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Online Real Time Monitoring - Peace of Mind?

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ON-LINE REAL TIME MONITORING - PEACE OF MIND?

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During the past five years, distribution systems have been responsible for 45% of outbreaks of waterborne disease (AWWA Journal, Sept 2001). The looming threat of bioterrorism and the vulnerability of the distribution system to attack have pressed the water industry to investigate the possibility of using on-line, real-time monitoring along with rapid screening of the water for toxic substances. Mohawk Valley Water Authority (MVWA) heightened its concern for the vulnerability of its distribution system after the September 11th terrorism attacks. The MVWA system has been classified as "high risk" due to the fact that it serves a population greater than 125,000 people and has two open finished water storage reservoirs located in the distribution system. Mohawk Valley Water's ten year capital plan includes additional covered water storage to eliminate these open reservoirs however; a more immediate plan to safeguard the system was recognized as an important priority.

Along with basic security measures such as site security, increased patrols of the distribution system, surveillance cameras and ID entry systems, MVWA has chosen an on-line monitoring system utilizing the Dascore "Six-CENSE" ceramic chip that utilizes CENSAR (**C**hemical **EN**vironmental **S**ensing **AR**ray) technology. Along with these systems several rapid screening processes designed to monitor for toxic substances have been evaluated. These include the Checklight Ltd. Toxicity Testing System, a rapid method of quantification of viable bacteria using an ATP assay, immunomagnetic separation and flow cytometry for rapid detection of pathogenic microorganisms and biological (fish) monitors.

The design and operation of an early warning system should be viewed as an integral part of the operation of a water system (Deininger et al 2001). Deininger's AWWARF research project centered on the design of early warning and predictive source-water monitoring however; the guidance for the design of such source water systems can also apply to predictive distribution monitoring systems. These systems should include the following elements: a way to detect the presence of a contaminant, a way of confirming the presence of a contaminant, procedures to manage the efforts associated with the contamination event, a communication network for information related to the contamination event and ways to respond to the contamination event and minimize its impact on the public.

The most important element of an on-line system is its ability to detect the possible occurrence of a contaminant. The system should be designed and operated such that there is sufficient lead-time to react to the event and actions can be taken to minimize the impact of the contaminant on the distribution system water.

REMOTE ON-LINE MONITORING

In December 2001, MVWA began planning an on-line distribution system monitoring network. The Dascore "Six-CENSE" CENSAR technology was chosen to be installed at representative points in the distribution system providing an electronic network monitoring surrogate water quality parameters. The Six-CENSE monitors six critical water quality parameters. A one-inch square ceramic chip forms the foundation for the technology used to measure the six parameters that include: chlorine or chloramines, dissolved oxygen, pH, conductivity, redox/ORP and temperature. The chip is based on standard electrochemical methodologies that eliminate the requirements for reagents in the measurement of chlorine, glass for the measurement of pH and membranes for the measurements of dissolved oxygen. The data output of the probe is available in various output formats to integrate into SCADA systems and telemetry options can be used for continuous monitoring at remote sites.

The Dascore Six-CENSE monitoring chip was installed at a representative point for a trial period. Following installation of the probe, several problems were encountered including scaling on the chip and SCADA communication problems. Following adjustments, expected readings were obtained from the Six-CENSE.

To evaluate the Six-CENSE probe a Hach pH meter and Cl-17 Chlorine analyzer were installed at the same location as the Six-CENSE probe. Readings from these meters have followed very closely the readings obtained from the probe. A Hydro-Lab water quality probe was used in parallel with the chip to confirm water quality parameters successfully.

Figure 1was generated by the Six-CENSE chip in response to an alteration in chemical addition at our treatment plant. Lime and soda ash are added for corrosion control purposes following filtration and chlorination. Time zero (t_0) represents when the chemical feed was discontinued for these two chemicals. At time t_1, the SixCENSE probe located downstream of the treatment plant sensed this change and registered both a drop in pH and conductivity.

