An Overview of U.S. EPA Research on Remote Monitoring and Control Technologies for Small Drinking Water Treatment Systems

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Abstract

There are approximately 160,000 small community and non-community drinking water treatment systems in the United States. According to recent estimates, small systems contribute to 94% of the Safe Drinking Water Act violations annually. A majority of these are for microbiological MCL violations. Small drinking water system research is being conducted at the U.S. EPA's Test & Evaluation (T&E) Facility in Cincinnati, Ohio with an emphasis on "package plants" for biological, physical, and chemical treatment of drinking water sources. Research studies are designed to provide guidance to operators of small Public Water Systems to ensure compliance with current regulations including the Surface Water Treatment Rule and the Groundwater Rule.

Several U.S. EPA studies have focused on packaged filtration and disinfection systems equipped with remote telemetry units and Supervisory Control and Data Acquisition (SCADA) systems. SCADA systems are commonly used by large (not small) water utilities to control and monitor their operations. However, the constant monitoring requirements for small system operators in remote locations can incur substantial costs in time and travel. Remote monitoring and control systems offer a cost-effective way to reduce manpower requirements by providing real-time monitoring of water quality, continuous control of operating conditions, and the reporting of information electronically from a "centralized" location.

Disclaimer

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names or commercial products in this paper does not constitute endorsement or recommendation for use by the authors, or by their respective employers. The trade names have been included to accurately represent the equipment used for the purpose of testing and evaluation.

Introduction

There are approximately 160,000 small community and non-community drinking water treatment systems in the United States. Of this number there are approximately 50,000 small community systems and 110,000 non-community systems that impact the drinking water of over 68 million people Small drinking water systems serve transient and non-transient populations of 10,000 people or less. Tens of thousands of the small systems are having difficulty complying with the ever-increasing number of regulations and regulated contaminants. Currently, it is estimated that small systems contribute 94% of the Safe Drinking Water Act (SDWA) violations annually. Nearly 77% of these are for Maximum Contaminant Level (MCL) violations. A majority of these violations are reported and are directly related to microbiological violations.

The EPA recognizes these constraints and it is for this reason the EPA conducts in-house technology development and evaluation to support small communities. This information is made available to the small system operators, consultants, and utilities. An example of this is the EPA's Small Drinking Water Systems Handbook, A Guide to "Packaged" Filtration and Disinfection Technologies with Remote Monitoring and Control Tools, EPA/600/R-03/041, May, 2003. This EPA document is provided through various outreach tools such as conferences, training workshops, and on-line.

Package Plant Research

The EPA is currently operating, testing, and evaluating several small system package plants at the T&E Facility Small Systems Research Center. Experimental tests on filtration and disinfection systems are designed to sufficiently challenge the treatment technology. The research is conducted with emphasis on biological, physical, and chemical treatment technologies and how they can be "packaged" with remote monitoring and control technologies to provide a healthy and affordable solution for small systems. Several commercially-available and EPA-designed package plants suitable for small systems have been evaluated by EPA. The EPA's Water Supply and Water Resources Division conducts this research at the EPA T&E Facility in Cincinnati, Ohio, and at other field locations. The WSWRD is a division of the National Risk Management Research Laboratory, Office of Research & Development. This paper presents an overview of this research.

Filtration Research

Filtration research at the T&E Facility focuses on "packaged" filtration systems including slow and rapid sand filters, ultrafiltration, bag/cartridge filters, and reverse osmosis units. Various configurations of these filtration system are set-up and operational. Some of these filtration system are interfaced with a Supervisory Control and Data Acquisition (SCADA) systems that can monitor and control operating conditions continuously.

