

Water Utilities Driving Water Security Research On Drinking Water Contamination Warning Systems

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Overview

Many water utilities are evaluating options for developing contamination warning systems (CWS) – monitoring and surveillance systems that can detect contamination incidents in distribution systems in time to allow mitigation of public health and/or economic impacts. In spite of the high level of interest, the water community is still wrestling with many difficult and fundamental questions, such as: what the objective of a CWS should be; where sensors should be placed; what monitoring devices should be used, and how to distinguish contamination incidents from background sensor noise or an erroneous sensor reading.

Recognizing that these questions were of concern to water utilities, EPA's National Homeland Security Research Center (NHSRC) established the Threat Ensemble Vulnerability Assessment (TEVA) Research Program to study these questions and others in 2003. Following discussions with water utilities about advanced contamination monitoring technologies and methods, AWWA proposed a partnership with NHSRC to explore these research questions. AWWA established the Water Utility Users Group consisting of more than 20 water utilities. The partner utilities volunteered to collaborate with the TEVA program and share information, data, and operational experiences. The partnership has ensured that NHSRC's research on CWS is focused on the development of relevant tools and methodologies which can be directly used by the water community. Two software tools have been developed and pilot tested through this partnership: TEVA-SPOT, a tool to identify the placement of optimal sensor locations, and CANARY, a tool to identify potential contamination incidents using real-time water quality monitoring data. NHSRC plans to pilot test and release additional software tools and methodologies, all of which are being developed and tested in partnership with the Users Group.

Becoming Partners

AWWA organized a series of meetings between 2003-06 with member utilities to discuss new security initiatives being implemented at utilities across the country and to identify the major informational and technological gaps in capabilities. Many utilities were interested in developing "early warning systems," testing sensor technologies, and integrating security concerns with compliance monitoring. The very notion of an "early warning system" was recognized by the group to mean different things to different people, ranging from a system that could "detect and protect" a water community to a warning system that could just "detect to treat," [J. A. Roberson and K. M. Morley, 2005a]. The group also

identified many research objectives, including the: (1) development of credible threat scenarios to focus research priorities, (2) development of guidance on the number and location of monitoring stations, (3) performance of cost-benefit analyses to compare physical security methods, improved operational policies and procedures, and online monitoring, and (4) development of methods to analyze and interpret water quality monitoring data [J. A. Roberson and K. M. Morley, 2005a and b].

In 2004, EPA's Office of Research and Development and EPA's Office of Water jointly authored the "Water Security Research and Technical Support Action Plan," which was influenced strongly by a series of stakeholder meetings with federal, state, local agencies, and industry groups [U. S. EPA, 2004]. The Action Plan was broad in scope, although the majority of research needs identified were in the areas of detection and response to contamination incidents in distribution systems. AWWA quickly recognized by working together the end products of water security research would be more relevant to the water community. Additionally, by working together, information could be communicated more rapidly to the water utilities, the primary end-user of EPA's research. Therefore, AWWA invited EPA researchers to participate in their meetings with member utilities.

AWWA established the Water Utility Users Group, a.k.a., Users Group, in 2003 which consists of over 20 water utilities. Ten of these utilities have entered into Memorandum of Understanding (MOU) agreements with the NHSRC. In order to participate, the water utilities were required to have well developed distribution system models and have plans to install sensors in their distribution systems in the near future. In these agreements, the water utilities agreed to share system specific information with the TEVA program for the purpose of the research. In return, the NHSRC promised to share research results and provide access to state-of-art tools and methodologies. In particular, the agreements said that the NHSRC would provide contaminant consequence assessment analyses and a preliminary sensor network design for each participating utility.

The TEVA Research Program

Through this partnership with AWWA and the Users Group, NHSRC researchers have tested a methodology to predict the impacts of contamination incidents in distribution systems. Using distribution system network models from partnering TEVA Utilities, contaminant specific data, an ensemble of possible contaminant release locations, and mathematical models to estimate public health and economic impacts, TEVA researchers have estimated the probable impacts of contamination at specific locations over time for the partner utilities. These models have shown that impacts are very unique to each water distribution system, and therefore, unique solutions are required in order to mitigate the impacts of contamination incidents.

