Better intervention strategies are needed to reduce the risk of waterborne outbreaks

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ABSTRACT

Field investigation of 27 medium to small water systems in Ontario Province has revealed a pattern of deviations in operations that is similar to those reported in the United States over the past 25 years. In this recent Ontario survey of water utilities, the key findings were: (1) a need for full cost pricing of public water supply to consumers; (2) better understanding of water treatment train performance; and (3) a need for management driven accountability to search beyond regulatory minimum requirements for safe water quality. Much of the deteriorating state of operations was a reflection of limited financial base to support an effective management programme. In the survey, small utilities were found to suffer the most from below cost operations which forced the application of a patchwork approach to water treatment and system repairs. Furthermore, small system water plant operators had rare opportunities to take part in workshops on technical issues. These utilities need to partner with the public on water supply issues for financial support to cover daily operations, infrastructure decay and emergency repairs. Ignoring system problems or applying patchwork remedies will eventually lead to unsafe water quality if the current state of affairs is not recognized as a dangerous public health risk.

Key words | distribution system integrity, drinking water, management issues, monitoring, public relations, watershed impacts

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INTRODUCTION

Recent waterborne outbreaks in Canada and the United States demonstrate that the threat to community public health still persists, partly because of lessening quality in some raw water sources, treatment barrier failures or infrastructure deterioration in the distribution system (Craun *et al.* 1991; Geldreich, 1996). For example, over the period from 1940 to 1994, there were 578 outbreaks in the United States that resulted in a total of 600,000 individuals becoming ill from drinking contaminated water (Craun and Calderon 2001). Furthermore, investigation of the causes have revealed that a variety of pathogenic agents were involved and in several cases two different agents were involved in the same out break.

Perhaps the Walkerton waterborne outbreak in 2000 that resulted in seven deaths and 2,300 illnesses from *E. coli* 0157:H7 was a wake-up call for many utilities, health officials and the public in both countries (O'Connor 2002a). Most alarming was the loss of public confidence in the municipal water service that reported some compliance issue or was the focus of a waterborne outbreak. In an effort to restore public trust in municipal water supplies within Ontario Province, the government created a Walkerton Inquiry Commission to investigate:

(a) the circumstances which caused hundreds of people in the Walkerton area to become ill and several of them to die in May and June 2000, at or around the same time as *Escherichia coli* bacteria were found to be present in the town's water supply:
(b) the cause of these events including the effect, if any, of government policies, procedures and practices, in order to make such findings and recommendations as the commission considers advisable to ensure safety of the water supply system in Ontario.

It is the second part (b) of this mandate that became the starting point for this field study: to investigate a cross-section of public water systems throughout the Province and provide recommendations for actions to be taken (O'Connor 2002b). To accomplish this part of the inquiry, the Commission created a series of expert teams to gather information on all aspects of the problem. At the initial briefing, it was specified that the investigators should not be influenced in their site visits by the findings of engineering reports required by the new Drinking Water Protection Regulations passed in Ontario in August 2000 (Ontario regulation 459/00) nor by inspection reports conducted by the Ministry of the Environment – a procedure usually done for background information during a sanitary survey. This survey was to be a truly independent investigation based on first-hand observations by recognized water experts who had no vested interest in Canadian affairs.

An invitation to participate from the perspective of a research microbiologist provided the opportunity to perform a small cross-section study of various utilities. While this report is based on two field trips (June and August 2002), the findings should not be viewed as unique to Ontario Province or to Canada, based on experiences investigating the compliance records for water supplies, laboratory certifications throughout the United States and outbreak occurrences ((McCabe *et al.* 1970; Geldreich 1971, 1975, 1996; Craun & McCabe 1973; Craun *et al.* 1991; Craun & Calderon 2001).

SURVEY STRATEGY

Achieving success in this 2-week survey had to rest on the selection of a cross-section of diverse waterworks serving communities throughout Ontario, since the total number of utilities visited would be constrained by travel time to selected sites. Selection of the cross-section of water utilities was done by Wayne Scott (recently retired from the Ministry of the Environment), who had acquired a professional knowledge of the status of water systems in the Province from years of interfacing with water plant operators on technical problems. A total of 27 waterworks in 19 communities were chosen from locations that ranged from the Canadian/American border to James Bay in northern Ontario. Factors in utility selection included: population size (large cities were not included), water source, treatment configuration, private vs. public ownership and other water system characteristics that cut across the wide range of treatment options for water supplies (Table 1).

