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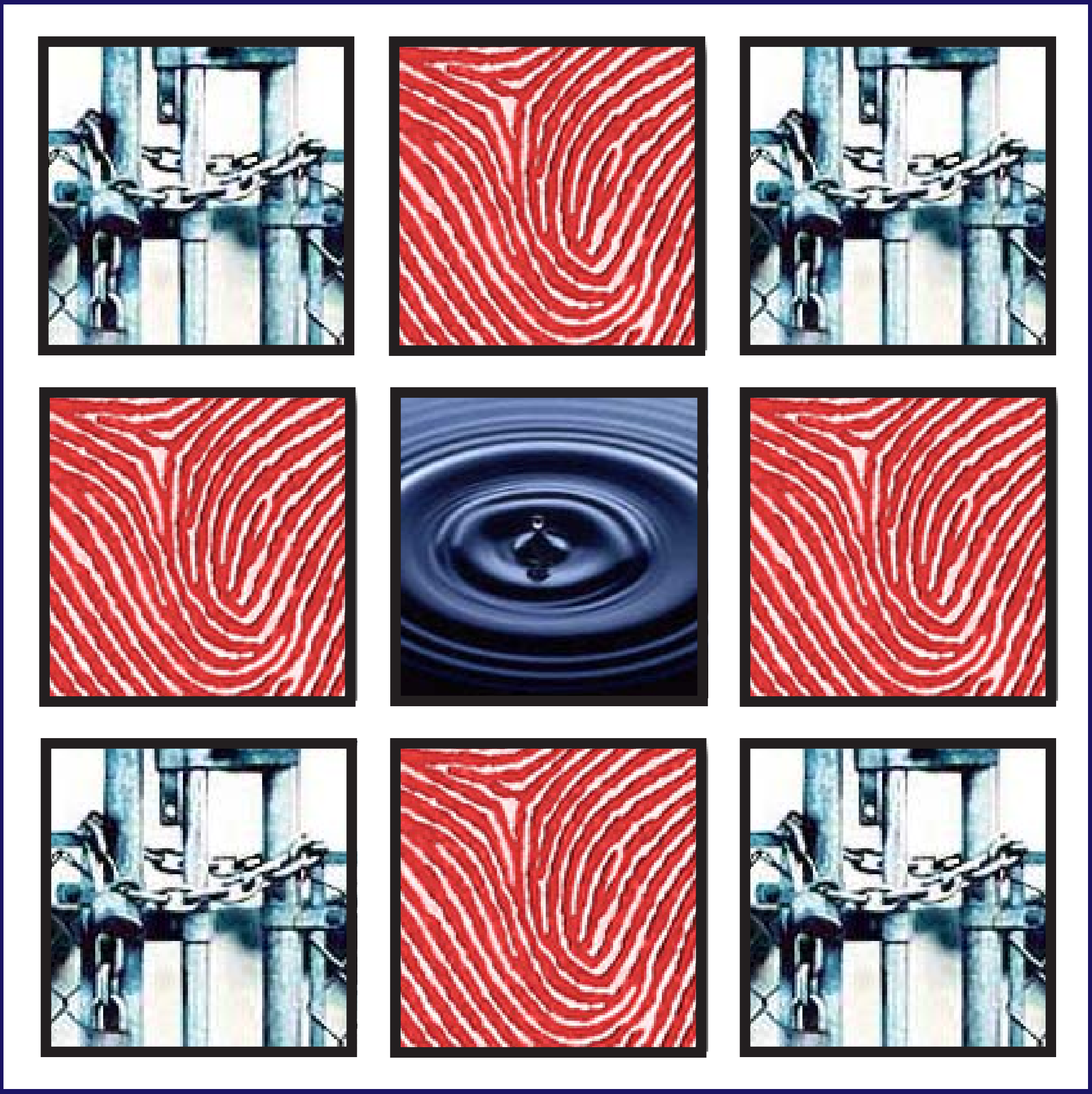

Water and Homeland Security

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Water and Homeland Security

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JOURNAL OF CONTEMPORARY WATER RESEARCH AND EDUCATION
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Water and Homeland Security: An Introduction

