

Drinking water supply systems: decreasing advisories and improving treatment through real-time water quality monitoring

Kerry Black and Edward McBean

ABSTRACT

Meeting the Government of Canada's renewed commitment to eliminate all drinking water advisories (DWAs) in First Nations communities within five years will require a multi-faceted approach. DWAs in First Nations communities are most often issued for equipment malfunction, inadequate disinfection and unacceptable microbiological quality; however, most DWAs are issued only on a precautionary basis. While the majority of DWAs are in place for long periods of time, they do not necessarily indicate unacceptable water quality. To this end, a method is proposed with considerable potential to decrease DWAs using real-time monitoring technology to monitor for flow rate, turbidity, pH, water temperature and free chlorine. Through real-time monitoring systems, communities can be re-empowered and gain increased control over their water systems, allowing operators to make corrections or repairs immediately, and to reduce the number of 'precautionary-based' DWAs, as well as reduce the frequency and duration of all DWAs. The potential decreases in the number of DWAs issued are estimated at likely greater than 36%, as determined from analyses of advisories.

Key words | advisories, drinking water, First Nations, real-time monitoring

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INTRODUCTION

The United Nations has recognized that access to safe water is a basic human right but despite worldwide attention to this issue, Indigenous communities in Canada continue to lack access to safe drinking water (United Nations 2010). It has been reported that from 2004 to the end of 2014, approximately 65% of First Nations communities in Canada experienced at least one drinking water advisory (DWA) (Levasseur & Marcoux 2015). As a further indication of the ongoing issues of DWAs, as of September 30, 2017, there were 144 DWA in effect in 98 First Nations communities across Canada, excluding British Columbia and the Saskatoon Tribal Council (Health Canada 2017). The number of advisories has increased from the reported 130 DWAs in 85 First Nations communities, in November, 2016 (Health Canada 2016). As an example, as of September

30, 2017, there were 15 boil water advisories (BWAs) and four do not consume (DNC) advisories in effect in 19 First Nation communities in British Columbia (which includes water systems with five or more connections and smaller water systems that have public facilities (FNHA 2017)). Over the past 10 years, the number of DWAs have continued to climb, with many communities on lengthy water advisories. Some communities continue to have DWAs periodically issued over several months, with no regular source of safe drinking water being provided. These various examples are clear evidence that there are substantial issues related to DWAs in First Nations communities.

As is apparent from the preceding, DWAs in First Nations communities are frequent and persisting. There is increasing pressure from both communities and government to address

what has been deemed as an unacceptable situation. As part of a commitment to improving quality of life for Indigenous people in Canada, the Prime Minister committed to eliminating BWAs within five years, to be achieved by expending 1.8 billion dollars CAD towards strengthening on-reserve water and wastewater infrastructure, as well as 141 million dollars CAD over five years to improve water monitoring and testing (Government of Canada 2016). The Government of Canada recently announced a lifting of 14 long-term DWAs in First Nations communities across Canada, including a renewed commitment to reducing by half the remaining advisories within three years, and all advisories within five years (Liberal Party of Canada 2016).

In response, since there are cases when DWAs are issued as a precautionary measure; an alternative strategy is to disaggregate precautionary events and actual disruptions to drinking water quality. A strategy is needed and, as described in this paper, reliance upon real-time monitoring is an option for early identification of problems that can help to reduce both the frequency and duration of DWAs, and alert operators to problems about which they might not have been aware.

This paper describes an approach which has the potential to significantly reduce the number of DWAs in First Nations communities. While it is clear that multiple approaches will be necessary in order to address the diverse nature of DWAs in communities across Canada, the proposal herein is a possible strategy for identifying when issues of unacceptable water quality conditions are *actually* occurring in individual communities, and avoid those incidences where historically, the advisory was issued for precautionary reasons that are not necessarily related to inadequate water quality.

METHODOLOGY

A cross-sectional study was undertaken of available information across data available on First Nations communities across Canada to describe trends and characteristics of DWAs issued in First Nations communities. There is significant heterogeneity across First Nations communities in Canada, including geographical location, socio-economic conditions, population, remoteness and other factors. Caution

was observed in making generalized statements about the state of drinking water systems in First Nations communities.

Two primary methods were used as part of this study: review of available DWA data and semi-structured interviews. First, data sources are limited with respect to DWAs for First Nations drinking water systems across Canada. Health Canada reports DWAs in First Nations communities south of the 60th parallel, excluding both British Columbia and the Saskatoon Tribal Council. Both organizations have recently taken authority for issuing DWAs and reporting on them. In addition, Health Canada does not report on DWAs that are issued for systems with five connections or less, including individual wells (Health Canada 2017); this is important because the number of DWAs reported is far less than the actual number of DWAs in place across First Nations communities in Canada. North of the 60th parallel, Territorial Governments typically have jurisdiction over drinking water, with support from Health Canada. The numbers of DWAs are not currently reported.

Due to the limited information available, this study also relied on information obtained from individual First Nations organizations and community members as part of a larger research project. Research methodologies relied upon in this research followed the principles of OCAP – ownership, control, access and possession – through which research can enable ‘a way for First Nations to make decisions regarding what research will be done, for what purpose information or data will be used, where the information will be physically stored and who will have access’ (NAHO 2007, p. 1).

Second, as part of a larger research project, a series of semi-structured interviews were held with community members and First Nations organizations in Ontario, Saskatchewan, Alberta and British Columbia. The research project that encompassed this work was approved by the University of Guelph Review and Ethics Board Protocol.

In addition, where possible, linkages were made from each DWA to data reported in the 2011 National Assessment of First Nations Water and Wastewater Systems – National Roll-Up Report. This report summarizes the results from a national assessment to determine deficiencies and operational needs, and identify strategies for improvement.

Characteristics of DWAs, including the reasons for issuance, were summarized using tables, figures and counts.

