Chapter 5 Drinking Water Quality Standards

Contents

5.1 Introduction 148

5.2 Setting Drinking Water Quality Standards in Canada .. 149

5.2.1 The Federal–Provincial Subcommittee on Drinking Water 151

5.3 Where the Canadian *Guidelines* Apply 155

5.4 The Province's Responsibility to Implement Standards 156

5.4.1 Ontario Can Initiate as Well as React 158

5.5 Contaminants and Current Standards 158

5.5.1 Standards for Acute (Microbial) Risk 159

5.5.1.1 Endemic versus Epidemic Levels of Exposure 159

5.5.1.2 Viruses 160

5.5.1.3 Bacteria 161

5.5.1.4 Parasites 163

5.5.2 Standards for Chronic Risks 165

5.5.2.1 Chemical Hazards 166

5.5.2.2 Disinfection By-products 170

5.5.2.3 Radiological Hazards 171

5.5.3 Operational Standards 172

5.5.4 Aesthetic Standards 172

5.5.5 Problems in Setting Standards 173

5.6 Emerging Issues 174

5.6.1 New Pathogens 174

5.6.2 Chemicals 175

5.6.2.1 Pesticides and Herbicides 175

5.6.2.2 Industrial Chemicals 176

5.6.2.3 Endocrine-Disrupting Substances 177

5.7 Standards Setting in Some Other Countries 179

5.7.1 United States 179

5.7.2 England and Wales 181

5.7.3 Australia 182

Chapter 5 Drinking Water Quality Standards

5.1 Introduction

This chapter is about standards, specifically the drinking water quality standards that are now part of Ontario Regulation 459/00. In discussing these standards, I do not intend to offer recommendations about maximum acceptable concentrations of contaminants but to examine the process by which they are set. There was no information presented at the Inquiry to warrant alarm with respect to existing standards. This Inquiry did not examine individual standards in detail; the purpose of my recommendations regarding the process of setting standards is to provide a vehicle for public review of existing standards, where necessary, and of emerging threats to drinking water safety.

There are many other kinds of standards. Some deal with mechanical, electrical, or plumbing matters, which have a bearing – but not a central one – on matters of drinking water quality. I deal with these standards only incidentally. More important are standards for treatment, monitoring, and laboratory testing, which are dealt with in Chapters 6, 8, and 9. Finally, there are essential standards for attaining consistent high quality in management and operations, which require drinking water quality standards as a base.[1] Quality management is dealt with in Chapter 11.

The failures at Walkerton were not failures of the drinking water quality objectives as such but of the systems that were supposed to ensure they were met. Reviews of outbreaks – see Chapter 3 – suggest that this pattern holds on a larger scale. As was the case in Walkerton, operational, managerial, and regulatory failures can lead to a major breakdown.

In this chapter, I make only a few recommendations. Some are directed toward the cautious approach that should be adopted in setting drinking water quality standards. The remainder are directed toward making the system for setting standards, both at the federal and provincial levels, more transparent. There is reason to have confidence that Ontario's drinking water quality standards are

[1] Contrasting the two, the executive director of the American Water Works Association said: "[A] table of numbers – whether they are guidelines or strict standards – does not protect public health in and of itself. Meeting the numbers is just part of an effective program. More important to me is whether utilities have continuous quality improvement systems to verify that the entire process of delivering safe drinking water is working as it should": J.W. Hoffbuhr, 2001, "The regulatory paradox," *Journal of the American Water Works Association*, vol. 93, no. 5, p. 8.

essentially based on sound principles of risk assessment and management and that they make due allowance for precaution. Conservative and enforceable water quality standards are an important basis for a multi-barrier approach to water safety, and it is likely true that improvements in management and regulation will yield greater safety benefits than will any general tightening of Ontario's present drinking water quality standards. Nevertheless, new threats will continue to be identified and old ones will be periodically re-evaluated.

I also recommend the establishment of an expert advisory council to advise the Minister of the Environment on setting standards. There are, in particular, two areas where current standards may be obsolete: the use of total coliform as an indicator, and the apparently lax standard for turbidity. These I assign to this expert advisory council to examine, in public, along with the rest of a lengthy agenda. Finally, I have included a description of the contaminants that pose the more serious threats to drinking water and the processes by which drinking water quality standards are set in Canada and elsewhere.

5.2 Setting Drinking Water Quality Standards in Canada

Drinking water quality standards are expressed as maximum acceptable concentration (MAC) limits for certain microbes, chemicals, and physical properties. Where data are insufficient but a hazard is suspected, an interim maximum acceptable concentration (IMAC) limit may be specified. Canada's drinking water quality standards are set in two steps. First, a committee of officials from the federal, provincial, and territorial governments, working without a great deal of public involvement or political oversight, examines toxicological and epidemiological evidence as well as other information and publishes a set of recommended *Guidelines*.[2] Second, provinces and territories decide which of the contaminants and MACs ought to be adopted in their jurisdictions.

Sometimes, as was the case for many years in Ontario, the federal–provincial *Guidelines* were carried over simply as guidelines or objectives by the implementing jurisdictions. In a few provinces, they were given the force of

[2] Federal–Provincial–Territorial Committee on Environmental and Occupational Health, Federal–Provincial Subcommittee on Drinking Water, 1996, *Guidelines for Canadian Drinking Water Quality*, 6th ed. (Ottawa: Health Canada) [hereafter *Guidelines*]. A more updated version of the *Guidelines* can be found at <http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/summary.pdf> [accessed April 30, 2002].

law by being made regulations under appropriate provincial legislation. In Ontario, a version of the *Guidelines* was incorporated as an objective into the Ontario Drinking Water Objectives (ODWO),[3] until shortly after Walkerton, when they were extended and incorporated into law as Ontario Regulation 459/00 under the *Ontario Water Resources Act*.[4]

Recommendation 18: In setting drinking water quality standards, the objective should be such that, if the standards are met, a reasonable and informed person would feel safe drinking the water.

I discussed this goal in more detail in Chapter 3.

Recommendation 19: Standards setting should be based on a precautionary approach, particularly with respect to contaminants whose effects on human health are unknown.

In setting up systems that affect human health, decision makers usually err on the side of safety, regardless of the costs. As discussed in Chapter 3, a refinement to this approach is the precautionary principle, a guide to environmental action that has been recognized in international law and cited approvingly by the Supreme Court of Canada.[5] Precautionary measures include setting standards to account for uncertainties, investments in risk mitigation or alternative technologies, and investments in research.[6] This prudent approach must still consider costs, but as prevention usually costs much less than remediation, the precautionary principle has a role to play in risk management and should be an integral part of decisions affecting the safety of drinking water.

Recommendation 20: Regarding drinking water quality research, I encourage Health Canada and other agencies to adopt as a priority the development of sufficiently detailed definitions of the susceptibility of vulnerable population groups to drinking water contaminant exposures to allow appropriate adjustments in drinking water quality guidelines.

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[3] Ontario, Ministry of the Environment, Water Policy Branch (1994 revision).

[4] R.S.O. 1990, c. O.40.

[5] See *114957 Canada Ltée (Spraytech, Société d'arrosage)* v. *Hudson (Town),* [2001] 2 S.C.R. 241.

[6] Some of the parties in Part 2 made the point explicitly: Sierra Legal Defence Fund, 2001, "A paper on the regulatory approaches to drinking water used in Canada and, selectively, abroad," and "Public submission to the Walkerton Inquiry," vol. 2, Walkerton Inquiry Submission, p. 39; and Canadian Environmental Law Association and Concerned Walkerton Citizens, 2001, "Tragedy on tap: Why Ontario needs a *Safe Drinking Water Act*," vol. 2, Walkerton Inquiry Submission, pp. 120–121.

Where identifiable groups are susceptible to certain contaminants, quality standards may be made more stringent and/or susceptible people must take measures to protect themselves. Immunocompromised people (e.g., people with AIDS, transplants, or cancer, whose drug regimes suppress immune responses) may need to take special precautions if there is a chance of *Cryptosporidium* in the water.[7] Sometimes it is practical to require general standards to take these problems into account, but at other times, medical advice and individual precautions are necessary.

5.2.1 The Federal–Provincial Subcommittee on Drinking Water

The Federal–Provincial Subcommittee on Drinking Water develops water quality guidelines as recommendations to its parent committee, the Federal–Provincial–Territorial Committee on Environmental and Occupational Health (CEOH),[8] which is composed of senior officials from the health, environment, and labour departments. The subcommittee consists of 14 mid-level managers appointed by the ten provinces, the three territories, and Health Canada. Its members are public servants who typically have regulatory experience in water or public health, but operational experience or professional qualifications in the subject are not prerequisites to appointment. The judgments they make are based on scientific evidence about risks to human health, costs, availability of suitable technologies, and the expressed views of the governments they represent. None of these categories is free of important value judgments.

Although the Walkerton Inquiry is a provincial inquiry, the standards in Ontario principally originate in the work of the federal–provincial subcommittee. Therefore, I consider it appropriate to make recommendations about that process.

Recommendation 21: I suggest that the federal–provincial process for proposing drinking water quality guidelines be refined to provide for greater transparency and public participation.

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[7] In 2001, people drinking Vancouver's unfiltered water were warned to boil it, as a precaution, if they were immunocompromised: see British Columbia, Ministry of Health, Health File #56, February 2000, "Weakened immune systems and water-borne infections" <http://www.hlth.gov.bc.ca/hlthfile/hfile56.html> [accessed April 22, 2002].