Regan Murray

U. S. Environmental Protection Agency

The possibility of terrorist disruption or contamination of the United States' water resources recently entered our national consciousness. Since September 11, 2001, several media reports revealed plots to contaminate drinking water. In 2002, suspected terrorists in Italy and France were arrested under suspicion of planning to contaminate drinking water systems—maps of water distribution systems and service connections were found in their possession. In 2003, an email from an al Qaeda spokesman to an Arabic media outlet stated the group's intention to poison the United States' water supply. In response, public and private entities have cooperated to determine effective preventative measures and counter-measures to improve the security of the water supply. The U.S. Environmental Protection Agency (EPA), as the lead federal agency for protecting the nation's water supply, began working with water utilities, water associations, other federal agencies, and the states to fortify the tens of thousands of utilities that provide water to the American people. The Public Health Prevention and Bioterrorism Preparedness Act of 2002, in part, provides funding and direction for water security initiatives.

Individual water utilities have incurred great expense and effort to improve their security. Many have spent large sums of money to harden their systems against attacks by adding locks, fences, security guards, new policies and procedures for employees, and updated computer systems. Utilities have also improved their emergency response capabilities, forming local and regional partnerships with law enforcement and public health officials. Now, to address the threat of contamination, water utilities are considering the use of sensors and early warning systems, and the use of computational models to track, isolate, and optimize treatment of contaminated water.

However, many questions remain about the nation's ability to protect water systems adequately. To a large degree, effective political policies and emergency response protocols are hindered by the lack of available and reliable scientific information.

An avalanche of research has been sparked to address these unknowns. Much is focused on the potential agents of contamination: Which agents pose a real threat to drinking water systems? How do these agents behave in drinking water systems? Can they be removed or inactivated with conventional treatment? Can better analytical methods and laboratory protocols be developed to sample, identify and verify these agents? Research also pertains to methods to detect contamination—improved sensors and hardware and public health surveillance networks. Much research is also focused on data analysis tools and computational models—vulnerability assessments, real time pattern recognition and data analysis for early warning systems, and improved hydraulic and water quality models to prepare for and respond to attacks. Research is also needed in the social sciences, including cost-benefit analysis for security improvements.

This issue of the *Journal of Contemporary Water Research and Education* outlines the current major areas of research in water security, and highlights the scientific unknowns that are preventing the development of reliable and robust protective measures for our nation's water supply. Experts from various government agencies, national laboratories, universities, water utilities, and water associations prepared the papers in this issue. The papers address the following topics: EPA's policy and research efforts in water security; methods to identify vulnerabilities of water systems; early warning systems; applications of hydraulic modeling; treatment and decontamination; emergency response protocols; public health initiatives; and wastewater security. Research in these areas promises to broaden our basic understanding of drinking water systems, improve water security, water quality and system operations. It is hoped that these papers will inspire readers to initiate research in these areas.

The papers in this issue are drawn largely from UCOWR's 2003 conference held in Washington, D.C., on "Water and Homeland Security in the 21st Century." We hope readers will consider participating in our 2005 conference to be held July 12-14, in Portland, Maine, on "River and Lake Restoration: Changing Landscapes." See the back of this issue for the call for papers.

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Water Security Research and Policy: EPA's *Water Security Research and Technical Support Action Plan*

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Water—every drop of it—is a precious natural resource that Americans once enjoyed with little thought to potential tampering by terrorists or others. Today, however, U.S. citizens are increasingly aware of threats of harm to our homeland. The terrorist attacks of September 11, 2001, and the delivery of anthrax-contaminated letters later that year have taught all of us to anticipate threats to our waters.

Terrorist threats are targeted not just at individuals, but also at the country's vital institutions and infrastructure, including the nation's drinking water and wastewater systems. Government, water utilities, state and local water agencies, public health organizations, emergency and follow-up responders, and academia, as well as the private sector from across the country must be ready to protect water infrastructure. These organizations are working together to reduce vulnerabilities to terrorism, prevent and prepare for terrorist attacks, minimize public health impacts and infrastructure damage, and enhance recovery from any attacks that may occur.