Plots were generated to illustrate monthly or annual variations, as well as identify trends. Note that counts using percentages were a means to describe monthly, seasonal or annual trends. Because of multiple reasons for DWAs in First Nations communities, and a lack of clarification on how and why certain DWAs are issued, the study relied on qualitative data obtained through interviews for additional clarification.

DWAs IN FIRST NATIONS COMMUNITIES

There are three types of DWAs: boil water advisories/orders (BWAs/BWOs); do not consume advisories/orders (DNCAs/DNCOs), also called 'do not drink' advisories/orders (DNDAs/DNDOs); and 'do not use' advisories/orders (DNUAs/DNUOs) (Health Canada 2016). Regardless of the type of advisory issued, it is obvious that the frequencies of DWAs (and the various subcategories) are unacceptably high in Indigenous communities. It is also important to recognize that there are many reasons that may trigger the issuance of a DWA. Specifically, across all Canadian communities in 2015, 78% of BWAs were issued on a precautionary basis due to problems with drinking water equipment or processes, and according to Environment and Climate Change Canada (ECCC).

Most BWAs are issued because the equipment and processes used to treat, store or distribute drinking water break down, require maintenance, or have been affected by environmental conditions. This broad array of reasons includes issues such as broken water mains, planned system maintenance, power failures or equipment problems. In some cases, extreme weather or heavy rains may cause the quality of surface or ground water sources to temporarily worsen, challenging the drinking water treatment system. BWAs issued for equipment and process related reasons are generally issued before any actual decline in drinking water quality and are in place until conditions return to normal (ECCC 2016, p. 6).

The precautionary nature of the DWAs indicates that the frequency of DWAs in communities may not necessarily be appropriate when there is no actual deterioration of the quality of the water being delivered. There may be, therefore,

the potential to decrease the numbers of DWAs being issued, on the basis that it is of utmost importance to issue DWAs when the water is not actually safe to consume, as opposed to for the DWAs which are just precautionary.

Health Canada works with First Nations communities south of the 60th parallel to monitor water quality by testing drinking water for bacteriological, chemical, physical and radiological contaminants (Health Canada 2009). Tests are carried out by a Community-Based Water Monitor, a Health Canada Environmental Health Officer (EHO), or a First Nations community member. If drinking water quality is unsatisfactory, with respect to the National Guidelines for Drinking Water Quality, Chief and Council are notified, which means it is the responsibility of Chief and Council to issue a DWA in the affected community (Health Canada 2009).

As of 2011, the National Assessment reported that 17% of communities had no treatment or chlorination in place. According to the assessment, the different treatment types across communities in Canada, including no treatment in place, are highlighted in Figure 1. Direct use (i.e., no treatment) is most common in British Columbia (where these sites are typically viewed as having 'pristine water sources'), whereas Ontario, for example, only has four cases of direct use with no treatment in place.

Overall, the mean duration of DWAs reported between 1995 and 2007 was 343 days (Health Canada 2009). Health Canada has reported that DWAs attributed to

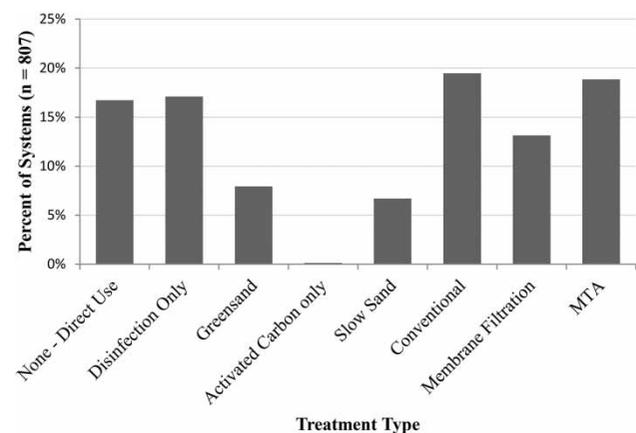


Figure 1 | First Nations community water treatment (Source: Neegan Burnside 2011). MTA refers to a municipal type agreement, where a First Nation community has a partnership with a surrounding municipality for delivery of drinking water.

inadequate disinfection or disinfectant residuals post-treatment had the longest mean duration, at 590 days (2009). This would suggest that these disinfection incidents are not necessarily unexpected or ‘surprise’ system failures, but rather chronic issues with providing adequate disinfection. Similarly, the reason of ‘Operation of the system would compromise public health’ also had a mean duration of 590 days. Microbiological quality, source water quality and equipment-related advisories had mean durations of 361 days, 324 days and 318 days each, respectively. As of October 31, 2016, the majority of DWAs (69 total) were in place for over five years (Figure 2). While these may be reasonable grounds for issuing a precautionary DWA, they do not necessarily indicate unacceptable water quality. According to Health Canada (2009, p. 6), ‘It is noteworthy that no advisory has ever been issued due to epidemiological evidence that drinking water is or may be responsible for an outbreak of illness.’

According to Environment and Climate Change Canada (2016), BWAs are issued when ‘the microbiological quality of drinking water is suspected or confirmed to be compromised, meaning disease-causing micro-organisms, such as bacteria, viruses or parasites, could be in the drinking water’. The advisories are precautionary in that these BWAs could also be due to water main breaks, planned maintenance, power failures or other equipment problems. Typically, these advisories are ‘generally issued before any actual decline in drinking water quality and are in place until conditions return to normal’ and hence may be

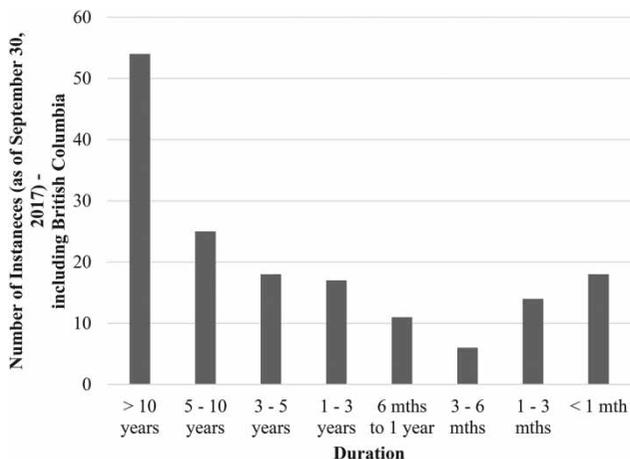


Figure 2 | Duration of DWAs in First Nations communities (including British Columbia).

precautionary in nature (Environment and Climate Change Canada 2016).

