Water Infrastructure Security and Safety

How to reduce recovery times for drinking water storage tanks following a catastrophic event.

By Larry Rice and José Hernández

"Be Prepared," the Boy Scout motto, is the new command given all water utility managers since 9/11.

On September 11, 2001 terrorism changed the lives of all Americans. Many of the changes we have seen in our daily lives have increased our security both at home and abroad. Much of this "visible" security has been directed toward the movements of people. The strides that have been made in airline security, train security, and in the security of our cities have been well documented. Homeland security issues now dominate our news and their incumbent budget expenditures dominate our national debate. According to some reports, the Bush administration spent nearly $38 Billion on Homeland Security and its associated issues in 2003 alone![1]

The supply of goods and services has also been an area in which security improvements have been well documented. Much of our food supply and import/export business has become increasingly safe through added security and other counter-terrorism measures. Although food and water safety and security are different aspects of our protection, they are inherently connected.

"FDA, at the direction of the Department of Health and Human Services (DHHS), has established a 10-Point Program for ensuring the safety and security of the food supply. Based on activities in FDA's 10-Point Program, the Agency is employing overall strategies to

"(1) develop increased awareness among federal, state, local, and tribal governments and the private sector by collecting, analyzing, and disseminating information and knowledge (Awareness);

"(2) develop capacity for identification of a specific threat or attack on the food supply (Prevention);

"(3) develop effective protection strategies to 'shield' the food supply from terrorist threats (Protection);

"(4) develop capacity for a rapid, coordinated response to a food-borne terrorist attack (Response); and

"(5) develop capacity for a rapid, coordinated recovery from a food-borne terrorist attack (Recovery)."[2]

One area that continues to be "at risk" is the area of public utilities. Our electrical infrastructure, water infrastructure, gas infrastructure, and other utilities remain at risk. Some of this is due to the old "out of sight, out of mind" syndrome, but some of it is simply too few resources chasing too many opportunities to improve.

Among the most problematic areas of infrastructure security is water supply. Though the United States water supply is perceived to be adequate and well protected, there remain many points of vulnerability throughout the systems. Water treatment facilities have seen increased levels of security and protection. The major area of vulnerability lies in the distribution network.

As with the FDA model, water utilities are increasingly being tasked with the same five measures of response to potential problems: awareness, prevention, protection, response, and recovery.

According to the EPA, "Over the past several years, various Presidential Decision Directives and other orders have assigned EPA responsibility for some very important aspects of the [infrastructure] security. These explicit responsibilities include being the lead federal agency charged with helping to protect the nation's water infrastructure from attack, being the lead agency responsible for the cleanup of any biological or chemical attacks, and having significant responsibilities in certain radiological attacks."[3]

While many of the primary source facilities and treatment plants are well secured behind guarded fences, the distribution systems are often spread over large geographic areas and through normal living areas of cities, suburbs, and even rural areas. These systems remain at significant risk.

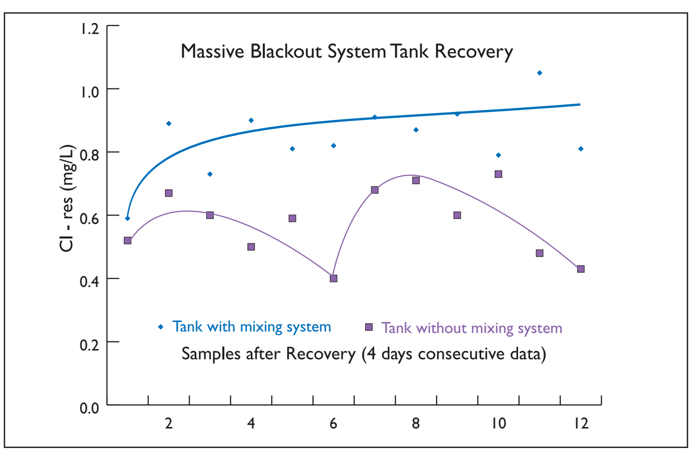

Figure 1. Two tanks on the same water system: one with a mixing system and one without. The incoming water is identical. Curves indicate short-circuiting in the tank without the mixing system.

"Since September 11th the EPA has taken a number of steps to ensure its abilities to meet its homeland security responsibilities. The agency is adding 75 response staff personnel to strengthen its ability to respond simultaneously to multiple incidents. In addition, the agency is providing advanced training and state of the art equipment to those who will respond to any chemical, biological, or radiological incident and is establishing a new Environmental Response Team West in Las Vegas to provide a quicker response time to any incidents that may happen in the western United States. The agency has already awarded nearly $50 million in grants to the nation's largest drinking water facilities to assess their vulnerabilities and make security improvements and upgraded its Cincinnati facility to handle level three contaminants. Last week, Whitman announced a Homeland Security Research Center in the Agency's Cincinnati labs to coordinate research in areas such as building decontamination, rapid risk assessment and drinking water protection."[4]

The purpose here is not to explore mediation of the potential threats through prevention. Many steps are being taken by water utility operators to secure facilities and make them attack resistant or attack proof. Large centralized facilities are more conducive to this level of prevention. However, as this effort moves out into the field (the distribution facilities) the ability to keep the facilities secure becomes increasingly difficult.