In 2002, the Administration developed a road map for securing the homeland—The *National Strategy for Homeland Security* [1] —which lays out specific objectives for border and transportation security, emergency preparedness and response, protecting critical infrastructure, domestic counterterrorism, defending against catastrophic threats, and intelligence and warning. This road map designates the United States Environmental Protection Agency (EPA) as the lead federal agency for protecting critical drinking water and wastewater treatment and distribution system infrastructure.

EPA's Role in Water Security

The Public Health Security and Bioterrorism Preparedness and Response Act (Bioterrorism Act) of 2002[2] is the legislative mandate for EPA's work in water security. This law, coupled with executive directives and the Agency's own strategic plan for homeland security, guide the Agency's research and technical support activities to protect water infrastructure. The Homeland Security Presidential Directive on Critical Infrastructure Identification, Prioritization, and Protection (HSPD-7)[3] reinforces EPA's role as the sector-specific lead for water infrastructure. It also assigns the responsibility of coordinating the overall national effort to protect critical infrastructure and key resources of the United States to the Department of Homeland Security.

As the sector-specific federal lead for protecting the nation's drinking water and wastewater infrastructures, EPA plays a critical role in the homeland security arena. To meet these responsibilities, the Agency's Office of Water (OW) established the Water Protection Task Force. In August 2003, the Task Force was organized formally as the Water Security Division (WSD). Additionally, the Agency's Office of Research and Development (ORD) officially established the National Homeland Security Research Center (NHSRC) in February 2003. These organizations work together to provide research and technical support for the drinking water and wastewater sectors.

NHSRC's Water Security Team contributes by conducting applied research and then reporting on ways to better secure the nation's water systems from threats and attacks. The Water Security Research Program produces analytical tools and procedures, technology evaluations, models and methodologies, decontamination techniques, technical resource guides and protocols, and risk assessment methods. All of these products are for use by EPA's key water infrastructure customers—water utility operators, public health officials, and emergency and follow-up responders (see Table 1). Other research programs in NHSRC deal with the protection of buildings and rapid risk assessment.

EPA's WSD provides support to drinking water and wastewater systems by preparing vulnerability assessment and emergency response systems and tools, providing technical and financial assistance, and developing information exchange mechanisms. WSD is also charged with supporting best security practices, providing security enhancement guidance, and incorporating security into the day-to-day operations of the drinking water and wastewater sectors. In addition, WSD works closely with NHSRC in delivering research results in a timely and appropriate fashion.

Along with providing research and technical support, both NHSRC and WSD encourage information sharing and risk communication strategies among key water infrastructure customers. This includes making use of the Water Information Sharing and Analysis Center (WaterISAC)[4].

Table 1. Potential users of information developed under the *Action Plan*.

Water industry representatives
State, regional, and local response organizations
Public health officials and organizations
Federal agencies and departments
Laboratories with water sample testing capabilities
Individuals and organizations with water expertise
Elected officials and the public

Water Security Research and Technical Support Action Plan

To better understand the security problems of the water industry in the United States, EPA has engaged in conversation with numerous water experts and stakeholders from government, industry, and academia. Other key participants are representatives from public health organizations, emergency responders and follow-up responders, law enforcement officials, environmental groups, and related professional associations.

As a result of these meetings, EPA has gained valuable insights on the vulnerabilities and technical challenges facing the water industry for which research and technical support are crucial. With assistance from other federal agencies and contractors, both WSD and NHSRC are addressing these challenges. Issues, needs, and projects are summarized in the comprehensive *Water Security Research and Technical Support Action Plan*, otherwise known as the *Action Plan.*

Much of the work described in the *Action Plan* has begun, and what is not underway will begin during the next few months. The *Action Plan* must be recognized as a snapshot in time. As new information is developed on threats, contaminants, and threat situations, adjustments will most certainly be necessary. Revisions to the *Action Plan* will be made periodically based on input from others dealing with drinking water and wastewater security. The *Action Plan* will also evolve based on changing needs in the homeland security arena.

The *Action Plan* addresses drinking water supply, water treatment, finished water storage, and drinking water distribution system infrastructure. It also addresses wastewater treatment and collection infrastructure, which includes sanitary and storm sewers or combined sanitary-storm sewer systems, wastewater treatment, and treated wastewater discharges to rivers, estuaries, and lakes.