Various management options were used by the different water purveyors to operate plants and distribution systems. In most cases, municipal personnel managed both treatment and distribution of the drinking water supply in the community; however in five cities, treatment and distribution was managed under contract with a privately owned Ontario Water Agency (OCWA). Eighteen of the water systems visited relied on groundwater sources, seven other utilities used either lakes or rivers while one system used a blend of river source and wells to meet the community needs. The population served by these waterworks ranged from 16 persons in the smallest water systems visited to 80,436 people in the mid-sized cities of Ontario (Table 2).

The mission of this survey was to identify possible problems, generic or local, that might affect the safety of drinking water in terms of treatment, compliance requirements and action response. In an effort to ensure a candid picture of operations, the staff was assured that there would be no assessment reporting of individual operator competence, deficiencies observed or identification of the utilities in the investigation to provincial authorities. The intent was to develop a mutual respect so that treatment issues, monitoring strategies, interrelationships with water authorities and the impact of compliance regulations upon management operations could be discussed.

Table 1 | Ownership of waterworks

Type of waterworks	Site visits
Regional government	2
Municipal government	15
Ontario Clean Water Agency*	5
Improvement district	1
First Nations (Native Indian tribes)	3
Ontario Government (prison)	1

*Contracted to private industry

Table 2 | Public water system survey in Ontario (June–August 2001)

Raw source	No. of systems	Water supply treatment	Population range
Wells	17	Chlorination only	16–25,000
Lakes	4	Conventional*	1,200–5,100
	1	Conventional + GAC	69,000
	1	Automated conventional	9,000
	1	Micro/ultra filtration	6,500
Rivers	1	Conventional	80,436
	1	Conventional + UV	10,000
River + Wells	1	Conventional + chloramines	9,000

*Conventional treatment = settling–coagulation–sedimentation–filtration–disinfection

To accomplish this task required the use of a structured checklist (Geldreich 1996; Geldreich & LeChevallier 1999) that covered the following areas:

- watershed management;
- raw source water quality;
- operational details of treatment processes;
- status of the distribution system (system configurations, water pressure issues, cross connection control activities, corrosion abatement, protocol for repair of water main breaks, flushing protocol, storage tank inspection frequency, record of coliform and biofilm occurrences);
- monitoring strategy and action response to unsatisfactory sample data (in raw source, treatment processes, finished water);
- management approach to staff training, interrelations with government agencies and public relations.

WATERSHED MANAGEMENT OF SOURCE WATER QUALITY

Overview

Effective watershed management can have a profound influence on source water quality. Pristine water resources (aquifers and surface waters) are becoming scarce worldwide as a consequence of humans' long-term abuses of the aquatic environment that divert poorly treated fecal wastes and industrial chemicals into source waters. In the process, deteriorating source water quality in many locations has placed a disproportionate burden on water utilities to upgrade treatment to protect public health in the community from fecal contamination and toxic chemicals.

While soil barrier protection of most aquifer resources still exists, there are significant instances where this natural barrier is becoming less effective. Much of the problem is a result of the intermittent by-passes of municipal waste discharges from expanding metropolitan communities, releases of complex organic wastes by industrial operations, drainage from mining activities, and the non-point discharges of storm water runoff from animal feedlots (cattle, hogs, poultry) located on poorly contoured fields in the watershed. As a consequence, watershed barrier protection deteriorates, surface water quality declines and associated aquifers develop variable water quality characteristics.

The signature characterization of a raw water resource is created by the natural geology of the watershed, wildlife habitation and human alterations to the land within the drainage basin. Climatic events also have an influence on the survival and transport of microbial populations into the flow of drainage water at the surface and percolation though soil into the aquifer below. These are the factors that have a major influence on the consistency of water quality.

Precluding human activity is not enough to ensure a high quality water resource.

