Chapter 8 Monitoring and Measurement

Contents

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8.1 Introduction

In the Part 1 report of this Inquiry, I concluded that proper instrumentation and monitoring could have prevented the Walkerton tragedy. In this chapter, I examine the roles of monitoring and measurement in a properly functioning water supply system. Source water quality, treatment process control, distribution system integrity, laboratory services, inspection and enforcement, public confidence, and emergency responses all depend on accurate and timely information.

8.2 Timeliness

There is a fundamental divide in the ways things can be measured. Many parameters – such as temperature, turbidity, pressure, and flow rates – can be measured instantaneously (in "real time"). The results can be flashed from the points of measurement to central control points, where operators can adjust processes to maintain high quality. However, measuring other critically important parameters (notably those dealing with the presence of pathogens, but also including many chemical pollutants) require that samples be sent to laboratories for analysis. All laboratory tests take time – time during which people will consume the potentially contaminated water unless a substantial amount of stored, treated water is available. But storage may degrade water quality in other ways. This distinction between real-time and lagging (or trailing) measurements leads to two observations:

- Since it is currently impossible to measure microbial contamination in real time, the engineers who design systems and the operators who run them must rely on the treatment process to safeguard the water. Measuring the presence or absence of microbes can be used only as an after-the-fact method of auditing the integrity of treatment.

- As long as direct, real-time measurements are not possible, there are significant advantages to the development of indirect or surrogate real-time measures for microbial contaminants.

8.2.1 Real-time Measurement

Many critical measurements can be carried out in real time in the field. These continuous measures (known as inline measures) can be sent to remote locations, used for process control, archived for regulatory compliance and troubleshooting purposes, and summarized for regulatory and public use. Among the parameters that can be measured accurately and economically inline are the following:

- **Turbidity** is a measure of the total suspended solids in the water. This measure is important because pathogens are fine particles. They may be shielded by other suspended particles, a matter of particular importance in ultraviolet radiation (UV) disinfection.[1] Increases in turbidity in treated water often result from failures that have allowed the passage of pathogens through treatment, so it is particularly important to be able to make quick adjustments to disinfection doses.

- **Conductivity** is another measure of the water's ability to conduct an electrical current. The conductivity level indicates the amount of dissolved solids in the water: the higher the conductivity, the more dissolved solids the water contains.

- **pH** measures hydrogen ion activity in water, a characteristic that is related to the water's alkalinity or acidity. Monitoring pH levels is important for process optimization, structural maintenance (including corrosion control), and aesthetic objectives.

- **Temperature** is particularly relevant to raw water; the efficiency of the treatment process may vary with water temperature. Changes in water temperature may require adjustments in the treatment sequence. Many of the parameters that influence corrosion rates in the distribution system are temperature-sensitive. Maintenance of chlorine residuals in the distribution system is also affected by temperature, since certain chemicals work better at certain temperatures.

- **Pressure** is a basic measure of service quality for the treatment plant and the distribution system. It is especially important for the latter system,

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[1] Thus, water is usually clarified before UV disinfection. One manufacturer has linked a turbidity sensor to its UV dose monitor so that the dose can be linked automatically to changes in turbidity. The efficiency of chlorination can also be reduced when pathogens are coated with particulate matter.

since rapid changes in pressure may indicate burst mains, whereas slower changes may be evidence of leaks.

- **Flow rates** help operators ensure that each part of a treatment sequence is working as designed.[2] They help localize leaks, and they allow accurate customer billing.

- **Chlorine residual** is the amount of chlorine in the water that remains available to achieve disinfection after a given contact time.[3] Free chlorine is converted in the oxidation of organic material, a process that includes the killing of pathogens. Thus the chlorine residual is a check on the adequacy of the disinfection dose. The oxidizing reaction will slow down and eventually cease with the decreasing availability of organic material to oxidize. If a chlorine residual is measurable after an appropriate contact time, it is highly likely that disinfection is complete.