DWAs can serve as a proxy for access to safe, reliable and clean drinking water (Hrudey *et al.* 2006; Patrick 2011). While DWAs are one way of assessing the situation in communities across Canada, there are limitations to using DWAs as a proxy for reliable access to safe drinking water, including inconsistent reporting behaviours, the precautionary nature of advisories and reporting timeliness; ‘very few measures are available to monitor progress toward improving access to safe and reliable drinking water in First Nations communities’ (Isfeld 2009, as cited in Galway 2016).

With respect to the duration of DWAs in First Nations communities, the most recent data available from Health Canada indicate that out of the 144 DWAs currently in place, 101 of these DWAs have been in place for over a year (Health Canada 2017). Table 1 highlights the recorded causes of DWAs across Canada from 2010 to 2015. According to data obtained from Environment Canada, the majority of advisories for all Canadian communities relate to issues with equipment and process (Environment and Climate Change Canada 2016). Advisories issued for other microbiological parameters relate to:

‘...changing conditions inside the drinking water system that typically do not represent a health risk to consumers. Under this category are total coliform bacteria and turbidity. Total coliforms are a broad family of bacteria commonly found in the environment and turbidity is a measure of the cloudiness of water caused by particles.

Table 1 | Causes of BWAs in all Canadian communities (First Nations included, as well as municipalities) from 2010 to 2015^a

Cause of BWA	Percentage of BWAs (for all of Canada)					
	2010	2011	2012	2013	2014	2015
<i>E. coli</i>	8	5	5	7	5	5
Other microbiological parameters (e.g., total coliform)	28	18	18	17	14	17
Equipment and process	64	77	77	76	81	78

^aBased on data obtained from Environment and Climate Change Canada (2016).

When unusual or elevated levels of these water quality parameters are measured in the drinking water system, the cause is investigated and the findings may contribute to the decision to issue a boil water advisory’ (Environment and Climate Change Canada 2016).

Based on available data (Figure 3), 74% of advisories in First Nations communities as of October 31, 2016, have been in place for over a year, with the remaining 26% considered short term, as defined by Federal government, as being in place for less than a year. While 133 advisories were in place as of October 31, 2016, in First Nations communities, an additional 24 advisories were issued and rescinded within the month, for a total of 157 advisories.

Figure 3 shows the duration of the DWAs issued and rescinded within one month, in October 2016. In total, 24 of the 157 DWAs (15%) that were issued in First Nations communities in October 2016 were issued and rescinded in less than a month. On average, for those advisories issued and rescinded within the month of October, the average DWA was issued for 10 days, with a median of 8 days (Figure 4).

According to SaskWater, the Province of Saskatchewan’s water regulator, precautionary advisories are most often issued during service and maintenance and are issued under these circumstances because the quality of water cannot be confirmed (SaskWater 2016). In this case,

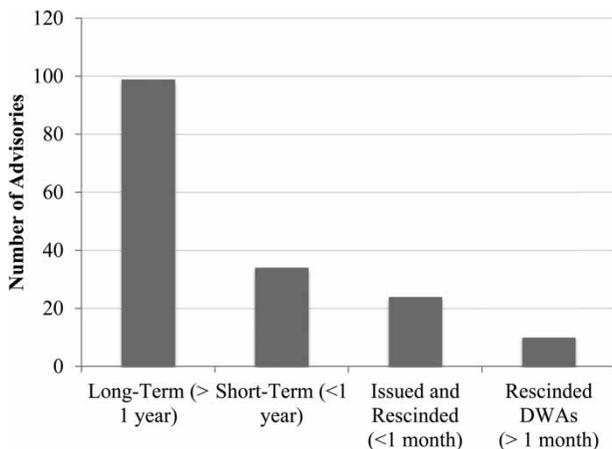


Figure 3 | Status of DWAs in First Nations communities across Canada, excluding British Columbia, as of October 31, 2016 (Health Canada 2016). The ‘Issued and Rescinded’ category refers to DWAs issued in October 2016, and also rescinded in the same month.

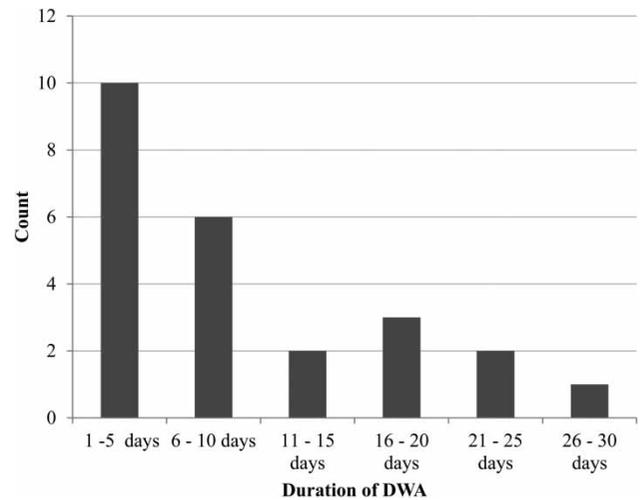


Figure 4 | Duration of those DWAs in First Nations communities that were issued and rescinded within the month of October 2016.

the advisories remain in effect until two consecutive laboratory samples, 24 hours apart, confirm the water meets regulations.