[8] Federal–Provincial Subcommittee on Drinking Water, 1999, *Canadian Drinking Water Guidelines Development Process* (Ottawa: Health Canada).

In recent years, the work of the subcommittee has become more visible. A Web site posts summaries of its proceedings. It also posts proposed recommendations and the supporting technical evidence for public comment before they are forwarded to the parent committee.[9] Few comments are received, however. Perhaps interested parties do not understand the process or they may not know where to look for the documentation. Possibly they are unsure where, in this multi-stage federal–provincial process, they may intervene most effectively. The subcommittee may need to become more involved in active outreach.

Transparency and public participation can be advanced in several ways. I suggest that all meeting and future research agendas should be published on the Health Canada Web site, as should the full minutes (not summaries) of the subcommittee's meetings. All the risk assessment research done or commissioned by Health Canada for the subcommittee, including copies of toxicological or epidemiological papers prepared as part of the characterization of specific risks, should be freely available through the Web site. Most important, the subcommittee should document and publish the reasons for its recommendations. It should allow for dissenting or minority opinions.

The Web site should include an up-to-date schedule of scientific and regulation-making work, the subcommittee's members' names with their contact information, and requests for comments about substance or process. All the information needed to facilitate efficient and informed participation by the interested public should be freely available.

In that context, when a matter of broad public interest is being considered for regulatory change, interested parties should be encouraged to attend, write, or make submissions. Specifically, academics, consumer and environmental groups, and water industry experts should be invited to attend on an agenda basis. For more controversial issues, the subcommittee should consider asking Health Canada to undertake research on relevant public values and attitudes. Since the standards-setting process is inherently subjective, the subcommittee should consider the values of Canadians in making its decisions and not limit its considerations to science alone.

At present, a 1996 edition of the resulting *Guidelines* is sold to the public in a

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[9] See <www.hc-sc.gc.ca/ehp/ehd/bch/water_quality.htm> and <www.hc-sc.gc.ca/ehp/ehd/bch/water_quality/consult/intro.htm> [accessed April 30, 2002].

print version. The current *Guidelines* should be made available on the Internet, free of charge.[10]

The CEOH receives recommendations from the subcommittee and in due course either passes them or sends them back for reconsideration. It also approves the subcommittee's plans for the technical and scientific work that underlies new guidelines. It is difficult to assess what value this committee brings to the process, since its proceedings are not public and there is no mechanism for public input. The CEOH does not even have a link on the Health Canada Web page. In my view, it should adopt the same procedures urged on its subcommittee in relation to transparency and public participation with respect to its own work on drinking water guidelines. The CEOH's guidance on the agenda, its reasons for accepting proposed guidelines or sending them back for further consideration, and its plans for drinking-water–related work at all levels, including the international level, should be published on the Health Canada Web site.

The first reason for opening the debate, at all levels, is that many of the decisions are inherently value-laden. Even experts do not always agree on what standards should apply.[11] It is important that the full debate on values should be as public as possible and open to comment from those who have an interest.[12] Some people may object that, if the real decisions lie with the provinces, then that is where the public debate should take place. I agree that more openness is needed at the provincial level, but the federal–provincial guidelines to a large extent set the agenda for provincial decisions, and the process establishing those guidelines should therefore be fully open to the public. In this respect, I urge the CEOH to mirror the improved process suggested for the subcommittee.

A second reason for calling for more transparency at the CEOH level is that there is always the chance that the federal government might decide to use the

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[10] A summary table can be found on <www.hc-sc.gc.ca/ehp/ehd/bch/water_quality.htm> [accessed April 30, 2002].

[11] A pioneering work in this regard is M.F. O'Connor, 1973, "The application of multiattribute scaling procedures to the development of indices of water quality," Report 7339 (Chicago: Center for Mathematical Studies in Business and Economics, University of Chicago); cited in R.L. Keeney and H. Raiffa, 1975, *Decisions with Multiple Objectives: Preferences and Value Tradeoffs* (New York: John Wiley & Sons), pp. 431–432. This work, completed the year before the discovery of disinfection by-products, surveys water professionals and identifies 13 attractive attributes of public water supplies, which cannot all be produced at once. There was no consensus on priorities.

[12] Observers have praised the process for developing air standards in Ontario for its transparency and opportunities for public input; this may serve as a useful precedent.

Guidelines as the basis for enforceable regulations within its own domain. Ontarians whose water may be regulated federally should have the opportunity to make their views known regarding the standards to be applied.

Finally, there is a danger that decisions arrived at without public scrutiny tend toward the lowest common denominator. Standards arrived at after public debate are likely to be more demanding and less skewed by any particular interests and more acceptable to the public because of the process.

Recommendation 22: **I suggest that the Federal–Provincial Subcommittee on Drinking Water focus on drinking water quality guidelines. I encourage Health Canada to commit the required scientific support to the federal–provincial process for proposing drinking water quality guidelines.**

The Federal–Provincial Subcommittee on Drinking Water already has a full agenda in developing water quality guidelines. The structure, and many of the resources, for carrying out the research and analysis for setting water quality guidelines are now in place. There is a substantial benefit in having the subcommittee focus on the primary task for which it was established and for which it is equipped and qualified.

Health Canada provides the secretariat and all the subcommittee expenses, including travel and research, except for the salaries of the provincial and territorial members. The expenses can be significant. In particular, Health Canada provides the toxicological and epidemiological research that is the primary basis for characterizing public health risks. The speed at which the subcommittee can operate is effectively set by the budget that Health Canada is able to provide for this research. Goff Jenkins, the member from Ontario for many years and the chair for a period of five years, told the Inquiry that there is a considerable amount of research requested by the subcommittee that must be continually deferred for budgetary reasons.[13]

The subcommittee reportedly goes to some length to achieve consensus. This means that any of its 14 members can veto, or at least substantially delay, the passage of a particular recommendation for a guideline. Not all provinces and territories share the same pattern of past investments in treatment facilities, and because new recommendations may entail large expenditures, individual

[13] G. Jenkins, Walkerton Inquiry (Public Hearing, September 11, 2001), transcript pp. 20–21.

provinces and territories have, from time to time, a financial concern that may cause their members not to approve an otherwise desirable guideline. The danger is that the recommendations to the parent committee, the CEOH, may reflect only the views of the jurisdiction that seeks the least protective standards. I have been informed, for instance, that the turbidity standard would be lower but for the fact that several provinces would have to spend a great deal of money on filtration.[14]

Since the content of the *Guidelines* is non-binding and advisory, it is not necessary that unanimity exist for the recommendations to go forward. A simple, or two-thirds, majority should suffice. It is likely that the removal of the effective consensus rule would lessen the ability of a small number of jurisdictions to hold up progress toward a standard otherwise widely anticipated and accepted.

5.3 Where the Canadian *Guidelines* Apply

Recommendation 23: I encourage the federal government to adopt standards that are as stringent as, or more stringent than, Ontario Regulation 459/00 for all federal facilities, Indian reserves, national parks, military installations, and other lands under federal jurisdiction in Ontario.

The final output of the federal–provincial process is called the *Guidelines for Canadian Drinking Water Quality*, published by Health Canada and now in its sixth edition. The *Guidelines* serve as advice to the provinces and territories, and as the objective in some areas of federal jurisdiction. Alberta, Ontario, and Quebec have adopted versions of the *Guidelines* as provincial regulations. In general, the federal government policy is to apply whichever standard is stricter – the *Guidelines* or the provincial regulation or objective – to installations for which it is responsible. These include First Nations, military installations, and national parks.[15] The *Guidelines* are not regulations, however, and thus do not have the force of law: there are no penalties for a failure to comply with them.

Federal officials are obviously aware of the unenforceability of the *Guidelines* in the federal domain. One step in the right direction has been the incorporation by reference of the *Guidelines* MACs in Part IV of the *Canada Labour Code*.

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[14] G. Jenkins, 2002, personal communication.

[15] J. Weiner, Health Canada, and J. Mills, Environment Canada, 2001, letter to H. Swain, Chair, Research Advisory Panel, Walkerton Inquiry, July 5 [Walkerton Inquiry files]. The federal government's policy and its actions sometimes diverge: see letter to H. Swain in Chapter 15.

This does not, however, require the sampling, testing, or reporting of the results, nor does it allow the prosecution of water suppliers who do not meet the quality standards.

It is important that sound and legally enforceable standards exist regardless of which of the two senior levels of government enacts them. Ontario residents drawing drinking water from areas under federal jurisdiction should not have lower standards than do other residents of the province. In this respect, it is important that this new obligation should carry requirements for sampling, testing, and enforcement that are as stringent as, or more stringent than, those standards established from time to time by Ontario regulations.

5.4 The Province's Responsibility to Implement Standards

Recommendation 24: The provincial government should continue to be the government responsible for setting legally binding drinking water quality standards.

Drinking water quality standards should, as they do now, have the force of law. I commented on this matter in the Part 1 report of this Inquiry.[16] Water quality standards should be set, on the initiative of the Minister of the Environment, by the Lieutenant-Governor-in-Council. The guidelines established from time to time by the federal–provincial subcommittee should be used as a starting point for establishing provincial standards.