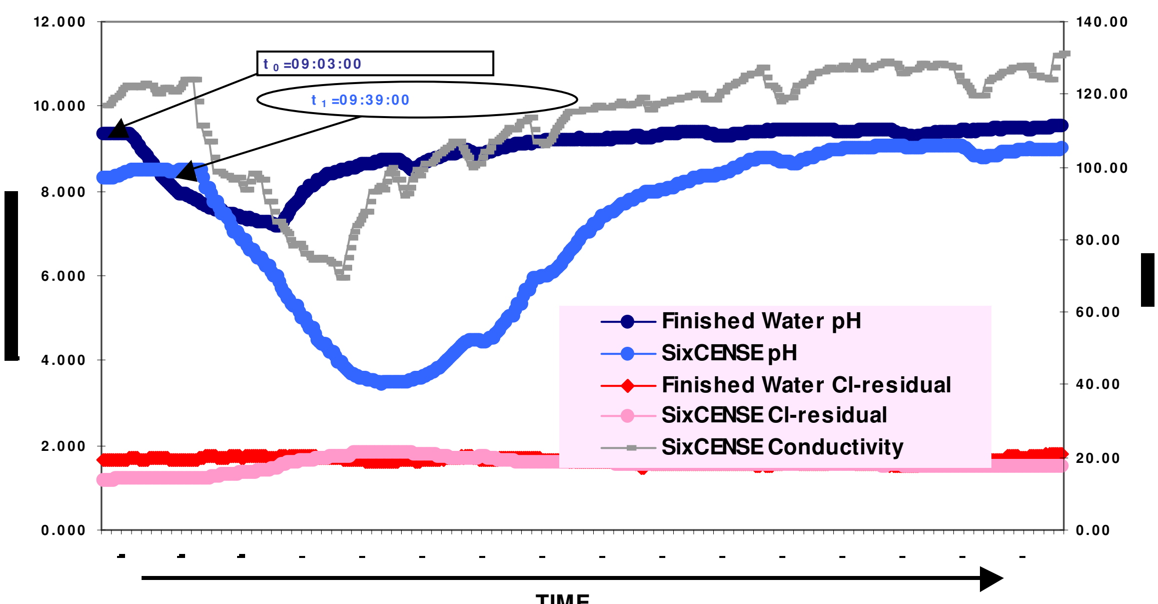

Figure 1

REMOTE SAMPLING STATION NETWORK

Mohawk Valley Water has over 600 miles of distribution mains that travel from areas of high population to sparsely populated remote areas. Gaining access to reliable taps for monitoring purposes is often a challenge. A network of 10 Kupferle Foundry Eclipse Sampling Stations was installed at strategic points in the distribution system. This network enables the Water Quality Department to get a better picture of the quality of the water in the remote areas of the distribution system.

TOXICITY TESTING AND BIOLUMINESCENCE-BASED ASSAYS

The bioassay developed by Checklight Inc. utilizes a highly sensitive variant of the luminescent bacterium *Photobacterium leiognathi* that allows the detection of a diverse group of toxicants, at levels below milligrams per liter, in water (Ulitzur *et al,* 2002).

The use of luminous bacteria for toxicity assessment has advantages that have been scientifically validated (Bulich and Isenberg, 1981; Kaiser 1998). The bacteria are self-maintained luminescent units that emit high and steady levels of luminescence (490 nm). Biological toxicants and chemical agents (pesticides, herbicides, heavy metals and chlorinated hydrocarbons) that effect cellular respiration, protein or lipid synthesis, or the integrity of the cell membrane alter the level of luminescence produced by the bacteria. The toxicity test kit contains the bacteria in a freeze-dried state and once hydrated the bacteria become luminescent. An aliquot of the bacterial culture is added to tubes containing the water in question. By comparing the levels of luminescence produced by bacteria added to a water sample suspected of being toxic with that of a clean control water sample plus the bacterial culture, low concentrations of a broad range of toxicants can be detected.