For instance, EPA is currently evaluating bag and cartridge filters in series. Depending on raw water characteristics, the bag/cartridge filters are set-up in series with decreasingly small pore sizes to increase treatment efficiency and prolong filter life. A 5000 gallon stainless steel tank has been retrofit with recirculation pumps and mixers for automated turbidity control using Mill Creek surface water. Treatment study turbidity is automatically controlled during each experimental run. Bag and cartridge filter housings have been automated with continuous monitoring of turbidity, differential pressure, and flow rate. Monitoring records are datalogged to a paperless chart recorder for control of treatment system operation and manipulation of water quality results.

Disinfection Research

Disinfection research is designed to provide guidance to operators of small Public Water Systems (PWS). The Surface Water Treatment Rule (SWTR) requires disinfection of PWS water obtained from surface water supplies or groundwater sources under the influence of surface water. The EPA is developing a Groundwater Disinfection Rule to address the public health risks from microbial contamination of groundwater systems.

Disinfection research systems at the T&E Facility include chlorination, chloramination, electrochemical oxidation generators, and advanced oxidation processes (combinations of ozone, hydrogen peroxide, and UV light). As shown by the MCL, Monitoring and Reporting violations of the SDWA and its amendments over the years, small systems are either (1) unable to simply disinfect their water or (2) unable to record and submit their data to the appropriate state agency. EPA has evaluated several disinfection technologies that are affordable and easy to use from a small systems perspective. These have included onsite chlorination units that can generate chlorine in small quantities by electrolyzing brine solutions. The EPA research has also included *Cryptosporidium* challenges and infectivity studies.

Remote Telemetry for Monitoring and Control of Small Drinking Water Systems

In 1996, the EPA first incorporated real time monitoring and control of a small treatment system at EPA's T&E facility in Cincinnati Ohio. Regulations require all conventional water treatment operators to provide constant monitoring to assure water quality of the treatment process. Small system operators are under the same reporting and water quality requirements as the large treatment operators. Constant monitoring of the water quality can add up to substantial costs in time and travel for operation and maintenance. EPA has conducted several studies using various package plants at the T&E Facility and in the field that have been equipped with remote telemetry units (RTUs). Drinking water distribution systems can also be controlled and monitored via remote telemetry. Remote telemetry is a potentially useful tool to support regulatory reporting guidelines by providing real-time continuous monitoring of the water quality and electronic reporting of information. The EPA is currently evaluating technologies at the T&E Facility and in the field that are related to remote monitoring and control of small drinking water package plant systems and distribution systems. A couple of case studies have been provided to exhibit the capabilities of remote telemetry for monitoring and control in source water, small drinking water treatment plants, and distribution systems.

Case Study 1 - Source Water and Treatment System Monitoring and Control

In collaboration with US EPA Region 2, ORD's Water Supply and Water Resources Division is working with a small community in Puerto Rico to improve compliance with the EPA's Surface Water Treatment Rules. EPA's goal is to find a solution to the problem of filtration for those small rural communities receiving water from surface sources in a tropical climate, so they can reduce their risk of waterborne disease. To achieve this goal, EPA is developing an integrated network approach that includes: watershed management, innovative water filtration technologies, real-time remote monitoring of the source water/watershed, and real-time monitoring and control of the water treatment systems. This integrated network approach is designed to assist circuit riders with small drinking water system operation and compliance. EPA believes that this concept will benefit small and rural tropical communities and will develop an approach that can be implemented in other communities in tropical regions with similar environmental, climatologic, & socioeconomic conditions or circumstances.

This case study consists of a side-by-side comparison between this new integrated network approach and the existing conventional Slow Sand Filter (SSF)/Horizontal Flow Gravel Pre-Filter (HFGP) approach in a tropical environment. The study is investigating the behavior and operational and maintenance costs associated with these water filtration technologies influenced by sudden fluctuations of water quality in the watershed. Alternative technologies (such as bag and cartridge filters or modular SSFs) need to be cost-effective, reliable and easy to operate and maintain, in accordance with the socio-economic reality in small rural tropical communities. Positive outcome from this project will help solve problems experienced by hundreds of systems in communities that do not receive filtered water, in direct violation of the SWTR.