For many years, as noted, the federal–provincial recommendations became "guidelines" or "objectives" in Ontario and other jurisdictions. Increased administrative flexibility resulted in weak enforcement. An offender could not be prosecuted for a breach of a guideline. In the 1980s, the MOE began to insert the Ontario Drinking Water Objectives (ODWO), as they then were, into Certificates of Approval. In the wake of Walkerton, the provincial government strengthened the process by incorporating the ODWO in Ontario Regulation 459/00. Now, recommendations from the federal–provincial process are scrutinized by the provincial government and, if found fitting, are added by Order-in-Council to the schedule in the regulation.

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[16] Ontario, Ministry of the Attorney General, 2002, *Report of the Walkerton Inquiry, Part 1: The Events of May 2000 and Related Issues* (Toronto: Queen's Printer), pp. 355–358.

A bill before the Senate, S-18,[17] would require the federal government to regulate drinking water quality standards for the whole of Canada. This is not necessary for the protection of drinking water quality in Ontario, where the Ontario government has already established a standard more stringent than exists in the federal *Guidelines*. A federal enactment of this nature would also imply a willingness to establish a federal inspection and enforcement regime or to negotiate the delegation of those functions to the provinces.

Recommendation 25: In setting drinking water quality standards for Ontario, the Minister of the Environment should be advised by an Advisory Council on Standards.

There are two principal reasons for creating this new body.[18] First, it is reasonable for the provincial government to seek expertise from the general public. The general public provides a broad base from which to draw people highly qualified in the many relevant disciplines. Second, there are benefits in terms of transparency and public access through the use of an advisory council.

Members should be Canadians distinguished in the fields of public health, engineering, microbiology, utility operations, and other related areas, and should be appointed by Order-in-Council for overlapping terms. Relevant professional organizations, notably the Ontario Water Works Association, the Ontario Municipal Water Association, the Aboriginal Water Works Association of Ontario, the Ontario Medical Association, and the Association of Local Public Health Agencies, as well as leading non-governmental organizations with a record of interest and accomplishment in areas related to drinking water, should be solicited for nominations.

A predecessor committee, the Advisory Committee on Environmental Standards, was discontinued in 1996. Such bodies, however, are an excellent mechanism for drawing upon expert members of the community at a relatively low cost in terms of the quality of advice that is available.

The advisory council should establish its own process, solicit public views on proposed regulations, be provided with staff support by the MOE, and make appropriate recommendations to the minister. Recommendations should be

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[17] Bill S-18, *An Act to Amend the Food and Drugs Act (Clean Drinking Water)*, 1st Sess., 37th Parl., 2001 (1st reading February 20, 2001).

[18] In subsequent chapters, I recommend that the Advisory Council on Standards also advise the minister with respect to management, treatment, testing, materials, and reporting standards.

made public and should be supported by the council's reasons. The advisory council should also provide advice to the MOE and Health Canada on drinking water research requirements; since this advice should be public, the universities and granting councils may also take note, with a consequent effect on the direction of the national research effort.The advisory council should make full use of the *Environmental Bill of Rights, 1993,*[19] and may decide to hold public hearings on matters of broad public concern. Under the *Environmental Bill of Rights*, the MOE operates a Web site where Ontario government agencies can post proposals with significant environmental impacts for public comment.[20]

5.4.1 Ontario Can Initiate as Well as React

Recommendation 26: The Advisory Council on Standards should have the authority to recommend that the provincial government adopt standards for contaminants that are not on the current federal–provincial agenda.

Although the federal–provincial subcommittee's work is important, it need not be the sole source of suggestions. Relevant work by the World Health Organization, the United States Environmental Protection Agency, and other leading authorities may be helpful, as may the work of public interest groups in Ontario. Recently, for instance, the Sierra Legal Defence Fund drew public attention to a less restrictive guideline for TCE (trichloroethylene) in Canada than exists in the United States.[21] This is the type of issue that the advisory council may wish to address.

5.5 Contaminants and Current Standards

The standards in Ontario Regulation 459/00 and the hazards posed by the contaminants they limit are worth examining in some detail. In order of decreasing risk to public health, the hazards fall into four groups. Those that can cause acute, serious, and immediate threats to public health are for the most part pathogens, such as viruses, bacteria, and protozoa. There is then a large class of chemicals that adversely affect public health in the case of long-

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[19] S.O. 1993, c. 28, as amended.

[20] See Environmental Registry Postings for Policies, Acts, Regulations, and Instruments at <www.ene.gov.on.ca/envision/env_reg/er/registry.htm> [accessed April 30, 2002].

[21] M. Mittelstaedt, 2002, "Ottawa urged to curb solvent in tap water," *Globe and Mail*, January 16, p. A9.

term exposure: these are called chronic risks. Third are some standards that relate to the efficient operation of water treatment systems themselves, and finally, there are aesthetic standards for otherwise harmless agents affecting taste, odour, and colour.

5.5.1 Standards for Acute (Microbial) Risk

Standards for microbial risk are the most important and the most difficult to establish. Of the uncounted millions of microbes, only a tiny proportion is harmful to humans and other animals. Many, in fact, are conducive to, or compatible with, good health. Science has identified some, but by no means all, of the harmful ones, and evolutionary processes continue to create new ones. These difficulties are compounded by the serious problems of finding and characterizing microbes (see Chapter 8), so a regulatory dilemma appears.

Globally, the contamination of water by pathogenic organisms poses the most significant threat to the health of humans.[22] Several types of organisms may be implicated in the spread of water-borne illness. Viruses, bacteria, and parasites may all cause disease. A common element among many of them is that mammals (including humans) and sometimes birds are the usual source of the contaminants that may cause disease in humans.[23]

5.5.1.1 *Endemic versus Epidemic Levels of Exposure*

Illnesses that result from pathogenic organisms occur at low levels in the population almost continually. The background level of infection of a given pathogen in a population is referred to as the *endemic* rate of infection. The Inquiry heard evidence that endemic levels of exposure to some important pathogens, such as *Giardia* and *Cryptosporidium,* may be due to low-level exposure through drinking water or through other potential pathways, such as contact with pets, contaminated fruits or vegetables, or undercooked meats.

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[22] L. Ritter et al., 2002, "Sources, pathways, and relative risks of contaminants in water," Walkerton Inquiry Commissioned Paper 10.

[23] D. Krewski et al., 2002, "Managing health risks from drinking water," Walkerton Inquiry Commissioned Paper 7, p. 77.

As much as one-third of the endemic level of exposure to enteric bacteria may be due to the low-level contamination of drinking water.[24]

Endemic exposure is with us all the time, but sometimes large populations are exposed to high concentrations of a pathogen all at once. Such exposure results in an *epidemic* – a large number of cases of the same disease occurring in a population at the same time. Walkerton was an epidemic. The recommendations in this report are cast with a view to reducing both endemic and epidemic exposure to pathogens.

5.5.1.2 *Viruses*

Viruses are tiny (typically 0.02–0.3 μm)[25] organisms consisting of little more than a strand of genetic material and a protein shell.[26] They cannot multiply outside a host, but some may survive long periods in the environment if they are provided with appropriate conditions. Any one of more than 140 enteric viruses may infect people through the digestive system. Some of these viruses cause well-known diseases, including hepatitis and meningitis; they also cause generic symptoms such as diarrhea, fever, and heart disease.[27]

There are no standards for viruses.[28] Historically, this has been justified by the small fraction of the uncountable viruses in nature that are harmful, the poorly known pathways and mechanisms by which most have their effect, and the fact that most are even more easily susceptible to chlorine than are bacteria. Among those tested, most, but not all, are easily inactivated with chlorine.

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[24] P. Payment et al., 1991, "A randomized trial to evaluate the risk of gastrointestinal disease due to the consumption of drinking water meeting current microbiological standards," *American Journal of Public Health*, vol. 81, pp. 703–708.

[25] Krewski et al., p. 53.

[26] American Water Works Association, 1999, *Waterborne Pathogens*: *Manual of Water Supply Practice,* M48 (Denver: American Water Works Association).

[27] Ibid.; Krewski et al., p. 54.

[28] O. Reg. 459/00 does not mention viruses. The companion O. Reg. 505/01, for "smaller water works serving designated facilities," requires the use of filtration and disinfection equipment capable of 4-log removal or inactivation of viruses. It would be better to specify one or more of the relatively resistant pathogenic viruses because "viruses" as a class have varying susceptibility to treatment.

5.5.1.3 *Bacteria*

Bacteria are small (typically 0.5–1.0 μm) single-celled organisms that are nearly ubiquitous on Earth.[29] Natural water systems contain massive communities of bacteria, most of which are free-living environmental bacteria that have no health consequences for humans. A small subset of the bacteria found in source waters may be of mammalian origin, and an even smaller subset of those is potentially pathogenic in humans.[30] Bacteria are responsible for two of the biggest historical threats to public safety through drinking water: typhoid and cholera. Although these diseases have been largely eradicated in the developed world through the disinfection of public water supplies, they are still threats in many parts of the world. However, as occurred in Walkerton, the potential exists for the bacterial contamination of drinking water to cause serious health problems in North America.