Recommendation 36: All municipal water providers in Ontario should have, as a minimum, continuous inline monitoring of turbidity, disinfectant residual, and pressure at the treatment plant, together with alarms that signal immediately when any regulatory parameters are exceeded. The disinfectant residual should be continuously or frequently measured in the distribution system. Where needed, alarms should be accompanied by automatic shut-off mechanisms.

This recommendation includes and goes slightly beyond my Recommendation 11 in the Part 1 report (p. 298), requiring "continuous chlorine and turbidity monitors for all groundwater sources that are under the direct influence of surface water or that serve municipal populations greater than a size prescribed by the MOE," to include all sources, pressure monitoring, alarms, and, where required for safety, automatic shut-off valves. I understand that the government has accepted my earlier recommendation and has moved to require some 205 wells to have chlorine and turbidity monitors in place by December 31, 2002. Given the exceptional importance of this particular barrier, the compliance date should be brought forward, if possible, and the requirement should be

[2] In treatment processes like disinfection, coagulation, and filtration, flow rates affect process efficiency, because they affect how much time is available for chemical reactions to take place. If the flow rate is too slow, the process will not be efficient; if the flow rate is too fast, the process will not be effective. Rapid changes in flow or rates outside design parameters are undesirable; flow must therefore be monitored to track such changes.

[3] The process of disinfection using chlorine is described in more detail in Chapter 6 of this report.

extended to all drinking water systems that come within Ontario Regulation 459/00. I would, however, recommend case-by-case extensions to this compliance deadline where, in the MOE's judgment, the risk is low and local circumstances make early compliance difficult.

8.2.2 Lagging or Trailing Measures

As noted above, it is technologically impossible at present to measure some contaminant parameters in real time. This is especially true for various pathogens but also for most chemical, physical, and radiological parameters. These delays occur for various reasons, including the time it takes to transport and prepare samples, the time it takes to grow cultures, and the need for sophisticated equipment that makes inline monitoring impractical.

8.2.2.1 *Microbial Parameters*

The most significant problems associated with pathogen measurement are the lag time involved in testing and, especially for protozoa, the large number of false results. Few direct detection techniques have been developed. Those that have been developed tend to be difficult, expensive, and still not fast enough to assist in process control. Most rely on the growth of cultures in the laboratory before identification tests can be carried out. Furthermore, identification is often a tedious process of elimination based on the known characteristics of each species. DNA analysis offers promise for the future as techniques are refined, but the methods available at present are too expensive and time-consuming for routine monitoring. Many of the tests require highly qualified analysts, and small variations in method can produce significant differences in results.

In some instances, interpretation can be more complicated than the test itself. Many tests return a high percentage of false positive and false negative results. Moreover, simply knowing that a pathogen is present does not give any information regarding its likelihood of infecting people served by that system or information on other pathogens that may be present.

One solution to this problem is to identify a surrogate measure, but this is not an easy task either. Any surrogate must be easy to measure, present when the pathogen is present, and present in large enough quantities to lend itself to inexpensive detection and identification. One surrogate currently used for pathogens of fecal origin is a group of organisms termed total coliforms (TC, measured in colony forming units, or cfu, per 100 mL of water counted after a specific culturing protocol). However, coliform bacteria are a large class of bacteria that share certain metabolic traits. They are ubiquitous in soil and the vast majority are entirely harmless. Total coliforms, like the even broader class captured by a heterotrophic plate count (HPC), is primarily a measure of biological activity and does not necessarily indicate fecal contamination of any kind. Nevertheless,TC became the standard surrogate measure early in the twentieth century because inexpensive tests that measured *E. coli* alone were unavailable. Today, specific tests for *E. coli* (including both the common, non-pathogenic and the less common pathogenic strains) are quicker, less expensive, and far more reliable and meaningful than the TC test. A positive *E. coli* reading is diagnostic of fecal pollution in a way that TC cannot be, because *E. coli* thrives only in the intestinal tracts of warm-blooded animals, and it exists in huge numbers in feces.