The data presented in Table 1 illustrate the situation across Canada for all communities. With respect to First Nations communities, similar trends for causes of DWAs such as equipment malfunction and microbiological quality occur. However, lack of disinfection (which could mean no disinfection in place or insufficient disinfection in place) or inadequate disinfection residuals is a major cause for issuing a DWA in First Nations communities. According to data from First Nations communities from 1995 to 2007 (Figure 5), the top three causes for DWAs in First Nations communities were: unacceptable microbiological quality (based on water quality testing results); inadequate disinfection or disinfection residuals; and equipment malfunction (Health Canada 2009).

Nevertheless, further disaggregation of data is needed in order to understand which microbiological parameters exceed drinking water guidelines, and where precautionary DWAs are issued because there may be impairment in the quality of drinking water. It is difficult to obtain detailed DWA information, particularly because the information is typically withheld to protect individual communities. It has been noted that ‘Canadian water advisory data lack coverage, timeliness and consistency, making it difficult to draw fair comparisons across regions or between First Nations

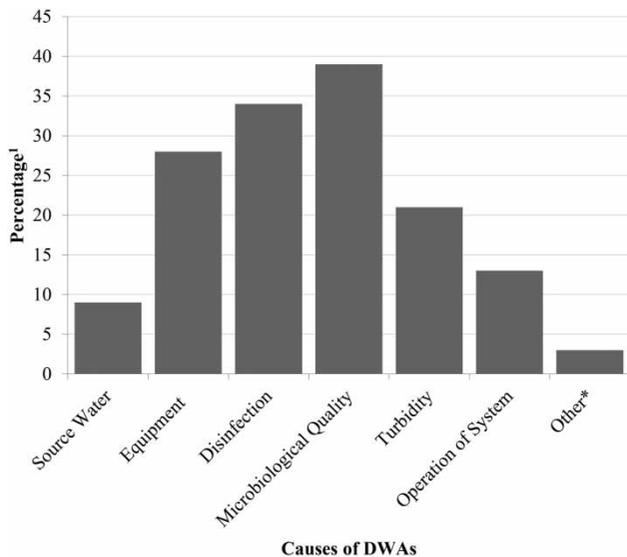


Figure 5 | Causes of DWA in First Nations communities. *Reported reasons for advisory issuance as of December 31, 2007 ($n = 939$) note that there can be more than one reason for a given advisory and that therefore the number of reasons ($n = 939$) exceeds the number of advisories ($n = 646$).

and non-First Nations populations' (Isfeld 2009). However, there has been increased pressure by external stakeholders to release more detailed information on the cause of DWAs in an effort to better understand the root causes and underlying reasons for the high rate of DWAs in First Nations communities.

REAL-TIME MONITORING: A POSSIBLE APPROACH

Worldwide, there has been significant use of online monitoring and early detection systems to detect contaminants. Technology has advanced substantially, including development of web-based technologies and advancements in online monitoring (Reed *et al.* 2010). Robust and reliable real-time technologies are available to measure physical and chemical characteristics of raw and finished water, including pH, turbidity, iron, manganese and chlorine (van der Gaag & Volz 2008).

Typically, laboratory-testing methods are slow, resulting in delays in response time; for these measurements, there are limitations to providing proper public health notice and protection. While there is evidence of improved laboratory technologies for rapid testing for water quality

parameters, it is real-time monitoring which provides the opportunity to ensure timely response and to improve system management, rather than to wait for laboratory results. Data obtained through real-time monitoring have the potential to be easily accessible by the operator in a timely fashion.

According to Storey *et al.* (2011), 'despite recent advances in biological monitors and microsensor technologies, there is no universal monitor for water quality monitoring', and therefore it is generally accepted to monitor a variety of parameters. Typically, pH, chlorine, temperature and turbidity are monitored using on-line instrumentation (Frey & Sullivan 2004). There is evidence that real-time monitoring of chlorine residual correlates to disinfection performance for susceptible pathogens. Monitoring of chlorine at different locations has the potential to be amenable to characterize chlorine residuals at different locations. Real-time monitoring has the benefit of providing early notification to changes in water quality conditions (Ziegler *et al.* 2006; Wagner 2009). In addition, real-time monitoring data on water quality allows for improved understanding of the current effectiveness of the *in-situ* treatment processes (Wagner 2009). To date, there is no universal monitor for water quality monitoring or contaminant detection (Storey *et al.* 2011).

The technology for real-time monitoring is used in many different applications. Glasgow *et al.* (2004) refer to real-time monitoring systems that are being installed for drinking water reservoirs with problematic cyanobacterial blooms. Rodriguez *et al.* (2002) mention use of biosensors for rapid monitoring of primary-source drinking water, especially for sunlight-exposed drinking water systems, although the focus in this case is on chemical warfare agents. Lambrou *et al.* (2014) have shown that new sensors can measure 'high impact contaminants' such as *Escherichia coli* or arsenic, at low concentrations for early warning and detection.

Real-time monitoring technologies are not without their disadvantages including needs for regular maintenance, the level of technical expertise required to interpret the information and the inevitable false alarms. There is additional training/capacity required to install these systems, as well as potential instrumentation problems and malfunctions. It has been noted that water utilities have difficulty managing large quantities of data and 'translating them into

meaningful information for operational processes' (van der Gaag & Volz 2008, p. 3).

Real-time monitoring technology can monitor a range of different parameters. Currently, the technology is frequently used for monitoring physical parameters such as flow rate, turbidity, pH and water temperature, as well as chemical and biological parameters such as free chlorine, fluoride and spectral adsorption (van der Gaag & Volz 2008). Changes in characteristics such as turbidity can provide indications that something within the treatment system has failed, and can be an important tool in helping operators with early identification of treatment train issues. Free chlorine is an important characteristic for monitoring, as low chlorine and chlorine residuals have been shown to be one of the major reasons for issuance of a DWA in First Nations communities.

Real-time monitoring in First Nations communities

Addressing DWAs in First Nations communities in Canada necessitates a strong partnership between communities and governments. The use of real-time monitoring data is a mechanism through which a community can regain control over their water systems. As was indicated above, some water quality testing can be done outside the community, but this typically involves considerable lag time between the time of testing and the delivery of results.