The main reservoirs for pathogenic water-borne bacteria are mammals, including humans and farm animals. Pathogenic bacteria are excreted in large numbers in the feces of mammals and work their way into source waters through surface runoff or infiltration. The ecology and health impacts of pathogenic bacteria are well described elsewhere.[31]

The regulatory requirement is that water should receive a minimum level of treatment: disinfection in the case of groundwater, chemically assisted filtration and disinfection in the case of surface water. "Disinfection" is not defined in the regulation. The Ontario Regulation 459/00 standard for pathogenic bacteria is expressed in terms of a treatment requirement if coliform bacteria, especially *E. coli*, are found in samples.[32] In essence, the operator is to increase the chlorine dose until two successive samples show no bacteria.[33]

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[29] Krewski et al., p. 54.
[30] HDR Engineering Inc., 2001, *Handbook of Public Water Systems* (New York: John Wiley & Sons), p. 87.
[31] American Water Works Association, 1999; the Part 1 report of this Inquiry has information on the two species implicated at Walkerton – *E. coli* O157:H7 and *Campylobacter jejuni:* Ontario, Ministry of the Attorney General, 2002, *Report of the Walkerton Inquiry, Part 1: The Events of May 2000 and Related Issues* (Toronto: Queen's Printer), pp. 49–51.
[32] O. Reg. 459/00, as amended, "Drinking water protection: Larger water works."
[33] The following is included in a list of indicators of adverse water quality: "*Escherichia coli (E. coli)* or fecal coliform is detected in any required sample other than a raw water sample. (Corrective action: Increase the chlorine dose and flush the mains to ensure that a total chlorine residual of at least 1.0 mg/L or a free chlorine residual of 0.2 mg/L is achieved at all points in the affected part(s) of the distribution system. Resample and analyze. Corrective action should begin immediately and

The regulation does not oblige the water provider, even as an objective that will guide the treatment requirements, to supply water that is free of pathogenic bacteria. The regulation for small systems is likewise treatment-based but allows for new technologies by saying they must be demonstrably as good as, or better than, chlorine. Operationally, this is specified as 2-log removal or inactivation of viruses if the source is groundwater, or 4-log removal or inactivation of viruses and 3-log removal or inactivation of *Giardia* if the source is surface water.[34] No inactivation limit is set for pathogenic or other bacteria.

Recommendation 27: The Advisory Council on Standards should consider whether to replace the total coliform test with an *E. coli* test.

For a century and a half, the focus of drinking water treatment has been on bacteria. For most of that time, the approach has been to erect defences against bacteria that are known to cause gastrointestinal disease and to assume that viruses and protozoa would be equally well challenged.[35] Bacteria that spent part of their life cycle in mammalian, especially human, gut were the focus.[36] These bacteria were hard to identify, but one, *E. coli*, was a sure indicator of fecal contamination because of its enormous numbers in feces and because it has no non-fecal source.[37] However, for the better part of a century, it was hard to separate *E. coli* from other bacteria, called coliforms, which shared one specific metabolic process. Thus most standards around the world refer to coliform counts, even though there are many coliform bacteria that never pass near, or through, a mammal's intestine. Recently, better tests specific for *E. coli* have become available. It is now cheaper and quicker to measure directly the species

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continue until *E. coli* and fecal coliforms are no longer detected in two consecutive sets of samples or as instructed by the local Medical Officer of Health.)": O. Reg. 459/00, Schedule 6.

[34] O. Reg. 505/01, "Drinking water protection – Smaller water works serving designated facilities," para. 4(3)(b); <http://www.ene.gov.on.ca/envision/WaterReg/Kit/reg505a.pdf> [accessed April 30, 2002].

[35] Authorities have long considered viruses and protozoa, but only recently have the assumptions about kill rates for *Giardia* and *Cryptosporidia* overturned longstanding practices.

[36] Virtually all the organisms that can cause water-borne gastroenteritis in humans – *Salmonella, Shigella, Campylobacter, E. coli,* and so on, as well as parasites such as *Entamoeba, Giardia, Cryptosporidia* and such viruses as hepatitis A – enter water supplies through fecal contamination.

[37] "By the late 1970s, it was established that *E. coli* was specific and abundant in human and animal feces at an average of approximately 10^9 g^{-1}": S.C. Edberg et al., 2000, "*Escherichia coli*: The best biological drinking water indicator for public health protection," *Journal of Applied Microbiology,* vol. 88, p. 109S.

of interest than the broad family of look-alike bacteria, and it is probably appropriate that regulatory standards should follow.[38]

In testing drinking water, the use of indicator organisms of some sort must remain a reality for the foreseeable future. However, the total coliform test is not efficient because of the number of non-fecal sources that can provide total coliform results.[39] This test may nevertheless have some limited value as a means for monitoring the general condition of a distribution system.

5.5.1.4 *Parasites*

Parasites are the largest of the water-borne pathogens and the leading causes of water-borne illness.[40] Most of them are larger than 3 μm in size. To put the sizes of the three types of pathogen in perspective, if viruses were the size of a marble, bacteria would be about the size of a grapefruit, and most parasites would be as big as beach balls. As with viruses and bacteria, mammals are the principal source of parasites of concern. The main parasites in drinking water are the protozoa *Giardia lamblia* (infection that leads to "beaver fever") and *Cryptosporidium parvum;*[41] several other protozoan parasites and some helminth worm eggs may be conveyed through drinking water. Protozoan parasites cause the usual array of gastrointestinal complaints. As with bacteria and viruses, infection in susceptible population groups can have much more serious health consequences.[42]

Parasites can exist outside their host for extended periods of time. Most, like *Giardia* and *Cryptosporidium,* are excreted from their hosts as cysts – dormant organisms with tough walls, which make them resistant to heat, light, and even disinfection by chlorination.

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38 Edberg et al.; M. Stevens, N. Ashbolt, and D. Cunliffe, 2001, "Microbial indicators of water quality – An NHMRC discussion paper," National Health and Medical Research Council, Canberra <http://www.health.gov.au/nhmrc/advice/microb.pdf> [accessed April 30, 2002]; J.B. Rose and D.J. Grimes, 2001, *Re-evaluation of Microbial Water Quality: Powerful New Tools for Detection and Risk Management* (Washington: American Academy of Microbiology).
39 Stevens et al.
40 American Water Works Association, 1999.
41 HDR Engineering, p. 87.
42 Krewski et al., pp. 57–59.

Recommendation 28: No formal maximum contaminant level for protozoa should be established until real-time tests are available. The objective, as with bacterial and viral pathogens, should be zero, and the regulations should so state; but the standard should be a treatment standard, specified in terms of log removal dependent on source water quality.

Only the provincial regulation dealing with smaller water systems, Ontario Regulation 505/01, currently says anything about protozoa, and it refers only to *Giardia*. Yet the incidence of gastrointestinal disease from *Cryptosporidium* and *Giardia* is considerable[43] because there is no practical way of detecting these organisms, or of determining their infectivity if detected, in a reasonable period of time. Small numbers – even as few as ten organisms – can give rise to disease, and a given sample from infected water may or may not contain the microbe. False positives and false negatives are prevalent in current testing methods. Even large and sophisticated operations can make serious errors: Milwaukee experienced an estimated 370,000 cases of cryptosporidiosis in 1993 (initial false negative).[44] Sydney, Australia, spent $50 million battling an epidemic that many experts now believe was merely a monitoring mistake – a series of false positives[45] – and Thunder Bay issued a boil water advisory on the basis of one report of one *Giardia* cyst in treated water.[46]

The United Kingdom has experienced a number of localized outbreaks of cryptosporidiosis, most recently in 1995 and 1997. In the aftermath of privatization, drought, and a failed legal proceeding, the United Kingdom enacted new legislation. Utilities, and their managements and directors, now face the possibility of criminal sanctions if they permit *Cryptosporidium* to contaminate the water system. The U.K. Drinking Water Inspectorate claims that its continuous and risk-based sampling techniques are workable and that storing the sampled water until the lab tests are done can obviate the risk of people drinking contaminated water while testing goes on. Many on this side

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[43] P. Payment, 1999, "Poor efficacy of residual chlorine disinfectant in drinking water to inactivate waterborne pathogens in distribution systems," *Canadian Journal of Microbiol*ogy, vol. 45, pp. 709–715; Payment et al., 1991.
[44] N.J. Hoxie et al., 1997, "Cryptosporidiosis-associated mortality following a massive waterborne outbreak in Milwaukee, Wisconsin," *American Journal of Public Health*, vol. 87, no. 12, pp. 2032–2035; various authors, 1993, "Fatal neglect," *Milwaukee Journal* (special reprint), September 19–26.
[45] J.L. Clancy, 2000, "Sydney's 1998 water quality crisis," *Journal of the American Water Works Association*, vol. 92, no. 3, pp. 55–66.
[46] D.W. Scott, 2002, letter to the Walkerton Inquiry, January 30.

of the Atlantic are skeptical, and a debate continues.[47] In North America, the weight of professional opinion is that the best safeguard against *Cryptosporidium* is provided by filtration rather than direct measurement. This relatively large (>4 μm, for the most part) parasite can be removed through chemically assisted filtration or through the use of membrane filters. More recently, its susceptibility to ultraviolet radiation has led to new treatment possibilities. For the present at least, the preferable approach is that the standard for *Cryptosporidium* should be based upon validated performance criteria for an effective treatment method, rather than specifying the unmeasurable absence of this particular microbe.