There is an important asymmetry regarding *E. coli* as an indicator for fecal pathogens. The presence of *E. coli* is a reliable indicator of the likelihood of fecal contamination, meaning that fecal pathogens may be present. Likewise, because *E. coli* is very sensitive to chlorine disinfection, the presence of *E. coli* is a clear indication of inadequate disinfection. On the other hand, some pathogens, particularly protozoan parasites like *Giardia* and *Cryptosporidium,* may be much more resistant than *E. coli* is to chlorine disinfection. The absence of *E. coli* therefore does not assure the absence of these more resistant fecal pathogens. Viruses are generally more susceptible to disinfection than are protozoa, but some may be more resistant than *E. coli*.[5]

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

[5] Enteropathogenic *E. coli* has been implicated in relatively few outbreaks of water-borne disease. The main enteric pathogens implicated in water-borne disease outbreaks in the developed world have been *Campylobacter, Giardia, Cryptosporidium*, Norwalk-like viruses, *Salmonella*, and enteropathogenic *E. coli*. In the developing world, cholera, typhoid, and hepatitis remain the primary threats. The relevant American Water Works Association manual, however, has 17 chapters on bacteria, 18 on parasites, and 8 on viruses: AWWA, 1999, *Waterborne Pathogens, Manual M48* (Denver: AWWA).

Problems with laboratory tests are exacerbated by sampling problems associated with pathogens. Micro-organisms are not uniformly distributed through a water column: when present, they are generally present intermittently and in low numbers. Samples taken from one location may or may not indicate the presence of micro-organisms in other locations. These sampling problems limit the confidence one can have in any statistical interpretation of the tests.

8.2.2.2 *Chronic Threats*

Chemical, physical, and radiological contaminants are almost always measured in a laboratory. Gas chromatography and mass spectrometry are the most frequently used methods for measuring organic contaminants. Atomic absorption spectrophotometry and inductively coupled plasma mass spectrometry are the methods of choice for measuring metals. These demanding techniques use expensive machines that must be operated by well-trained specialists. Great care is needed to separate signals, which are often exceedingly weak for trace concentrations, from background noise. This is also true with respect to measuring the radioactivity emanating from dissolved or suspended isotopes. Properly done, however, these tests can offer great quantitative precision.

8.3 Sampling

A test can only be as good as the sample on which it is performed. The location of and procedures under which the sample is taken, and the conditions under which it is transported to the lab, affect the quality and usefulness of the result. The MOE may wish to consider developing a guidance manual on the design of sampling protocols for analyses of regulated parameters that will produce more accurate and statistically representative results and allow inferences about the status and functioning of water supply systems. Those who collect the samples must have proper skills and training.

In this context, producing representative results requires going beyond taking a few samples at source, in the treatment plant, and in the distribution system. It must also entail taking measurements under conditions that challenge the system (e.g., after heavy rainfall, and at the farthest or most sluggish ends of the distribution system). It means gathering enough data to have confidence about water quality for each regulated parameter throughout the distribution system. Finally, it should include the data necessary for sustainable asset management.

In an ideal system, sampling and measurement locations would be identified using the Hazard Analysis and Critical Control Point (HACCP) framework discussed in Chapter 11 of this report. This procedure, originally developed for the food industry, focuses on key points where failure will produce the most serious impacts.[6] If implemented from source to tap, this approach would concentrate measurement effort at points that are most likely to be compromised or that reveal the most about system behaviour. The timing of measurement and the location of measurement points would aim to allow an accurate representation of the system to be monitored at any moment, to allow testing and diagnosis when things go wrong, to plan for sustainable asset management, and to respond to emergencies.[7]

Sampling design is critical to knowing with confidence both the quality of the water and the efficacy of the barriers. An overly mechanical approach could add unnecessary expense, but protocols based on HACCP and on microbial sampling under the most challenging conditions, as well as ordinary conditions, can substitute for some of the procedures that are now in place. This is one area in which MOE circuit riders, as discussed in Chapter 13 of this report, may be able to provide assistance.