Groundwater extracted from deep aquifers is protected from much of the influences of surface contamination by the filtering action of the soil barrier and rock strata. The major exception is the porous nature of limestone which is a poor barrier to organisms and fine particulates. Springs may also be under the influence of surface water contamination that drains agricultural pastures or wildlife areas of high population densities, thereby bringing fecal pollution into a mix with high quality aquifers. The point of outflowing spring water may be at some distance from the surface source of contamination so it is not always obvious in a field investigation. Other reasons that deep aquifers may be threatened include improper sealing of abandoned wells that provide a contamination conduit from the surface, mining activities, injection of waste into the ground, improperly constructed landfills and poor well construction practices. Such practices are often the cause of water quality deterioration in what may have been an excellent drinking water resource.

Survey observations

Many of the Ontario water systems visited did have some involvement in watershed management through membership on various committees concerned with the growth and types of activity over the drainage basis. However, there was little evidence that water supply was given a priority concern over agricultural development and community growth on the watershed. For example, two waterworks withdrawing raw water from the Grand River reported the greatest fluctuations in water quality of any of the sites visited. Turbidity and coliform fluctuations in this river are driven by inputs of soil particulates carried in stormwater runoff from farming activities and the flushing of urban concrete and asphalt surfaces during wet weather events. Operators from these two utilities also reported that, within this river basin, acid mine drainage often resulted in periodic fish kills. One utility reported that sewage treatment by-passes and industrial waste enter the river system and are not reported to the utility in time to modify treatment or by-pass raw source water withdrawal before the spill event enters the intake area.

In northern Ontario, some watersheds are controlled by First Nation communities (Native North American Indian tribes). These communities have no organized watershed management oversight because the land is considered to be 'vacant' or unpopulated by humans. This status may change for one such utility as a result of the discovery of diamonds in the vast watershed area. Since the resource appears to be extensive, it is proposed to initiate a commercial diamond mining operation within the next few years. This proposed mining activity will have an impact on the economy of the remote area and increase the demand for water supply, housing and new roads through the forested watershed. At the interview, the water plant operator was most concerned about the need to increase water supply for fire suppression in the community since most of the available surface water supply is being used to meet existing water demands.

In another part of the Province, one high quality lake is protected for raw source water through city ownership. Recreational use of this water resource is strictly limited and supported by enforceable community laws. Many of the watersheds that are used for water supply are not protected from detrimental agricultural, mining and logging operations. As a consequence, several of the water utilities that have been using minimal treatment schemes for their surface water source have abandoned these traditional water resources for groundwater extraction to improve barrier protection from the protozoan pathogens, *Cryptosporidium* and *Giardia*. Development of a well field was considered more cost effective than building a filtration plant to improve barrier protection from the pathogens.

Another waterworks was concerned that their lake water resource may not be large enough to meet new water demands as the community plans for future expansion of the population. Other utilities had water quality problems with high total organic carbon (TOC), high chorine demand, elevated manganese and iron concentrations or anaerobically derived taste and odour compounds that enter the intake from a temperature stratified lake.

Microbial quality of groundwater was generally found to be excellent but one utility reported that there are coliform occurrences in their well field when the weather is hot, possibly related to high water demand in the summer that lowered the water table thereby providing pressure differential opportunities for surface runoff to enter the well casing. Another utility was concerned that the aquifer resource was receding below pipe intake and deeper wells may be needed in the future to meet increased water extraction. One First Nations community visited had a well water contamination problem traced to leakage from a fuel oil storage tank which went undetected for months. On the positive side, another community successfully blocked the proposed use of abandon mines in the watershed as a depository for garbage brought in by trucks from Toronto. The public concern was justifiable fear of polluting the aquifer used as a water supply source.

WATER SUPPLY TREATMENT

Overview

Today, few water supply sources are of such a consistent high quality to be approved for public water supply without some specific treatment. While chlorination once provided a sufficient barrier to microbial contamination, increasing problems with poorly treated municipal wastewater discharges to receiving streams and stormwater runoff from agricultural activities can produce major fluctuations in raw source water quality (Smith *et al.* 2002). The net result has been an increased burden on basic water treatment processes. The vast majority of waterborne outbreaks, with the possible exception of some *Giardia* and *Cryptosporidium* outbreaks, are the result of very basic failures (disinfection irregularities, intolerance to elevated raw water turbidities, cross connections, etc.). Usually these failures are due to operator error in adjusting treatment requirements to changing raw water qualities. Even with the expansion of water treatment schemes into more complex and costly processes, there still exists the risk that water treatment barriers will be breached by some overwhelming pollution event or breakdown in treatment process operation.