5.5.2 Standards for Chronic Risks

An enormous array of chemicals may be present in drinking water sources. Metals such as lead, cadmium, or chromium; organics including benzene, toluene, vinyl chloride, pesticides, herbicides, and some pharmaceuticals; radiological contaminants like radon or uranium; and even the by-products of drinking water disinfection may all be present to one degree or another. Possible sources include industry, landfills, urban runoff, sewage disposal, agriculture, atmospheric transport, and nature itself: cyanotoxin, for example, is produced by blue-green algae. Ontario Regulation 459/00 specifies maximum acceptable concentration (MAC) levels for 54 chemicals, 14 natural radionuclides, and 64 artificial radionuclides. In addition, there are interim maximum acceptable concentrations (IMACs) for another 22 chemicals. Appendix A to this report compares the limits specified in Ontario Regulation 459/00 with those in the federal-provincial *Guidelines* and the standards set by the U.S. Environmental Protection Agency, Australia, and the World Health Organization.

This Inquiry commissioned a team from the Canadian Network of Centres of Excellence in Toxicology to report on the relative risks of various types of potentially toxic contaminants in Ontario drinking water generally.[48] The brief was to quantify, as best as available data allow, the relative risks associated with

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[47] At the AWWA annual meeting in June 2001, Michael Rouse, the head of the Drinking Water Inspectorate, defended his position stoutly. He claimed that continuous filter sampling of risky sources, strict chain of control, interim storage, and regulation-induced diligence on the part of privatized utilities had effectively eliminated *Cryptosporidium* from U.K. drinking water, and it was therefore sensible to have a regulation banning the microbe. British water providers also rely on filtration.

[48] L. Ritter et al. There are, of course, specific local contamination concerns, such as the NDMA problem at Elmira, Ontario, which was discussed at the town hall meeting in Kitchener-Waterloo on March 22, 2001.

toxic contaminants that have had demonstrated or potential effects on human health through exposure from drinking water. Some chemicals ranked low on the risk scale simply because scientific information was lacking. Those most likely to repay investment in further research were nitrates and the pesticide atrazine in rural drinking water wells, and lead and disinfection by-products in municipal systems. An expert meeting in April 2001 added fluoride, water treatment chemicals, endocrine-disrupting substances, and pharmaceuticals to the list as chemicals that should receive closer scrutiny.

The current levels are set on the basis of tests of elevated levels of the contaminant in question on laboratory animals – usually rats or mice that have been selected to be especially susceptible to possible effects. A level at which there is no observable adverse effect is determined. At this point, safety factors are entered: an order of magnitude (factor of ten) for interspecies differences in susceptibility, a correction for body mass, perhaps another order of magnitude to ensure that especially susceptible humans are not affected, and so forth. For carcinogenic chemicals, the aim is to strike a standard that would assure less than one statistically expected additional case in a population of 100,000 over a lifetime, a level below the capacity of epidemiological analysis to measure. The final recommendation for a MAC is thus usually explicitly precautionary. Nevertheless, new research sometimes results in a need to rethink a standard, and there will be substances for which, because of scientific uncertainty, further precaution is required.

5.5.2.1 *Chemical Hazards*

Arsenic: A case in point is the current controversy in the United States over arsenic.[49] The old standard, 50 parts per billion (ppb), was a rough rule of thumb struck in 1942 by the U.S. Public Health Service. In recent years, concerns have arisen that the standard is too lax. Congress asked the U.S. Environmental Protection Agency to take action, and the National Academy of Sciences was asked to provide advice. Its view was that a lower level was justified. The controversy was over how low: 20, 10, 5, and 3 ppb were all suggested. The outgoing administration made 10 ppb the limit in January 2001 – a decision that was suspended by the new administration. After an extensive review, the U.S. Environmental Protection Agency reiterated the 10

[49] “Senate supports tougher arsenic standard” <www.safedrinkingwater.com/alerts/alert080201.htm> [accessed August 2, 2001]. The U.S. Environmental Protection Agency’s Web site has exhaustive coverage: see <www.epa.gov/safewater/arsenic.html>.

ppb limit, and the administration confirmed it. An issue arises because the expense of achieving arsenic removal at the lower end of the range is large, and some argue that the expected gain in public health is small.[50] We can expect the Federal–Provincial Subcommittee on Drinking Water to take careful note of the U.S. debate and the scientific evidence underlying it and to propose any necessary change to the Canadian *Guidelines* IMAC level of 25 ppb (0.025 mg/L). Ontario is not known to have arsenic problems, even though arsenic is often a by-product of gold mining and occurs elsewhere in groundwater in Canada. Recent news articles have reported elevated levels of arsenic in groundwater in Saskatchewan and Newfoundland. If the proceedings of the subcommittee and the Advisory Council on Standards are open and accessible, as I recommend, the public will be able to participate in the debate as it sees fit.

Arsenic has dominated the debate on inorganic chemicals in recent years. The debate has been driven by the enormous tragedy of water-borne disease arising from groundwater contaminated with arsenic in Bangladesh[51] and by the U.S. political and regulatory agenda.[52] However, a number of other chemicals are being evaluated on a preventive basis, notably hexavalent chromium, boron, vanadium, radium, cyanide, bromate, and perchlorate. These chemicals are usually present, if at all, only in very small concentrations, which poses difficult engineering questions. Ion exchange methods and enhanced membrane treatment are the focal points of much current work. The U.S. Environmental Protection Agency has a formal process in which larger water systems screen for the presence of a long list of suspect chemicals.[53]

Lead: Lead in drinking water sources can occur naturally at low levels (up to 0.04mg/L) as a result of geological deposits. This level can be increased as a

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[50] As an example, at the June 2001 American Water Works Association annual meeting in Washington, there was a lively debate between U.S. EPA officials and local utility operators, encapsulated by one small-town water provider from the U.S. Southwest who noted that the agency's then-proposed standard of 5 ppb would require the expenditure of several thousand dollars per household per year to prevent less than one statistically predicted but empirically unmeasurable cancer in 250 years. He said he did not expect his mayor to agree to make the investment. See also F.J. Frost et al., 2002, "Evaluation of costs and benefits of a lower arsenic MCL," *Journal of the American Water Works Association*, vol. 94, no. 3, pp. 71–80.

[51] The Bangladesh–West Bengal case of naturally occurring arsenic in groundwater is extensively covered on the Internet. See, for example, <www.angelfire.com/ak/medinet.arsenic.html>, <www.unicef.org/arsenic>, and <phys4.Harvard.edu/~wilson/arsenic_project_main.html>.

[52] National Research Council, Subcommittee on Arsenic in Drinking Water, 1999, *Arsenic in Drinking Water* (Washington, DC: National Academy Press), c. 4.

[53] United States Environmental Protection Agency, 2001, "Reference guide for the unregulated contaminant monitoring regulation," EPA 815-R-01-023 (Washington, DC).

result of activities such as mining.[54] However, the principal source of lead in drinking water is lead in the distribution system. Lead piping used to be a common component of drinking water systems, and in many older systems today there remain some lead components. Lead is also much more soluble in soft water than in hard. It is therefore not surprising that there are some instances of elevated lead concentrations in distributed drinking water in Ontario.

Acute effects from lead exposure are rare. Its toxicity almost always occurs as a result of chronic exposure. The effects include a wide variety of physiological complications, including cognitive difficulties, kidney dysfunction, anemia, reproductive problems, and delayed neurological and physiological development. The U.S. Environmental Protection Agency classifies lead as a probable human carcinogen,[55] although a 1982 study by the U.S. National Academy of Sciences[56] concluded there was little evidence of carcinogenicity, mutagenicity, or teratogenicity. The effects of lead are particularly serious in children, where exposure can lead to mental retardation or death. Most exposure to lead, however, occurs through ambient air and food.[57]

Nitrates: Nitrates are found in concentrations exceeding the levels specified in Ontario Regulation 459/00 in many wells in rural Ontario. One study indicated that 14% of Ontario's rural wells contain nitrates in concentrations exceeding the MAC set out in the regulation.[58] Nitrates are also found in treated municipal water, but they rarely exceed provincial standards.[59]

The principal sources of nitrates in water are runoff from fertilized agricultural lands, feedlots, municipal and industrial waste discharges, landfill leachate, and decaying vegetation.[60] Nitrates normally occur in concentrations of less than 2 mg/L in surface water and of up to 20 mg/L in groundwater. They may be found in much higher concentrations in shallow aquifers polluted by sewage

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[54] United States Environmental Protection Agency, 2001.
[55] J. DeZuane, 1997, *Handbook of Drinking Water Quality*, 2nd ed. (New York: John Wiley & Sons), p. 80.
[56] DeZuane, p. 83.
[57] Ibid.
[58] M.J. Goss, D.A.J. Barry, and D.L. Rudolph, 1998, "Contamination in Ontario farmstead domestic wells and its association with agriculture: 1. Results from drinking water wells," *Journal of Contaminant Hydrology,* vol. 32, pp. 267–293; cited in Ritter et al., p. 85.
[59] Ritter et al., p. 69.
[60] HDR Engineering, p. 47.

or the intensive use of fertilizers.[61] Nitrates are highly soluble in water and, as such, are not filtered out as water percolates through the ground.

Nitrate contamination above the regulation's limit of 10 mg/L is most common in agricultural areas,[62] and the presence of nitrates in groundwater is an important indicator of potential contamination from agricultural sources.