At a minimum, weekly sampling of water systems should be required, as is currently the case under Ontario Regulation 459/00. This standard should include the requirement to sample certain parameters more frequently than others on the basis of a risk assessment of source water quality, which includes assessing potential sources of contamination within the watershed and the likelihood of the occurrence of contamination.

Recommendation 37: Every municipal water provider should be responsible for developing an adequate sampling and continuous measurement plan as part of its operational plan, as recommended in Chapter 11 of this report.

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[6] For a practical example, see Canada, Canadian Food Inspection Agency, 2001, *The Food Safety Enhancement Program Manual* <www.inspection.gc.ca/english/ppc/psps/haccp/manu/manue.shtml> [accessed April 24, 2002].

[7] E. Hargesheimer, for Ontario Water Works Association/Ontario Municipal Water Association, 2001, "Measurement of source and finished water quality: Review of issue 7," Walkerton Inquiry Submission.

With MOE guidance, water providers should capitalize on the nature of their raw water and historical records, where such records are available and reliable, to produce a sampling strategy that is economical and effective for their specific location. A customized sampling plan must be designed for each individual water system. In general, such plans will result in samples being taken at different times and places in order to build a complete and reliable picture of the substances in question. An individual sample must be small enough to manage but large enough to be representative. It must be handled in a manner that maintains its characteristics between the time it is taken and the time it is analyzed. Samples must also be identified clearly and recorded in a coherent manner that indicates where and when the sample was taken. As regulatory enforcement improves, questions regarding the documentation of the chain of custody (chiefly its clarity and completeness) will assume more importance, because enforcers will need the information that a carefully documented chain of custody provides. In general, the sooner a sample is analyzed after collection, the better the results of the test.

The weather is a key influence on water quality, as well as quantity. The timing, amount, and type of precipitation all affect water quality and quantity, as do snow melts, freezing and break-up, temperature, and wind regimes. Strong correlations exist between high-rainfall events and outbreaks of water-borne disease.[8] Sampling should always take place when risk analysis shows that the system is most likely to be under abnormal stress.

> The importance of the timing of sample collection is frequently overlooked and misunderstood. If the timing of sample collection misses the target event, information gained from the program will be deceptive and the best sampling techniques and laboratory quality-control practices will not improve the final results. The only way to avoid this problem is to thoroughly understand the system being sampled.[9]

Recommendation 38: Sampling plans should provide for sampling under the conditions most challenging to the system, such as after heavy rainfalls or spring floods.

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[8] F.C. Curriero et al., 2001, "The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994," *American Journal of Public Health*, vol. 91, no. 8, pp. 1194–1199.

[9] J. Bloemker and K.R. Gertig, 1999, "Water quality monitoring, sampling, and testing," ch. 3 in American Water Works Association, 1999, p. 29.

Complacency about what may be seen as a matter of routine is always a danger. The Inquiry asked two distinguished U.S. experts to visit a selection of smaller municipal water suppliers in the summer of 2001.[10] In the words of Ed Geldreich,

> Continued strings of negative coliform results over several years [have] given some utilities a false sense of security. In reality, it is normal for a water supply[,] treatment[,] and distribution system to occasionally detect coliform occurrences in a few samples each year. Several systems in this survey reported no coliform occurrences over the past 3 to 5 years. This unusual record may be due to two factors: always collecting samples from the distribution system on a specific day of the week, and maintaining a fixed pattern of sampling sites selected from the distribution system. Water utilities, particularly surface water systems and those plants that are processing groundwater [that is] under the influence of surface water, need to be more active in their dedicated vigilance for irregular contamination breakthroughs in treatment and at intermittent cross-connections in the distribution system.[11]

Recommendation 39: Ontario Regulation 459/00 should be modified to require standard protocols for the collection, transport, custody, labelling, testing, and reporting of drinking water samples, and for testing all scheduled contaminants, that meet or better the protocols in *Standard Methods*.

