Source Water Contaminant Detection Workshop: Early Warning and Response

Considerations for examining the technical and economic feasibility of implementing an early warning monitoring system

Purpose

The information in this fact sheet is provided to assist West Virginia drinking water suppliers as they implement the source water protection planning requirements set forth in West Virginia Code Chapter 16.

Background

In response to a chemical spill on January 9, 2014 in the Elk River in Charleston, West Virginia, lawmakers passed legislation to protect drinking water supplies statewide by decreasing the risk of source water contamination from above ground storage tanks (ASTs) and improving utility resiliency to effectively deal with spills should they occur. A workshop was held on August 19, 2014 to provide West Virginia drinking water utilities with information on meeting the requirements of West Virginia Code Chapter 16. The workshop addressed requirements for updating or completing source water protection plans and public water utility monitoring requirements. The workshop further focused on the technical and economic feasibility of implementing an early warning monitoring system.

By bringing together water sector experts to discuss existing contaminant monitoring technologies, the workshop provided an overview of the newest monitoring approaches and expert opinions on deployment feasibility. Although continuous real-time monitoring was discussed in depth throughout the workshop, it was noted that it is not the only method for early detection of contaminants in source water.

Protecting Source Water – Early Warning Monitoring and Response Systems

Implementing an early warning monitoring and response system may be approached in different ways depending upon the water utility's resources and threats to the source water. This fact sheet describes the following components of an early warning system that should be considered by utilities as they examine the technical and economic feasibility of implementing these systems:

I. Baseline Monitoring
II. Alternatives for Real-time Source Water Monitoring
III. Real-time Sensor Monitoring System Considerations
IV. Consequence Management
V. Communication and Planning

I. Baseline Monitoring

Baseline monitoring is an initial step that should be implemented to monitor ambient source water quality and establish baseline conditions against which anomalies can be evaluated. Baseline monitoring can include basic data collection and analysis activities as well as more advanced, continuous on-line sensor monitoring applications. Basic data collection can include grab samples on a regular or periodic basis to analyze for specific parameters in the water. Regardless of the type of monitoring (continuous or grab), source water samples should be collected throughout the year to better understand the baseline water quality conditions and natural seasonal fluctuations. It should also be noted that it will take at least six months to one year to develop sufficient data to understand baseline source water quality and be able to detect anomalies.

Workshop participants stated that monitoring for traditional water quality parameters would provide adequate baseline data for future early detection of contamination incidents. Water quality parameters suggested for baseline monitoring include dissolved oxygen (DO), temperature, pH, total organic carbon (TOC) and ultraviolet (UV) absorption as a surrogate for TOC. Monitoring of changes in chlorine demand in the treatment process can also support the establishment of baseline conditions.

Workshop participants also highlighted that other agencies collect ambient water quality information that could be made available to a utility to provide baseline information. For more information on these data, refer to the Ambient Water Quality Monitoring[i] presentation available on the West Virginia Source Water Contaminant Detection Training website[ii].

II. Alternatives for Real-time Source Water Monitoring

The purpose of real-time source water monitoring is to detect changes in water quality relative to the established baseline (see Section I) in sufficient time to determine the cause of the change and take corrective action if necessary. This includes detecting source water contamination incidents in time to mitigate the consequences of the incident to the utility and its customers. Specific goals and objectives for the monitoring program should be established and used to select a real-time monitoring approach that best meets those goals and objectives.

The most common approaches to source water monitoring include:

- Continuous monitoring of conventional water quality parameters (e.g., pH, conductivity, temperature, turbidity, dissolved oxygen) using either a sensor-based flow-through or buoy system.
- Continuous monitoring using advanced instrumentation such as on-line UV-Visible spectral absorption or total organic carbon monitors.
- Continuous monitoring using biological indicators of toxicity such as fish, clam, and daphnia monitors.
- High frequency (at least hourly) grab sampling and analysis using advanced instrumentation such as gas chromatography/mass spectroscopy.

Of the most common approaches mentioned above, the workshop discussion focused on complex advanced monitoring applications that have been implemented in some source water systems in the U.S. and globally. These systems often involve the use of advanced sensor technologies and equipment to perform continuous monitoring for harmful contaminants and offer real-time or near real-time data reporting from sensors directly to utilities or watershed managers. While costs associated with implementing these advanced water quality monitoring technologies may be high, watershed partnerships can enable multiple entities to share the financial burden in return for basin-wide or watershed-scale data sharing.

