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Water safety plans: planning for adverse events and communicating with consumers

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ABSTRACT

A wide range of microbial and chemical characteristics in drinking water have the potential to affect human health. However, it is not possible or practical to test drinking water for all potentially harmful characteristics. If drinking water is contaminated, people may already be exposed by the time test results are available. The 'boil water alert' issued in Sydney, Australia in 1998 following the detection of *Cryptosporidium* and *Giardia* in the finished water supply, highlighted the uncertainties associated with the public health response to test results.

The Sydney experience supports the international consensus that a preventive risk-management approach to the supply of drinking water (manifesting as water safety plans (WSPs)) is the most reliable way to protect public health. A key component of a comprehensive WSP is that water suppliers and health authorities must have plans to respond in the case of water contamination and/or outbreaks. These plans must include clear guidance on when to issue warnings to consumers, and how these warnings are to be communicated. The pressure on health authorities to develop clear and systematic boil-water guidance will increase as utilities all over the world develop their WSPs.

Key words | boil water, communication, risk management, water contamination, water safety plans

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INTRODUCTION

A wide range of microbial and chemical characteristics in drinking water have the potential to affect human health. Historically, public health authorities have required the monitoring of finished drinking-water quality and carried out surveillance for disease. However, these strategies rarely prevent outbreaks (Deere *et al.* 2001). It is not possible or practical to test drinking water for all potentially harmful characteristics. Water monitoring programs generally lack representativeness and have poor predictive value. Results must be interpreted with caution (Hrudey & Leiss 2003). It would appear that few public health officials appreciate the limitations of water monitoring programs (Jalba *et al.* 2005). If drinking water is contaminated people may already be exposed by the time test results are available. Disease surveillance data must be reviewed regularly if it is to provide early warning of outbreaks. Depending on incubation periods, an outbreak may have passed by the time surveillance data is available.

Responses to water testing and disease surveillance are generally retrospective and reactive. For this reason, there is international consensus that a preventive risk-management approach is the most reliable way to protect public health.

WATER SAFETY PLANS

WSPs and the *Framework for Safe Drinking-Water* are an important part of the World Health Organization's *Guidelines for Drinking-Water Quality* (World Health Organization

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(WHO) 2004; Davison *et al.* 2005). The five key components of the WHO's *Framework for Safe Drinking-Water* are:

1. health-based targets based on an evaluation of health concerns;
2. system assessment to determine whether the drinking-water supply (from source to treatment to the point of consumption) can meet the health-based targets;
3. operational monitoring of control measures in the drinking water supply;
4. water safety (or management) plans documenting the system assessment and monitoring plans and describing actions to be taken in normal operation and incidents, including upgrade and improvement, documentation and communication; and
5. a system of independent surveillance that verifies that the above are operating properly.

WSPs take a preventive-risk management approach, and build on the principles of multiple barriers and Hazard Analysis and Critical Control Points (HACCP). HACCP has been adopted internationally by the food industry as a system to assess hazards and establish control systems (FAO/WHO 2003) and by the water industry (Deere & Davison 1998). The contemporary application of this preventive-risk management approach in the food industry is ISO 22000:2005, *Food Safety Management Systems – Requirements for any Organization in the Food Chain*, which is also finding application in the water sector (Davison & Deere 2006). An important part of WSPs is planning for adverse events and emergencies, including:

1. protocols to respond to contamination, including increased monitoring;
2. responsibilities and authorities (internal and external);
3. plans for emergency water supplies;
4. communication protocols (internal and external, media and public); and
5. mechanisms for enhanced public health surveillance to track the incident.

Adverse events or 'incidents' that have the potential to affect the safety of drinking water may arise from:

- 'predictable deviations' (which are managed through existing plans such as changing the source water or increasing disinfection);
- unforeseen events (may include contamination with a previously unknown chemical); and
- emergencies (such as flooding or other natural disasters) (WHO 2004).

Incident response plans may be triggered by extreme rainfall, unusually high turbidity or poor performance of the treatment plant, adverse events affecting source water quality (e.g. sewage contamination), deterioration in drinking water quality and a suspected waterborne disease outbreak.

Incident response plans may include the issue of warnings to consumers, for example to boil or avoid the water. Where warnings are issued, the public health authority must be convinced that ongoing risks from drinking water outweigh the risk associated with the warning itself. The potential benefits of a warning should be weighed up against the impacts, including the need to avoid a range of foods and beverages that may contain tap water, the risk of burns and scalds, and ongoing costs where filters or bottled water are used (Byleveld *et al.* 1999). The incident response plan should include criteria on when to remove the warning and any advice provided must be clear and easy to understand (WHO 2004).