The volume known as *Standard Methods*[12] is the bible of sampling. It is worth noting some of the difficulties and considerations that must be taken into account in designing a sampling plan, if only because some of these considerations give rise to – or at least *should* give rise to – regulatory requirements for standardized testing. Ontario's requirements are not wholly satisfactory with regard to sampling.

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[10] E.E. Geldreich and J.E. Singley, 2002, "Ontario water suppliers: Two experts' assessments," Walkerton Inquiry Commissioned Issue Paper 24, s. 3.
[11] Ibid., p. 17.
[12] L.S. Clesceri, A.E. Greenberg, and A.D. Eaton, 1998, *Standard Methods for the Examination of Water and Wastewater,* 20th ed. (Washington, DC: American Public Health Association, American Water Works Association, and Water Environment Federation).

Samples can be obtained manually or continuously. Either method can affect quality, the former typically through human error and the latter through contamination.

The number of samples required will depend on the desired confidence level. The more samples taken, the more representative the results.

Different substances require different sampling protocols. Samples for metal concentrations should be taken in tandem – one filtered and one not – in order to differentiate between the dissolved fraction and total amounts. Problems with adsorption onto the filter must be allowed for. Samples for most metals should be acidified for preservation (pH <2). Samples for volatile substance testing should not be taken at turbulent locations because the mixing will increase loss of these components to the atmosphere.

The conditions of surface water sources vary with area, depth, time, and discharge rates. These variations must be accounted for so that representative samples are collected.

Samples from distribution systems should be taken after the system has been flushed in order to obtain a representative sample. There may be exceptions for lead and other tests that are taken under reduced or restricted flow conditions.

To avoid contamination, bacteriological sample locations must be considered with respect to sanitary conditions in the vicinity of the sample point. Moreover, a single sample is rarely adequate for any precise evaluation. Good evaluations usually require an established baseline that has been built up over a significant length of time.

Samples should be collected in sterilized, non-reactive containers. After collection, they should be refrigerated until they are analyzed. Treated water samples must be dechlorinated to prevent biodegradation. One study proposes using larger sample volumes for greater sensitivity and measuring multiple fecal indicators to improve the reliability of assay results.[13]

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[13] R.S. Fujioka and B.S. Yoneyama, 1999, “A microbial monitoring strategy to assess the vulnerability of groundwater sources to fecal contamination,” proceedings at the 1999 American Water Works Association Conference on Water Quality Technology, Tampa, Florida, October 31–November 3.

Raw water sources should be sampled as close to the point of withdrawal as possible, without being too close to the bank or bed. For surface waters, baseline samples should be collected upstream of the intake.

In distribution systems, samples should be taken at a tap that is directly connected to the main line and yet not affected by any storage units (since otherwise stagnation could interfere). The tap should be flushed before the sample is taken. Also, the tap should always be disinfected before the sample is taken, because bacteria may have been left on the tap by a previous user, a matter that cannot be judged by visual inspection. Hand-pump wells must be flushed until the water temperature stabilizes before a sample is taken. Sample locations should include dead ends and be established in cooperation with the local health authority.

Some water providers, such as those in Toronto and Waterloo, sample much more frequently than is required by regulation so as to improve their understanding of system behaviour beyond the bare minimum. This is a desirable practice.

Sampling for comparison purposes or trend analysis requires, above all, adherence to rigid sampling and analysis protocols. The U.S. Environmental Protection Agency, for example, established an Information Collection Rule (1997–1998) to collect data on protozoa. However, the techniques used were questioned, resulting in the Information Collection Rule Supplemental Surveys, which used different techniques, a rigid experimental design for the collection of more reliable data, and quality control through a chain-of-custody approach.[14] The superiority of the data gathered in the supplemental surveys demonstrates the importance of establishing a rigid sampling and testing framework as well as central control.