For example, the Ohio River Sanitation Commission (ORSANCO)[iii] monitoring network includes numerous monitoring systems along the Ohio River and its tributaries. Some of the advanced ORSANCO applications include robotic monitoring systems that analyze continuously with little human interaction after placement of the instrument (Figure 1). These applications can also include advanced measurement initiatives that monitor for parameters such as temperature, conductivity, DO, pH, turbidity, chlorophyll, and flow.

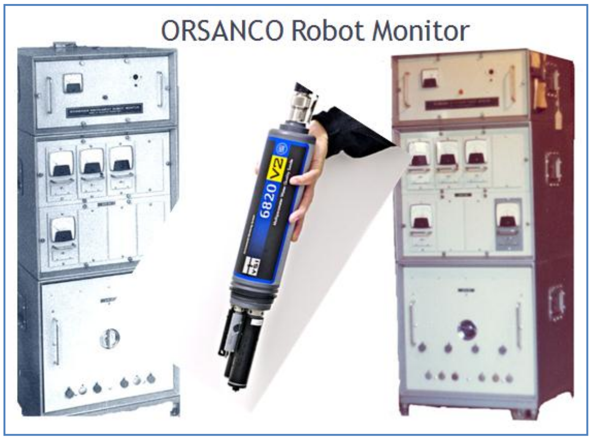
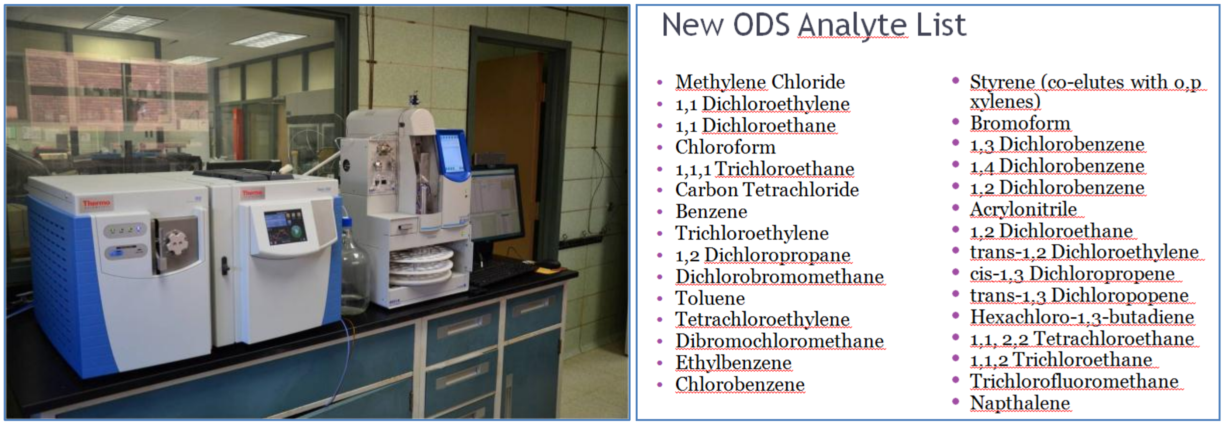


Figure 1. ORSANCO Monitoring Equipment
Source: Workshop Presentation by Jerry Schulte, ORSANCO, August 19, 2014.

Another example of ORSANCO's advanced monitoring network is their Organics Detection System (Figure 2). This in-situ monitoring network utilizes mass spectrometry instrumentation to monitor and analyze approximately 30 volatile organic compounds (VOCs) across multiple states within the Ohio River Basin. Collecting data from 16 active stations, this network monitors more than 1,000 miles of river water. In 2008, Congress appropriated funding to upgrade this system, and in 2013, more than 4,500 raw river water samples were analyzed. This type of more complex monitoring system allows for near real-time communication between source water sensors and water utility operators.