Long-term continuous monitoring of water quality is critical to identify severe impacts and to develop appropriate management strategies for protecting water quality and water treatment systems. Many alternatives have been proposed including weather stations to monitor storm events, stream gages to monitor flood events, and continuous turbidity meters to detect the buildup of solids in the watershed. Continuous monitoring of weather parameters (precipitation, barometric pressure, wind velocity/direction, and air temperature), stream levels, and turbidity readings can serve as indicators of changes in water quality, supply and demand. RTUs programmed to monitor for excessive levels of precipitation, stream levels, and/or turbidity can reduce treatment system operation and maintenance costs. During a rain or flood event, intake valves to the treatment plant can be automatically closed to prevent flooding and/or excessive solids from shutting down treatment system operation. While the turbidity increase is short-lived, the high solids loading at the treatment system tends to overwhelm the treatment capacity of the system leading to high maintenance costs and often, premature equipment failure. Knowledge of the watershed and source water conditions prior to the influx of high-turbidity water to a treatment system provides an operational advantage for a treatment system. It is critical to insure that the best source of raw water is used in the treatment process to prevent premature deterioration and poor performance of the treatment system thus exposing people to lower quality drinking water.

Case Study 2 - Distribution System Monitoring and Control
In a second study, EPA worked with the City of Burlingame, CA and the local utility (East Bay MUD) on an insitu pipeloop study to understand the disinfectant kinetics associated with chlorine and chloramines residuals and nitrosodimethylamine (NDMA) formation. An abandoned 90-year-old unlined cast iron pipeline about 2000 ft long was acclimated to assess the disinfectant kinetics using state-of-the-art remote monitoring technologies.

Remote monitoring stations provided pump control, continuous monitoring, and storage of water quality data every 15 minutes in compressed digital format. Various water quality parameters (temperature, pH, ORP, conductivity, disinfectant concentrations) were continuously monitored at the source and at several different locations within the loop. Flow-thru water quality stations with probe type analyzers provided continuous display and storage of water quality results via radio units (RTUs). Field measurement of flow rate and pressure were also recorded at various locations within the loop.

Benefits of Remote Monitoring and Control Systems
The research at the T&E Facility has focused on evaluating real-time remote monitoring and control (RMC) for small drinking water package plant systems. It was assumed that implementation of RMC systems could reduce manpower requirements for operating packaged drinking water plants by providing the ability to monitor and control treatment systems remotely from a "centralized" location.

There are many other benefits of real-time monitoring and data collection. The operator can remotely monitor hard-to-reach sites, eliminating the need for frequent trips to a site for compliance. Real-time monitoring can detect events that spot-checking may have missed. Remote telemetry units automatically deposit data onto a website preventing the need for the operator to travel to a site to view, upload, and process monitoring data. Remotely monitored water quality sensors are easier to maintain and service because the operator can evaluate their performance using real time data. Finally, tracking and recording ongoing events facilitates more accurate planning and decision-making.

The SCADA component of RMC systems is widely used in industrial environments and by larger water utilities to control and monitor their individual facility operations. Small water utilities typically do not utilize the available SCADA systems for conventional water quality monitoring. Since regulations do not clearly specify that real-time monitoring of water quality is required, small utilities have been reluctant to install and operate such devices.

However, after the events of 911, many utilities have become more interested in the "dual purpose" potential for implementing SCADA for monitoring water quality as well as an early warning system (EWS) for detecting contaminants. These systems can constantly monitor water quality within the source water, treatment, and distribution systems. In the source water, they can shutdown the raw water intake until water quality improves. Thus, reduce the cost of treatment, protect the end user, and extend the operational life of a treatment system. Also, they can control the water quality in various areas of the treatment and distribution systems. These RMC systems can potentially reduce the risk of security threats or even non-security related problems, and detect undesirable water quality changes within the system.

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