# Chapter 3 A Multi-Barrier Approach to Drinking Water Safety

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# Chapter 3 A Multi-Barrier Approach to Drinking Water Safety

## 3.1 Multiple Barriers in Drinking Water Supply

The best way to achieve a healthy public water supply is to put in place multiple barriers that keep water contaminants from reaching people.[1] The voluminous technical literature and all of the submissions made to the Inquiry on this point emphasized the importance of the multiple-barrier approach in ensuring the safety of drinking water.

Much reform in government in recent years has focused on overlap and duplication, which are considered to be sources of waste and inefficiency. In the area of public health, however, this approach has limits, because single barriers are never entirely effective. Thus, a degree of redundancy guards against the failure of any one barrier. A low tolerance for system failures requires placing a number of processes in series, each of which has a low failure rate and each of whose modes of failure is independent of the others. Every step in the chain, from water supply through treatment to distribution, needs careful selection, design, and implementation, so that the combination of steps provides the best defence against calamity if things go wrong.

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[1] See P. Huck, testimony, Walkerton Inquiry (Part 1 Hearing, October 16, 2001), transcript p. 111: [T]he multi-barrier approach or defence in depth … has been an approach which has long been used by the water industry … to provide safe and secure supplies of drinking water … [W]e don't rely only on one barrier in the system, we rely on a series of barriers"; Ontario Water Works Association/Ontario Municipal Water Association, 2001, "Final submissions relating to the provision of safe drinking water in Ontario," Walkerton Inquiry Submission, p. 73: "Watershed protection and source evaluation should be emphasized as an integral part of the multi-barrier concept of drinking water protection"; and R.G. Luthy, 2001, *Water Supplies Need Better Protection* <www4.nationalacademies.org/onpi/oped.nsf/(Op-EdByDocID)/97AF7365F3DOC7D 385256B1000777B81> [accessed May 6, 2002]: "The best approach to ensuring water quality is through application of multiple barriers to contaminants in supply, treatment, and distribution." See also D. Krewski et al., 2002, "Managing health risks from drinking water," Walkerton Inquiry Commissioned Paper 7, p. 91; L. Gammie, 2001, for Ontario Water Works Association/Ontario Municipal Water Association, "Review of Issue #5 – Drinking Water Standards – in the Krewski et al. report 'Managing health risks from drinking water,'" Walkerton Inquiry Submission, p. 4; M. Murray and K. Seiling, for the Regional Municipality of Waterloo, Walkerton Inquiry (Kitchener-Waterloo Town Hall Meeting, March 22, 2001) transcript p. 16.

Five types of barriers are commonly used in the provision of drinking water.[2] I discussed them at some length in the Part 1 report of this Inquiry and briefly summarize them here.[3]

- ***Source protection*** keeps the raw water as clean as possible to lower the risk that contaminants will get through or overwhelm the treatment system.

- ***Treatment*** often uses more than one approach to removing or inactivating contaminants (e.g., filtration may be followed by chlorination, ozonation, or ultraviolet radiation).

- Securing the ***distribution system*** against the intrusion of contaminants and ensuring an appropriate free chlorine residual throughout is highly likely to deliver safe water, even when some earlier part of the system breaks down.

- ***Monitoring programs,*** including equipment fitted with warning or automatic control devices, are critical in detecting contaminants that exist in concentrations beyond acceptable limits and returning systems to normal operation.

- Well-thought-out, thorough, and practised ***responses to adverse conditions***, including specific responses for emergencies, are required when other processes fail or there are indicators of deteriorating water quality.

Although each barrier offers protection, no single barrier is perfect. Thus, an over-reliance on only one barrier at the expense of another may increase the risk of contamination. Leaving out key steps at one stage can negate the effect of other stages; for example, the uncovered storage of post-treatment water may undermine the earlier steps taken to ensure water safety.

Independent failure modes should be established; that is, barriers should be selected so that a failure of one barrier does not result in the failure of all. The disinfection part of the treatment sequence should guarantee that if the source water is polluted, bacteria do not pass through to the distribution system. It

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[2] Different sources give different numbers of stages, usually depending on whether they include a variety of management or training activities, or stick to more technical matters. All, however, would include this basic five in one form or another. I treat quality management and effective regulation of water facilities as the means by which the five barriers are achieved.

can do this by, for example, requiring the installation of alarm-equipped chlorine monitors and possibly automatic shut-off valves. The existence of one barrier does not, therefore, mean that others can be ignored. The concept of multiple barriers entails the balanced presence of all five types of barriers, to the greatest extent possible.