Ontario Regulation 459/00 mandates sampling requirements that define in detail minimum protocols for various system sizes. These requirements are more stringent than are those recommended by the federal–provincial *Guidelines* (discussed in Chapter 5 of this report) and include weekly sampling.[15] Plant owners must also comply with any additional, site-specific requirements contained either in a Certificate of Approval or in an order issued by an MOE director. Even so, Ontario's sampling protocol can be improved in several areas:

[14] K. Connell et al., 2000, "Building a better protozoa data set," *Journal of the American Water Works Association*, vol. 92, no. 10, pp. 30–43.

[15] Hargesheimer.

- HPC counts are currently required on only 25% of distribution system samples,[16] even though high HPC can interfere with some techniques for TC detection;[17]

- there appears to be an overemphasis on TC testing, when more specific *E. coli* tests are available;[18]

- standardized methods are not prescribed for *E. coli* and TC testing;[19] and

- sample storage times are inconsistent with those in *Standard Methods*.[20]

Departures from industry-standard best practices should occur only for good and well-documented reasons. In Northern Ontario, it has become accepted practice to allow bacteriological samples to age for longer than, and to exceed the temperatures that, good practice would allow.

Recommendation 40: Where remoteness dictates that samples for bacteriological analysis cannot be delivered to a lab either within regulated times or under guaranteed conditions, the Ministry of the Environment should determine the feasibility of alternative means of providing microbiological testing that meet the requirements of *Standard Methods*.

8.4 SCADA Systems

The MOE, municipalities, and water industry associations may wish to encourage greater use of automation to promote the safe and efficient operation of water systems, both large and small.

Automation offers great potential both for public health and for efficient operations: "[T]he development of reliable analytical and supervisory control equipment … can make remote operation of a treatment facility low risk." [21]

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[16] Ontario Regulation 459/00, Schedule 2.
[17] Hargesheimer, p. 21.
[18] M. Allen, cited in Hargesheimer.
[19] Ibid.
[20] An Ontario MOE technical brief states that microbiological analysis should be undertaken within 48 hours if the sample has been refrigerated and 4 hours if it has not; and *Standard Methods* requires analysis within 30 hours for coliform bacteria and 8 hours for HPC if refrigerated and within 1 hour if not: Hargesheimer, pp. 22–23.
[21] K. Mains, Walkerton Inquiry Submission (Public Hearing, September 12, 2001), transcript p. 97.

Good automation can allow human operators to concentrate on non-routine activities requiring judgment and experience while freeing them from boring and repetitive work that can lead to inattention.

Automation begins with real-time data collection. What the industry calls SCADA (Supervisory Control And Data Acquisition) systems combine telemetry (automated data transfer) with automated data collection technology and automated control systems.[22] Data from pumps, valves, motors, level gauges, flow gauges, pressure gauges, temperature and water quality sensors, alarms, and electrical contacts are collected at remote sites and sent to a central control point, where they can be monitored and evaluated before changes to operations are ordered. Measurements that fall outside norms can trigger alarms, automatic control sequences, and even regulatory compliance reports. Process adjustments can be undertaken manually or, in whole or in part, automatically.[23]

In more sophisticated systems, trend data and time series analyses can help to pre-empt potential problems and can also make a tamper-proof record of system operations. The highest level of SCADA system employs advanced decision models that make and execute decisions based on mathematical probabilities and data history.[24] Some systems can even test and diagnose their own components, alerting human operators to the need for new parts. Fewer people need to visit sites simply to monitor performance or adjust machinery, and the systems can be easily integrated with longer-term models that are used for scheduling preventive maintenance and capital replacement.

Automation offers two large advantages. It increases reliability by reducing the likelihood of human error. In addition, computers can respond quickly to water quality changes in order to optimize treatment processes – a matter of particular importance for assuring important performance characteristics like maximum turbidity removal.