Survey observations

Treatment configurations for water supply varied greatly. Chlorination as the sole treatment process was common for most of the groundwater sources which relied on the soil barrier for protection from protozoan cysts and oocysts. Utilities using surface water employed treatment trains that ranged from conventional treatment schemes using coagulation, sedimentation, filtration (mixed media or activated carbon) and disinfection to advanced treatment technology using membrane or ultrafiltration of a large lake.

Several of the water utilities included in the field survey do not process raw surface waters 24 hours a day, electing instead to limit operations to 8 or 16 hour periods. At these waterworks, output and storage is perceived to always exceed community demand. The reason for this management strategy is to reduce operations to one or two work shifts thereby providing a cost/saving benefit. The danger from such daily start-up operations is the uncertainty in achieving treatment barrier stability before water supply is released into the distribution system. Unstable filter beds are a particular concern because of the threat of microbial breakthrough into the drinking water supply. Operators at one of the automated systems have extended the by-pass of process effluents whenever the raw water turbidity exceeds 100 ntu during the initial start-up period. The concern is with passage of pathogens embedded in particles through the disinfection contact basin without being inactivated. Another utility recognized this concern and used an in-plant Coli Alert coliform test to monitor the impact of system start-ups every day when source water has high turbidities. Unfortunately, the test results are not instantaneous (18–24 h), but do provide a historical record of microbial barrier effectiveness during treatment operations.

Several water systems did not utilize significant disinfection contact time as required by regulations. One of the smallest systems with this problem is operated by volunteers since the community of retired people has no formal public service operations. Private wells for these homes had been found to be unsafe without chlorination so the families banded together to share a treated supply as a cost effective solution. The volunteer staff do seek advice from several water professionals who have made them aware of the treatment problem. Unfortunately, there is no stable financial reserve to pay for installation of baffles in the disinfection contact basin to extend the exposure time. Forced to be innovative, the volunteer staff planned to generate the necessary funding by holding a special needs event in the community to cover this cost and other daily system expenses.

Application of chlorine gas in water disinfection requires care and should always meet strict safety protocols.

Several years ago, personnel at one utility were exposed to a near fatal accident from a chlorine gas leak because proper safety equipment was not readily available at the site. Chlorine gas is safely used routinely by many medium to large utilities which follow special precautions for chlorine storage and provide gas masks on site as a mandatory item of apparel when changing cylinders or adjusting gas flow. In terms of cost/benefit, the smallest utilities should consider the application of a 12% solution of sodium hypochlorite as a better risk management alternative.

Chemical quality achieved from treatment of Lake Erie source water was the main focus at one utility in the survey serving a population of 69,032. Since microbial quality had never been a problem in the past, there was little interest in acquiring any further bacteriological information within the treatment train beyond the required daily coliform tests of raw source water and finished water leaving the treatment plant. This utility utilized conventional treatment + granular activated carbon (GAC). The utility management position was that the lake source was always very uniform, easy to treat for coliform bacteria and bacterial colonization or by-passes within the treatment train were not an issue. This was interesting because the GAC process relies on carbon absorption and microbial activity to remove organic contaminants in the process water. No microbiological data was made available to demonstrate the passage of elevated heterotrophic bacteria populations from the GAC process into the disinfection contact basin nor the effect warm summer temperatures might have on stimulating bacterial passage into the finished water.

DISTRIBUTION SYSTEM INTEGRITY

Overview

The final barrier for protecting water quality is the distribution system. Once drinking water treatment is complete, it should move quickly into storage tanks and out into the distribution system within a few days to prevent quality deterioration. Stagnation of the water supply encourages biofilm development, accelerated corrosion with enhanced accumulation of heavy metals in sediments, and taste and odour problems. A significant water pressure (>20 psi/137 kPa) is critical and should be present at all times, along with a sustained residual to provide a measure of protection from various cross-connection possibilities that may suddenly develop. Loss of disinfection residual is an important indicator of contamination and should be quickly investigated by further testing and flushing of all lines in that area of the distribution system (LeChevallier *et al.* 2003; Karim *et al.* 2003).