Although nitrates do not directly affect human health, they are rapidly reduced to nitrites in the gastrointestinal tract. Nitrites then bind with hemoglobin, the oxygen-carrying molecule of the blood, converting it to methemoglobin, which is not capable of carrying oxygen. In adults this does not appear to have any significant effect, but methemoglobinemia can cause serious problems in young children and lead to "blue baby syndrome," a potentially fatal condition. The difference in susceptibility may be due either to the small amount of nitrate consumed relative to body weight in adults[63] or to the fact that children under three years of age convert all ingested nitrates to nitrites in the gastrointestinal tract, whereas older people convert only about 10%.[64] There is also some indication that nitrates in high concentrations may react with other substances to create potentially carcinogenic compounds (notably nitrosamines), although the U.S. Environmental Protection Agency, one of the leading agencies examining issues of this nature, has yet to make any determination in this matter.

Fluorides: Fluorides are found in fertilizers, chemicals, and aluminum smelting, coal burning, and nuclear power plants.[65] The Federal–Provincial Subcommittee on Drinking Water revisited its guideline in 1996. Two health conditions are associated with excess fluoride. Fluorosis mottles young teeth and, in severe cases, results in enamel erosion and tooth pain, which can impair chewing. Long-term exposure to fluorides may result in skeletal fluorosis, a progressive disease in which bone density increases. Bones become more brittle and joints may stiffen, leading to reduced mobility and skeletal deformation in extreme cases.[66]

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[61] DeZuane, p. 89.
[62] M.J. Goss et al., 2002, "The management of manure in Ontario with respect to water quality," Walkerton Inquiry Commissioned Paper 6, p. 9.
[63] HDR Engineering, pp. 47–48.
[64] DeZuane, p. 89.
[65] Health Canada, "It's your health: Fluorides and human health" <http://www.hc-sc.gc.ca/english/iyh/fluorides.html> [accessed April 30, 2002]; G. Glasser, "Fluorine pollution" <http://home.att.net/~gtigerclaw/fluorine_pollution.html> [accessed April 30, 2002].
[66] Health Canada.

There is a long-standing debate over the fluoridation of water.[67] Most water providers in Ontario add fluoride, where necessary, to maintain the regulation's recommended level of 1.0 ± 0.2 mg/L, "the optimum level for control of tooth decay."[68]

Chemicals Used in Water Treatment: The chemicals used in water treatment (see Chapter 6) can, in large enough quantities, cause health problems of their own. Regulations, and standards such as those set by the U.S. National Sanitation Foundation, provide for the maintenance of chemical doses below adverse health levels. However, accidents happen: in 1998 in Camelford, Cornwall, United Kingdom, 20 tonnes of aluminium sulphate were accidentally dumped into the wrong tank at a treatment works. The consumption of contaminated water affected 20,000 households; the effects ranged from mouth ulcers to vomiting and rashes.[69]

5.5.2.2 *Disinfection By-products*

The chemicals added to water for disinfection can form disinfection by-products (DBPs). Chlorine may react with dissolved organic material in water to form trihalomethanes (THMs) and haloacetic acids.[70] At high-dose levels, some of these chemicals, when fed to mice that are bred to develop cancers easily, are carcinogenic. Clearly, DBPs should be minimized in finished water; equally clearly, doing without disinfection to prevent the occurrence of DBPs is substituting an acute risk for a relatively remote, chronic risk. The Peruvian tragedy of 1991, when officials reduced disinfection in a manner that may have contributed to infecting 320,000 people with cholera, which resulted in 3,000 deaths, shows the importance of keeping risks in proper perspective.[71] The balance of evidence is that Ontario standards for THMs have been set at

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[67] Two examples of the opposing views of fluoridation are at <http://www.fluoridation.com> and <http://www.all-natural.com/fleffect.html>.

[68] O. Reg. 459/00, Schedule 4, note b.

[69] A draft report from the committee investigating the incident is due in 2002: <http://news.bbc.co.uk/hi/english/uk/newsid_1490000/1490142.stm> [accessed April 30, 2002].

[70] Canada, Department of National Health and Welfare, Environmental Health Directorate, Health Protection Branch, 1995, *A National Survey of Chlorinated Disinfection By-Products in Canadian Drinking Water* (Ottawa, Supply and Services Canada), p. 7. See <http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/95ehd197.htm> [accessed April 30, 2002].

[71] C. Anderson, 1991, "Cholera epidemic traced to risk miscalculation," *Nature*, vol. 354, November 28; Pan American Health Organization, 2002, *Cholera: Number of Cases and Deaths in the Americas (1991–2001)* (Washington, DC).

quite safe levels,[72] but the human health effects of other DBPs have yet to be assessed.

In addition to a review of old standards on the basis of new evidence, there is a need to provide a first round of examination for many chemicals, particularly when a standard has been struck on the basis of the precautionary principle, in advance of experimental evidence. Cases in point include bromate, aluminum, and uranium. Ontario should contribute to the national effort, and the Ministry of the Environment (MOE) laboratory, in particular, should have as one of its missions the ability to provide authoritative advice to the provincial government on the scientific basis for standards setting.

A greater level of research effort should be devoted to DBPs of all sorts, not just those arising from chlorination. The economies of scale are considerable, however, and the effort would make the most sense if it were mounted cooperatively by many nations. Human susceptibility to toxic substances is similar everywhere. Canadians need both to contribute to the worldwide effort and to keep fully abreast of the work of others. Given the magnitude of the issue, I am of the view that Canada's contribution is best coordinated by Health Canada, working together with international bodies, leading institutions in other countries, the granting councils, the National Research Council, and the provinces. Not all provinces have the resources to be much more than consumers of this research, but this is certainly not the case with Ontario.

5.5.2.3 *Radiological Hazards*

Most countries specify maximum acceptable concentrations of contaminants or their equivalent in terms of an aggregate radiation exposure. Ontario, following the model of the federal-provincial *Guidelines*, specifies individual limits for a large number of natural and manufactured radionuclides as well as an aggregate limit. See Appendix A to this report.

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[72] S.E. Hrudey, 1999, *Assessment of Human Health Risks in Relation to Exposure to THMs in Drinking Water* (Toronto: Pollution Probe).

5.5.3 Operational Standards

A third group of standards is related to treatment and distribution techniques. For obvious engineering reasons, water should not corrode the materials through which it flows. It should be neither too acidic nor too alkaline. It should not be so efficient an electrolyte that it promotes unwanted galvanic reactions among the metals used in water treatment and distribution systems.

Recommendation 29: The provincial government should seek the advice of the Advisory Council on Standards regarding the desirability of a turbidity limit that is lower than the limit specified in the federal–provincial *Guidelines*.

Turbidity is important because microbes can shelter themselves on, within, or behind (in the case of ultraviolet radiation disinfection) suspended particles. Moreover, to the degree that the particles have an organic origin, their downstream reaction with chlorine will not only reduce the chlorine residual but may also produce unacceptable levels of DBPs. The current standard of 1 NTU[73] is an example of the Federal–Provincial Subcommittee on Drinking Water lagging behind good practice among the better water providers, most of whom now routinely produce water at 0.3 NTU or better. Turbidity by itself has little meaning for public health. Rather, it is the consequences of turbidity that are worrisome: the lower the level, the better.

5.5.4 Aesthetic Standards

Finally, there are purely aesthetic standards. People prefer to avoid the smells associated with summer algal blooms or the tea colour of tannic northern waters. Thus, standards are set for taste, odour, and colour. These standards are not without importance from a public health standpoint: if their tap water is unappealing, people may turn to other, less secure, sources, with consequent increases in public health risk. Furthermore, aesthetic problems can indicate other water quality problems. Foul water is never acceptable.

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[73] "Nephelometric turbidity unit: A unit for expressing the cloudiness (turbidity) of a sample," in J.M. Symons, L.C. Bradley, Jr., and T.C. Cleveland, 2000, *The Drinking Water Dictionary* (Denver: American Water Works Association), p. 495.

5.5.5 Problems in Setting Standards

In the case of drinking water safety, the pure model for setting standards implies that relationships between the amount of exposure to a drinking water contaminant (the dose) and the illness caused (the response) are known. In practice, a number of problems arise; the following are two examples.[74] First, the necessary experiments must usually be performed with animal models, but the differences between these laboratory species and humans can, and have been shown to, lead to wrong conclusions about whether a given contaminant can actually cause a given disease. For instance, chloroform in drinking water is no longer regarded by experts to be a serious cancer risk, after almost 25 years of suspicion.[75] There are also contaminants that distress humans but not the animal models.[76] Second, the laboratory animals must be exposed to high doses of contaminants to ensure that some measurable response (to be used to estimate risk) will occur with a reasonable number of experimental animals. An experimental population of 100 animals at each exposure level, for instance, can only reveal a risk of 1 in 100 or more. Attaining a high degree of statistical certainty may require unrealistically large sample populations when the contaminant is rare or the effect small. Thus the laboratory budget decision itself is an expression of relative values.