The First Nations Technical Services Advisory Group (TSAG) in Alberta argues that real-time monitoring systems can allow First Nations communities to have real-time access to their own drinking water quality, allowing them the opportunity to respond in real time to issues that may occur (TSAG 2012). Other benefits of real-time monitoring systems include: the opportunity to increase the safety of drinking water; real-time alerts to operators in the event something goes awry; an additional level of security; mitigating the risk of water contamination; and added features to ensure reporting and regular maintenance is conducted (TSAG 2012).

According to a 2012 report by John Duncan, through a contract with TSAG, Indigenous and Northern Affairs Canada invested \$10.1 million CAD in broadband connectivity and infrastructure to develop remote water monitoring capacity for First Nations water systems in Alberta. As of

March 31, 2012, remote monitoring systems were installed and became fully operational, providing real-time monitoring of water quality to 57 First Nations water treatment plants. This continued in 2012/2013 with further installation of real-time monitoring technology. According to Vaughn Paul, CEO of TSAG (Parliament of Canada 2013),

'We've installed remote water (quality) monitoring devices in every First Nation water treatment plant in Alberta. They're quite unique in their design and implementation. They don't use reagents or chemicals to do the testing and the monitoring. They give us real-time information on the quality of drinking water as it leaves the water treatment plant, using a sophisticated model and algorithm.'

TSAG also uses a remote water monitoring portal to allow for: real-time monitoring and aggregation of First Nations data; remote identification of variances and alarm conditions for plant operators; and fast and accurate reporting of water quality data to stakeholders (TSAG 2015). In addition, according to TSAG, it can allow operators to instantly know about water quality issues without having to be at the plant, and the early detection system helps to reduce frequency and severity of water quality incidents (TSAG 2017). All real-time monitoring data are housed in a centrally located website (rwms.tsag.net) which allows those with access to view the data at any time. According to TSAG, the systems installed include four monitoring probes that measure pH, total suspended solids, free and total chlorine, colour, temperature, chemical oxygen demand (COD), biochemical oxygen demand (BOD), electrical conductivity, dissolved oxygen, ammonium, and nitrate as nitrogen, which are connected to a computer with specialized event detection software that can detect abnormalities or departures from typical operating levels (TSAG 2017). The software 'continuously measures water quality parameters at set intervals and sends out an alarm if parameters fall outside of a specified range. The data are collected in real-time and are transferred to an information network that links all First Nation water treatment plants to the Alberta Supernet' (TSAG 2017).

Their mission, according to the TSAG remote monitoring water portal, is to provide 'real-time based water quality information of Alberta First Nations. Through fast

and correct actions from detection of abnormality to recovery of water quality, we will help the communities keep the best water quality' (TSAG 2017). In 2013, the federal government invested \$4.3 million CAD towards the development and implementation of the Remote Water Monitoring System delivered by TSAG in partnership with their Circuit Riders Training program, to respond to recurring issues at water treatment plants including staff turnover, improper maintenance and repair, and troubleshooting and response time (AANDC 2012). The hope was that this remote monitoring would help identify potential problems more quickly and alert authorized personnel immediately (AANDC 2012). Further information is required to understand the long-term benefits of real-time monitoring, and whether these treatment plants experienced less frequent advisories. The Province of Alberta currently has 13 advisories in place (Health Canada 2017). According to most recent data, as of September 30, 2017, 46% of these advisories have been in place for less than one month, 31% have been in place for up to three years, and the remainder (23%) have been in place for over five years. However, as noted through conversation with TSAG, many community DWAs are unreported because they are systems with less than five connections, and a majority of these are private wells.

Since the program has started, there have been issues that have prevented the real-time monitoring units from accurately reflecting water quality in some communities, including low operator capacity, technology aversion, source water quality and ageing infrastructure (TSAG 2017). For example, in some communities, poor source water quality creates challenges for probe accuracy and have been identified as systems to be removed from the pilot project until underlying water quality issues are resolved (TSAG 2017). As this was the first phase of the project, next steps include heightened focus on training operators for monthly maintenance of probes, and development of training videos and resources (TSAG 2017). As the program continues, it is expected that more information will be available on the number of DWAs that have been reduced or eliminated.

Other recent examples in real-time monitoring use in Ontario First Nations communities include the Safe Water Projects in Deer Lake, Fort Severn and Poplar Hill First Nations, which were previously on BWAs for close to 1,000 days over the past 10 years (Wilson 2015). In 2013,

the federal government invested \$1 million CAD for the pilot project in these five communities (INAC 2016). Through the Keewatinook Okimakanak (KO) Northern Chiefs Council's Safe Water Project, Triton Intelligence Water Surveillance systems were installed, which deliver water quality results in real time to operators (Kelly 2016; Safe Water Project 2016). The five units are being connected to monitoring equipment in the Keewatinook Centre of Excellence in Dryden which is capable of displaying and archiving the data from the units (INAC 2016). According to available information, the three communities of Deer Lake, Fort Severn and Poplar Hill are no longer on DWAs (Safe Water Project 2017).

In a public statement, Minister Bennett, Indigenous and Northern Affairs Canada highlighted the Department's recent work in Pic Mobert First Nation and Slate Falls First Nation. In June of 2016, the Minister highlighted that the new water treatment plant would put an end to long-term BWAs in the Pic Mobert community and Slate Falls First Nation, which has had nine BWAs that have been in place for 12 years. Further clarity is needed, to understand the impacts of these investments on reducing BWAs, especially the investments in real-time monitoring.