An excellent water supply cannot be sustained without attention to protected storage and delivery through a clean pipe network. Unfortunately, the service life of tanks and pipes is not infinite and water quality will not remain unaltered during prolonged storage and static retention in the pipe environment. An annual system-wide flushing programme that encompasses the entire pipe network is essential in combating the adverse effects of water quality deterioration induced by chemical corrosion and microbial colonization. Likewise, storage tanks and standpipes should be taken out of service on a 5-year cycle to flush out sediments, repair broken vent screens (to keep birds and rodents out) and do maintenance work on corrosion activity. The purpose of flushing is abatement of sediment accumulation from active corrosion sites and suppression of biofilm development that occurs in stratified water during storage, static water zones and dead ends of the pipe network. All of these situations also have an adverse impact on maintaining a disinfection residual.

Keeping water supply moving throughout the distribution system with minimal retention time (less than 1 week) will avoid accelerated biofilm development and taste and odour problems. Future projections for extending water service in the community should recognize the adverse effects of creating excessive pipe network extensions and storage capacity that far exceed anticipated growth over a 10-year time frame. Overestimates of distribution system growth will result in extended water retention in new parts of the pipe network and possible water quality deterioration unless the pipe network is flushed more intensively and designed to be free of dead-end lines by looping long pipe runs. Oversized storage tanks may lead to stratified water that creates taste, odours and coliform biofilms unless water circulation inside the tank and flow into the pipe network is accelerated periodically as a water quality measure.

Cross-connection control is another important aspect in maintaining the integrity of the distribution system.

Cross-connection prevention is complicated by numerous attachments associated with service lines: low water pressure in the pipe network (interruption of service, pipe breaks, fire suppression demand) and interconnection to private cisterns or neighbouring public water systems with water quality problems. Perhaps the greatest threat of cross-connections lies with service within community hospitals and clinics where there are many different types of water-use devices that should have effective backflow prevention. Where utilities serving resort communities have seasonal interconnections with the water distribution system of a neighbouring waterworks, there is always a concern that purchased water may introduce contaminated drinking water into the system unless these supplemental supplies are treated by booster chlorination at each entry point into the municipal pipe network.

Plumbing inspection personnel authorized by local health departments should be actively involved in a programme of inspecting all commercial plumbing systems in new construction and in periodically re-certifying plumbing at those established businesses that pose the greatest risks for backflow of wastes into the public water supply. Provincial programmes for cross-connection prevention of plumbing systems in every city need not only the mandate to conduct inspections but also the effective support of an enforceable penalty system for violators.

Survey observations

Several of the water utilities visited have resolved a problem with water quality deterioration in distribution by looping many of the dead-end lines to achieve a better flow of water. These waterworks reported that circulation of water improved free chlorine residual movement throughout the system, reduced taste and odour problems and was helpful in suppressing microbial growth in static water. Other utilities were unable to minimize the large numbers of dead-end lines because of terrain or construction costs in densely populated areas.

Information on water supply retention time and flow patterns in the distribution network were not always available for many systems. Operators that gave some travel time estimates said that these values 'were in the ball park' but not based on a careful study of water movement. More accurate information is needed to understand water movement from each storage tank during different demand periods, locate areas of periodic flow reversals, and discover the extent of slow flow areas. Water supply retention times in various zones of the pipe network should be better understood for positive improvements in water movement throughout the pipe network. This information could provide valuable data needed in developing flushing frequencies and in locating potential contamination pathways in the pipe network. It is essential that operators thoroughly understand these important characteristics of their system in order to produce a uniformly safe water supply throughout their communities.

Enquiry into cross-connection control programmes to search out and prevent potential incursions of fecal contamination was disappointing. In many of the utilities visited, this activity is the responsibility of the Building Division whose mandate is to review all new building and remodelling plans. Several utilities reported having a good communication link with this local government programme. No utilities visited reported that their local Building Divisions had a plan to revisit those sites that are always potential threats (industrial operations, car wash establishments, interconnection of private cisterns, hospitals, clinics, funeral homes, etc.). In several cities, the cross-connection control programme was delegated to the water utility which had yet to start any activity to assess the status. Another utility reported knowledge of several cisterns with interconnections to the public water system but, as a result of an adverse legal decision, the utility concluded it no longer had enforcement support to ban these interconnections to the public water supply. This anomaly reflects poor legal counsel and the failure by the court to appreciate the public risk that is created by asserting individual rights are above public health concerns.

