water safety issue, at least in smaller communities, long after Walkerton.

Recent Canadian History Regarding Unsafe Drinking Water

In modern history, Canada has been fortunate to have experienced few fatal drinking water disease outbreaks. The case studies outlined below include

1 Interested readers should read Appendix A for a summary of the challenges in developing countries.

only two outbreaks with fatalities – Drumheller, Alberta, and Walkerton, Ontario – and one with considerable notoriety – North Battleford, Saskatchewan, happening as it did only 11 months after Walkerton. Finally, Kashechewan, Ont., is included, even though it was not a drinking water outbreak, because of its implications for drinking water policy in Canada.

Drumheller, Alberta

In 1983, Drumheller, a town of about 6,500 people, experienced a short but intense outbreak of gastroenteritis, most likely viral, infecting about 3,000 people and causing two deaths of vulnerable nursing home patients. The outbreak was caused by a spill of raw sewage upstream of the town's drinking water intake. The sewage overflows were later determined to be common at this location during heavy storm flow conditions, but the sewage spill on this occasion occurred because of a pump failure.

The contamination potential was certainly foreseeable through a risk assessment that would be part of a water safety plan. Even though the town operated both the sewage pump station and the drinking water treatment plants, no notice of the incident was provided to the water plant operators, precluding any chance of implementing additional drinking water treatment measures. Likewise, a precautionary boil-water advisory might have been issued if the sewage spill had been reported and understood. As it happened, the boil-water advisory was issued almost five days after the first signs of illness.

Walkerton, Ontario

The May 2000 outbreak in Walkerton, a town of 4,800 residents at the time, is estimated to have caused over 2,300 cases of gastroenteritis. Sixty-five patients were hospitalized, 27 developed haemolytic uremic syndrome (a severe kidney condition) and seven died. This disaster attracted intense national media attention and Walkerton became a Canadian icon for contaminated water.

The media attention contributed in part to widespread misunderstanding among Canadians about what really went wrong in Walkerton. The outbreak involved a litany of failures by the actors involved, ranging from the operators and managers, to the provincial regulator and the Government of Ontario (O'Connor 2002a). The media focused mainly on the misdeeds of the manager and operators, along with various political accountability and responsibility controversies related to the provincial government at the time. While the popular media issues were relevant, they masked the underlying complacency and lack of operational and regulatory competence for the entire system.

The outbreak was the result of a shallow well being contaminated by cattle manure following heavy spring rainfall and widespread flooding. The well had been identified as vulnerable to agricultural contamination by the hydrogeologist who installed it in 1978. His warnings were not fully heeded, and over the years adverse microbiological monitoring results had been largely ignored by operators and regulators alike. These failures in regulatory oversight occurred over 22 years and involved provincial governments of every major political party, somewhat invalidating many of the simplistic accusations after the outbreak based on political considerations.

In fact, the water operators were inadequately trained to recognize the risks or the need for adequate chlorination. In particular, they were oblivious to the compelling need for disinfection and for monitoring chlorine residual as a real-time measure of disinfection performance for susceptible pathogens (Hrudey and Walker 2005). That failure was a key opportunity missed for preventing this outbreak, despite all the other deficiencies (O'Connor 2002a). Ultimately, failing to ensure a reasonable level of competence on the part of both the operators and the regulators was the key causative factor in allowing the Walkerton tragedy to occur.

North Battleford, Saskatchewan

North Battleford is a rural, agricultural service community which had a population of about 15,000 in 2001 when it experienced an outbreak of cryptosporidiosis affecting an estimated 5,800 to 7,000 people (Stirling et al. 2001). This outbreak was noteworthy, not just because of its size, but because it happened less than 11 months after the Walkerton outbreak with all of its massive media coverage. The North Battleford water treatment plant intake was located three kilometres downstream from the city's sewage treatment outfall. This proximity represented a chronic risk, and the outbreak occurred because the operators performed a maintenance operation on the water treatment plant in an ineffective manner that left the plant vulnerable. The chronic sewage contamination risk had been recognized by the provincial regulator and the city for almost 40 years without being resolved (Laing 2002).

After Walkerton, the North Battleford plant's foreman took early retirement in December 2000, citing job stress as a factor. Afterwards, the water treatment plants were operated by less experienced operators who initiated the maintenance in late March 2001 that resulted in negligible fine particle removal, leaving chlorination as the only barrier to microbial pathogens. As in Milwaukee (see Box 1), chlorination is not effective against *Cryptosporidium,* which allowed this outbreak to occur. Likewise, despite attempts by the City to blame the contamination on agricultural runoff upstream, molecular typing of stool samples from victims by the B.C. Centre for Disease Control documented that the human-only strain had infected all of the individuals providing useable samples, thereby establishing a sewage source for the contamination (Hrudey and Hrudey 2004).

Although there were several parallels between the North Battleford and Walkerton outbreaks, there were also some key differences. In North Battleford, some level of water treatment was being provided and the operators had better training and awareness of water treatment and safety issues. They knew enough to have been pressuring management for water treatment improvements even though they were unaware of the public health risk of relying solely on chlorination for a water supply that was vulnerable to *Cryptosporidium* contamination. The commissioner of the public inquiry into the outbreak summed up the city's role by stating:

> "There was a systematic failure on the part of the City of North Battleford to recognize its responsibility to produce safe drinking water. This failure was brought about by the city's collective lack of knowledge on what it takes to produce safe drinking water and policies that discouraged the possibility that it might acquire such knowledge." (Laing 2002).

Kashechewan, Ontario

Kashechewan is a remote Aboriginal reserve in northern Ontario on the shores of James Bay with a population of approximately 1,700. Unlike the foregoing case studies, there was no waterborne disease outbreak in this community, but media reports in October 2005 described a major water safety crisis that left many people believing that an outbreak had occurred. The circumstances regarding what happened in Kashechewan and the political response to these events highlight that even water safety decisions made at the highest levels of government (the Ontario premier and prime minister in 2005) may have little to do with scientific evidence and a lot to do with ill-informed perception and political expediency.

A water sample taken in Kashechewan on October 12, 2005 by Health Canada detected *Escherichia coli (E. coli)*, a species of bacteria normally found in the intestinal tract of humans and warm-blooded animals where it helps digest food. Most strains of *E. coli* are harmless, but a few can cause human disease and are recognized as pathogens, the best known of these being *E. coli* O157:H7, responsible for illness and deaths in the Cabool, Saitama, Washington County and Walkerton outbreaks (Appendix B, Table B1). The critical misunderstanding in the public discourse over Kashechewan was confusion between normal, harmless *E. coli* and the pathogenic *E. coli* O157:H7.

The normal, harmless and exceedingly more common *E. coli* is used as an indicator organism of possible fecal pollution of water because it is excreted in huge numbers – 100 billion to 10 trillion per day – in human and animal feces. When disinfection by chlorine is functional, there should be no *E. coli* found in drinking water because chlorination is extremely effective at

Box 1: Fatal US Drinking Water Outbreaks over the Past 20 Years

Cabool, Missouri – 1989
In 1989, Cabool was a town of about 2,100 people that experienced 243 confirmed cases of infection by *Escherichia coli (E. coli)* O157:H7, including four deaths. The outbreak was apparently caused by sewage contamination of drinking water during water main repairs following unusually cold weather. The specific location of contamination was not found, but the distribution system was in poor repair and clearly vulnerable to sewage contamination. The sewer system was in worse condition, experiencing regular back-ups and overflows. The deep groundwater drinking water source was free of any indication of microbial pathogen contamination, but it was distributed without disinfection. The combination of poorly maintained infrastructure, lack of drinking water treatment (disinfection) or monitoring capacity and unusual weather events resulted in the upset conditions leading to this fatal outbreak.