Real-time monitoring data – an example

As an example, real-time monitoring data were obtained from sample communities. Figure 6 shows an example of real-time turbidity data experienced at a small community in southern Ontario. In this case, real-time monitoring technology is characterizing treatment performance at various stages including pre- and post-filtration, and finished water quality. Figure 6, for example, shows the turbidity values for the finished water quality; real-time monitoring can alert the operator to any issues that might arise, as a result of a sudden spike in turbidity. Hence, the operator can address whether components of the treatment system need to be modified, chlorine dosages need to be altered, or other operational fixes that might be required to ensure that clean and safe drinking water continues to be produced. In this example, the operator was able to look into the issue, and double-check that all systems were running correctly, or make modifications as needed. In both

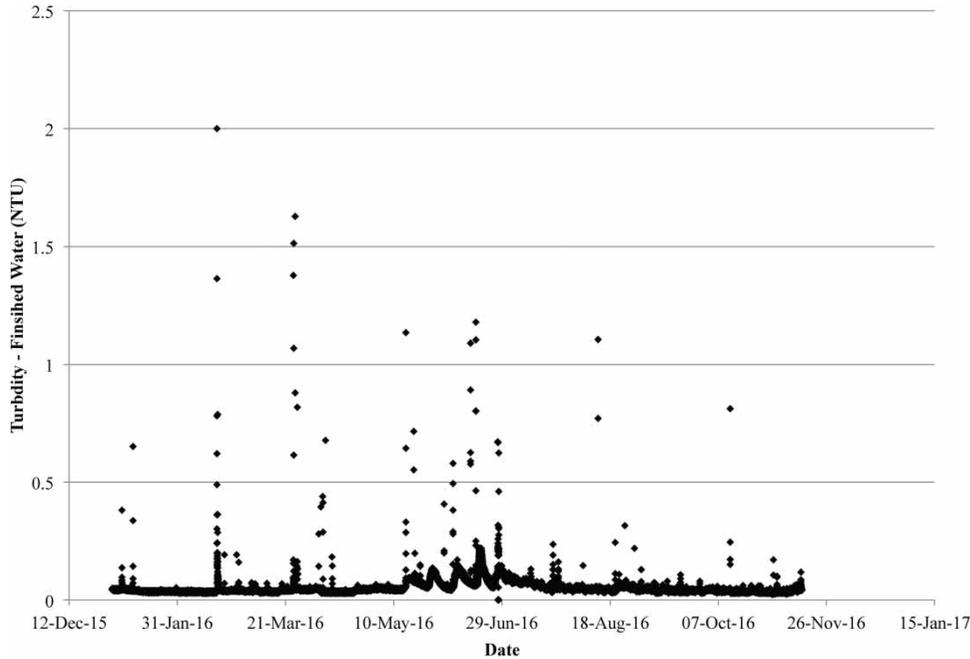


Figure 6 | Sample real-time finished water turbidity data.

cases, a minor operational issue was the cause of the discrepancies observed.

If a system alarm was to be set to send an alarm for any abnormal turbidity values, it is clear from [Figure 6](#) that several incidents would be reported to the operator. If a setting of 0.5 NTU were to be set as abnormal, the operator would have received 34 alerts between January and November, 2016. While 0.5 NTU is still below the 1 NTU value set by the Drinking Water Quality Guidelines, 0.5 NTU is obviously an abnormal result for this particular plant, which typically operates around 0.05 NTU. In this case, 11 cases were observed over the same period where the effluent turbidity exceeded the guideline values ([Table 2](#)). However, it is clear from these data that due to the frequency of monitoring of elevated turbidity values, changes in treatment performance could be observed at much smaller values.

Similarly, as seen in [Figure 7](#), real-time monitoring technology in this community was monitoring the pH level of finished water.

During this period, the operator would have been alerted to six instances where the pH of the finished water dipped below 7.0, on February 18 and June 27, 2016 ([Table 3](#)).

Enhanced operator and community-based control

Increasingly, engineering consultants that work with First Nations communities include real-time monitoring as part of their packages in order to help in the ongoing operation of treatment plants, and to troubleshoot problems, without

Table 2 | Real-time turbidity monitoring data

Turbidity events (> 1 NTU)	
Date (Log)	Turbidity value observed
18-Feb-16	2.00
25-Mar-16	1.63
24-Mar-16	1.51
24-Mar-16	1.38
18-Feb-16	1.36
17-Jun-16	1.18
15-May-16	1.13
12-Aug-16	1.10
17-Jun-16	1.10
14-Jun-16	1.09
24-Mar-16	1.07

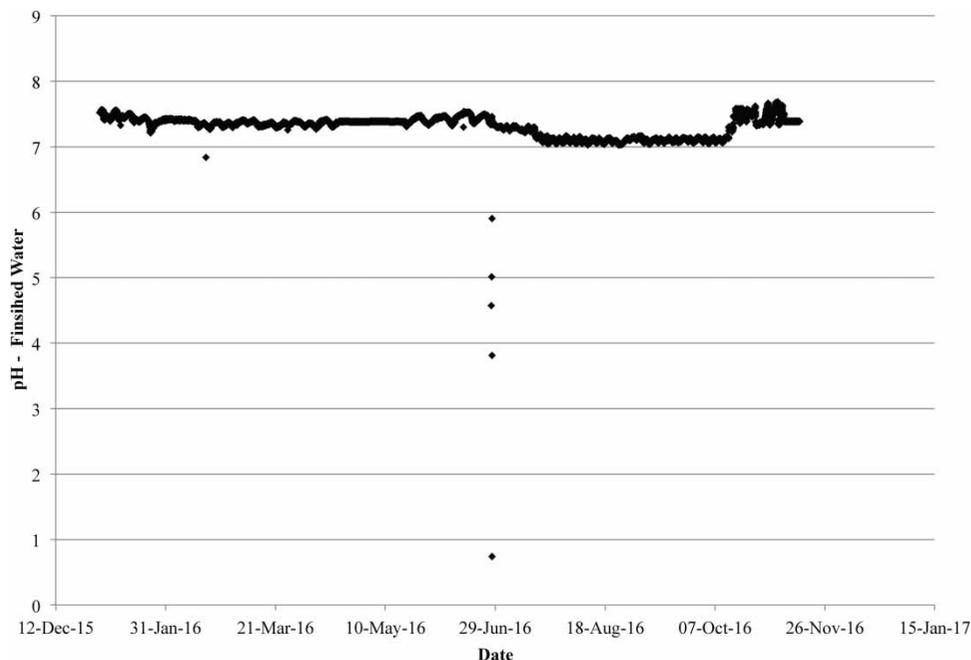


Figure 7 | Sample real-time pH data.