MONITORING FOR SAFE WATER QUALITY

Overview

The purpose of monitoring is to maintain a frequent characterization of treatment effectiveness and a distribution system integrity that will ensure a safe water supply to the entire community, at all times. While many of the chemical and physical characteristics can be determined in a few minutes or a few hours, microbial characterization of indicator bacteria is complicated by the need to grow and differentiate the indicator organisms selected. In the search for pathogenic bacterial, viral and protozoan agents, even more time is needed to concentrate their low densities in a litre or more of water sample, then selectively cultivate or identify by microscopic examination. The goal in achieving an early alert to a pathogen breakthrough is further complicated by the fact that breakthroughs into water supply may occur at any time, day or night, when treatment falls below specifications, distribution integrity is compromised by physical disruptions in the pipe network or water quality in storage has become contaminated by wildlife or terrorism threat.

Since instantaneous detection of pathogenic agents is not yet a reality, various sudden changes in physical and chemical parameters should be considered as 'first alerts'. The rationale is that these potential surrogates often provide real time evidence of circumstances associated with a microbial contamination episode. Some of the monitoring signals are: sudden increases in turbidity, loss of line pressure and disappearance of a disinfectant residual. The immediate response is to give priority attention to treatment adjustments and verification of the microbiological data by appropriate testing of additional water samples from treatment basins and distribution sites, above and below the positive sample location.

Survey observations

One of the most glaring deficiencies discovered in the field survey was the often inflexible approach to monitoring water quality in public supplies. The attitude of many small and a few medium-sized utilities was one of blindly meeting the regulations with a fixed monthly schedule for sample collection and using a permanent site selection pattern that was never altered. Attempts by a few water utilities to submit some samples on different days of the month were rebuffed by the service laboratory because of their fixed schedule for meeting the needs of different clients and curtailing work over weekends and holidays. To combat this inflexibility, yet achieve some information on water quality for recent days without bacteriological monitoring, it is important to collect samples that are taken at the ends of the system each month. These site locations are often the places where residual evidence of recent microbial contamination might still persist. Several of the utilities were found to be inflexible in their selection of sampling locations. By contrast, one utility had developed an excellent approach to monitoring the pipe network by creating a pool of sample sites from which collections were made on a monthly basis in an effort to cover major areas of the system.

Small water systems face the greatest uncertainty in recognizing a potential contamination episode. Monitoring for turbidity breakthroughs was rarely done and disappearance of disinfection residuals was often not investigated or data collected was ignored. It is also essential that the data are developed from approved methods in a certified laboratory under contract to the Ministry of the Environment or by the Provincial district for the Ministry of Health. As a further safeguard, one set of samples collected during each year should be submitted to a different certified laboratory under contract to the responsible Provincial Ministry. This action would provide a quality control check by another laboratory and a second opinion on the public water utility meeting drinking water standards. Such an approach was taken by one medium-sized utility which sent a set of collected samples to a second laboratory for processing every Thursday.

Provincial health laboratories of the Ministry of Heath have limited their laboratory services to small utilities because of budget constraints. The justification is that these smallest utilities do not have laboratory capability while medium-sized waterworks have the financial resources to either have the work done by a private laboratory or have in-house laboratory capability. How often these contract laboratories or in-house laboratories are certified for their compliance to specified Provincial test procedures was not established.

Collecting the appropriate samples during each month, then promptly processing them within 30 hours is essential, as is the need to expediently report the test results back to the water authority. However, this was not universally followed. Several utilities reported problems with delivery service that caused delays in reaching the laboratory within the 30-hour time frame. Other utilities reported that laboratory reports from official samples collected by the inspectors of the local Ministry of Health unit were often delayed. This situation weakens the monitoring effort and could lead to the assumption that occasional positive coliform results are also of minimal significance. The end result is a decline in prompt action responses to investigate evidence of potential water quality problems.