The *Framework for Safe Drinking-Water* and WSPs, in some form, are becoming part of the guidelines or regulations in many countries including Australia, China, Iceland, New Zealand, Sweden and the United Kingdom.

THE AUSTRALIAN DRINKING WATER GUIDELINES

Australia is the driest inhabited continent and has highly variable rainfall patterns. The majority of Australia's population is concentrated in large urban centres with many smaller towns and communities scattered around the country. The arrangements for water supply in Australia present a challenge to service providers and public health authorities.

The national *Australian Drinking Water Guidelines* (ADWG) (NHMRC/NRMMC 2004) provide guidance on safe drinking water and take a similar approach to the WHO Guidelines. The ADWG are directed by six fundamental principles vital to ensuring safe drinking-water quality:

- The greatest risks to consumers of drinking water are pathogenic microorganisms. Protection of water sources and treatment are of paramount importance and must never be compromised.
- The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of potential contamination facing the raw water supply.
- Any sudden or extreme change in water quality, flow or environmental conditions (e.g. extreme rainfall or flooding) should arouse suspicion that drinking water might become contaminated.
- System operators must be able to respond quickly and effectively to adverse monitoring signals.
- System operators must maintain a personal sense of responsibility and dedication to providing consumers with safe water, and should never ignore a customer complaint about water quality.
- Ensuring drinking-water safety and quality requires the application of a considered risk-management approach.

WSPs in Australia – framework for management of drinking water quality

Perhaps the most important part of the ADWG is the *Framework for Management of Drinking Water Quality* that emphasises a preventive management approach (Cunliffe 2001). The Framework consists of 12 elements that form part of a risk-management approach for water utilities. The Framework moves away from the reliance on end-point testing and encourages early identification and correction of problems, reducing likelihood of contamination and 'boil-water alerts'. The Framework advocates the development of incident and emergency response protocols, and provides guidance on communication with consumers.

The relationship between the elements of the Framework is illustrated in Figure 1. The Framework addresses four general areas describing good management of a water supply system:

- *Commitment*. Organisational commitment to drinking water quality management.
- *System analysis and management*. Understanding the entire water supply system, the hazards and events that can compromise drinking-water quality, and the preventive measures and operational control necessary for ensuring safe and reliable drinking water.
- *Supporting requirements*. Activities and attitudes that support management of the supply system such as employee training, community involvement and validation of the effectiveness of processes.
- *Review*. The evaluation and audit of the effectiveness of the management system, and the adoption of improvements based on the evaluation.

Across Australia there are many small, remote and indigenous communities, which are often a long distance from public health and engineering expertise. In order to support the implementation of the ADWG and the Framework, the National Health and Medical Research Council has developed the *Community Water Planner – A Tool for Small Communities to Develop Drinking Water Management Plans* (NHMRC 2005). The *Community Water Planner* is a CD-based tool that helps smaller water suppliers identify potential hazards and their sources, assesses the risk associated with these hazards, and helps evaluate existing preventive strategies and the need for additional measures.

The *Community Water Planner* tool generates a water supply management plan that considers water quantity and availability, the water supply (catchment or source, storage and reservoirs, treatment, distribution and consumers), infrastructure organisation, and management of incidents and emergencies.

The Australian Government and the states and territories are promoting the implementation of risk-based WSPs such as the *Framework for the Management of Drinking Water Quality* and the *Community Water Planner* through the National Water Initiative. There is a commitment to report annually on a range of performance indicators, including whether a risk-based drinking-water quality management plan is in place and whether it has been assessed externally (WSAA *et al.* 2006). Some states have introduced regulations that require water utilities to implement risk-based management plans (such as Victoria, through the *Safe Drinking Water Act 2003*).