These features of dose-response determination inevitably introduce major uncertainties. Obvious ethical considerations preclude deliberate human testing,[77] although epidemiological evidence and accident case histories are sometimes able to provide key inferences about human health risk. An even more serious problem arises when the existence of a causal relationship between exposure and health is unknown – when uncertainty about causation itself

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[74] D. Hattis and D. Kennedy, 1986, "Assessing risks from health hazards: An imperfect science," *Technology Review*, May/June, pp. 60–71.
[75] F. Pontius, 2000, "Chloroform: Science, policy and politics," *Journal of the American Water Works Association*, vol. 92, no. 5, p. 12.
[76] Odours and other sensory irritants can be severe sources of human distress, for example, but cannot be assessed by any animal models.
[77] The U.S. Environmental Protection Agency was recently criticized for proposing the use of human experiments in setting pesticide limits. Manufacturers who felt that these more accurate tests would allow higher pesticide doses favoured the move. The agency sent the matter to the National Academy of Science for a report on the ethical and scientific issues involved (*New York Times*, December 15, 2001). Human experimentation is not allowed for these purposes in Canada; drinking water standards will continue to be set by using animal models.

makes uncertainty about the form of the dose-response function pale in comparison.[78]

5.6 Emerging Issues

Ontario has no established system for examining candidates for regulation and does not mention the standard-setting process on its Web site. However, both the Federal–Provincial Subcommittee on Drinking Water and the U.S. Environmental Protection Agency publish priority lists of contaminants that are candidates for regulation.[79] Ontario does, however, have a monitoring program that can help to identify emerging issues. The Drinking Water Surveillance Program (DWSP), undertaken by the MOE Environmental Monitoring and Reporting Branch, Environmental Science and Standards Division, monitors trends and contaminant levels for a wide variety of parameters, improving our knowledge of new contaminants and supporting standards and policy development. The program is not mandatory, but as of 1997, it consisted of 145 municipal waterworks, serving 88% of the population.[80]

5.6.1 New Pathogens

New pathogens arise from time to time. Sometimes a microbe is discovered that has been quietly making people ill for a long time; at other times, a mutant form of an organism emerges. Microbes are continually evolving, just as humans and other animals are continually developing antibodies and other defences against them.[81] Some scientists view the O157:H7 strain of *E. coli* as biologically novel. Cyanobacterial and algal toxins are beginning to receive attention. There is little to be said about this as a matter of public policy, except to emphasize the necessity for a robust, long-term research effort.

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[78] S.E. Hrudey, 1998, "Quantitative cancer risk assessment: Pitfalls and progress," *Issues in Environmental Science and Technology,* vol. 9, pp. 57–90.
[79] See <www.hc-sc.gc.ca/ehp/ehd/bch/water_quality/priority_lst.htm>; <www.epa.gov/safewater/ccl/cclfs.html> [accessed April 30, 2002].
[80] Krewski et al., p. 8.
[81] J. Diamond, 1997, *Guns, Germs and Steel* (New York: Norton); T. McMichael, 2001*, Human Frontiers, Environments and Disease: Past Patterns, Uncertain Futures* (Cambridge: Cambridge University Press). The latter is reviewed in D. Morens, 2001, "Certain diseases, uncertain explanations," *Science*, vol. 294, p. 1658.

Treatment for protozoan pathogens has been a major topic of professional debate in the past few years. This will likely continue. There will be more discussion of water-borne viruses, which as a group are poorly understood. More research is needed, not only to understand the risks they pose to people, but also to gain basic information about their sources and persistence in raw and finished waters.

5.6.2 Chemicals

The case of arsenic has been discussed above. Other chemicals that bear a closer degree of scrutiny for possible regulatory action as drinking water constituents are water-soluble pesticides and herbicides, certain industrial chemicals, nitrates (especially in agricultural areas), and the large family of chemicals, including human and veterinary antibiotics and other pharmaceuticals, that may disrupt endocrine systems in humans and other animals, in addition to other public health concerns.

5.6.2.1 *Pesticides and Herbicides*

Pesticides and herbicides are regulated by Health Canada's Pest Management Regulatory Agency, which follows the classic process of testing the substances on laboratory animals and establishing a human threshold at least an order of magnitude lower than the level at which no effects are observed in the test animals. Some pesticides and herbicides are long-lived and accumulate in the body – a substantial reason for great care. On the other hand, the worst culprits, the bioaccumulative ones, appear to be dangerous precisely because they are soluble in fats and nerve tissue and only sparingly or not at all soluble in water. The likelihood is that Canadians are more exposed to these chemicals directly and through food than through water supplies.

The only pesticide identified by one study as being a potential problem in Ontario drinking water was atrazine, detected "in 6.6 and 10.5% of approximately 1,300 domestic wells sampled in the winter and summer respectively" of Ontario farm wells surveyed in 1998.[82] This is a small number, but it indicates that atrazine may be a health risk in some parts of Ontario.

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[82] Goss et al., 1998, cited in Ritter et al., 2002, p. 74.

Atrazine is a herbicide commonly used on corn and soybeans. The effects of chronic exposure to atrazine are not well documented.[83] However, the U.S. Environmental Protection Agency

> has found atrazine to potentially cause the following health effects when people are exposed to it at levels above the MCL [3 ppb] for relatively short periods of time: congestion of heart, lungs and kidneys; low blood pressure; muscle spasms; weight loss; damage to adrenal glands … Atrazine has the potential to cause the following effects from a lifetime exposure at levels above the MCL: weight loss, cardiovascular damage, retinal and some muscle degeneration; cancer.[84]

The interim maximum acceptable concentration for atrazine in Ontario is 0.005 mg/L (5 ppb).

5.6.2.2 *Industrial Chemicals*

There is a wide range of industrial chemicals about which relatively little is known, at least insofar as these chemicals may be delivered in water. Lipid-soluble chemicals are not the first concern for water systems for the reasons mentioned above, but chemicals such as NDMA (nitrosodimethylamine),[85] TCE (tetrachloroethylene, used for drycleaning and industrial degreasing), MTBE (methyl-*tert*-butyl-ether, an octane enhancer), and perchlorate (an oxidant for rocket fuels) have all been matters of at least local interest in parts of the United States.[86] The Sierra Legal Defence Fund, as mentioned, has drawn

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[83] DeZuane, pp. 268–269; <http://www.horizononline.com/MSDS_Sheets/968.txt> [accessed April 30, 2002].

[84] United States Environmental Protection Agency, Office of Water, 2002, *Technical Factsheet on Atrazine*, National Primary Drinking Water Regulation, Washington, DC <www.epa.gov/safewater/dwh/t-soc/atrazine.html> [accessed April 30, 2002].

[85] For NDMA, Ontario sets an IMAC of 0.000009 mg/L. NDMA is not mentioned in the federal–provincial *Guidelines,* which illustrates why Ontario needs its own expertise in risk assessment: NDMA is a serious, although localized, matter.

[86] The U.S. EPA's Unregulated Contaminant Monitoring Regulation requires large utilities to assist in identifying candidates for future regulation by screening three lists of possible contaminants. The difference among the lists is the degree to which analytic methods have been developed. United States Environmental Protection Agency, 2001, *Reference Guide for the Unregulated Contaminants Monitoring Regulation,* 815-R-01-023 (Washington, DC: Environmental Protection Agency), s. 1.2.

attention to TCE in the Ottawa River and to the existence of a less restrictive guideline for TCE in Canada than in the United States. The *Guidelines* do not currently have a maximum acceptable concentration for NDMA, MTBE, or perchlorate, but Ontario has an interim maximum acceptable concentration of 0.000009 mg/L for NDMA, and MTBE is on the current priority list for development of a federal–provincial guideline. TCE is subject to a maximum acceptable concentration of 0.05 mg/L in Ontario, but the World Health Organization and the United States have not yet developed a standard. Although rocket fuel intrusions into groundwater are unlikely to become a Canadian concern, the other chemicals may occur in specific locations in Ontario. Elmira, Ontario, is the unfortunate locus of serious groundwater pollution by industrial NDMA, which is water-soluble, able to penetrate skin, and known to be carcinogenic at extremely low doses.[87]

5.6.2.3 *Endocrine-Disrupting Substances*

A large and ill-defined class of pharmaceutical and other chemicals are suspected of disrupting animal endocrine systems.[88] The endocrine system consists of glands and organs that release chemical messages in the form of hormones to other parts of the body. These glands and hormones are fundamental to growth, reproduction, and behaviour. Endocrine-disrupting substances (EDS) either prevent the hormone from being released, block the hormone receptor in a cell, or mimic the hormone. These "could lead to irreversible effects in the organism or its offspring."[89] Some of these chemicals (e.g., the artificial estrogens in birth control pills) pass untransformed through the human body and are not destroyed or sequestered in sewage treatment systems. They thus pass into rivers, lakes, and ultimately oceans. There is some suspicion among fisheries

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[87] S. Bryant, Walkerton Inquiry (Kitchener-Waterloo Town Hall Meeting, March 22, 2001), transcript pp. 197–199; see also E.O. Frind, D.L Rudolph, and J.W. Molson, 2001, "The case for groundwater protection in Ontario: Results of the workshop held at the University of Waterloo, May 1, 2001 – A contribution to the Walkerton Inquiry, Phase II," Walkerton Inquiry Submission.
[88] United States National Academy of Sciences, *Hormonally Active Agents in the Environment* (Washington, DC). See also <www.emcom.ca>, a service of the Institute for Population Health at the University of Ottawa. A recent workshop surveyed the state of research in the United States: P. Weyer, G. Parkin, and D. Riley, 2001, *Endocrine Disruptors and Pharmaceuticals in Drinking Water,* Project 2598 (Denver: American Water Works Association Research Foundation).
[89] M. Servos, G.J. Van Der Kraak, and M. Wade, 2001, "Introductory remarks: Scientific assessment of endocrine disrupting substances in the Canadian environment," *Water Quality Research Journal of Canada*, vol. 36, no. 2, p. 171 (a special issue of the journal dedicated to EDS in Canada).

and aquatic ecosystem scientists that these chemicals, even in minuscule doses, may cause reproductive anomalies in fish.