Research and Technical Support Questions

In various meetings with EPA, federal partners and water stakeholders discussed issues, needs, and projects to secure water infrastructure and safeguard water quality. The *Action Plan* developed as a result of these meetings describes research and technical support that addresses many questions focused on protecting water infrastructure. Some of the questions are as follows:

Drinking water questions

1. What are the most plausible threats, contaminants, and threat scenarios facing the water industry? How does this information compare with intelligence information on possible threats?
2. How could computers be tampered with, particularly supervisory control and data acquisition systems to negatively impact water system operations? What might those impacts be and how best can such tampering be prevented or minimized?
3. What would be the cascading effects of an attack on a water system, and what are the impacts on water systems when other critical infrastructure systems malfunction? How can these effects or impacts be minimized?
4. What types of biological and chemical contaminants could be introduced into water systems and what are their physical, chemical, and biological properties? What are the potential health impacts of these contaminants?
5. What are the most effective means to detect contaminants in water? How can this information be combined with reporting, analysis, and decision making to arrive at a reliable and cost effective early warning system?
6. Do surrogates, or chemical, biological, and biochemical alternatives exist that might be safely used for research and testing purposes in place of hazardous and potentially lethal agents? How reliable are these surrogates in representing actual agent characteristics in water?
7. Can effective methods be developed to ensure that a sufficient number of qualified laboratories exist to perform rapid analysis of water contaminants in the event of an attack?
8. If contaminants are introduced into a water system, where will they travel? How quickly will they travel? What will be their concentration at various points along their path? Can the human health impacts of these contaminants be effectively minimized?
9. How can water that has been contaminated be effectively treated so that it can be released to wastewater systems or otherwise effectively disposed of?
10. How can water materials and equipment that are contaminated, be cleaned, and returned to service as quickly as possible after an attack? What are the best ways to determine residual contamination, if any, that might linger over the long term?
11. Are alternative water supplies available in the event of an attack? How would water utilities or governments most effectively supply clean water to affected communities and business in both the short and long term?
12. What are the routes of human exposure to contaminants if a water system is attacked?
13. What are the acute and chronic impacts from these exposures and can they be adequately represented based on existing risk information?
14. Can a health surveillance network be established to rapidly identify disease outbreaks associated with contaminated water? Are there other means of providing early warnings or alerts from water contamination using surrogate health data?

Wastewater questions

1. What are the risks of hazardous substances that may be introduced into wastewater treatment systems?
2. Can intrusion and surveillance monitoring technologies be improved to rapidly detect water contamination and alert authorities should a wastewater facility be compromised?
3. Are alternative wastewater treatments and discharge locations available in the event of an attack?

Information questions

1. How best can emergency responders, public health officials, health care providers, and the public be effectively and efficiently informed in the event of an attack?

Recommendations from partner and stakeholder meetings are organized in the *Action Plan* under the seven issues listed in Figure 2. The plan describes significant research needs for these categories and lists specific projects for each need (refer to the *Action Plan* for more information). Although the *Action Plan* focuses primarily on biological and chemical (including radiological) contaminants in drinking water systems, it also addresses physical

Table 2. Example *Action Plan* Needs

- **Ensure the protection of existing water infrastructure**
- **Enhance cyber security and other external means of disrupting water systems**
- **Identify and characterize threats that could be used to disrupt water systems**
- **Develop methods for detecting and monitoring contaminants in water**
- **Create rapid screening technologies for the identification of unknown contaminants**
- **Test and evaluate the performance of sensors and biomonitors**
- **Improve detectors and early warning systems for water distribution and collection systems**
- **Enhance models for contaminant transport in pipes and distribution systems**
- **Refine fate and transport information for contaminants in water**
- **Develop treatment or inactivation techniques for water contaminants**
- **Evaluate and improve decontamination and disposal techniques for contaminated materials and equipment**
- **Establish contingency planning and infrastructure backup procedures**
- **Improve methods for assessing risks to the public from water contamination**
- **Enhance risk communication and information sharing among individuals and organizations dealing with a threat or attack**
- **Provide training and exercises that enhance preparedness, response, and mitigation to water system threats or attacks**

and cyber threats, contingency planning, risk assessment and risk communication, and infrastructure interdependencies. The *Action Plan* focuses on research to:

1. Protect drinking water systems from physical and cyber threats
2. Identify drinking water threats, contaminants, and threat scenarios
3. Improve analytical methodologies and monitoring systems for drinking water
4. Contain, treat, decontaminate, and dispose of contaminated water and materials
5. Plan for contingencies and address infrastructure interdependencies
6. Target impacts on human health and inform the public about risks
7. Protect wastewater treatment and collection systems

Action Plan Schedule and Products

The challenges facing the Agency in protecting water infrastructure are interdependent and complex. The goal of the *Action Plan*, however, is to provide useful and timely products to key customers by the end of 2005 and, of course, along the way. To accomplish this goal, EPA is partnering with other federal agencies, national laboratories, non-governmental water industry research groups, and the private sector to build on existing strengths, share the workload, and take advantage of related research already underway. One example of this is the Distribution System Research Consortium, formed by NHSRC and WSD. The consortium meets twice a year to address research and technical support issues around distribution systems. Members include representatives from the Department of Homeland Security, the Centers for Disease Control and Prevention, the Department of Defense, the Department of Energy, and the U. S. Geological Survey, among others. Work in progress will also be shared in open forums such as journals, conferences, and workshops. If the information is sensitive, it will be shared through more limited venues such as the WaterISAC.

EPA's research and technical support activities will result in various types of products, tools, and technologies, such as those listed in Table 3. These will be available to the water industry, public health officials, elected officials, health care providers, emergency responders, and others to aid in the fight against terrorism. A listing of all available research products, as well as many of the products themselves, will be placed on NHSRC's Web site at: http://

Table 3. *Action Plan* Products

Computerized data compendiums
Response guides and protocols
Technical resource documents, case, studies, and model procedures
Laboratory methods and protocols
Communication tools and frameworks
Technology screening, evaluation, and verification
Workshops and seminars
Computerized tools and software systems
Risk assessment methods and procedures
Journal articles, fact sheets and technical bulletins

www.epa.gov/ordnhsrc. An internet-based catalog with publicly-available products from both WSD and NHSRC will be located on the WSD Web site at: http://www.epa.gov/safewater/security. EPA information clearinghouses, booths at conferences and workshops, and announcements and press releases will be used to deliver *Action Plan* results as well.

Additional Information

With a long history in environmental protection, and assessing and managing risks, EPA is well positioned to develop the tools and technologies that address threats to and attacks on drinking water and wastewater systems. As the lead for the research under this *Action Plan*, NHSRC is providing applied research that can be used quickly by those with a stake in securing water system infrastructure. As the lead for technical support to key customers in the water arena, WSD is charged with a much broader responsibility that is informed by NHSRC's research. The *Water Security Research and Technical Support Action Plan* is a joint and collaborative undertaking that involves both organizations. Such an approach in addressing water security has worked well to date and will continue into the future.

Acknowledgements

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Notes

1. U.S. Environmental Protection Agency (USEPA). 2004. Water Security Research and Technical Support Action Plan. EPA/600/4-04/063. Cincinnati, OH: U.S. Environmental Protection Agency, Office of Research and Development, and Washington DC: U.S. Environmental Protection Agency, Office of Water. Available at http://www.epa.gov/ordnhrc/pubs/bookActionPlan031204.pdf
2. United States Congress. 2002 Public Law 107-188. Public Health Security and Bioterrorism Preparedness and Response Act of 2002. Available at http://www.epa.gov./safewater/watersecurity/pubs/security-act.pdf.
3. The Whitehouse Office of Homeland Security. 2002. National Strategy for Homeland Security. Available at http://www.whitehouse.gov/homeland/book/nat_strat_hls.pdf
4. The Whitehouse Office of the Press Secretary. 2003. Homeland Security Presidential Directive/HSPD-7. Critical Infrastructure Identification, Prioritization and Protection. Available at http://www.whitehouse.gov/news/releases/2003/12 20031217-5.html

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Assessing the Vulnerabilities of U.S. Drinking Water Systems