WSPs in New South Wales

In the state of New South Wales (NSW), Australia, the Department of Health (NSW Health) is the public health

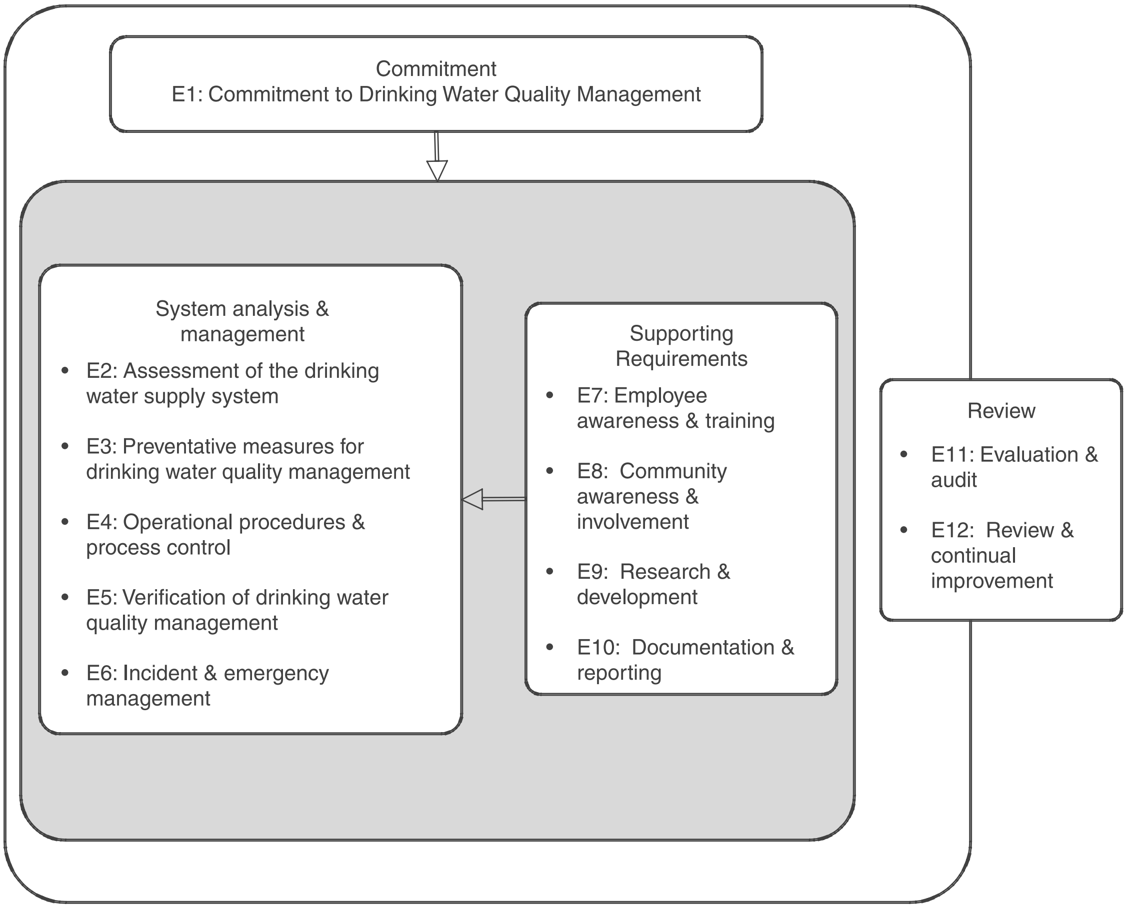

Figure 1 | Framework for management of drinking water quality (developed from NHMRC/NRMMC 2004).

regulator of drinking-water quality. NSW Health has recommended that each water supplier implement a risk-based WSP. The major water utilities serving the large cities are well advanced in the development of WSPs. Some smaller water suppliers are also implementing WSPs. The challenge in future years will be to support all small independent water suppliers, including private water supplies, in the implementation of WSPs.

A regional water utility

Riverina Water County Council (RWCC) was the first water utility in NSW to gain certification of a risk-based WSP using the HACCP system. RWCC provides drinking water to approximately 65,000 people over an area of 15,400 square kilometres in southern NSW. RWCC operates some 16 water supply systems drawing on ground water and surface water.

To develop the HACCP-based WSP, RWCC engaged independent technical facilitation to conduct a gap analysis to assess the status of water quality management and actions needed for certification (RWCC 2006). Resources were allocated to the project and a HACCP team was established which included members from all sections of RWCC, NSW Health and other NSW Government agencies.

RWCC held a series of workshops to develop the HACCP WSP. The HACCP WSP provides a system of identifying and managing any potential sources of contamination from the source (catchment) right through to the consumer's tap. Once these hazards are identified, Critical Control Points (critical steps in the water supply process such as disinfection) are established. For the Critical Control Points there are Target Limits (parameters that can be monitored, for example the target chlorine dose) and Critical Limits (for example, the minimum acceptable chlorine dose). If water does not meet the critical limit it may not be safe to drink. Each Critical Control Point is summarised in a control loop table which sets out: what the potential hazard is and its cause, control measures, Target Limits, Critical Limits, how Critical Limits are monitored, and corrective action required if critical limits are breached.