Table 3 | Real-time pH monitoring data

pH events (<7.0)

Date (Log)	pH value observed
27-Jun-16–11:59 am	0.74
27-Jun-16–1:59 pm	3.81
27-Jun-16–6:59 am	4.58
27-Jun-16–7:59 am	5.01
27-Jun-16–12:59 pm	5.90
18-Feb-16–8:59 am	6.84

having to visit the site directly. Operators in the past have commented on the benefit of having the ability to take a second look at their treatment performance, to help them troubleshoot, and as a way to train new operators. It is important to note that cost is an important parameter to take into account as technologies for real-time monitoring can be expensive, and may be too expensive for some First Nations communities, so suitable funding would be needed.

The concept of using real-time monitoring technology as a tool for community empowerment was noted in the recent work of the Safe Water Project, previously discussed.

According to KO’s Public Works Manager, real-time monitoring has provided an avenue for communities to assert control over their water systems, allowing communities to ‘start owning what happens in their community, rather than relying on somebody else to come and fix things for them’ (Northern Ontario Business 2016).

There are, however, some concerns and challenges to using real-time monitoring to address DWAs. There is concern from some community members that real-time monitoring systems may pose threats in terms of a third-party ‘big brother’ watching over communities, as well as issues over liability. Several community members, interviewed as part of a larger research project at the University of Guelph (Black & McBean 2017), indicated that they had concern with being watched from the outside, from people who may not have specific community context or who may be judging the operator’s performance. One community member noted,

‘I would be concerned about who has access to this information, how it might be used, and whether it would be used against (the community).’

Some comments were related to an increase in real-time monitoring technology being offered as part of a package

deal when consultants install newer treatment systems in communities. Consultants can include this feature as a way to provide guidance and enhanced security, and assist with any troubleshooting that may be needed. Often, this is viewed as a positive addition, providing operators with troubleshooting assistance in the short term, while they are working to get certification, or while they are learning a new treatment system. However, some community members noted that this can also be viewed as a community not having full control or autonomy over their water treatment, and having to rely and depend on external consultants. There was also a comment pointing to a general distrust of technology, the issue with information being available online and, ultimately, a concern for privacy. Community members noted,

‘(Real-time monitoring) is a great feature, and I love being able to check how the system is working, but sometimes I do worry whether someone will access this information to check-in on how I’m doing, how the system is running... and maybe they might make changes on their own, without notifying the operator who is working on the plant.’

‘You have to be careful about how this information is shared, and who is ultimately the owner of this information.’

Several community members commented on the issues of liability. If a third-party consultant has access to this real-time monitoring information, and if they are providing consultation on the treatment system, there was concern as to who was ultimately responsible if any issues were to arise. It would be necessary to have a clear understanding of responsibilities.

‘You need to know if an alarm goes off, who is responsible and what happens if you can’t answer it right away.’

This comment speaks more to the reality in many First Nations community. One community member noted that water operators in Indigenous communities often have multiple roles (in some instances, a water operator also manages the wastewater plant, or other public works activities such as snow removal). There is also the question of whether there is a backup operator, as in the absence of a backup

operator, they cannot necessarily respond to alerts right away. In this case, there was concern that the operator would be held liable and/or responsible if a public health issue were to arise. There would therefore need to be a system in place for responding to alerts in the event that the primary operator is otherwise occupied, or not available.

There is an argument to be made that real-time monitoring serves as a tool for a community to empower itself to be more pro-active against possible issues in its water treatment system. When operators and community members have access to real-time monitoring technology, it enables the community to take more initiative in the running of their treatment plant, to address system issues right away in order to minimize issuance of a DWA. Over time, this information allows operators to be more accustomed to the typical performance of the plant, such that small disturbances are easily noticed, and rectified.

Potential benefits for First Nations

Through real-time monitoring systems, it is proposed that both the frequency and duration of DWAs can be reduced, through the re-empowerment of communities, including increased control over water systems. Real-time monitoring would allow for: immediate notification and improved process and control; reduction in DWAs related to equipment malfunction and planned outages; and opportunities for enhanced training and capacity building.

As was discussed, a clear advantage of real-time monitoring technology is the ability to be alerted to potential issues in the treatment process that could provide early signals to operators. The technology helps a community to monitor treatment performance such as disinfection or other operational issues, which would alert operators to potential problems or issues much more quickly so they can be addressed immediately. However, given that this is a technology-based solution, caution will be needed in order to address the potential for false negatives and false positives. Further research is needed to address the potential impact on the issuance of DWAs.

As was previously discussed, DWAs are issued to protect public health because drinking water is either potentially unsafe, or confirmed to be unsafe (Health Canada 2017). Precautionary DWAs can also be issued for communities that

may be at risk of contamination (e.g., groundwater supplies under the influence of surface water), or for known and planned maintenance and repairs to distribution systems (Leblanc 2017). The First Nations Health Authority in British Columbia indicates that precautionary DWAs are issued, for example, during emergency repairs or when a community lacks staff to support proper operation. Based on the numbers reported in the previous figures, estimation of the potential effectiveness of using real-time monitoring data to reduce the frequency and duration of DWAs can be made. According to Figure 5, one-third of the reasons for issuing a DWA in First Nations communities relate to equipment-related issues (as noted above) and can be treated as precautionary DWAs. In this case, real-time monitoring would provide operators with immediate updates as to the quality of the treated water, and whether drinking water quality was actually compromised, as opposed to precautionary.

In addition, 12% of the cited reasons for DWAs relate to operation that may compromise public health, which can also be treated as precautionary DWAs and may benefit from real-time monitoring technology.