Milwaukee, Wisconsin – 1993
In 1993, Milwaukee experienced an enormous outbreak of cryptosporidiosis – as many as 400,000 cases. At the time, Milwaukee had 600,000 people within a metropolitan region of about 1.6 million, which was served by two water treatment plants. These plants were practising what was accepted as full conventional water treatment and were meeting treated water quality standards. Years after the outbreak, archived stool samples revealed a strain of *Cryptosporidium* that only infects human, making sanitary sewage discharge from Milwaukee the most likely source of contamination. While Milwaukee had an adequate water treatment system to cope with bacterial raw water contamination, *Cryptosporidium*, being chlorine resistant, demands optimum filtration performance, as measured by maximum turbidity removal and additional disinfection capable of handling the chlorine-resistant pathogen. Milwaukee had not implemented recommendations on how to avoid cryptosporidium outbreaks and operating personnel failed to respond to both a turbidity spike in filtered water and a sharp rise in consumer phone complaints that in retrospect signaled the contamination episode.

Gideon, Missouri – 1993
Gideon in 1993 was a town of about 1,100 when a drinking water outbreak made more than half the population ill and caused seven deaths. Like Cabool, Gideon had a high-quality groundwater supply feeding into a poorly maintained distribution system without disinfection. The specific cause of the outbreak of salmonellosis was not clearly identified, but it was most likely caused by poor maintenance of water storage facilities. One tank was found to have fecal contamination from birds. The outbreak investigation inferred that the contaminated water was washed into the distribution system during an effort to flush it because of consumer water quality complaints about odour.

Alamosa, Colorado – 2008
Almosa, a community of about 9,000 people in 2008, experienced a drinking water outbreak of salmonellosis causing an estimated 1,300 cases of illness and one death, precipitating a state declared emergency. The groundwater system, which was not chlorinated, became contaminated with pathogenic *salmonella*, most likely because of a poorly maintained surface storage tank that became contaminated by feces from small animals or birds.

These fatal outbreaks, with the exception of Milwaukee, all occurred in smaller communities and could have been prevented if chlorination had been required. Meanwhile, chlorination was supposed to have been in place in Walkerton, but was not maintained because the operators failed to measure chlorine residual that would have told them in real time about the failure of chlorine disinfection (Hrudey and Walker 2005). In Milwaukee, the failure was inadequate filtration performance because of an inability to understand the risk posed by chlorine-resistant *Cryptosporidium*, similar to the failure in North Battleford eight years later. These case studies illustrate a failure to learn from experience.

inactivating all enteric bacteria, including both normal and pathogenic strains of *E. coli.* Confirmed detection of *E. coli* in treated drinking water is indicative of inadequate disinfection and some fecal contamination, which raises the possibility of a health risk.

The presence of the indicator *E. coli* is a warning that must be dealt with. However, detection of *E. coli* in treated drinking water does not make it certain, nor even necessarily likely that the water is contaminated with pathogen numbers sufficient to cause disease. The normal response is to issue a boil-water advisory and to investigate and fix the problem. In the case of Kashechewan, it had already been on a boil-water advisory for over two years because of elevated turbidity, a signal that its filtration treatment was not as effective as it should have been.

The band council was immediately informed, technical specialists were contracted and a plane was chartered to fly the technicians into Kashechewan. They located the problem – a malfunctioning chlorinator – and fixed it in a few hours. Water samples reported on October 17 showed the treated water to be free of *E. coli.* Chlorination was increased for two or three days to assure that the water distribution system would be free of *E. coli* before returning to normal chlorine residual levels. Throughout the episode, Ontario's guidance for maximum chlorine residual concentration was never exceeded.

The incident began receiving increasing national media attention with reports of the *E. coli* detection, which drew no distinction with the notorious *E. coli* O157:H7 pathogen of Walkerton infamy. On October 25, a physician from a regional hospital met with the Premier of Ontario and showed him distressing photos of infants with severe skin rashes that were claimed to be worsened by the high chlorine levels in the drinking water.

The Premier announced an evacuation – to be paid for by the federal government – which would over the next few weeks remove about 60 percent of Kashechewan's 1,700 residents to various Ontario communities. The federal government then reacted to show that it was responding to the "crisis" by sending Kashechewan a Hercules military transport plane with an emergency field water treatment plant to supplement massive bottled water shipments that had started shortly after the initial *E. coli* results were reported. The sobering reality is that there was no disease caused by *E. coli*-contaminated water in Kashechewan.

The skin rashes were real, but were caused by scabies and impetigo, skin conditions well known to be caused by poor sanitation and over-crowded, sub-standard living conditions. Suggestions that high chlorine levels were exacerbating the rash problem were unfounded and in any case did not justify a community-wide evacuation. (Notably, Australia has found chlorinated swimming pools to be effective at reducing the prevalence of skin rashes among Aboriginal children in remote communities [Lehmann et al. 2003, Audera et al. 1999].)

Kashechewan's extraordinary series of events was driven by many factors beyond the reporting of *E. coli* in the drinking water, including the deplorable housing and social conditions in this community with 85 percent unemployment. However, the costs, which surely reached into the tens of millions of dollars for the evacuation and other extraordinary measures taken, most of which were not justifiable on the grounds of health protection, would clearly have been better invested in measures to improve the community's underlying problems. In any case, the obvious disconnect between the knowledge of what the detection of indicator *E. coli* means versus the government responses, as if it were dealing with a continuing and urgent health threat, reveals a government inability to respond accurately to drinking water safety issues in 2005, even after the Walkerton trauma five years earlier. Now, another six years later, there is only limited evidence that the Kashechewan debacle could not be repeated.

Seeking to Turn Hindsight into Foresight

We should be able implement improved programs and procedures based on our experience with waterborne disease. While there have been substantial international advances in institutionalized management of the most critical elements for assuring safe drinking water, considerably less advancement is evident across Canada even after the wake-up call from Walkerton. In my experience, the mistakes of Walkerton have attracted more interest and inspired more enlightened foresight among some water providers and regulators outside of Canada than within.

Responses for Assuring Safe Drinking Water in Other Jurisdictions

In the past decade, an international consensus has developed around the need to focus more on operational competence rather than relying on a narrow and somewhat naive focus on compliance with numerical water quality criteria. The latter approach is naive because there are very few water quality parameters (e.g., turbidity, chlorine residual, pH, conductivity, UV absorbance) that can be measured continuously or in real time. Consequently, compliance monitoring with individual drinking water guideline numbers means that water is likely to have already been consumed by the time laboratory results become available, providing an inherently reactive, rather than a preventive system (IWA 2004). Likewise, most of the numerical guideline values involve expensive analyses (some costing hundreds of dollars per sample) that are generally performed as infrequently as once or twice a year, if at all, making the coverage of compliance monitoring extremely limited.

At this point, it is useful to consider two jurisdictions that have made considerable progress in developing an effective water safety plan approach.

New Zealand

With its introduction in 2000 of public health risk management plans (PHRMP), New Zealand developed a pragmatic and effective program to support a competency-based safe water program. The PHRMP approach, supported by a number of background documents and guides available at the New Zealand Ministry of Health website, http://www.moh.govt.nz/water, follows a very logical assessment of a drinking water system that has universal application.