RWCC's progress was externally reviewed by independent technical facilitators to ensure that the system was fundamentally sound. A pre-audit was conducted, outstanding issues were addressed and records updated prior to the certification audit. Three months following implementation, to allow time to accumulate evidence that the WSP was in place and effective, the HACCP WSP was audited for certification.

The HACCP process and the WSP itself have helped to promote awareness of water safety issues within the RWCC. It has also demonstrated to work teams that all areas of the organisation are responsible for maintaining water quality. Operators have become more proactive, preventing contamination incidents before they occur and are taking more responsibility for their own supply systems. The HACCP WSP process has a number of prerequisites including the development of robust incident management (contingency) plans. Incident management plans are only required if a Critical Limit is breached and the corrective action fails to return the process to specifications.

An additional benefit of the HACCP process is the establishment of a Water Quality Continuous Improvement Action Plan. Working through these identified actions will continue to improve the safety and the quality of drinking water provided by RWCC.

Private water supplies

Although outbreaks rarely affect public reticulated water supplies in NSW, from time to time there are outbreaks associated with private water supplies (Cowie & Byleveld 2003). These outbreaks can have serious impacts on consumers and communities. The largest waterborne outbreak recorded in NSW in recent decades occurred at a caravan (trailer) park in southern NSW and affected 305 of 351 patrons, with 79 hospitalised with a Norovirus infection (McAnulty *et al.* 1993). It would appear that few private water suppliers have developed risk-based WSPs or incident management plans (NSW Health, unpublished data). To improve the management of these systems, NSW Health has provided advice to local councils and private suppliers, and has published *Private Water Supply Guidelines* that will require the development of WSPs (NSW Health 2007*a*).

Aboriginal communities

Across Australia there are hundreds of Aboriginal communities. Some of these communities receive treated drinking water from a nearby water utility. In more remote areas, Aboriginal communities are responsible for managing and maintaining their own drinking-water systems. These arrangements present a number of challenges, especially for very small communities that are a long way from service providers. In the past, inadequate water supply and sewerage systems were identified as a major factor in the poor health status of some Aboriginal communities (NAHSWP 1989). Throughout Australia there are several programs that focus on improving services for Aboriginal communities. Some of these have the specific aim of improving the capacity within Aboriginal communities for better management of drinking-water supplies and sewerage. NSW Health is working with pilot Aboriginal communities to help develop risk-based WSPs using the *Community Water Planner* CD tool.

Sydney 1998 – drinking water incident

In 1998, drinking water in Sydney, NSW became contaminated with *Cryptosporidium* and *Giardia* (McClellan 1998). The incident resulted in a series of boil-water alerts affecting more than 3 million consumers over two months. Initially, contamination appeared to be restricted to a small part of the central business district and was possibly caused by localised ingress of contaminated material. A limited boil-water alert was issued to the affected area. After *Cryptosporidium* and *Giardia* were detected in other suburbs the boil-water alert was progressively extended to cover the whole city over the next three days. The boil-water alert was gradually lifted as satisfactory test results were obtained over the next five days. Over the following six weeks there were a further two city-wide boil-water alerts issued.

Sydney is served by a series of river catchments and dams that deliver water to water filtration plants. Prior to the first and second boil-water alerts, heavy rain (the first in 12 months) fell in the catchments. One rain event caused the main storage dam (Warragamba) to fill rapidly and overflow – a very rare event in Sydney's catchment. At the time there were many potential sources of *Cryptosporidium* and *Giardia* in Sydney's catchments including sewage treatment plants, septic tanks and cattle grazing in the outer catchments. Floodwater-borne *Cryptosporidium* and *Giardia* short-circuited the main storage dam and entered the treatment plant in pulses that also produced rapid fluctuations in water chemistry (Cox *et al.* 2003). Before the incident, the dam was expected to provide an average detention time of three years (Cox *et al.* 2003).

In order to determine whether these events were causing an increase in disease, NSW Health instituted heightened surveillance through general practices, pharmacies, hospital emergency departments, pathology laboratories and nursing homes (NSW Health 1998). Two telephone surveys were also conducted of residents in affected and non-affected areas. There was no measurable increase in disease attributable to drinking water (NSW Health 1998). During the contamination events, there were almost certainly periods when the entire population was exposed. There is always a delay between sampling and results becoming available. Compliance with the boil-water alerts was variable. The telephone surveys found that, during the first and second boil-water alerts, 7% and 13%, respectively, consumed unboiled tap water. It was concluded that the *Cryptosporidium* and *Giardia* present were not infective for humans.