New ODS Analyte List

- Methylene Chloride
- 1,1 Dichloroethylene
- 1,1 Dichloroethane
- Chloroform
- 1,1,1 Trichloroethane
- Carbon Tetrachloride
- Benzene
- Trichloroethylene
- 1,2 Dichloropropane
- Dichlorobromomethane
- Toluene
- Tetrachloroethylene
- Dibromochloromethane
- Ethylbenzene
- Chlorobenzene
- Styrene (co-elutes with o,p xylenes)
- Bromoform
- 1,3 Dichlorobenzene
- 1,4 Dichlorobenzene
- 1,2 Dichlorobenzene
- Acrylonitrile
- 1,2 Dichloroethane
- trans-1,2 Dichloroethylene
- cis-1,3 Dichloropropene
- trans-1,3 Dichloropopene
- Hexachloro-1,3-butadiene
- 1,1, 2,2 Tetrachloroethane
- 1,1,2 Trichloroethane
- Trichlorofluoromethane
- Napthalene

Figure 2. Thermo Gas Chromatograph with Mass Spectrometer Detector (GC/MS) and Organics Detection System Parameters
Source: Workshop Presentation by Jerry Schulte, ORSANCO, August 19, 2014.

III. Real-time Sensor Monitoring System Considerations

There are many benefits to implementing sensor-based continuous monitoring technologies including obtaining real-time data, enhancing early warning capabilities, and reducing reliance on utility staff labor. The large quantity of real-time source water quality data can also inform treatment process operations and optimization. However, if a utility decides to implement a more advanced monitoring network, there are factors such as costs, data management, and false alarms that should be considered.

a. Costs

Real-time monitoring can be accomplished using a variety of instruments. However, capital, labor, and operation and maintenance (O&M) costs vary based on the instruments selected and can range from approximately $2,000 to $10,000, annually (see Table 1). Real-time sensor-based technologies present a variety of opportunities to reduce labor and O&M costs. For example, it is often more cost effective to implement on-line sensors for data collection, rather than spending money on labor costs associated with traditional field data collection or monitoring efforts. Furthermore, there are opportunities for multiple communities to combine financial resources to purchase equipment and share O&M and data management costs.

Oversight, management, and training costs are also key considerations because without them, real-time monitoring operations could not effectively produce and analyze data reliably to initiate appropriate emergency response actions.

Instrument	Parameters	Annual O&M Labor	Annual O&M Cost[1]	Annualized Capital Cost[2]	Total Annual Cost[3]
GE-Sievers 900	TOC	30 hours	$5,643	$4,312	$9,955
Hach Astro 1950	TOC	40 hours	$5,556	$3,880	$9,436
S::Can Carbo::lyser	UVA surrogate for TOC	4 hours	$360	$1,417	$1,777
YSI 6920 DW Sonde	Cl2, pH, COND, TEMP, TURB, ORP	40 hours	$3,643	$1,849	$5,492
Hach WDMPsc	Cl2, pH, COND, TEMP, TURB	20 hours	$1,891	$2,584	$4,475
Siemens (USF) Depolox 3+	Cl2, pH	20 hours	$1,170	$639	$1,809

Table 1. Annual Operations and Maintenance Cost Exerperience, EPA's Water Security Initiative

[1] Includes cost of consumables, service contracts, and labor at $40/hr.; [2] Assumes a 5% cost of capital and a 7 year life expectancy; [3] Total Annual Cost = Annual O&M Cost + Annualized Capital Cost

Source: Allgeier, S.C., Hall, J., Rahman, M. and Coates, W. 2010. Selection of Water Quality Sensors for a Drinking Water Contamination Warning System. In proceedings of the 2010 AWWA Water Quality Technology Conference.

While costs are often a limiting factor for utilities when developing monitoring systems, it was concluded by workshop participants that utilities do not necessarily need to utilize complex, advanced monitoring technologies to have a successful baseline and early warning monitoring system. For example, the River Alert Information Network (RAIN) [iv]in the Ohio River Basin employs monitoring systems to protect a watershed for over two million people along the Allegheny, Monongahela, Beaver and Youghiogheny Rivers in northern West Virginia and southwestern Pennsylvania. RAIN monitors water quality in near real-time and sends electronic updates to RAIN headquarters to alert downstream

RAIN partners about potential contamination threats. RAIN partners monitor for common contaminants such as conductivity, pH, and temperature. Some RAIN partners also monitor for total suspended solids (TSS), DO, oxidation-reduction potential (ORP), turbidity, phosphates, nitrates, or ammonia. In addition, RAIN conducts a series of outreach programs to inform the public about the importance of source water protection. These types of monitoring networks and public outreach can provide significant downstream protection in the event of a contamination incident.