Under the PHRMP approach, a water supply system is first assessed to identify which of several water safety guides may be applicable. A checklist of the barriers against contamination in the system is developed. These barriers fall into four categories that, if maintained effectively, will adequately control hazards (Nokes and Taylor 2003). They are:

- prevention of contaminants entering the raw water of the supply;
- removal of particles from the water;
- inactivation of microorganisms in the water; and,
- maintenance of water quality during distribution.

The applicable guides are used to identify events which may pose a threat to water safety, then to identify possible causes of each hazardous event, preventive or protective measures that can be taken and, finally, corrective actions to take should the preventive measures fail. From this overview assessment, decisions are made regarding improvements that are needed, the order of priority for improvements and a timetable for implementation. Contingency plans are prepared and an overall performance assessment is performed to judge how well the PHRMP is performing.

The PHRMP approach is now enshrined as a requirement in New Zealand's safe drinking water legislation for all systems supplying a population of more than 500 people (NZMOH 2008). Smaller systems can also use the PHRMP approach because it has been designed particularly to support and guide smaller systems.

Australia

Australia experienced a water-quality crisis in Sydney in 1998, two years before hosting the summer Olympics. This event had three million residents on and off a boil-water advisory from late July through September. The event was most likely the result of a monitoring mistake whose impact was quickly compounded by overwhelming media criticism and political reaction (Hrudey and Hrudey 2004). Health surveillance demonstrated that there was no evidence of waterborne illness, but the subsequent inquiry led to the firing of several senior officials and the breaking up of the water company supplying the city.

The events and resulting fallout, along with a number of other changes in the structure of Australia's water industry that were underway, set the stage for the development and adoption of a comprehensive new approach for drinking water quality and safety based on widely accepted Total Quality Management (TQM) principles (Sinclair and Rizak 2002; Rizak et al. 2003).

A key feature of the resulting Framework for the Management of Drinking Water Quality was to shift the primary focus from drinking-water guidelines based on numerical water quality criteria to an emphasis on achieving optimum performance of the processes known to produce high-quality, safe drinking water. The Australian Drinking Water Guidelines (ADWG) were substantially restructured to introduce this Framework as the overall organizing concept. (NHMRC 2004). For a further discussion on other international approaches to safe drinking water, see Box 2.

Canadian Responses

Over the past decade, the discourse on drinking water in Canada has largely been shaped by Walkerton, as might be expected. Given what happened there, and the reality that the conditions leading to the disaster existed to varying degrees elsewhere in Canada, there was a need for a mature national discussion about drinking water safety. Unfortunately, other than the attention given by the Walkerton Inquiry to international practices and approaches for ensuring safe drinking water, many provincial drinking water programs have generally continued to focus on US regulatory practices and have not explicitly adopted the international movement toward a water safety plan approach.

Walkerton Inquiry and the *Ontario Safe Drinking Water Act*

The Walkerton Inquiry produced two reports. Part 1 dealt with the causes of the outbreak, including the role of the Ontario government (O'Connor, 2002a). Part 2 proposed a strategy to avoid such a disaster happening again (O'Connor, 2002b). The Part 2 report made 93 recommendations to implement a multiple-barrier approach to drinking water protection across Ontario, with particular attention on:

- improved coordination of source protection;
- improved standards-setting with greater transparency;
- improved provincial oversight, including regulatory obligations under comprehensive legislation to manage water quality from source to tap; and
- special considerations for small systems.

The province accepted all the recommendations, making more comprehensive efforts to focus on source water protection than in other Canadian jurisdictions. The most important recommendations related to assuring competence have taken the longest to implement. Justice O'Connor described these as follows:

> "Perhaps the most significant recommendations in this report address the need for quality management through mandatory accreditation and operational planning. Sound management and operational systems help prevent, not simply react to, the contamination of drinking water. Also, as part of the quality management approach, I recommend that each municipality be required to have an operational plan for its water system."

The emphasis of Justice O'Connor's findings on promoting and sharing competence seems clear enough, but the roll-out of the *Ontario Safe Drinking Water Act* and enforcement of new regulatory provisions have added complexity without creating an adequate support system that can effectively foster competence, especially in smaller communities. The new regulatory scheme, which is detailed and complex, appears more

Box 2: International Approaches to Safe Drinking Water

World Health Organization

The 2004 World Health Organization revised water guidelines provide a broader perspective on safe drinking water with a primary emphasis on better knowing one's system (WHO 2004b). The WHO guidelines are based on a water safety plan approach that builds upon the New Zealand PHRMP concept and some of the broader quality and risk management features of the ADWG. Essentially, this approach aims to insure that all those who are engaged in operating a drinking water system will fully understand:

- the threats the system faces;
- the capability of the system to deal with those threats;
- the capabilities to respond if the system fails; and
- the measures that can be used to improve the capability of the system to assure that it can deliver safe drinking water (Bartram et al. 2009).

Bonn Charter

In 2004, with the support of the International Water Association and WHO, water organizations from several countries and regions – Australia (2), Europe, Germany, the Netherlands, Portugal, the United Kingdom and the United States (3) – negotiated a framework of institutional, managerial and operational requirements for assuring safe drinking water (IWA 2004). These included key principles for managing drinking water effectively and described the roles and responsibilities of various stakeholders. Notably, no organization from Canada participated in this initiative. The Bonn Charter emphasizes an integrated approach to the effective management of drinking water. Subsequently, the IWA has sponsored the Bonn Network (IWA 2007) that recruited 15 water authorities from 12 countries to develop tools for assuring safe drinking water. No Canadian water provider accepted an invitation to participate.

England – Badenoch Expert Reports and Drinking Water Inspectorate

Drinking water delivery in England experienced a major restructuring in the 1980s with the privatization of the public water authorities responsible for drinking water and municipal wastewater treatment. A subsequent series of cryptosporidiosis outbreaks, most notably in Swindon and Oxfordshire (Hrudey and Hrudey 2004), drew immediate attention to the issue of water system safety. An expert inquiry was undertaken to find out the causes and necessary preventive measures (Badenoch et al. 1990, 1995). The reports produced by the Badenoch inquiry yielded extensive technical advice which, if it had been widely heeded, would have likely prevented outbreaks like the one in Milwaukee in 1993. A new regulator, the Drinking Water Inspectorate (DWI) was formed in 1990 to assure that these newly created private water authorities provided high quality, safe water. The DWI is a small regulatory agency for England and Wales with only 38 employees, but it has been relatively effective in assuring that the drinking water industry meets high quality and safety standards. In particular, the DWI has adopted the water safety plan approach as a central element of its regulatory scheme.

United States and the European Union

These jurisdictions have many different agencies, programs and approaches some of which have resulted in excellent advances in drinking water quality technology and practice. For example, water authorities in France, Germany and the Netherlands are recognized as world leaders in many aspects of safe drinking water supply. However, the European Union had been following a numbers-oriented regulatory scheme similar to the US Environmental Protection Agency. Since the 2004 release of the WHO guidelines, individual European Union members (e.g., Britain, Germany, Portugal) have strongly embraced the water safety plan approach.