NSW health response protocol

In NSW, the Chief Health Officer (CHO) has the responsibility for issuing advice to the public regarding the safety of drinking-water supplies. During the 1998 incident, NSW Health convened an Expert Panel and developed an Interim *Cryptosporidium* and *Giardia* Response Protocol to assist the CHO in making the most appropriate response, including 'boil-water alerts'. The Expert Panel consists of specialists in public health, pathology, catchment management, water engineering and water testing. Following the incident the Response Protocol was reviewed and protocols developed for *E. coli* and chemical contamination (NSW Health 2007*b*).

The NSW Health *Response Protocol Following Failure in Water Treatment or Detection of Giardia or Cryptosporidium in Drinking Water* is enacted following:

a. breakdown in the water treatment system, such as failure to meet turbidity or disinfection targets;
b. contamination of the water supply; or
c. illness, potentially due to the above.

The protocol involves the following components.

(a) breakdown in the water treatment system. A failure of water treatment or disinfection triggers an investigation by the water utility. In the case of disinfection failure, the CHO considers the need for a boil-water alert where an adequate disinfection residual cannot be maintained at the last point of primary disinfection before the consumer.

The CHO considers the need for a boil-water alert in the case of treatment failure where treated water turbidity is not satisfactory and water cannot be diverted before entering the water supply system, and either:

1. there is rapidly changing raw water turbidity which cannot be improved by changing the level of offtake or water source; or
2. there has been an influx of water from a contaminated source in the catchment in the last week (even if raw water turbidity is not rapidly changing).

(b) Investigation of positive findings in treated water. The detection of *Giardia* or *Cryptosporidium* triggers an investigation (sanitary survey) by the water utility for potential failures of water treatment. There is a separate response protocol following the detection of *E. coli* (which is considered to be a more reliable indicator of recent faecal contamination). The investigation includes an assessment of:

(a) the accuracy of the findings (i.e. confirmation that parasites are present, were proper sample collection and analysis techniques used?, is the laboratory accredited?);
(b) water treatment (including flocculation, filtration and chlorination);
(c) presence of *E. coli* and other indicators;
(d) pre-treatment contamination of the raw water;

(e) post-treatment contamination of the water (e.g. local ingress of material); and
(f) turbidity in raw and treated water and particle counts, where available.

If *Cryptosporidium* is detected, immediate resampling of the affected part of the system, adjacent areas of the system and areas downstream from the affected area of treated water is carried out. If *Giardia* is detected (but not *Cryptosporidium*), NSW Health and the water utility review the conditions of disinfection in order to determine the need for resampling.

(c) Public health action. The CHO will consider the need for a boil-water alert or other public health response. The CHO may seek advice from the Expert Panel in situations including:

(a) where deficiencies are identified and it is possible that persons will consume contaminated water but the health consequences are unclear and/or;
(b) where the results of resampling indicate that the contamination is persistent, but no deficiencies are identified and/or;
(c) where contaminated drinking water is suspected to be the cause of an outbreak of illness.

In deciding on the issuing of a boil-water alert, the CHO considers:

- detected levels of contamination;
- effectiveness of current disinfection (and whether organisms may be viable);
- likelihood of identification and correction of the problem (i.e. consider findings of contamination investigation and sanitary survey);
- time and scale of exposure including the likely recency of the contamination (when were people exposed?, are they still exposed?, how many people are exposed?, estimate daily water consumption levels, are the samples representative of water that is actually consumed?);
- evidence of increased illness (or complaints about the quality of water) in the present or previous events;
- exposure of the community;
- the need to communicate accurate and appropriate information to the community in a timely and effective way;
- the community impact of any public health action; and
- the advice of the Expert Panel.

In considering the community impact, the CHO considers whether there are any vulnerable populations exposed and the possible adverse consequences of a boil-water alert, for example scalds. Protection of public health is a dominant element.

The potential responses available to the CHO include:

(a) no further public health response required and continued surveillance for illness;
(b) issuing of public reminders of precautionary measures for immunocompromised individuals (those who would normally boil their drinking water as a routine) and possibly other groups with higher risk of secondary infection (nursing homes, preschools, daycare centres);
(c) boil-water alert;
(d) public alert for need for increased hygiene measures.