MANAGEMENT ISSUES

Overview

Production of a safe drinking water supply that is always reliable and adequate for community needs plus a reserve of water supply for use in fire suppression is always a primary concern for every utility manager. Achieving these goals requires a professional staff to operate the plant and a strategy for scheduled maintenance and repairs to the infrastructure. These objectives cannot be achieved without an adequate financial base that includes a contingency fund for emergency repairs. For all utilities, this revenue base should originate from realistic fees for water service based on the metering of all customers' supply lines. Unfortunately, the real cost of water production in many smaller systems is often not realized. These systems often charge a flat rate to consumers that was established years ago and is below present day cost and must be subsidized by local government or left to crisis management using a patchwork approach to water treatment and system repairs. Eventually, these utilities begin to experience problems maintaining water quality, more frequent line repairs and increasing water loss in the distribution network. It is no surprise then that, with few exceptions, many of the waterborne outbreaks reported in North America are often associated with some of the small water utilities that serve a population of 5,000 or less.

The public has a right to know the status of their community water system. As a start, a positive strategy should include prompt responsiveness to daily print and electronic media enquires, provide reporters with press releases on utility activities such as efforts to upgrade treatment, resolve distribution network problems of taste and odours, correct problems with low water pressure, and schedule of system wide flushing of lines. A brief annual report in brochure format summarizing only key water quality characteristics compared with national standards for safe drinking water could be inserted with water utility bills. Keeping the public informed deflects erroneous criticisms and misunderstandings about their public utility.

Survey observations

The biggest issue facing the small utilities visited in this survey was an operating budget that was often not stable and frequently inadequate to take care of emergency repairs and maintenance. One utility reported that they needed Can$400,000 to extend disinfection contact time; however, there was no utility-designated revenue in their local government budget to cover the cost. For many of these small utilities, the customer base was charged a flat fee per month for water service established many years ago. Furthermore, several communities were also facing water shortages due to reduced yield from utility operated well fields, but the cheap cost of water made the public appear insensitive to water conservation requests.

Public education on water utility issues is important for achieving community support for financial issues. Some of the utilities visited were actively involved in a variety of interfaces through community projects, student visits and media reports on waterworks improvement projects. Other waterworks have made little progress in this direction, preferring to maintain a low profile. As a consequence, public confidence in these latter municipal water systems continues to erode as water quality problems arise and there was great reluctance in those communities to support any justified proposals to increase the cost for water service.

Many of the utility managers, particularly those working in systems using high quality groundwater, complained about the excessive cost of annual reports (imposed by regulations) that were often nothing more than a compilation of very stable data on all required parameters. Presenting an annual one-page summary of only those water characteristics of health interest with a brief statement of significance would contribute more to public understanding.

Another major issue identified in management of small utilities was the need for all operators to be involved in a continuing education programme on water treatment/distribution system problems and their solutions. Too often the small water plant operator was not able to participate in essential training programmes that could expand his or her work skills. The frequent explanation was lack of funds for travel to regional workshops designed for water plant operators, or the fact that there was no back-up operator available for duty during scheduled training sessions. This shortage of manpower also had an impact on some operations in terms of lack of backup for personnel during vacation periods and illnesses. Scheduling operator workshops in sparsely populated areas (particularly in the northern part of the Province) was not cost effective for organizers of training programmes. Possible solutions may be in the creation of an on-site link-up via satellite to operator oriented workshops, computer networking with experts and operators over Internet link-ups, and use of videotapes prepared by the American Water Works Association and/or other water training authorities. Unfortunately, these educational approaches by themselves do not provide the benefits of person-to-person contacts with other operators to discuss issues of mutual interest. Perhaps the use of a certified expert to be a 'circuit rider' who can provide technical support during scheduled visits to small utilities in the Province is the most realistic approach.