The US regulatory system has developed some of the best technical information for assuring safe drinking water. However, the US emphasis on compliance with drinking water quality standards has too often overshadowed some excellent initiatives that focus on operational excellence through treatment requirements, peer review and support. These initiatives include QualServe, the International Water Treatment Alliance (IWTA), the Partnership for Safe Water sponsored by the American Water Works Association (AWWA 2010) and the US Environmental Protection Agency (EPA) Area Wide Optimization (AWOP) Program that has been adopted by four US EPA regions and 21 states. Nova Scotia adopted IWTA standards, a peer review program for promoting good practice in piloting the treatment component of its drinking water strategy. AWOP is a strategy for targeting higher risk systems for state assistance to maximize public health protection with a focus on optimization of treatment performance, including enhanced operator training (US EPA 2003).

focused on providing authority for legal enforcement than on building a system that ensures operational competence and fosters knowledge transfer from the best operators to those who need to improve. An important exception has been the creation and Ontario support for the excellent training programs of the Walkerton Clean Water Centre (http://www.wcwc.ca/en/)

North Battleford Inquiry

The report from the North Battleford outbreak inquiry (Laing 2002) provides an excellent insight into the problems of providing water and sanitation services in a rural community where safe drinking water was clearly not a priority. Although some of the indifference to public health among local politicians and civic administration may seem exceptional, such occurrences are too common where responsibility for providing water is downloaded to the municipal level without an adequate supporting framework. This is particularly true for smaller municipalities where, unless very effective provincial oversight and support is provided, a knowledge-oriented, competence-based operational approach is unlikely to develop spontaneously and flourish. Recent experience in Germany with promoting a water safety plan approach has revealed that smaller communities need to have this approach required by regulation to allow it to compete for limited resources with other local priorities (Schmoll and Castell-Exner 2010).

Watertight: The Case for Change in Ontario's Water and Wastewater Sector

Following the reports from the Walkerton Inquiry and passage of the *Ontario Safe Drinking Water Act,* an expert panel was commissioned to explore the sustainability of the province's water and wastewater infrastructure. The panel report, known as the Watertight report (Swain et al. 2005), found that Ontario's current water and wastewater system was not sustainable because of inadequate past and current investment while future costs were escalating, in part because of more than $800 million in additional capital costs resulting from *Safe Drinking Water Act* requirements. The panel's recommendations were clear and well-founded and indicated that economies of scale were necessary, meaning that the scale and capacity of systems must increase generally through regional consolidation.

There are some examples of successful regionalization in Alberta, Ontario and Nova Scotia. Alberta, for one, has pursued regionalization through investment in treated water pipelines from larger centres to serve smaller communities. This approach has improved drinking water quality in many cases, but does not address the need for competence in maintaining local distribution systems. Distribution system failures have been responsible for at least four fatal outbreaks in the past 20 years (Appendix B, Table B1). The Watertight report findings were not prescriptive about how consolidation should happen, recognizing that different circumstances may dictate different approaches. However, it found a clear economic case for larger, more efficient systems with the obvious corresponding benefits of being more competent and better run. This report also made a case for keeping regulations "lighthanded" to allow the emphasis to be on achieving and demonstrating competence.

Unfortunately, Watertight was met with opposition from some municipalities and public sector unions. Despite the recent introduction of the *Water Opportunities Act* in Ontario, which proposes to require regulated water providers to develop a sustainability plan to address some of the earlier identified problems, there is as yet little evidence of progress toward encouraging consolidation of water providers to achieve necessary economies of scale and functional competence.

Expert Panel on Safe Drinking Water for First Nations

In September 2005, before the Kashechewan episode, the federal Commissioner of the Environment and Sustainable Development tabled her annual report in Parliament, which included a critique of Canada's $600 million investment program for water infrastructure on First Nations reserves. Among her concerns was the absence of any regulatory regime for assuring safe drinking water on these reserves.

I participated as one of a three-member expert panel, which conducted public meetings in all regions of Canada on the need for a regulatory water regime and reported on the regulatory options to the Minister of Indian and Northern Affairs. Our panel was specifically barred from making recommendations. However, we stressed that implementing any regulatory regime in circumstances where the capacity to perform was lacking or limited would be unlikely to improve drinking water safety (Swain et al. 2006).

Given 85 percent unemployment at Kashechewan, the panel's observation of difficulties in funding the operation of facilities on remote reserves, particularly when external personnel were used, is sadly ironic. The serious disconnect between having high local unemployment while needing to use expensive external personnel suggests that increasing investment in capital facilities without investing in better ways to improve local recruitment and training for operators fails to resolve water safety issues in a sustainable way.

We heard from consultants experienced with small community water systems at our public hearings, for example, that given the choice between a gold-plated water treatment plant with an inadequate operator and a limited water treatment plant with a highly competent operator, the latter would be the best choice for safe drinking water. However, the existing funding regime places a clear emphasis on infrastructure with inadequate attention paid to the importance of commitment by well-trained personnel to assuring water safety.

An extremely valuable initiative we learned of during our public hearings is the circuit-rider system first developed in Saskatchewan for First Nations water operators and now adopted in most administrative regions for First Nations of Canada. This program entails developing a cohort of skilled operators who travel on a scheduled basis to visit individual water treatment plants, including remote facilities to provide hands-on training and operator support. Unfortunately, these programs are generally over-subscribed and underfunded.

Other Provincial Responses

In the years following Walkerton, almost every province or territory outside Ontario published some policy statement or took a legislative initiative to address public drinking water safety concerns.[2]

2 Including B.C. (Government of B.C. 2002), Alberta (Alberta Environment 2003), Saskatchewan (Government of Saskatchewan 2003), Manitoba (Government of Manitoba 2003), Quebec (Government of Québec 2002), Nova Scotia (Government of Nova Scotia 2002), Prince Edward Island (Government of Prince Edward Island 2001), Newfoundland (Government of Newfoundland and Labrador 2001), Northwest Territory (Government of the Northwest Territories 2001, 2005) and Yukon Territory (Government of the Yukon 2005).

These public documents and associated programs generally reflect the valuable source-to-tap, multiple-barrier concept for assuring safe drinking water that was adopted by the Walkerton Inquiry (O'Connor 2002b). However, the depth of practical commitment and guidance provided varies from brief glossy brochures to more in-depth summaries of potential valuable and tangible improvements. While there has been a major improvement in public access to information on drinking water quality in most jurisdictions, overall there remains considerable variability in regulatory regimes (Willms and Shier 2006, Carter 2008), much more than might be justified on grounds of regional variations.

British Columbia likely provides the best documented evidence for the scope of challenges with assuring safe drinking water for smaller communities. Growing expressions of concern about the occurrence of numerous and ongoing boil-water advisories precipitated an investigation by the B.C. Ombudsman (Carter 2008). The subsequent report documented that the number of small drinking water systems to be regulated under the province's *Drinking Water Protection Act* was not accurately known, with estimates ranging between 3,000 and 4,360 systems serving between 2 connections and 300.

Looking Backwards about Safe Drinking Water

The Drinking Water Regulatory Reality in Canada

The current Canadian regulatory system for drinking water is largely dictated by our constitutional division of powers, which has historically seen the provinces take responsibility for regulating municipal services such as drinking water. While this clearly has merit for a country as large and diverse as Canada, the particular characteristics of drinking water safety as a policy issue lead to some problems with assigning responsibility to municipalities.

The Federal/Provincial/Territorial Committee on Drinking Water (CDW), supported and coordinated by a secretariat within Health Canada,[3] provides a valuable level of national coordination, but the CDW focus is primarily on setting the Guidelines for Canadian Drinking Water Quality (GCDWQ).[4] These are a list of essential numerical water quality values, generally set as maximum acceptable concentrations (MAC) for chemical, physical and biological parameters affecting the quality, including aesthetic factors, and safety of drinking water.

In addition to the guidance documents on the multi-barrier approach mentioned earlier, there has been some guidance published by the CDW on operational performance for corrosion control (CDW 2009a) and on issuing and rescinding boil-water advisories (CDW 2009b, c). Provision of such guidance is a positive departure from the previous focus on publishing MAC tables and documents to support MAC-derivation.