Galway (2016) notes that a large number of DWAs from 2004 to 2013 were issued due to high levels of turbidity, primarily from surface water sources. These high turbidity values have been shown to reduce the effectiveness of water treatment, as well as contributing to microbial growth in source waters, increasing the risk of waterborne illness (Health Canada 2005; Mann *et al.* 2007; Galway 2016). This is the type of situation where real-time

monitoring could help to alert operators to changes in source water quality (most often associated with spring and fall seasonal surface water changes) and would provide an opportunity for operators to adjust treatment, provided that adequate treatment processes exist to respond to the elevated turbidity in the source water.

Based on these data, Table 4 summarizes an assessment of the potential benefit of real-time monitoring technology for the reduction of frequency and duration of DWAs. These numbers were analysed based on available data from Health Canada on the nature of DWAs in First Nations communities.

The estimated percentage of DWAs issued for precautionary reasons were chosen based on previous reports and personal communication with subject matter experts. Although the available data are dated from 2007, more recent personal communications confirmed that, on average, 30% of DWAs that are issued each year relate to equipment malfunction (Leblanc, personal communication 2015). Based on the direction of Environment and Climate Change Canada, 100% of these advisories were deemed precautionary (ECCC 2016). Equipment-related DWAs, whether long-term or short-term, are likely more precautionary advisories, and would benefit from real-time monitoring technology to determine whether an advisory is necessary.

Similarly, according to available information, 70% of DWAs related to the reason that ‘operation would compromise public health’ and are short-term advisories of less than one month (Leblanc 2016). These short-term advisories are likely precautionary DWAs, and would also benefit from

Table 4 | Per cent reduction in DWAs from real-time monitoring

Cause of DWA	% of reported reasons for advisory issuance ^a	Estimated % of those DWAs issued for precautionary reasons	% reduction in DWAs ^b
Equipment malfunction	28%	100%	19.3%
Operation would compromise public health	13%	70%	6.3%
Turbidity	21%	15%	2.2%
Lack of disinfection or disinfection residual	34%	15%	3.5%
Microbiological quality	38%	15%	3.9%
Deterioration in source water quality	9%	15%	0.9%
		Total	36.0%

^aNote that there can be more than one reason for a given advisory and that therefore the number of reasons ($n = 939$) exceeds the number of advisories ($n = 646$).

^bAs advisories are listed for more than one reason (for example, according to available data, there were 939 reasons cited for the 646 advisories issued between 1995 and 2007), this number is adjusted by a correction factor of 0.69 (646/939) to reflect this discrepancy. This adjustment is based on data obtained from Health Canada (2005).

real-time monitoring technologies. The estimates for the remaining causes of advisories were selected based on a conservative estimate of 15%, which is estimated as the percentage of DWAs that may be precautionary.

It should be noted that real-time monitoring represents only one tool towards helping to reduce DWAs and re-empowering community-based operators for increased control of water treatment plants. It is also important that sufficient funding is present to address fundamental needs (i.e., ensuring adequate treatment is in place). Real-time monitoring provides one avenue through which DWAs can be addressed.

It has been estimated that over 90% of DWAs (in Ontario First Nations communities) that are issued are precautionary; real-time monitoring can help to reduce a proportion of these DWAs (Makie, personal communication, February 2017. Regional Environmental Health Manager, First Nations and Inuit Health Branch, Health Canada, Government of Canada 2017). Based on the analysis summarized in Table 4, it is estimated that real-time monitoring has the potential to reduce or eliminate approximately 36% of existing DWAs. Real-time monitoring data can also help to reduce the overall duration of DWAs, by alerting operators to issues in a more timely manner, and therefore potentially reducing the time it takes to address issues.

It would be essential to ensure proper policies are in place to support this type of initiative, including oversight, which could be covered by existing Health Canada environmental health officers. In this way, real-time monitoring technology could provide a benefit to both the community, as well as to the regulating body.

CONCLUSION

The Government of Canada recently announced a lifting of 14 long-term DWAs in First Nations communities across Canada, including a renewed commitment to reducing by half the remaining advisories within three years, and all advisories within five years (Liberal 2016). Inadequate access to safe and reliable drinking water for First Nations across Canada continues to be a top priority; however, there remains a lack of information on how best to proceed. A multi-faceted approach is needed to address the diverse range of DWAs plaguing First Nations communities across Canada.

As part of a larger research project, this specific study examined real-time monitoring as one potential tool to help reduce the frequency of DWAs. However, it is noted that this should be combined with efforts to address existing deficiencies in policy, which have been addressed in previous research work (Black & McBean 2016a, 2016b).

Reducing DWAs through real-time monitoring technology could mean that the focus can be placed on those communities which are facing real and urgent water quality issues, rather than having these issues aggregated with precautionary DWAs. Specifically, it could allow for the triaging of urgent DWAs, versus precautionary DWAs that are issued without any certainty on whether there is a real risk to public health. It is expected that real-time monitoring technology could contribute to reductions in a number of DWA categories including: alerting the operator to changes in source water quality; alerting the operator to equipment malfunctions; monitoring finished water quality during any upgrades or power failures; alerting the operator to microbiological issues (depending on the type of monitoring technology used); alerting the operator to changes in turbidity so that adjustments can be made; monitoring finished water quality; and monitoring water quality in the distribution system. Based on analysis, it is estimated that real-time monitoring has the potential to reduce either the frequency or duration of likely more than 36% of existing DWAs.

Real-time monitoring therefore promises to be a more sustained solution to decreasing drinking water treatment advisories in communities. However, eliminating DWAs is only one of the necessary steps toward the provision of clean and safe drinking water in First Nations communities. A concerted effort is needed to address policy gaps and regulatory issues as part of addressing drinking water quality in First Nations communities. The technology allows for enhanced training of new operators, faster response times to issues, and the opportunity to use remote monitoring for those communities that are isolated or do not yet have capacity to monitor drinking water treatment performance, in order to address chronic and systemic issues. The use of real-time monitoring technology as part of a holistic and First Nations-centred approach to addressing drinking water treatment issues is one way of addressing access to clean drinking water for First Nations.

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