Table 3.1 provides a general indication of how the multi-barrier approach might be put into effect.

**Table 3.1 An Example of the Multi-barrier Approach**

| Hazard | Barrier | Typical Risk Management Approach |
|---|---|---|
| Pathogens<br>Chemical contaminants<br>Radionuclides | Source protection | Watershed protection plan<br>Upgraded sewage treatment<br>Choice of water source |
| Pathogens<br>Disinfection by-products<br>Chemical contaminants | Treatment | Water quality standards<br>Chemically assisted filtration<br>Disinfection |
| Infiltration<br>Pathogen regrowth | Distribution system | Chlorine residual<br>System pressure<br>Capital maintenance plan |
| Undetected system failures | Monitoring | Automatic monitors<br>Alarms and shut-offs<br>Logbooks, trend analyses |
| Failure to act promptly on system failure<br>Failure to communicate promptly with health authorities and the public | Response | Emergency response plans<br>Boil water advisories (orders) |

## 3.2 The Goal: Safe Drinking Water

The goal of any drinking water system should be to deliver water with a level of risk that is so negligible that a reasonable and informed person would feel safe drinking it. This goal must inform all the decisions that affect the safety of drinking water and should provide the objective against which risk assessment and management decisions are to be made. The goal as I have set it out above implies that there will always be some risk. The point made repeatedly in the literature and by those knowledgeable in the area is that removing all risk is not possible. That said, I base my approach to this issue on the premise that in regard to the safety of drinking water, the reasonable and informed public will not feel safe with anything other than the most imperceptible level of risk, a level that is simply not practical to remove.

Tying the risk assessment and management processes to the safety of drinking water and to public acceptance requires that those who make decisions affecting drinking water – the setting of standards, the selection of water sources, the choice of treatment – must involve those who bear the risks (the public) in the decision-making process. The type of confidence in the safety of drinking water that is necessary to achieve the goal I have set out will result only when members of the public are fully informed of the relevant factors leading to such decisions and are able to hold those who make the decisions accountable for the consequences of those decisions. The recommendations made throughout this Part 2 report reflect the need for transparency and accountability in the risk assessment and risk management process.

## 3.3 Risk Management

The multi-barrier approach is put into effect by assessing and managing the risks to drinking water safety that can be addressed by each barrier. It is important to assess the degree of each risk and to determine how to reduce it effectively in order to select the most appropriate actions for each of the barriers. Often these actions are obvious; for example, surface water should be treated by filtration before being treated by disinfection. In other situations, such as determining the acceptable concentration of a contaminant – a step relevant to the selection of a water source (barrier 1) and to the treatment of the source water (barrier 2) – the decision-making process can be far more complicated. However simple or complex a particular decision may be, it is necessary to address risk and to settle on the approach that most effectively reduces risk.

The key features of a good approach to managing risk include being preventive rather than reactive; distinguishing greater risks from lesser ones, and dealing first with the former; taking time to learn from experience; and investing resources in risk management that are proportional to the danger posed.[4]

Risk management is not a formulaic exercise best left only to the experts. Each stage in the process is informed by human values. In relation to drinking water safety, risk management means choosing among alternative strategies to reduce risk, usually on the basis of the greatest lowering of risk for available resources,

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[3] 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. 108–112.
[4] Adapted from S.E. Hrudey, 2001, "Drinking water quality: A risk management approach," *Water*, vol. 26, no. 1, pp. 29–32.

or on the minimum resources needed to attain a pre-set standard. Because public perceptions and values are so fundamental to these choices, there must be effective opportunities for public debate and advice before important decisions are taken.