The problem is that, unlike the World Health Organization Drinking Water Guidelines (WHO 2004b) or Australian Drinking Water Guidelines (NHMRC 2004), the GCDWQ do not effectively address the process and operational side of assuring safe drinking water. Rather, the GCDWQ are primarily a table of MAC numbers, which unfortunately help perpetuate the pervasive misunderstanding that numbers assure safe water rather than competence and good practices. The earlier case studies all show to varying degrees, with Walkerton and North Battleford at the forefront, that the unsafe water, illness and even deaths resulted from a failure to operate the water

3 "The CDW is a well-established national committee that has been active for more than 20 years. Health Canada provides scientific and technical expertise to the Committee, and coordinates its activities. The CDW reports to the Federal-Provincial-Territorial Committee on Health and the Environment (CHE). CHE, in turn, reports on health issues to the Advisory Committee on Population Health and Health Security (ACPHHS) and on environmental issues to the Canadian Council of Ministers of the Environment." http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/fpt/index-eng.php

4 "The main responsibility of the Federal-Provincial-Territorial Committee on Drinking Water (CDW) is to establish the Guidelines for Canadian Drinking Water Quality." Ibid.

system effectively, not a failure to have more stringent numerical criteria.

What Does Safe Drinking Water Mean?

If one looks at drinking water legislation or guidance, there is very little written as to what is meant by "safe drinking water." The GCDWQ, the *Ontario Safe Drinking Water Act* and the *US Safe Drinking Water Act* all fail to define the term. The WHO Drinking Water Guidelines (WHO 2004b) state:

> Safe drinking-water, as defined by the Guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages.

This is a well crafted definition that accurately describes the premise for the WHO parameter guidelines. However, a close reading reveals why governments are apparently so reluctant to define safe drinking water in legislation.

Two observations are important regarding the WHO definition. First, it indicates that safe drinking water does not pose zero health risk, but rather the risk is so low as to be negligible. However, different people will have different views about what is negligible – the assessment of the scientists who recommend the WHO guidelines may not align with everyone among the consuming public. Certainly the many urban Canadians who spend money on expensive bottled water because of health concerns, rather than for reasons of convenience or taste, are showing they believe their municipal tapwater, which almost universally meets WHO guidelines, may not be safe.

Statistics Canada (2009) has reported that in 2007, 30 percent of Canadian households drank mostly bottled water and about half treated their tap water with a home water-treatment device. Meanwhile, Dupont et al. (2010) report that health concerns about tap water and a belief that bottled water is safer are the most significant factors among Canadians choosing bottled water or home water-treatment over tapwater.

Second, Canadians should understand that the difference between safe and unsafe is not a sharp line.[5] For example, driving through a red light is probably unsafe, but driving through a green light is not risk-free. Ultimately, the pragmatic judgment that we individually make about safety is that if the risk is small enough, we do not need to worry about it – we will accept a very small risk and treat it as effectively safe (Hrudey and Krewski 1995). Any drinking water supply in Canada can meet this pragmatic and functional definition of safety with only a modest investment in assuring competence. However, based on inadequate competence there are still many small drinking water supplies that would not qualify as safe, even by that modest standard.

Narrow Focus on Water Quality Guideline Numbers

Rather than recognizing and delivering what is required to assure Canadians of a safe drinking water supply – a serious investment in training and operational support – there are far too many distractions that perpetuate a misguided focus on the wrong things. For example, the claim that even very low-level contamination of water by a wide array of pollutants poses a health risk to Canadians is alarmist and non-scientific (see, for example, Boyd 2006).

To take a purely numbers-driven approach that compares the maximum acceptable concentrations for contaminants in the GCDWQ with numerical guidelines and standards in other western jurisdictions (ibid) may miss the point. On the face of it, who can argue with going for the best numbers in the world? The problem is that simply specifying lower numbers for compliance monitoring does not address the causes of the many documented failures in drinking water safety.

5 "…(standards) represent, in general, imaginary lines between good and bad; necessary for the enactment and enforcement of rules and regulations, but nevertheless inadequate expressions of real fact" (Phelps, 1948).

Bottled Water and Home Water-Treatment

Despite substantial improvements since Walkerton, the regulation of drinking water in Canada is guided and managed in a fragmented, almost ad hoc, manner that leaves us vulnerable to future water-quality failures, most likely in smaller communities, and to the continuing commercial exploitation of fears about water safety by highly profitable marketers of bottled water and home water-treatment devices (Hrudey 2008). From 1999 to 2004, per capita bottled water consumption in Canada grew an estimated 40 percent.[6] Ironically, the growing expenditures on bottled water in Canada come at a time when many Canadians seem largely indifferent or complacent about the need to invest in assuring high-quality municipal water supplies.

The Challenge for Those Who Must Deliver Safe Drinking Water

The GCDWQ emphasis, nationally, on water quality numbers combined with the reality that our provincial regulatory schemes largely place the responsibility for delivering safe drinking water on municipal authorities, remains a recipe for allowing failure. Our current system means that the level of government with the least financial capacity – notably when it comes to medium and smaller communities – and the lowest level of technical resources is held accountable for the often complex task of ensuring that water is safe to consume.

If smaller communities rely on the GCDWQ as the guide for achieving this task, they will find a document that lists MACs for 88 different physical and chemical parameters with 68 of these based on health concerns, plus another 18 for radionuclides. Currently, the GCDWQ is comparable to specifying a destination without providing any map or directions on how best to get there or even knowing if you got there.

Furthermore, if water providers consult the GCDWQ technical background documents, they will find little help with determining how important or relevant an individual parameter is to the safety of their water system. Anyone studying these documents could also be forgiven for deciding to drink bottled water after reading the sections describing health effects of various parameters on experimental animals, without realizing that most animal evidence is obtained at massively higher dose levels, generally not even delivered by a drinking water exposure route.

Because the route and means of exposure matter in determining health effects, the relevance of experimental results on animals to human drinking water consumption has been shown to be suspect in major cases such as chloroform (Hrudey 2009) and bromodichloromethane (BDCM).

Even though the overall guidelines package is reasonably careful to stress that microbial pathogens pose the greatest risk to human health from drinking water, there remains an inordinate focus on chemical hazards. Many, if not most, of those engaged in delivering water to the public believe that science has proven that disinfection by-products (DBPs), a largely inevitable consequence of disinfecting water to prevent waterborne disease, are certain to cause cancer among consumers (Chowdhury and Hall 2010). This view lacks credible scientific evidence despite being widely held (Hrudey 2009).

Operating personnel can be forgiven for finding it unsettling to be told that doing what must be done to control microbial pathogens is giving their consumers cancer. The problem is largely one of communication. The information available to operational personnel does little to inform them about the level of precaution that is wisely – in most cases[7] – built in to setting MAC values and the often relatively low confidence that can be placed in knowing that particular chemicals cause serious disease via drinking water exposure.

6 These are estimated from data provided by Pacific Institute (2007) www.worldwater.org/data.html data Table 13.

7 In some cases (e.g., the rationale for the MAC for dichloromethane), adoption of additional uncertainty factors or very weak evidence for cancer causation drives an extremely low MAC value that is inadequately justified in the standard-setting process.

That limited confidence is not an inherent criticism of those who do the background health research; rather it is a reality linked to the limitations of our means for studying extremely low population health risks and a general lack of effective risk communication within professional (health and operational) communities. This is not to say that chemical risks should not be addressed and all reasonable efforts made to reduce these risks in the few circumstances where they apply. Rather, the efforts at insuring neglible health risk from any conceivable drinking water contaminant must not undermine the primary focus on managing those risks that can have real and significant public health consequences as incidents like Walkerton and those in Appendix B demonstrate.