(d) Lifting a boil-water alert. When deciding when to lift a boil-water alert, the CHO will review each of the factors considered prior to issuing the alert. The CHO will also take into account the following factors:

(a) the predicted clearance or flow time of clear water through the water distribution system;
(b) the need for additional testing;
(c) the need to communicate to the public which areas have been released from the boil-water alert in a timely and effective way; and
(d) the adverse impact to the community, which may be associated with delaying lifting.

DISCUSSION

Even in the absence of detected increases in illness, the boil-water alerts issued in Sydney in 1998 caused great anxiety and disruption to the community and businesses that rely on drinking water. There was intense political and media interest. Several groups took legal action to recover costs (in the region of tens of millions of dollars) from the water utility. The Sydney incident generated numerous enquiries regarding the use of water in restaurants, safety of water in swimming pools, use of water by hospitals, schools and other institutions, use of water by dentists, safety for pets and efficiency of water filters. Many of the questions arising during the incident would be common to this type of event, can be anticipated and advice can be prepared in advance (Mayon-White & Frankenberg 1989).

The finding that up to 13% of Sydney residents did not boil their water during the incident is not surprising. Surveys conducted during boil-water alerts in other countries have found that many households engage in behaviour that may increase risk (O'Donnell *et al.* 2000) and that, in the case of the fatal outbreak in Gideon, Missouri with seven deaths attributed to the consumption of contaminated water, up to 31% ignored the warnings and drank unboiled water because they either did not remember or disbelieved the order (Angulo 1997). There is a need for clear risk communication and wide dissemination of warnings and advice.

The benefits and risks of issuing a boil-water alert for *Cryptosporidium* and *Giardia* must be carefully evaluated, especially in the absence of any detectable illness. Boil-water alerts can take months to recover from and may result in loss of faith in the public water supply (Irvine & Blair 2004). A boil-water alert may only be of benefit when people are currently consuming contaminated water (containing organisms likely to cause illness) and there is no prospect that the cause can be rectified in the short term. However, where results of a test are positive for the presence of a particular hazard, but subsequent tests are negative and continued exposure to contaminants is unlikely, then there is no clear public health benefit from a boil-water alert.

The Sydney incident highlighted the difficulties in responding to *Cryptosporidium* and *Giardia* test results and emphasised the importance of a preventive risk-management approach, rather than relying on end-point testing (Davison *et al.* 1999; Clancy 2000; Hrudey & Hrudey 2004). The Sydney experience drove the development of the *Framework for Management of Drinking Water Quality* as a central element of the ADWG (Fairley *et al.* 1999). Given uncertainties with testing and the ability to detect infectious organisms, the ADWG do not recommend routine monitoring for *Cryptosporidium* and *Giardia* in treated drinking water but relegate pathogen testing to part of investigative monitoring (NHMRC/NRMMC 2004).

The Sydney incident gave NSW Health the opportunity to develop comprehensive Response Protocols to guide public health decisions, initially for *Cryptosporidium* and *Giardia* and subsequently for *E. coli* and chemical contaminants. The Response Protocols have been applied successfully to the management of incidents within metropolitan and rural water utilities. The application of the Response Protocols in country areas has provided the impetus for conducting sanitary surveys, which have identified sources of contamination and brought about improvements to drinking-water systems. Experience has shown that failure to act promptly to identify and control a waterborne disease outbreak can lengthen and exacerbate the severity of the event (e.g. the Walkerton, Canada, outbreak (O'Connor 2002)).

CONCLUSION

Communities cannot rely on monitoring of finished drinking-water quality or population-based surveillance for disease as measures to prevent outbreaks. There is a strong international consensus that a preventive risk-management approach (manifested as WSPs) is the most reliable way to protect public health. The implementation of a WSP allows risks to be identified and managed through robust multiple barriers. A WSP will benefit not only large utilities but also those that may be most vulnerable to contamination events, including small independent, remote and indigenous communities.

As part of a WSP, water suppliers and health authorities must have response protocols for water contamination and/or outbreaks. Response protocols must include clear guidance on when to issue warnings to consumers, and how these warnings are to be communicated. By definition a response protocol is retrospective: however, if implemented promptly, the response may minimise the extent of an outbreak. The pressure on health authorities to develop clear and systematic boil-water guidance will increase as utilities all over the world develop their WSPs. Response protocols need to be tested, verified and kept current and those that will be involved need to be trained in their application.

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