Risk assessment and management have become increasingly common features of public policy in recent decades.[5] Some resist this trend, in part because the activity as it is typically practised is seen as remote, bureaucratic, and insufficiently open to public involvement. For some, risk management has acquired a stereotypical image: unaccountable experts telling those who are potentially affected not to worry, that everything is under control, and that in any case those who are affected would not understand the deeply scientific arguments.[6] That approach would of course be ineffective, because risk management inevitably involves the influencing of human behaviour; alienating those who are to be protected is not helpful. The management of risks to public health is a value-driven exercise that must be informed by and must respond to the views of the public, just as it must call on the best that science can offer.[7]

## 3.4 The Precautionary Principle

One way to overcome the difficulties of purely rationalist risk management is to err systematically on the side of safety. A refinement of this approach is the precautionary principle, a guide to environmental action that has now been

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[5] The federal government published its current risk management policy in 1994 and expanded on it in 2001. It devotes a Web page to listing its own publications and policies in the area. The policy is meant to guide the whole federal government. See Canada, Treasury Board Secretariat, 1994, *Risk Management Policy*; and Canada, Treasury Board Secretariat, 2001, *Integrated Risk Management Framework* <www.tbs-sct.gc.ca/pubs_pol/dcgpubs/RiskManagement/siglist_e.html> [accessed December 23, 2001]. See also Canada, Privy Council Office, 2000, *Risk Management for Canada and Canadians: Report of the ADM Working Group on Risk Management* (Ottawa: Privy Council Office); and S. Hill and G. Dinsdale, 2001, *A Foundation for Developing Risk Management Learning Strategies in the Public Service* <www.ccmd-ccg.gc.ca/pdfs/risk_mgnt_rt_e.pdf> [accessed April 17, 2002]. The basic concepts have been widely applied in fields as diverse as public health, insurance, aeronautics and aircraft design, and banking.

[6] For example, in the expert meetings, the Canadian Environmental Law Association (CELA) was skeptical about whether adequate allowances are made for vulnerable populations and whether the development of standards lags because of pressures to require unattainable proofs of harm. CELA argued for a more explicit and transparent process.

[7] See, for example, W. Leiss, 2001, *In the Chamber of Risks: Understanding Risk Controversies* (Montreal and Kingston: McGill-Queen's University Press).

recognized in international law[8] and cited with approval in a Supreme Court of Canada decision.[9] This principle, which has been formulated in many ways,[10] says that the absence of scientific certainty about a risk should not bar the taking of precautionary measures in the face of possible irreversible harm. It addresses situations in which risk cannot be estimated with any reliability and in which uncertainty prevails regarding the relationship, if any, between cause and supposed effect. Under such circumstances, precautionary measures such as investments in risk mitigation, alternative technologies, and research are called for. At worst, such an approach means that resources that might have been devoted to more productive use elsewhere may be consumed to reduce certain risks. Although this prudent approach must still take account of costs, when the potential consequences of the hazard in question are large, the precautionary principle has a role to play in practical risk management and should be an integral part of decisions affecting the safety of drinking water.

Sometimes the precautionary principle is described as an alternative to the risk management approach. It strikes me that these two approaches should be complementary. Properly applied, what they are designed to achieve is not perfect safety, but a level of risk that a broad spectrum of citizens finds tolerable. This is a pragmatic notion of safety.[11] The precautionary approach is inherent in risk management, and the need for precaution rises where uncertainties about specific hazards are expected to persist and where the suspected adverse effects may be serious or irreversible.

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[8] "The precautionary principle/approach appears in a large number of international instruments, and Canada's obligations in that regard are governed by its expression in those instruments. Due to an absence of clear evidence of uniform State practice and opinio juris, Canada does not yet consider the precautionary principle to be a rule of customary international law": Canada, Privy Council Office, 2001, *A Canadian Perspective on the Precautionary Approach/Principle: Discussion Document* <www.pco-bcp.gc.ca/raoics-srdc/docs/precaution/Discussion/discussion-e.html> [accessed April 17, 2002]. On the other hand, the Supreme Court of Canada has said that "there may be a 'currently sufficient state practice to allow a good argument that the precautionary principle is a principle of customary international law'": *114957 Canada Ltée (Spraytech, Société d'arrosage) v. Hudson (Town)*, [2001], S.C.J. No. 42 at para. 32.

[9] *114957 Canada Ltée (Spraytech, Société d'arrosage) v. Hudson (Town).*

[10] See, for example, K. Ogilvie, 2001, *Applying the Precautionary Principle to Standard Setting for Toxic Substances in Canada* (Toronto: Pollution Probe); J. Abouchar, 2001, "Implementation of the precautionary principle in Canada," pp. 235–267 in T. O'Riordan et al., eds., *Reinterpreting the Precautionary Principle* (London: Cameron May); and Canada, Privy Council Office, 2001.