A Rational Way Forward

On the face of it, Canadians should be asking why Canada appears to be out of step with the international leaders in assuring safe drinking water. If it is not practical to replace our current system of downloading responsibility for safe drinking water to the lowest level of public authority, we at least need to provide appropriate oversight and guidance systems. Regulatory systems should not only hold those public authorities accountable for the provision of safe drinking water, but also assist them in understanding the full nature of the challenge they have been dealt and provide the appropriate and effective support to help them deliver on their responsibility. Ontario's initiative in creating and supporting the Walkerton Clean Water Centre (http://www.wcwc.ca/en/) is an excellent example of what is needed. Likewise, the Canadian Municipal Water Consortium of the Canadian Water Network (http://www.cwn-rce.ca/research/consortium/municipal-water-management/) which seeks to facilitate municipal access to and use of Canada's considerable water research capabilities, is another promising example of promoting the way forward.

Setting and Understanding Priorities in Drinking Water Safety

Those engaged in the process of setting MACs for drinking-water-quality parameters see the process largely as one of risk assessment – identifying the hazard, describing the hazard in terms of its toxicological properties to animals and humans, quantifying the relationship between potential drinking water exposure and predicted health outcome and, finally, selecting a deemed acceptable level of risk via drinking water exposure that determines the MAC value. While it is true that setting MAC values relies upon this kind of risk assessment, the process is an act of risk management because it inherently involves a number of judgment choices that are contingent upon a variety of assumptions.

There is nothing inherently wrong with this process, and in general it is simply our best way of coping with incomplete knowledge in a precautionary way that seeks to protect public health. What is wrong is that MAC values often implicitly convey a message that a failure to satisfy these values will result in a real and unacceptable effect. Likely harm from drinking water exposure, based on experiential evidence, is only a valid expectation for the relatively short list of drinking water parameters reviewed in Appendix C (WHO 2007).

Most of the long list of MAC values are set in a precautionary manner to prevent the possibility, not the inevitability, that these parameters will represent any kind of health risk via drinking water exposure. Indeed, in most cases MAC values are irrelevant for routine risk management because the parameters are generally not found in drinking water at levels that represent any possible health risk. Understanding the distinction between "remote possibility" and "real inevitability" needs to be conveyed clearly and effectively to those who must deliver safe drinking water so that they are not distracted from rigorously controlling the contaminants that we know pose a serious human health risk.

The ever-growing list of MAC values based on largely precautionary grounds must be considered but cannot be allowed to siphon resources or attention away from those health risks that must be addressed.

The Canadian Municipal Consortium has proposed the following risk management priorities for drinking water (Douglas et al. 2010, Hrudey et al. 2010), using a hierarchy that applies to providing safe drinking water and that can be adapted to fit local needs.

1. *Highly certain and pervasive risks require action for any water system* – microbial pathogens are the best example of this type of risk as they are known to cause human disease via drinking water exposure. Because of their fecal origin, they present a pervasive risk to all surface water systems, many groundwater sources and to all distribution systems.
2. *Reasonably certain but less pervasive risks (appearing in some drinking water systems) should be identified and addressed as necessary* – some parameters have been shown to cause human illness (or adverse effect) via drinking water exposure at some time, somewhere in the world (e.g., arsenic, fluoride, selenium, nitrates and lead [WHO 2007]). These are site-specific (e.g., local geology, distribution system materials or other local factors) and only apply to some drinking waters.
3. *Common but comparatively uncertain risks (produced in water treatment) require a rational precautionary response* – various parameters (e.g., DBPs, aluminum, water treatment chemicals) warrant scrutiny because they are produced or added in the water treatment process, are very common, making exposure pervasive, and may be amenable to reduction through process refinements.
4. *Site-specific contaminants with noteworthy toxic potential require localized plans commensurate with locally assessed risk* – various parameters (e.g., pesticides, cyanobacterial toxins) with toxic potential relevant to drinking water exposure and that can be found in water need to be assessed to determine site-specific relevance.
5. *Emerging contaminants* – these are parameters that require research to characterize the nature of the problem they may pose. Advances in analytical chemistry guarantee that many hitherto undetected contaminants will be identified in drinking water and these require research to characterize their nature to determine if they pose a credible drinking water health problem versus a conceivable but highly unlikely problem. Because this distinction is too often not understood, the latter commonly becomes a source of unwarranted concern. Once research has adequately characterized the risks relative to other sources of human exposure, emerging contaminants may be appropriately classified. In the meantime, treatment barriers should not be altered unless there is reasonable certainty that such alterations will not simply create other, as yet uncharacterized, risks.

The challenge is to get drinking water regulators to recognize and adopt the logic behind this risk characterization hierarchy. Otherwise, the drinking water providers will continue to be largely driven by the letter of their regulatory approval and may not have any discretion to prioritize actions relative to these different risks. At the very least, there needs to be acceptance and application of the reality that all risks to drinking water safety are not equal and that drinking water treatment strategies must address the important risks before limited resources are substantially diverted to dealing with the hypothetical issues.

Competence – Know Your System

The bottom line for assuring safe drinking water for Canadians is ensuring that those engaged in the process of delivering and regulating drinking water are knowledgeable, competent and committed. Whether water systems are municipally, regionally or privately owned is not the critical test; it is whether the entity is fully competent and able to discharge the heavy responsibility that continuously providing high-quality, safe drinking water demands. This is essential and there are no easy-fix alternatives. Simply throwing money at a problem without having the money guided by those who understand what is required will achieve little, or may even be counter-productive, as shown by the monumental misunderstanding and misguided investment in the Kashechewan evacuation.

The first step is to recognize that providing safe drinking water is a knowledge-based activity. This activity cannot be downloaded to the same level of municipal priority as garbage collection and snow removal. Those assigned to provide drinking water have to be afforded the training, intellectual support and compensation that is commensurate with taking responsibility through their actions or inactions for the health of an entire community.

Think about whether you would be willing to travel in a plane being flown by a pilot who is paid a minimal wage, received limited training and had no or minimal technical or functional support to fly safely. Yet many communities in Canada today, over 10 years since the Walkerton disaster, employ water operators with the lowest level of training and financial compensation that the community can get away with.

Requiring certification of operators, which has been a common regulatory response in Canada, particularly over the past decade, still does not assure that the operator has been equipped with the tools to fully understand her or his own system, the site – and system-specific contaminant challenges it faces and the capabilities and limitations of the water safety barriers in place to deal with these challenges.

Even a well-trained and highly committed operator is likely to encounter circumstances that are unfamiliar and may signal trouble. Effective support systems are needed to allow operators to call for help when faced with a problem they do not understand or cannot resolve. The circuit-rider system mentioned in the discussion of the Expert Panel on Safe Drinking Water for First Nations is an excellent example of such a support mechanism, but such programs are generally under-resourced compared with capital funding or administrative bureaucracy. There is no equivalent system in place for small or remote non-First Nations communities except for a few exceptional pockets of provincial enlightenment (e.g., the Walkerton Clean Water Centre) where support for assuring safe water is regarded as being at least as important as prosecuting regulatory offences.

Training programs also need to make greater use of experience in dealing with failure. Case studies of health outbreaks and their causes are an obvious source for such training material. Fortunately, most operators will not experience an outright failure, but they can surely benefit from reviewing the negative experience of others as well as the more common close calls. At present, there is no means for gathering such experiences and incorporating them into training materials.