There are probably tens of thousands of EDS, or hormonally active agents, as the U.S. National Research Council calls them.[90] Some of these are well-known persistent organic chemicals. Although maximum contaminant levels have been established in the United States for several suspected EDS,[91] problems exist on several levels. Some EDS are difficult to detect at the levels required to produce adverse results. Also, their effects in the human body are slow and might not be manifested in the affected individual but in that individual's offspring, and perhaps not until the offspring mature. This slow emergence of symptoms makes the collection of scientific evidence about EDS difficult.

To date, research has mainly focused on estrogen look-alikes. Current research is concentrating on how individual substances might affect various hormonal relationships. This research is being undertaken globally. In Canada, a federal working group has been established whose terms of reference instruct it to "identify knowledge gaps from a Canadian perspective, and anticipate international developments that may influence Canadian policy."[92]

Endocrine-disrupting substances and links with human health will continue to be an area of research, both with regard to the environment as a whole and in the water industry in particular.[93] Water providers must keep up with scientific research and disseminate this information among their employees. Potential risks and treatment should be evaluated on an individual plant basis, as techniques to monitor and remove the substances are developed. Furthermore, treatment plants must communicate with the public regarding both the potential risks and the measures being implemented to mitigate them.[94]

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[90] United States National Research Council, Committee on Hormonally Active Agents in the Environment, 2000, *Hormonally Active Agents in the Environment* (Washington, DC: National Academy Press), c. 2.
[91] American Water Works Association, 2000, *Endocrine Disruptors* <http://www.awwa.org/endocrine> [accessed April 29, 2001].
[92] M. Servos et al., 2001, "A Canadian perspective on endocrine disrupting substances in the environment," *Water Quality Research Journal of Canada*, vol. 36, no. 2, p. 331.
[93] Foundation for Water Research, 1999, *Exposure to Endocrine Disruptors Via Materials in Contact with Drinking Water*, Report No. DWI0809 <http://www.fwr.org/> [accessed May 3, 2002].
[94] R. Rhodes Trussell, 2001, "Endocrine disruptors and the water industry," *Journal of the American Water Works Association*, vol. 93, no. 2, pp. 58–65.

5.7 Standards Setting in Some Other Countries

The Australian Productivity Commission has most helpfully published a detailed comparison of standards-setting processes in Australia, the United States, Canada, New Zealand, England and Wales, France, and the European Union.[95] Following is a summary of some features that may be relevant to the discussion in Ontario.

5.7.1 United States

Drinking water standards are established as part of the *Safe Drinking Water Act*.[96] The standards apply to public water systems that have a minimum of 15 service connections or that supply more than 25 people. The U.S. Environmental Protection Agency is responsible for establishing and implementing these standards, although implementation is usually devolved to the tribal or state level, often with the agency's financial assistance.

Standards can be primary or secondary: primary standards are legally enforceable, whereas secondary standards are a guideline for aesthetic effects that can be made legally enforceable at the state level, if required. Primary standards are applied to contaminants with known or suspected adverse health effects. They may be based on a maximum concentration limit (MCL) approach or a treatment technique approach. They come into effect three to five years after being established. The United States has almost completed a new codification of its primary surface water standard, the Long-Term Stage 2 Enhanced Surface Water Treatment Rule, which will come into effect over the next several years.[97]

Before a standard is set, water problems are identified and prioritized. Substances are identified in a National Drinking Water Contaminant Candidate List (CCL), last published in 1998. On a five-year cycle, substances are prioritized, and five substances are examined in detail to see whether they warrant a primary standard; if so, a standard is drafted. The standard is based on scientific evidence

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[95] Australia, Productivity Commission, 2000 <www.pc.gov.au/research/benchmrk/drink> [accessed April 30, 2002]. For the World Health Organization, the United States, and the state of New York, see DeZuane.

[96] See <www.epa.gov/OGWDW/sdwa/sdwa.html> [accessed April 30, 2002].

[97] M.A. Scharfenaker, 2002, "Draft LT2ESWTR out of the box," *Journal of the American Water Works Association*, vol. 94, no. 2, pp. 24–37.

as well as a broad technological assessment that includes the presence of the contaminant in the environment, risk assessment, detection technology, and removal feasibility, as well as the impacts of the standard and variations of it on health, utilities, and the economy. Within each five-year cycle, 30 unregulated contaminants are identified for monitoring by systems that serve more than 100,000 people. At the end of the cycle, the CCL is updated. Meanwhile, on a six-year cycle, existing standards are revisited and updated as necessary.

A maximum contaminant level goal (MCLG) is established by the U.S. Environmental Protection Agency (U.S. EPA) as an unenforceable guideline. This is the level at which health effects do not, or are not expected to, occur. Since the MCLG is based purely on health, it does not always coincide with technical feasibility. In these cases, the MCL is established as close to the MCLG as possible. If the MCLG is unattainable, a treatment technique standard may be established.

Once a standard has been drafted, an economic analysis is undertaken to ensure that the benefits justify the costs. A standard can be adjusted for certain system types so that the costs are justified by the risk reduction benefits. For all standards except microbial, variances can be granted to systems serving fewer than 3,300 people at a state level, if they cannot afford to comply with a rule and if they install U.S. EPA-approved technology to minimize risks. A state can grant variances to systems serving up to 10,000 people with U.S. EPA approval. Exemption periods from standards can also be granted to find alternative funding sources, but at the end of the period, the system is expected to be in full compliance. There is an obligation for the U.S. EPA, particularly in the case of small systems, to identify point-of-use or point-of-entry and low-cost options, such as modular systems, to attain standards. The U.S. EPA has a duty to identify affordable technologies that reduce contaminant levels and protect public health.

Public input is solicited throughout the standards-setting process. A key platform for this is the National Drinking Water Advisory Council.[98] Public participation is solicited at public meetings and through comments on postings on the Federal

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[98] A 15-member committee consisting of five members of the general public, five representatives from private organizations concerned with water hygiene and supply, and five representatives from state and local agencies. Two of the representatives for private organizations have to represent rural systems. The council was formed under the *Safe Drinking Water Act* and advises the U.S. EPA on all matters relating to drinking water: National Drinking Water Advisory Council <http://www.epa.gov/safewater/ndwac/charter.html> [accessed April 30, 2002].

Register. Special meetings are held to obtain input from specific target groups, such as small businesses, minority groups, and low-income communities.

The U.S. system of full public disclosure and wide-open debate, mandated under law, can be studied by Ontarians who are interested in continuously improving standards and performance.

5.7.2 England and Wales

The European Union (EU) has incorporated World Health Organization guidelines into its *Drinking Water Directive 98/83/EC*. Enforcement is through national legislation, which must be established by a certain compliance date. In the United Kingdom, standards beyond those dictated by the EU are developed under the *Water Industry Act* (1991). A regulatory impact statement is required for standards other than those directed by the EU, as in the case for *Cryptosporidium.*

Britain's unique *Cryptosporidium* legislation arose at least in part from a failed legal proceeding (see section 5.5.1.4 of this report). In 1995, about 600 people in a town in South Devon were infected with water-borne *Cryptosporidium*. The Drinking Water Inspectorate prosecuted the water company for the event but was unsuccessful: epidemiological evidence was deemed hearsay. The *Cryptosporidium* legislation came into force in 1999 as the Water Supply (Water Quality) (Amendment) Regulations.[99] Operating agencies must perform a *Cryptosporidium* risk analysis, and if they are found to be at risk, the companies must implement a stringent monitoring program that demands continuous sampling via inline filters. Treated water cannot contain more than 1 oöcyst in 10 L of water. Failing to meet this standard is considered a criminal offence.

This is an interesting approach, but not one I would recommend for Ontario. The standards required for criminal prosecution imply extremely low levels of measurement error and a large investment in documentation, chain of custody, and the like that could better be spent on quality upgrades by water providers and on inspection and enforcement on a civil basis by the MOE.

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[99] See <http://www.dwi.gov.uk/regs/si1524/index.htm> [accessed April 30, 2002].

5.7.3 Australia

In Australia, guidelines are developed at the Commonwealth level. A joint committee of the National Health and Medical Research Council (NHMRC) and the Agriculture and Resource Management Council of Australia and New Zealand established the current version of the guidelines in 1996. Specialist panels under this committee presented reports on micro-organisms, organic and inorganic chemicals, and radiological and physical parameters. The panels included members from universities, the NHMRC, utilities, and private industry. Territories and states are responsible for implementing these guidelines and can adopt them as standards. Various regions adopt different versions of the guidelines.

The guidelines are based on the World Health Organization's 1993 guidelines and "provide a framework for identifying acceptable drinking water quality, emphasising flexibility and community consultation."[100] They are meant to be used as part of the management framework approach to water quality. Multiple barriers are intended to constitute a comprehensive treatment system. From an Ontario perspective, the Australian "rolling revision" process is notable for, among other things, its inclusion of non-governmental people in the process and the provision of a reasoned response to commentary from the public.[101]

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[100] Australia, Productivity Commission, p. 170.

[101] See <www.waterquality.crc.org.au/guideRR.htm> [accessed April 30, 2002].