Toxicity testing has been phased into the daily routine monitoring performed by the MVWA Water Quality Laboratory. The Authority has open finished water storage reservoirs within the distribution system and toxicity testing is performed daily on the effluent from these reservoirs as well as representative points throughout the distribution system.

RAPID QUANTIFICATION OF VIABLE BACTERIA USING AN ATP ASSAY

The heterotrophic plate count (HPC) is used to estimate the number of heterotrophic bacteria that form colonies on agar plates. The present Standard Method currently used takes 48 hours to seven days to obtain a result.

The determination of adenosine triphosphate (ATP) using a bioluminescence assay (New Horizons Diagnostic's Profile-1 System) is based on a reaction between the enzyme luciferase, the substrate luciferin and ATP (Trudil, D. et al. 2000, Lee and Deininger 2001). Light is emitted during this reaction and can be measured quantitatively to estimate the amount of bacteria present in a water sample.

The ATP assay of viable bacteria has also been phased into the routine monitoring program of the MVWA distribution system. The procedure has been compared to the Standard Method

Heterotrophic Plate (HPC) count method (48-hour incubation at $35^{o}C$) and the Heterotropic plate count on R2A agar (7-day incubation period at room temperature). The ATP assay showed better correlation with bacterial counts obtained from the 7-day plate count method.

BIOLOGICAL MONITORS

Organisms such as fish, clams, mussels, daphnia, algae and bacteria have been used as biomonitors. Prior to September 11th there were very few biomonitors in the United States. However, since that time water systems have been investigating their usefulness. While biological monitoring systems that rely on a single species have limitations, they may prove useful when used in conjunction with other monitoring methods.

A simple fish monitor that utilizes the "avoidance principal" (Grayman, Deininger, Males, 2001) was constructed in the laboratory at MVWA's treatment plant. The monitor is based on the fact that fish will swim away from water that is contaminated with toxic agents. Five tanks connected in series are stocked with native fish. When fish sense a toxic substance they tend to move downstream. If the fish in tanks 3,4, or 5 exceed the number of fish in tanks 1 and 2, treatment plant operators will be alerted to a possible contamination event.

IMMUNOMAGNETIC SEPARATION METHODS AND FLOW CYTOMETRY

Flow cytometry has traditionally been used in hospital laboratories for the identification of bacteria in clinical samples of body fluids. Flow cytometric methods are rapid, and quantative and can be versatile since many methods can be combined such as nucleic acid probes and immunofluorescence. They are also rapid and may be used to monitor viability. (Grayman, Deininger, Males, 2001). The RDB2100, an instrument manufactured by Advanced Analytical Technologies Inc. (Ames Iowa), is a low-level microbe detector utilizing the principles underlying flow cytometry. The use of the instrument in the water industry has been evaluated for the identification of *Escherichia coli* O157:H7 and *Cryptosporidium parvum* (Smith and Rice 2000, Laskey and Chen 2001, Schreppel, Tangorra, Harkins, Harrigan and Fredericksen 2002).

CONCLUSIONS

Water system distribution networks are a major area of vulnerability. Water systems need the ability to predict the movement of contaminates and to monitor these levels at points throughout the distribution system. This is an extremely complex process that will require distribution water quality modeling and real-time monitoring. The combination of these two processes will begin to provide an effective tool for enhancing the security of the water system. While it isn't reasonable or feasible to use real-time monitoring for every agent that could be introduced deliberately into a water system it is practical to monitor using indicator parameters where a change can signal the possibility of hazards in the water. Monitors must be able to be remotely operated, maintainable, not overly sensitive, quality assured, and last but not least affordable. Mechanisms must also be in place to interpret the data that the monitoring produces and communications and response actions must be planned. While September 11th taught us that there is no such thing as an "unthinkable act" it has prompted utilities to better monitor distribution systems for water quality, which in turn will benefit our everyday lives. Peace of mind? Better water quality monitoring may bring us one step closer but will we ever really have peace of mind again?

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