Recovery from Attack

Recently, significant work in a major water utility has shown that steps can be taken in advance to enhance the speed with which a system can recover from an attack. Through some coincidental and fortuitous events, important data were gathered on the ability of a water utility to immediately recover from a catastrophic situation.

During the blackout of 2003, a major Midwestern water utility was forced to drain all the water in all of its distribution system storage tanks to supply the water needs of its local citizens. When the power outage occurred, in August, demand was high and pumping ability was immediately suspended. During the outage, all available water was used from many tanks in the system as a result of generalized distribution system depressurization.

After power was recovered, the utility began immediately to pump water into the storage tanks at the highest rate possible. Interesting comparisons became available when data on this tank recovery process were evaluated. Inspection of the analysis data allowed water quality managers and engineers to look at tanks of different sizes and types to see how well they recovered with respect to each other. This information became particularly insightful in light of the EPA's interest in system recovery after a catastrophe.

While it is well known that the recovery of these systems can take place over an extended period of time, it was interesting to view how the systems could be recovered with the addition of adequate mixing and blending equipment in the individual tanks.

Due to a fortuitous set of circumstances, two redundant ground storage tanks were situated on the same service area and were supplied from the same water production facility. One of the tanks has a capacity of 3 MG and is fitted with an integral mixing system. The other tank, 10 MG capacity on the same system, did not include mixing capability.

Quality-control experts for the utility viewed closely the differences in the water drawn from these tanks as the system began to recover. Initial thoughts were that the tanks would exhibit similar chlorine retention characteristics as they were filled and drafted. The chlorine residuals in the tanks were measured as a function of time to determine how quickly the tanks could recover to a fully operational status. (Note: During the hours following the restoration of power, there was a general boil alert instituted as a precaution for the general public. As the tanks were being put back into full service, people were encouraged to boil all water prior to drinking or cooking.) Figure 1 demonstrates the performance curves for these two tanks.

In the tank with the mixing system (upper curve) it should be noted that the chlorine residual continues to increase over time as the tank is filled and drafted. This is because the inflow of high disinfectant residual water that enters the tank mixes with all of the ambient water previously in the tank, thus better sustaining a stable chlorine residual level in the tank over time.

The lower curve in the figure demonstrates the performance of the tank that did not include a mixing system. In this particular case, the tank chlorine residual cycled, as would be expected, from the relatively high distribution system flows, accentuating the short-circuiting phenomena taking place in this "unmixed" tank. Short-circuiting is a common trait of tanks with at least one inlet and one outlet and no adequate mixing pattern. When water is allowed to enter the tank at the same time water is drawn out of the tank, a flow pattern develops that bypasses the majority of the tank's volume. In essence, water moves directly from the inlet to the outlet without mixing with the older water in the tank. Disinfectant residual in tanks diminishes with tank residence time. The rate of reduction is dependent on many factors. These factors, such as the amount of biological or chemical reactivity inside tanks, may be aggravated during emergency conditions.

The graph shows the chlorine residual peaking at times when short-circuiting was taking place. High chlorine residual water moved directly from the inlet to the outlet without interaction with resident tank water. Whenever the supply of water to the tank stopped, the older (low chlorine residual) water in the tank was removed and the measured chlorine residual at the tank's outlet dropped. Figure 1 shows that the chlorine residuals were almost exactly the same when the chlorinated water was originally introduced into the tanks, but that over time the tank without the mixing system exhibited wild fluctuations in quality due to short-circuiting and water residence time.

Customers on the outlet of the tank with the mixing system had more consistently better water quality much sooner than customers on the tank without the mixing system.

What does all of this mean with respect to security in water systems? Unfortunately we must view future terrorist attacks on water utility systems as a potential for which we must be prepared. And, we must be prepared for recovery and remediation of these tanks.

The EPA has designated several "Critical Infrastructure Protection Goals" as a part of its future response to security attacks. The first item on its goal plan reads, "EPA will work with the states, tribes, drinking water and wastewater utilities (water utilities), and other partners to enhance the security of water and wastewater utilities."[5]

The key to the recovery of the water distribution system will depend on several factors.

- How quickly can the water be drained?
- How quickly can the tank be cleaned?
- How soon can fresh disinfected water be reintroduced into the system?
- How quickly can customers be back on stream, using disinfected water?

It is obvious from the work done in this utility that having a mixing system in the tank will significantly improve the "time to quality" ratio for the consumer. In addition, there are other significant benefits that accrue after the installation of the mixing system:

- Higher and more consistent chlorine residuals
- Reduced disinfection byproducts, such as trihalomethanes (THMs)
- Reduction in structural and coatings maintenance costs due to damage caused by seasonal ice formation

Without question, the addition of the mixing system in potable waters storage tank significantly improves the quality of water and the ability of the water utility to more quickly recover from a catastrophic event. GE

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Footnotes

1 *The Washington Times*, William Glanz, June 10, 2002.

2 Ensuring the Safety and Security of the Nation's Food Supply, A Progress Report by Secretary Tommy G. Thompson,

July 23, 2003, Downloaded from the Center for Food Safety & Applied Nutrition.

3 Environmental Protection Agency, United States of America Environmental Protection Agency Website, http://www.epa.gov/epahome/headline_100202.htm. Created: October 2, 2002, accessed November 18, 2004.

4 Ibid

5 Strategic Plan for Homeland Security, Environmental Protection Agency, United States of America, September 2002. Exhibit 1, Page 9.