The TEVA Research Program at NHSRC was formed by bringing together a group of engineers, physical scientists, and computer scientists from the EPA, two national laboratories (Sandia and Argonne), and the University of Cincinnati to develop software tools that would help design system-specific CWS. These system-specific designs take into account the characteristics of each water distribution system, and identify sensor locations that offer the greatest potential to mitigate public health risks. TEVA-SPOT (the TEVA sensor placement optimization tool) is one product that has resulted from this collaboration, and EPA researchers have been applying this tool to the participating TEVA Utilities, and providing them with sensor network designs to help locate monitoring stations [J. Berry, et. al., 2006] [W. E. Hart, et. al., 2007].

Given the current state of sensor technologies, and the interest in better understanding water quality in distribution systems, most of the TEVA Utilities have been installing water quality sensors as part of a CWS. Researchers have shown that in the presence of contaminants, water quality sensors are able to detect “changes” in free chlorine, TOC, ORP, specific conductance, and other parameters [J. Hall, et. al., 2007]. However, data analysis tools are needed to differentiate between normal changes in water quality (due to daily, seasonal, or operational fluctuations) and changes that may be indicative of contamination incidents. Several commercial vendors have been working on similar data analysis tools; however their methods are proprietary and therefore unavailable for researchers and water utilities to easily investigate and evaluate. To address this need, the TEVA Research Program developed CANARY, an event detection tool that integrates data from water quality sensors in real-time and predicts whether the recorded water quality changes are anomalous or otherwise unexpected [D. Hart, et. al., 2007]. This tool, in addition to tools developed by other groups, is being pilot tested and evaluated through the TEVA Program.

The TEVA Research Program is also developing a series of tools that work in conjunction with the popular EPANET distribution system modeling package. These tools will include EPANET-MSX (Multi Species eXtension) [F. Shang et. al., 2006], EPANET-DPX (Distributed Processor eXtension), EPANET-MCX (Monte Carlo eXension), and EPANET-RTX (Real-Time eXtension). Development principles for the EPANET extensions include commitment to open source software development and cooperation with commercial software developers. To build a stronger foundation for water security research, EPA’s attention will be directed at improving distribution system models and quantifying their accuracy. For more information about the TEVA Program, see <http://www.epa.gov/nhsrc/water/teva.html>.

Ongoing Partnership

The Users Group and TEVA Utilities have met annually since 2004. The meetings have been forums for the researchers to present the most up-to-date results of their work, and for the participating water utilities to provide feedback to the TEVA research team to help focus their program. At the August 2005 meeting, the utilities identified their top research priorities:

- (1) Field verification of the TEVA models,
- (2) Development of response tools, methodologies, and guidance, and
- (3) Development of improved capabilities for data analysis and integration.

At the next meeting in September 2006, the Users Group received an update on the research program from EPA and AWWA, highlighting efforts focused on the above utility-identified priorities. This latest meeting was organized according to *focus track* discussions on the following topics: utility applications of the TEVA-SPOT software; how to utilize CANARY; plans to develop tools which could assist utilities in responding to contamination incidents; field verification of TEVA methods through EPA's Water Security Initiative; and, upcoming improvements to the EPANET distribution system modeling software.

NHSRC's TEVA Research Program has benefited enormously from the collaboration with the AWWA Users Group. The partnership has enabled EPA researchers to rapidly apply and test the tools and methodologies on actual distribution systems. Through this process, the tools were improved to be able to handle very large distribution system models on desk top computers in a short amount of time, making the tools accessible to most water utilities. Moreover, the research plans have been modified to meet the needs and interests of the water utility community, EPA's primary customer of their water security research. The Users Group has gained a better understanding of the science and engineering associated with the design, deployment, and operation of a CWS. Partnering utilities have received utility-specific vulnerability and consequence assessments and sensor network designs.

Future Efforts

The Users Group will be meeting again in 2007 to allow the utilities to report back on their experiences with pilot testing CWS technologies and the EPA to report back on more recent research results. As the technologies are tested and evaluated in field settings, improvements will be made to the TEVA software tools. Ultimately, tools to help improve modeling, security, and operation of distribution systems will be available to the public on the EPA/NHSRC website (www.epa.gov/nhsrc). Future directions will focus on the development of tools for responding to contamination incidents, real-time modeling capabilities, and field evaluations. Continued collaboration and input from the Users Group will ensure the relevancy of EPA's research programs while also providing a conduit for rapid deployment and testing.

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