b. Data Management

Real-time sensor technologies offer water utilities the ability to collect more data than ever before; thus, effective data management is critical to ensuring that early warning systems are successful in the protection of source water. Given that utilities can collect more and more data continuously with sensors, understanding how best to manage that large amount of information will be key to finding a data anomaly and deciding upon appropriate emergency response actions in a timely manner. The workshop identified data management as an on-going need. While there are some commercially available products to manage and analyze real-time water quality data, interpreting the data and analytical results requires trained personnel who are knowledgeable of the instrumentation and data being generated.

c. Identification of False Alarms

Early warning system are often criticized for raising a large number of false alarms. However, a number of event detection algorithms are available that can reduce false positives without sacrificing sensitivity. A 2013 EPA study, *Water Quality Event Detection System Challenge: Methodology and Findings*[v], provides a summary of the performance of several event detection systems.

Regardless of the degree to which an event detection algorithm has been optimized to reduce false alarms, they will occur at some frequency. A systematic investigation process is needed to quickly and efficiently discriminate between true and false alarms. This process is codified in the 2008 EPA operational strategy, *Water Security Initiative: Interim Guidance on Developing an Operational Strategy for Contamination Warning Systems*[vi].

IV. Consequence Management

After implementing an early warning monitoring system, a water utility may be faced with data which indicates a change in the quality of source water. That utility should consider the following consequence management principles to confirm whether a threat is credible and decide on appropriate response actions:

Credible Determination:
1. Determine whether or not the water is contaminated
2. Establish the identity of the contaminant
3. Determine contaminant properties
4. Establish the extent of contamination

Response Actions:
1. Limit the spread of contamination
2. Limit exposure of the public to contaminated water
3. Limit adverse health impacts

a. *Emergency Response Plans and Exercise Scenarios*

Emergency response plans and tabletop exercise scenarios are also useful in preparing utility staff to better respond to a contamination incident. These measures can ensure that watershed partners develop collective actions based on early contaminant detection. Below is a list of resources that exist to help utilities develop and update emergency response plans and conduct spill exercise scenarios:

- State Drinking Water Program All-Hazard Preparedness, Mitigation, Response and Recovery Checklist (EPA, 2013) [vii]
- Drinking Water Advisory Communication Toolbox (CDC, 2013)[viii]
- How to Develop a Multi-Year Training and Exercise (T&E) Plan (EPA, 2011)[ix]
- Tabletop Exercise Tool for Water Systems: Emergency Preparedness, Response, and Climate Resiliency (EPA, 2011)[x]
- Water Security Initiative: Interim Guidance on Developing Consequence Management Plans for Drinking Water Utilities[xi]
- Water Security Initiative: Interim Guidance for Developing Risk Communication Plans for Drinking Water Utilities[xii]
- Water Security Initiative: Guidance for Building Laboratory Capabilities to Respond to Drinking Water Contamination[xiii]

b. *Response Sampling and Analysis*

If source water or distribution system contamination is suspected, possibly due to an alert from an early warning system, it will be necessary to identify and quantify the contaminant. In many cases this will require sample collection and analysis. Without thorough planning for these critical activities, it will be difficult to conduct them in a timely and reliable manner. EPA's 2013 *Water Security Initiative: Guidance for Building Laboratory Capabilities to Respond to Drinking Water Contamination*[xiii] provides information and guidance on planning for response sampling and analysis.

V. Communication and Planning

Regular communication and planning between upstream and downstream utilities, emergency responders, and other watershed partners can ensure preparedness in the event of major changes in source water quality. Developing partnerships creates a network to transmit information quickly.

a. *Watershed Collaboration*

As demonstrated by the ORSANCO and RAIN examples above (see Sections II & III), collaboration at the river basin or watershed scale can benefit multiple users. Monitoring networks that span multiple source waterbodies promote early detection and act as a contamination warning system for many utilities. In addition to real-time monitoring, data from required monitoring efforts, enhanced security monitoring, customer complaints and public health surveillance information from throughout the watershed can serve as early warning mechanisms. Furthermore, collaboration among basin or watershed partners distributes the financial burden of costly equipment among multiple water utilities and users.