DISCUSSION

It is apparent from this field investigation that there are significant opportunities for an undetected breakdown in safe water production and in the protected delivery of a safe water supply to the consumer's tap. Often these occurrences do not produce a waterborne outbreak in the community because: (1) dilution of the contaminate by high quality water may reduce the pathogen density below the infective dose level; (2) persistence or accumulation of viable pathogens in drinking water is limited by low nutrient concentrations and minimal particulate shelters in this austere aquatic environment that is unlike the organic rich, fecal cell-host habitat of the intestinal tract; (3) available disinfection residuals in the potable water are often sufficient to inactivate many microbial agents; and (4) most contaminating events involve a transient pulse of fecal contamination rather than a continuous incursion of pathogens into the water supply. These factors create a false sense of confidence that water treatment and its distribution to the public are always providing safe drinking water. As a consequence, utility operators may conclude that the intensity needed to be vigilant can be relaxed since all operational parameters and laboratory data are consistently negative for signals of a potential public health threat. Unfortunately, a variety of scenarios can be found in various case history studies to demonstrate how barriers to contamination may be breached, given the circumstances at any moment.

Some utilities lose sight of the fact that compliance regulations are a minimal set of requirements to verify the safe quality of water supply. Part of the 'don't want to know' mentality of some operators is inherent in the assumption that if the regulations are met, the requirements to verify the water supply is safe have been satisfied and there is no reason to 'rock the boat' with further investigation. Added to this is the stigma of public notification whenever there is a non-compliance issue of exceeding the total coliform limit. This requirement had driven some water supply operators to carefully select 'permanent sites' on the distribution system that have a long history of meeting the coliform standard. Such a strategy avoids the risk of being out of compliance if sample collection from random sites yields several unsatisfactory test results. Fortunately such tactics were not a common occurrence but did appear to be part of the site selection strategy by a few small waterworks.

Issuing an automatic boil water order every time there is a contamination event does not solve the problem. What is needed is a re-sampling of the site(s) for fecal coliforms/*E. coli* taken together with a prompt, credible and rigorous investigation to validate evidence consistent with contaminating events. Another response to be avoided is the repeated sampling at the site for total coliforms with the hope that the problem will go away because 'the coliform result is an artefact created by sampling technique'. All operators interviewed were more apt to take the laboratory results seriously and perform some action plan such as flushing and increasing the amount of chlorine residual in the system after which other samples were submitted from the site.

Perhaps an incentive programme is needed that provides some public recognition to those waterworks who take initiatives to improve the reliability of treatment and integrity of the distribution system. The intent would be to encourage improvements by all utilities in the creation of a proactive attitude towards watershed protection, treatment innovations, safe water delivery, monitoring practices, and developing positive public relations with stakeholders in water supply. The biggest reward for many utilities is solving the financial crisis created by unrealistic user rate structures that do not support the cost of producing a safe water supply. Most often in many small to medium sized Ontario communities, the utility does not meter customer service. Instead, the utility is still charging a fixed rate below cost for water service. The consequences have often resulted in postponing infrastructure repairs, reduction in water production to 16 or 8 hour periods per day, and deficit spending to cover emergency repairs. This state of affairs can only lead to crisis management of water service as treatment processes deteriorate, more frequent line breaks occur, cross-connection possibilities emerge, and water loss leaks in the system escalate. In the worse case scenario, any of these weaknesses can become pathways to a waterborne outbreak. The findings are not unique to this Province, or to Canada alone, but can be found in various investigations reported elsewhere (Geldreich 1996; Craun and Calderon, 2001).

SUMMARY AND CONCLUSIONS

A survey of 27 small to medium water systems in Ontario Province has identified a variety of problems facing these utilities. Potential problems include declining source water quality, infrastructure deterioration of the system components, inadequate monitoring strategies and little attention to a proactive strategy to prevent breakdowns in public water service.

Key findings of the survey were: (1) the need for full cost pricing for water supply service in many of the communities visited; (2) better understanding of drinking water production that includes effective monitoring; and (3) the need for accountability to ensure safe water beyond regulatory minima. The Walkerton Inquiry contains 93 recommendations directed to meeting the deficiencies briefly discussed in this report.

What is needed are innovative solutions, new approaches, attitude adjustments to encompass a preventive approach to operating a waterworks, and more interaction with the public who are the shareholders in community health status. To that end, responsible governmental agencies must recognize a need to develop more focus on small utilities' problems and their solutions. In the absence of better intervention and guidance, many small water systems, in particular, are heading towards a status of second-class service. The exposure of these communities to greater risk of waterborne outbreak occurrence should not be tolerated.

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