Performance Verification Testing
Rapid Toxicity Monitoring and Detection Systems
Overview and Analysis

Background

As part of its role in protecting the nation's drinking water supplies and systems from acts of terrorism, the United States Environmental Protection Agency (EPA) has supported the testing and evaluation of rapid toxicity monitoring and detection systems. EPA's efforts in drinking water system security focus on physical security, including cyber security, destruction and disruption of services to both water and wastewater systems, and the threat of delivering chemical, biological, and radiological contaminants into water systems.

An integral part of the Agency's approach to meeting its mission is testing and evaluating the performance of commercially available technologies that may be useful for monitoring and detecting contaminants; as early warning systems; for mitigation and treatment; and, for providing alternative water supplies. The testing of rapid toxicity monitoring and detection systems was conducted under the auspices of the EPA's Environmental Technology Verification Program (ETV). The seven vendors, who voluntarily participated, represent eight technologies: Aqua Survey, Inc's IQ Toxicity Test™; Strategic Diagnostics Inc's Deltatox® and Microtox®; Severn Trent Services' Eclox; InterLab Supply, Ltd's PolyTox™; Hach Company's ToxTrak™; CheckLight, Ltd's ToxScreen; and Hidex Oy's BioTox™.

Prior to the inception of testing, a water security stakeholder group was formed to help guide testing and evaluation efforts. The vendors had not previously tested their technology's ability to detect the presence of several of the contaminants included in this effort. Despite the lack of vendor testing and evaluation of some of the contaminants, they were in wide agreement with the approach. This was in part due to the fact that the stakeholder group strongly advised that technologies be challenged using contaminants that required testing in special facilities which typical water utilities do not have access. This document provides a broad summary of the data generated in the test. The reader is encouraged to obtain copies of each report from the ETV web site (www.epa.gov/etv) for more detailed individual technology information.

Principle of Operation and Use

The rapid toxicity technologies are all bioassays designed to use living organisms or enzymatic reactions as toxicity indicators either directly or in combination with reagents. These organisms or reactions produce a baseline level of light or use dissolved oxygen at a steady rate in uncontaminated water. When subjected to water containing toxics, these indicator organisms should ideally react by exhibiting a reduced light intensity or dissolved oxygen uptake rate.

Rapid toxicity technologies are intended to serve as quick screening tools for determining whether water being tested contains contaminants at concentrations harmful to human health or the environment. Until recently, these technologies have been used for water monitoring at facilities that discharge effluents, such as industrial production facilities, to monitor the potential ecological impact of the effluents. A potential new use for this type of technology is to monitor for early signs of intentional acts of chemical contamination on drinking water systems. The rapid toxicity monitors are not intended to be used to identify a specific contaminant or to measure the amount of contaminant. Their envisioned role is to provide a relatively quick analysis of a water sample to determine whether a contaminant exists in a quantity that could pose a risk to consumers. Once the sample is prepared for analysis, these technologies typically can be used to generate a result in less than an hour. By comparison, standard EPA methods for measuring acute toxicity take between 24 and 96 hours to generate a result.

Performance Verification Test Design

The objective of the verification testing was to rigorously test the ability of each rapid toxicity technology to detect selected toxic threat contaminants (excluding biological warfare agents) in water and to determine their susceptibility to commonly occurring but potentially interfering compounds and matrices. Stakeholders from the water utility industry and others, including vendors, helped design the test. The target contaminants were chosen as representatives of five different classes of potential contaminants: industrial chemicals, pesticides, pharmaceuticals, nerve agents, and biotoxins. The five toxic industrial chemicals and four chemical warfare agents are aldicarb, colchicine, cyanide, dicrotophos, thallium sulfate, botulinum toxin, ricin, soman, and VX. Testing also included five potentially interfering elements (aluminum, copper, iron, manganese, and zinc) and two samples that were each treated using two different disinfection processes (chlorination and chloramination). Vendors participated during testing and reviewed results as did quality assurance managers from EPA and the testing organization. Test plans and reports were also reviewed by technical peer reviewers external to EPA and the testing organization.