[11] S.E. Hrudey and D. Krewski, 1995, "Is there a safe level of exposure to a carcinogen?" *Environmental Science and Technology*, vol. 29, no. 8, pp. 370A–375A.

In an ideal world, resources would be allocated so as to reduce risks to the greatest extent possible.[12] Where drinking water is involved, the costs associated with any particular barrier tend to rise the more we rely on that barrier. It therefore makes sense to invest in a balanced way in all five types of barriers.

## 3.5 Outbreaks of Water-borne Disease

Was the Walkerton tragedy an isolated incident brought about by an unlikely combination of events, or was it a warning of a more general problem? Unfortunately, tragedies of the sort experienced in Walkerton are not as uncommon as many may think. They typically involve the simultaneous failure of two or more barriers in systems operated with more complacency than rigour. An April 2002 paper summarizing the causes of 19 outbreaks in six countries[13] concluded that nine of the outbreaks in question resulted from source waters that were polluted during heavy precipitation, two from poorly located intakes, and three from local geographical problems – all source water problems. Three had filtration failures, and five had no or inadequate disinfection – treatment failures; six had distribution system failures; two had monitoring failures; and five had inappropriate responses to adverse conditions. It usually takes the failure of more than one barrier to cause an outbreak. Outbreaks would be more frequent if multiple barriers were not the norm.

Too often, either such outbreaks are inadequately analyzed or the results of the analyses that are done are not drawn to the attention of people who are in a position to respond to them. In England, for instance, a 1980 outbreak affected up to 3,000 residents served by the Bramham water supply. The outbreak was caused by a sewer blockage that resulted in sewage seeping through fractured limestone to contaminate one of four wells. Consumers had earlier complained about the taste of chlorine in the water, so the chlorine dose was kept below 0.01 mg/L total chlorine. When coliforms were observed in treated water, staff had no equipment with which to check chlorine levels downstream of the

[12] R. Dobell, 2002, "Social risk, political rationality, and official responsibility: Risk management in context," Walkerton Inquiry Commissioned Paper 13. Compare with C.G. Jardine et al., in press, "Review of risk management frameworks for environmental, human health, and occupational health risks," *Journal of Toxicology and Environmental Health:* "Seek actions that will achieve the greatest overall reduction of risk."

[13] S.E. Hrudey et al., 2002, "A fatal waterborne disease outbreak in Walkerton, Ontario: Comparison with other waterborne outbreaks in the developed world," proceedings at the International Water Association World Water Congress Health Related Water Microbiology Symposium, Melbourne, Australia, April 7–12.

dosing pump. Later it was discovered that the pump was not adding chlorine at all but was passing it straight to the drain. It was also discovered that a number of similar outbreaks with similar causes had previously occurred in Britain. An article discussing the Bramham outbreak noted that

> [e]vidently, the lessons of earlier incidents were not learnt and applied in such a way as to prevent the Bramham outbreak. However, little detailed information is available in the water supply literature about circumstances of [such] incidents. More publicity and detailed analyses are required.
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> At borehole sites it is required to have automatic shutdown of the pumps if the residual falls below an absolute minimum level.
>
> At sources with an excellent bacteriological record…the role of the chlorine residual would be principally to act as an indicator of chlorine demand. Thus, if the source became polluted the chlorine residual would quickly drop below the acceptable minimum and would thus trigger an alarm and possibly an automatic shut-down. In-house training schemes for operators have been developed, covering the purpose of disinfection as well as the operation of chlorination and chlorine monitoring equipment.[14]

The critically important themes of vigilance and quality management arise throughout this report. In protecting public health, the first step is to ensure that adequate technology is in place. This technology in turn should be operated by trained and conscientious people as part of a well-managed organization. Together with effective oversight and regulation, these are the elements necessary to ensure a very high level of drinking water safety. A tragedy like the one in Walkerton need never happen again.

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[14] C.S. Short, 1988, "The Bramham incident, 1980: An outbreak of water-borne infection," *Journal of the Institute of Water and Environmental Management*, vol. 2, pp. 383–390.