International water utility operators who are converts to the water safety plan approach can verify that they previously thought they were doing everything right. It was only through the most rigorous and consistent commitment to being self-critical that some well-established entities discovered system vulnerabilities that they never would have recognized under a business-as-usual approach (Walker 2010, Breach 2011).

How to Get There From Here – A Call for Leadership!

The water safety plan approach that is being implemented around the world offers Canada a valuable model and a timely opportunity to place a greater emphasis on drinking water providers knowing their own water systems much better, regardless of system size. Currently, Canada appears to be a "water safety plan-free zone" because we have had little evident institutional interest in or demonstrated uptake of this concept. Perhaps Ontario's new accreditation system with a requirement for developing an operational plan comes closest, but its complexity may prevent smaller water providers from grasping the key elements of understanding their own system. In any case, we should ask: Which jurisdiction in Canada can argue credibly against fully implementing a system based on operational competence and water safety plans?

Municipalities are not going to volunteer to adopt a new approach in addition to their current responsibilities. Many are already stretched in their capacity to meet regulatory requirements, so a move toward a water safety plan approach must be phased in with some sensible easing of the total regulatory burden. Ontario, which argues that it already has such a system in place, should be willing to demonstrate how well its system meets the emerging international norms for assuring safe drinking water, and promote a national effort to make water safety plans a standard approach across Canada.

Canadians have taken pride in our history of embracing evolution rather than revolution. Reforming and revitalizing our system for managing safe drinking water presents a unique opportunity to demonstrate that we can logically and rationally evolve to a better system. We need some modest institutional leadership to show a meaningful commitment to recognizing drinking water provision as a knowledge-based activity worthy of appropriate investment.

Canada has many of the necessary pieces, with initiatives such as the Canadian Municipal Consortium and the Walkerton Clean Water Centre providing cause for optimism, but we need to have more explicit leadership towards the water safety plan approach from our drinking water regulators than is currently apparent. The one Canadian institution that could move a water safety plan – "know your own system" – approach forward nationally is the Committee on Drinking Water (CDW). But this can happen only if CDW seeks and accepts a mandate broader than its current primary focus on numerical water quality criteria, something that its provincial members must endorse. If CDW cannot or will not move explicitly to a water safety plan approach, then individual provinces will need to pursue this eminently sensible approach on their own. We can deliver safer water anywhere in Canada – we only need to exercise the will to do so.

Appendix A: Microbial Risks in Developing Countries

Unfortunately, the public health triumph of delivering safe water achieved in the industrialized, developed countries has not been implemented worldwide. While some may believe that this depressing reality has little relevance to drinking water safety in Canada, the continuing causation of illness and death worldwide from contaminated drinking water provides a stark and highly relevant reminder that drinking water which is not managed and treated will cause microbial illness anywhere. We are only as far removed from this global threat to drinking water safety in Canada as competent water and sanitation practices will allow us to be.

Even now diarrhoeal disease alone is estimated to be responsible for approximately 2 million deaths every year, with most of those attributable to inadequate water supply, sanitation and hygiene, mainly among children in developing countries (WHO, 2004a). This represents approximately 4 percent of total deaths and 5 percent of health loss to disability worldwide. These problems with disease in the developing world are generally known, but their depressing magnitude and pervasive cause that occurs wherever humans reside (human and animal pathogens) may not be fully appreciated in the comfort zone of urban Canada.

Appendix B:

Table B1 Summary of Fatal Drinking Water Outbreaks in Affluent Countries since 1983 (Hrudey & Hrudey 2004)

Date	Location and Reference Sources	Source Water /Treatment	Major Failure Factors	Pathogens	Health Consequences	Risk Management Comments
1983 Feb.	Drumheller, Alberta, Canada O'Neil 1984, O'Neil et al. 1985	river intake / granular media filtration chlorination	Sewage spill upstream of water intake not reported, likely leading to pathogen contamination of drinking water supply that was vulnerable because of treatment by filtration only without coagulation during winter when river water was clear	no pathogen was identified but likely viral	1,326 confirmed cases of gastroenteritis, 3,000 estimated cases, **2 deaths reported among nursing home patients**	• vulnerable situation of sewage pump station upstream intake not recognized • failure of internal organizational reporting of sewage spill to water operations • operating winter treatment without coagulation made system vulnerable
1990	Saitama, Japan Hamano et al. 1993, Akashi et al. 1994	ground water / none reported	Contamination of the well water supply occurred but no explanation was provided	*Escherichia coli* O157:H7	42 confirmed cases of E. *coli* O157:H7 186 total cases, estimated 20 cases of haemolytic uremic syndrome (HUS), **2 deaths**	• no details were given about how the outbreak was caused • the median age of HUS victims was 3.9 years • the 2 deaths were 4 and 5 years old
1989-1990 Dec.-Jan.	Cabool, Missouri, U.S.A. Swerdlow et al. 1992, Geldreich et al. 1992	deep ground water / none	Likely contamination of distribution system by unseasonably cold weather causing water main breaks leading to sewage cross contamination	*Escherichia coli* O157:H7	243 confirmed cases of E. *coli* O157:H7, 32 hospital admissions, **4 deaths**	• risks associated with water main break repair during extreme weather not recognized • poor sewer systems maintenance exposing water distribution to risk • no treatment barrier in place
1993 Mar.-Apr.	Milwaukee, Wisconsin, U.S.A. Mackenzie et al. 1994, Corso et al. 2003, Hoxie et al. 1997, Fox and Lytle 1996	large lake / chlorination, KMnO4, coagulation, granular filtration, chloramination	Sanitary sewage contaminated drinking water intake either directly or via combined storm sewer outfalls during winter storms filtration was not being operated at optimum performance and measures recognized in the UK for reducing Cryptosporidium risk were not in use.	*Cryptosporidium parvum* (genotype I, human strain).	285 confirmed cases, 400,000 estimated cases, ~4,400 hospital admissions, **~50 deaths** among immune-compromised over the following 2 years	• risks associated with sewage contamination of water intake not recognized • apparently not aware of *Cryptosporidium* risk • failure to maintain optimum filtration performance • failure to recognize signal from consumer complaints
1993 Nov.-Dec.	Gideon, Missouri, U.S.A. Clark et al. 1996, Angulo et al. 1997	deep ground water / none	Bird faeces likely contaminated water storage tanks and flushing of the distribution system drew contaminated tank water into service	*Salmonella typhimirium*	31 cases confirmed, 650 cases estimated, 15 hospital admissions, **7 deaths**	• poor maintenance of water storage allowed fecal contamination • water quality management not based on good knowledge of system • no treatment barrier in place