b. Spill Notification

Although water utilities regularly test for various contaminants, the frequency may not provide for an early warning as water quality can quickly change. Support from upstream water utilities is helpful as they may be able to provide advance notice when levels of certain contaminants are higher than the standards set by EPA or states. These exceedances can occur because of changing weather patterns (e.g., heavy rainstorms) or an accidental spill of a hazardous substance. Spill notices alert downstream water utilities of a potential emergency or contamination incident when changes in source water quality conditions occur.

c. Risk Communication

If there is a risk of customer exposure to contaminated water, it may be necessary to issue public notification of use restrictions (e.g., do not drink/do not use). Furthermore, status updates will need to be provided to the public and media during this stressful time. Under these circumstances, principles of effective risk communication should be applied to public communication to ensure that the message is clear and appropriate. Templates and message maps can be developed prior to an incident to help expedite external communication. Guidance on risk communication is available in EPA's 2013 *Water Security Initiative: Interim Guidance on Developing Risk Communication Plans for Drinking Water Utilities*[xii].

Summary

According to West Virginia Code Chapter 16, utility source water protection plans must be submitted to the West Virginia Department of Health and Human Resources (DHHR) on or before July 1, 2016. DHHR will be releasing a schedule to facilitate utilities' submissions of source water protection plans starting in July 2015. DHHR staff will review and approve, reject, or suggest modifications to the source water protection plans within 180 days of utility submission.

Baseline monitoring information is a first line of defense against source water contamination, allowing water utilities to detect anomalies before harmful contaminants are introduced into drinking water systems. Protecting drinking water and public health has been vastly improved by the use of on-line sensor technologies and advanced real-time monitoring networks, as these tools allow a utility to detect incidents shortly after they occur and respond sooner.

Based on the information in this fact sheet, the following items should be considered by utilities as they work to address the requirements of West Virginia Senate Code Chapter 16.

- Utilities should define their goals for early warning monitoring and design their monitoring strategy or network around them.
- Monitoring for basic water quality parameters can provide baseline data for future early detection of contamination incidents. Parameters should be chosen after considering the possible sources of contamination in the watershed.
- All potential early warning signals of source contamination should be considered (e.g., upstream spill notifications, customer complaints, and data from local public health agencies), not just real-time water quality monitoring data.
- A better understanding of the costs and benefits associated with different monitoring approaches and parameters is needed, as the costs associated with implementing more advanced, real-time sensor monitoring technologies may be high.

- Watershed partnerships enable multiple entities to share the financial burden in return for watershed-scale data sharing.
- Fostering watershed-scale collaboration also offers the co-benefit of shared monitoring responsibilities.
- Develop consequence management and emergency response plans in coordination with watershed partners before monitoring begins to ensure proper procedures are followed to understand if, when, and where a contamination threat may exist.
- Holding response exercises with partners based on a variety of contamination scenarios are helpful in building an understanding of stakeholder roles and responsibilities in the event of a contamination threat.
- Utilities do not necessarily need to utilize costly advanced, real-time monitoring technologies to have a successful early warning monitoring and emergency response plan.

Contacts and Links for Additional Information

Scott Rodeheaver, West Virginia Bureau of Public Health
Phone: 304-356-4270
Email: Scott.J.Rodeheaver@wv.gov or EEDSourcewaterprotection@wv.gov

For the full list of workshop presentations, please visit the West Virginia Source Water Contaminant Detection Training website.

References

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[v] USEPA. *Water Quality Event Detection System Challenge: Methodology and Findings*. EPA 817-R-13-002. April 2013. http://water.epa.gov/infrastructure/watersecurity/lawsregs/upload/epa817r13002.pdf.

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[xi] USEPA. *Water Security Initiative: Interim Guidance on Developing Consequence Management Plans for Drinking Water Utilities*. EPA 817-R-08-001. October 2008. http://water.epa.gov/infrastructure/watersecurity/upload/2008_10_24_watersecurity_guide_interim_cmp_wsi.pdf.

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[xiii] USEPA. *Water Security Initiative: Guidance for Building Laboratory Capabilities to Respond to Drinking Water Contamination*. EPA 817-R-13-001. March 2013. http://water.epa.gov/infrastructure/watersecurity/lawsregs/upload/epa817r13001.pdf.