There are many opportunities for implementing better SCADA systems in the water industry. They offer a route to high quality at reasonable cost. Reliability, the rapid detection and correction of adverse events, and scale economies that can bring these advantages to small systems are all important from a public

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[22] A basic reference relevant to Ontario's smaller systems is A.J. Pollack et al., 1999, *Options for Remote Monitoring and Control of Small Drinking Water Facilities* (Columbus: Battelle).
[23] Applied Technology Group, Inc., 2002, *What Is SCADA?* <www.scadaproducts.com/sp_scada.html> [accessed April 20, 2002].
[24] Ibid.

health perspective. Of course, technology is no panacea. It is especially not a substitute for trained and skilled operators. But together, skilled people and good technology are more effective than either alone.

8.5 An Improved Data Collection and Management System

8.5.1 Operational and Regulatory Data Management

At the level of the individual water supplier, a good monitoring system would integrate real-time and lagging measures to produce a picture that faithfully represents the whole system, both spatially and temporally. Instruments, testing protocols, and data handling procedures would accord with established performance standards, facilitating trend analysis and intersystem comparisons. Documenting the chain of custody and improving data-archiving procedures would allow for public accountability, supplier evaluation, and system planning. Performance summaries would be made available online or in periodically published reports to customers. The MOE's current approach is commendable in this regard, but it could benefit still further by being considered in comparison to certain U.S. utilities' practices.[25] I discuss the issue of information management in some depth in Chapter 13 of this report.

8.5.2 Consumer Reporting

In regard to customer reports, water providers should report perhaps twice a year in bill-stuffer form. More detailed information should be available to any member of the public on the supplier's Web site or at its premises. The summary bill-stuffer should, at the least, report the minimum, maximum, and average values of tests for *E. coli, Cryptosporidium*, and *Giardia* in delivered water, together with any exceedances of the regulatory values specified in Ontario Regulation 459/00 for the reporting period. It should tell the customer how and where to get further information.

The utility may, of course, also wish to report on rates, plans, and service matters that are not so directly related to public health. Although the current Ontario Regulation 459/00 does not require summary reporting directly to

[25] For instance, the Internet can be used to increase public awareness and participation. See, for example, the approach described in Delaware River Basin Commission, 2000, "Utility's Web site doubles as education tool," *Journal of the American Water Works Association*, vol. 92, no. 10, p. 14.

the consumer, such reporting has become accepted practice in the United States. Many U.S. water providers devote more time and attention than is required by regulation to assuring their customers that their water does not just barely meet the quality standards but exceeds them by increasing margins.[26]

It should be understood that the purpose of such reports is to provide consumers with comprehensible summary information, not to limit their access, or that of interested non-governmental organizations, to the raw data and reports that are on file at the MOE.

8.6 Reporting to the Ministry of the Environment

What the regulator and the public need, by way of first-order reporting, is condensed information on the water system's overall performance. With regard to drinking water quality, I suggest that this information include, at a minimum, measures of water quality as delivered to the customer.

Good SCADA systems can turn data into information. After all, the amount of data needed for minute-by-minute plant operation is vastly greater than that required for accountability, whether to the water provider's governing body, to the MOE, or directly to the public. At the least, the monitoring system should be equipped with alarms, so that regulatory exceedances can be immediately detected, corrected, and reported. Better monitoring systems will sound a warning as some critical parameter moves toward a regulatory or operational limit, and they might automatically initiate actions that will deal with the problem long before the limit is reached.

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[26] See California, Department of Health Services, Division of Drinking Water and Environmental Management, 2002, *Preparing Your California Drinking Water Consumer Confidence Report (CCR): Guidance for Water Suppliers* <www.dhs.cahwnet.gov/ps/ddwem/publications/CCR/ccrguidance1-28-02.pdf> [accessed April 22, 2002]. U.S. practice is now quite advanced in this respect. For an example of one small city's report, see City of Rapid City, 2001, *Rapid City Water Division Annual Drinking Water Quality Report: January 1, 2000–December 31, 2000* <www.rcgov.org/pubworks/water/rcccr2000.pdf> [accessed April 24, 2002].