Date	Location and Reference Sources	Source Water /Treatment	Major Failure Factors	Pathogens	Health Consequences	Risk Management Comments
1999 Sept.	Washington County Fair New York U.S.A., Novello et al. 1999, Novello et al. 2000	shallow ground water / none	Some food and drink vendors used unchlorinated well water for beverages and ice; shallow well was located ~11 m from a septic tank seepage pit with a rapid hydraulic connection to this well	*E. coli* O157:H7 *Campylobacter jejuni*	161 confirmed cases, 2800 – 5000 estimated, 71 hospital admissions, 14 cases of HUS, **2 deaths**	• not aware of risk to well from septic seepage field • allowed use of unchlorinated water from a shallow well • failure to consider that extreme drought of previous summer might affect water supply safety
2000 May.	Walkerton Ontario, Canada, O'Connor (2002a)	shallow ground water / chlorination only	Inadequate chlorination or other barriers to cope with influx of manure contaminated water following heavy rains	*E. coli O157:H7* Campylobacter jejuni	163 cases of *E. coli* confirmed, 105 cases of *Campylobacter*, 12 cases with both, 2,300 cases total estimated, 65 hospital admissions 27 cases of HUS, **7 deaths**	• ignored warnings about vulnerability of shallow well when first installed in 1978 • failed to adopt source protection recommendations at installation • regulator failed to implement policy requiring continuous chlorine residual monitors on vulnerable shallow wells • operators inadequately trained with no knowledge that contaminated water could kill consumers • failure to recognize that extreme weather and flooding could cause water contamination • failure to maintain chlorine residuals • failure to monitor chlorine residuals as required
2007.	Nokia, Finland Rimhanen-Finne et al 2010, Laine et al 2010	"secure" groundwater chlorination only	A valve connecting the water treatment plant to the sewage treatment plant was mistakenly opened and drinking water was contaminated with up to 25% sewage effluent for at least 2 days	At least 7 pathogens *including: Campylobacter, Giardia, Salmonella, Clostridium difficile, Shigella* and norovirus	An estimated 6,500 excess cases of gastroenteritis were reported, including **2 deaths**	• Value between the water treatment plant and sewage treatment plant which could contaminate drinking water if opened • a mistake left the cross connection valve open during scheduled maintenance • monitoring did not detect this problem which was first detected by consumer complaints which were not adequately responded to
2008.	Alamosa, Colorado, U.S.A. Falco and Williams 2009	"secure" groundwater no chlorination	The undisinfected water supply was contaminated in the distribution system, most likely because of a poorly maintained surface water storage which likely allowed small animals or birds access leading to faecal ontamination	*Salmonella*	Up to 1,300 cases of gastroenteritis including **1 death**	• distribution of undisinfected water invited health problems • poor maintenance of surface water storage allowed contamination of high quality groundwater

Appendix C: Chemical Risks

Current popular focus on drinking water over the past few decades has shifted to chemical contamination despite the compelling death toll noted above. The popular focus is commonly directed to exotic trace contaminants and pesticides which pose a negligible risk to human health from drinking water exposure. Perhaps less well known are some globally recognized chemical causes of waterborne disease or health effects. These details are outlined below.

The four chemicals described in the following are the main chemical contaminants identified by the World Health Organization in a review aimed at setting risk management priorities for drinking water (WHO 2007). These four chemical contaminants stand in stark contrast to the 88 parameters listed in the Guidelines for Canadian Drinking Water Quality (GCDWQ). We need to understand why there is such a large difference between the small number of contaminants that are known to have caused human health effects and represent a clear risk via drinking water exposure wherever these mostly natural contaminants occur in sufficient concentration versus the total much larger number of chemical parameters listed in the GCDWQ.

Drinking water guidelines are essential to serve as a benchmark for judging water quality risks for chemicals that may be found in water, but the premise that all of these chemicals represent a serious health risk to humans via drinking water exposure lacks credible supporting evidence. Consequently, monitoring regularly for all of the parameters is generally an unjustified investment and simply monitoring this list rather than focusing on assuring effective operation of treatment processes will not provide a preventive approach for assuring safe water. Such assurance requires effective process monitoring (i.e. monitoring parameters which provide an understanding of process performance) but monitoring strictly for treated water compliance with GCDWQ parameters does not assure that level of understanding for operations. Obviously consumers will need to know how any water supply satisfies these quality criteria and having a baseline of quality data is important for comparison purposes.

Arsenic

Arsenic is certainly the most common and serious agent of waterborne illness caused by strictly chemical contamination. Arsenic is the 20th most abundant element in the earth's crust and it is found to some degree in almost all water sources. Based on relatively valid epidemiologic evidence, arsenic is believed to cause various forms of cancer, particularly skin cancer, if ingested via drinking water at high enough levels over sufficient years of exposure. Consequently, drinking water standards for arsenic have been lowered over the past decade, generally to a maximum acceptable concentration (MAC) for daily consumption over a lifetime of less than 0.01 mg/L (WHO 2010a).

Countries with arsenic concentrations found in groundwater supplies that substantially exceed the MAC include Argentina, Bangladesh, Chile, China (Taiwan), India, Mexico, Thailand and parts of the United States. Some localized high arsenic groundwaters have been found in Canada, mostly in rocky areas of Newfoundland and Nova Scotia. Some of the most serious cases of high arsenic exposure have occurred in Bangladesh where aid programs had installed tube wells to provide drinking water that is more microbiologically safe than surface waters in this flood-prone country. Unfortunately, the groundwater contains high natural arsenic. An estimated 35 to 77 million residents of Bangladesh are at risk of consuming arsenic-contaminated drinking water with the corresponding resultant increased risk of cancer.

Fluoride

Fluoride is another naturally occurring substance found in drinking water. Low levels of fluoride in drinking water (< 1 - 2 mg/L) have been found to provide strengthening of dental enamel and reduction of tooth decay. Slightly higher levels of fluoride exposure can cause dental fluorosis which is manifested by staining and pitting of dental enamel, but ingestion of fluoride above the age of six will not cause dental fluorosis (WHO 2010b). At even higher levels of chronic (long term) fluoride exposure, skeletal fluorosis is possible leading to stiffness, joint pain and in extreme cases, changes in bone structure. Acute (short term) high level fluoride poisoning causes immediate responses such as abdominal pain, excessive saliva, nausea, vomiting, seizure and muscle spasms.

Excess fluoride exposure in drinking water typically only occurs in groundwaters, commonly in foothills to high mountains or in geological deposits associated with marine areas. Fluoride – impacted geological regions are known in the Middle East, Africa, Asia and the Americas. In the case of fluoride in drinking water, there is a relatively narrow range between the well-documented beneficial effects of fluoridating drinking water on dental health and negative effects of excessive natural fluoride exposure leading to dental fluorosis.

Lead

Lead is a metal contaminant with well-documented adverse health effects in humans (WHO 2010c). The most vulnerable group for lead contamination are young children and workers exposed to lead sources. Lead exposure via drinking water is generally small, particularly in hard or alkaline water. Lead exposures from contaminated soil, lead-based paint, air emissions and lead contaminated food are generally much higher than drinking water exposures to lead.

The main source of lead contamination of drinking water is from lead pipes used in water distribution. Historically lead was the preferred metal for service lines and in alloys for plumbing fixtures. For the past several decades installation of lead pipes has been discontinued in developed countries, but local circumstances differ regarding the removal of lead service lines. Drinking water has also been contaminated by lead-containing solder, which has also now been generally discontinued for new plumbing fixtures and local circumstances will dictate the degree of exposure to legacy fixtures.

Nitrates and Nitrites

Nitrate (and nitrite) in drinking water can cause methaemoglobinaemia, a decreased ability of blood to carry essential oxygen to body organs (WHO 2010d). Ingested nitrate is converted to nitrite in the digestive system. Nitrite can bind to haemoglobin in the blood more strongly than oxygen, thereby reducing oxygen-carrying capacity. Methaemoglobinaemia mainly poses a risk to bottle fed infants, mostly below 3 months of age. The condition has been called “blue baby syndrome” because those infants affected can show a blue tinge around the mouth, hands and feet. It can lead to vomiting and diarrhea with serious cases leading to lost consciousness, seizures and even death.

Risk of methaemoglobinaemia is usually limited to groundwater, most commonly rural water supplies affected by agricultural nitrogen pollution. Water containing less than 50 mg/L of nitrate (as NO_3) poses no risk of this disease.

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