The contaminant-spiked drinking water samples that were evaluated by each technology were prepared from a single drinking water source. The drinking water samples were dechlorinated and then spiked with various concentrations of contaminants or interferents. Individual solutions containing each contaminant or potential interferent were prepared and analyzed. Samples containing a contaminant were prepared at a lethal dose concentration, estimated for a 154 lb person ingesting about 8 oz of water, then diluted multiple times (by a factor of 10 each time) to determine the sensitivity of the technology to each contaminant at several concentration levels. Samples containing the interferents were analyzed at a single concentration. Each technology also analyzed contaminant-free drinking water samples from two disinfection processes (chlorination and chloramination) to determine if commonly occurring disinfection byproducts would affect performance. Endpoints and precision, toxicity threshold (for each contaminant), false positive/negative responses, ease of use, and sample throughput were evaluated. Samples used in the verification test included spiked drinking water test samples and quality control samples including method blank and positive and negative control samples.

Performance and Results

The rapid toxicity detection systems varied in their responses to specific toxics introduced into the water samples. All eight technologies responded to cyanide and thallium sulfate; six of the eight identified toxicity in response to the presence of aldicarb and dicrotophos; five of the eight responded to colchicine and ricin; three to VX, only two to botulinum toxin; and one to soman. Results were considered false negative if the response to the lethal dose concentration of each contaminant was not significantly different from the negative control. Table 1 gives the number of technologies that exhibited false negative results for each contaminant.

Cations that are likely present in water sources were evaluated as potential interferences in this test, including: copper, zinc, iron, and aluminum. In addition, chlorinated water samples (from either chlorination or chloramination processes) without any spiked contaminants or interferents were also analyzed. The interferents tested were considered to interfere if the percent inhibition detected with the interferent alone was likely to cause an error (in the positive or negative direction) when determining the toxicity of an unknown water sample. Table 1 also gives the number of technologies susceptible to each potential interferent. The potential for responses that falsely indicate the presence or absence of toxic contaminants due to the presence of background interferents or byproducts of chlorination and chloramination processes or both must be carefully considered and accounted for by potential users. The three systems that were not affected by chloramination by-products were also the least sensitive to the contaminants of interest. Conversely, those technologies that were sensitive to the widest variety and concentrations of contaminants were also inhibited by the commonly occurring interferents.

It is important to simultaneously consider the response of each technology to the contaminants of interest and the interferents to fully gauge and understand performance. The fact that there were numerous false positive and negative results suggest that these technologies must be used with care by water utility managers. The prudent water utility manager would use these types of technologies in conjunction with other analytical methods that can confirm the presence or absence of a toxic contaminant, rather than as stand-alone early warning devices. Another option is for the water utility manager to fully characterize the performance of the technology using a range of samples that represent the typical distribution system water quality. It would then be necessary to fully characterize the chemical and physical characteristics of the water using standard methods to sufficiently understand the rapid toxicity monitoring system.

The data generated in this verification test are not indicative of performance for every possible combination of contamination, water source, and potential interferent, but the data do represent a reasonable snapshot of performance. It is important to note that users should fully understand typical performance in their water systems for the most accurate interpretation of positive and negative results. Users of these technologies are encouraged to carefully review the verification reports and verification statements posted on the EPA ETV Web site (www.epa.gov/etv) and to discuss performance data generated for their water systems with vendors.

For further information:

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Table 1. Number of Technologies Exhibiting False Negative Responses and Susceptibility to Interferents

Contaminant (Lethal Dose - mg/L)	Technologies Giving a False Negative Response at the Lethal Dose	Potential Interferent (Concentration-mg/L)	Technologies Susceptible to Interference
Aldicarb (280)	2	Aluminum (0.36)	1
Colchicine (240)	3	Copper (0.65)	4
Cyanide (250)	0	Iron (0.069)	2
Dicrotophos (1,400)	2	Manganese (0.26)	1
Thallium Sulfate (2,400)	0	Zinc (3.5)	4
Botulinum Toxin (0.3)	6	Chloramination	5
Ricin (15)	3	Chlorination	3
Soman (0.2)	7		
VX (0.2)	5		