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During the Clinton administration, the importance of our critical infrastructure was highlighted by the National Security Council in Presidential Decision Directive 63 (PDD 63). PDD 63 was superseded recently when President Bush signed Homeland Security Presidential Directive 7 (HSPD-7). HSPD 7, like its predecessor PDD 63, establishes a national policy under which federal departments and agencies are required to identify and prioritize United States critical infrastructure and the key resources needed to protect them from terrorist attacks. PDD 63 and HSPD 7 also encourage Federal departments and agencies to form public and private partnerships to pursue the goal of lowering risks to our national assets due to malevolent events. The Environmental Protection Agency (EPA) is assigned responsibility for the water infrastructure, which includes both drinking water and wastewater systems.

Subscribers (mainly water utilities) of the American Water Works Association Research Foundation (AwwaRF) were also becoming concerned about security at drinking water utilities and encouraged AwwaRF to assist them in understanding potential malevolent threats. In response to PDD 63, and with input from public water utilities, both EPA and AwwaRF initiated programs to understand and mitigate the security vulnerabilities of drinking water utilities. The events of 9/11 accelerated the development of these programs.

This paper describes efforts to assess and mitigate the vulnerabilities of drinking water utilities. (See O'Neill and Hais, this issue, for a discussion of wastewater security issues.) This paper covers several key areas, including threat assessment, water contamination, and response effectiveness.

Law Requires Vulnerability Assessments

On June 12, 2002, President Bush signed the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 into law (PL 107-188). This Act requires community water systems that serve populations of greater than 3,300 persons to conduct vulnerability assessments. According to EPA statistics, approximately 4,800 water utilities fit into this category. When combined, these water utilities serve over 256 million people.

Large drinking water utilities, defined as those serving more than 100,000 people, were required to conduct their vulnerability assessments and submit a report to the EPA by March 31, 2003. Drinking water utilities serving 50,000 to 100,000 people were to conduct their vulnerability assessments and submit a report by December 31, 2003. Drinking water utilities serving 3,300 to 50,000 people were to conduct their vulnerability assessments and submit a report by June 30, 2004.

Vulnerability Assessment Process

In cooperation with the EPA and AwwaRF, Sandia National Laboratories (Sandia) created the Risk Assessment Methodology for Water Utilities known as RAM-W^{TM}. RAM-W^{TM} is the most widely used methodology to assess security risks at large water utilities. Several thousand water utility owners/operators, regulators, and water industry consultants have been trained in the use of RAM-W™. Other tools have been developed by other entities and were used at several large water utilities, but were applied more prevalently to medium and small water utilities.

Figure 1 illustrates the process followed in RAM-W™ and demonstrates the iterative nature of the methodology. This methodology was developed through decades of security research and development at Sandia, initially focused on safety of nuclear facilities. Ideally, the entire analysis is driven by the threats one wants to protect against. In many high-security applications, this threat level is determined by a federal entity (e.g., the Department of Energy or the Nuclear Regulatory Commission) and a designated security analyst then evaluates the effectiveness of the security system. Most high-security applications also employ an on-site guard force, usually armed and well trained, to respond to malevolent incidents. Managers of the majority of civilian infrastructures do not employ a dedicated response force and operate geographically distributed assets, the majority of which reside in the public realm.

Each major block of the methodology has multiple steps and/or requirements. For a complete description of RAM-W™, please contact the American Water Works Association for a copy (the requestor must demonstrate a need-to-know and must sign a nondisclosure agreement). AwwaRF subscribers may contact them directly.

Results

Sandia conducted several vulnerability assessments during the development and validation of RAM-W ™ and water utility owners/operators and consultants applied the methodology at several hundred additional locations. As a result, the water community gained a good understanding of the state of security at water utilities and identified challenges that may lie ahead. In a recent project, AwwaRF and Sandia teamed to collect information on the vulnerability assessments conducted by the large water utilities to better understand (1) how well the process worked, (2) remaining areas of concern, and (3) what further developmental efforts to pursue (AwwaRF 2004).

Defining the Threat to Water Utilities

Although encouraged to contact local law enforcement and other authorities, most water utilities found it difficult to obtain relevant threat data.

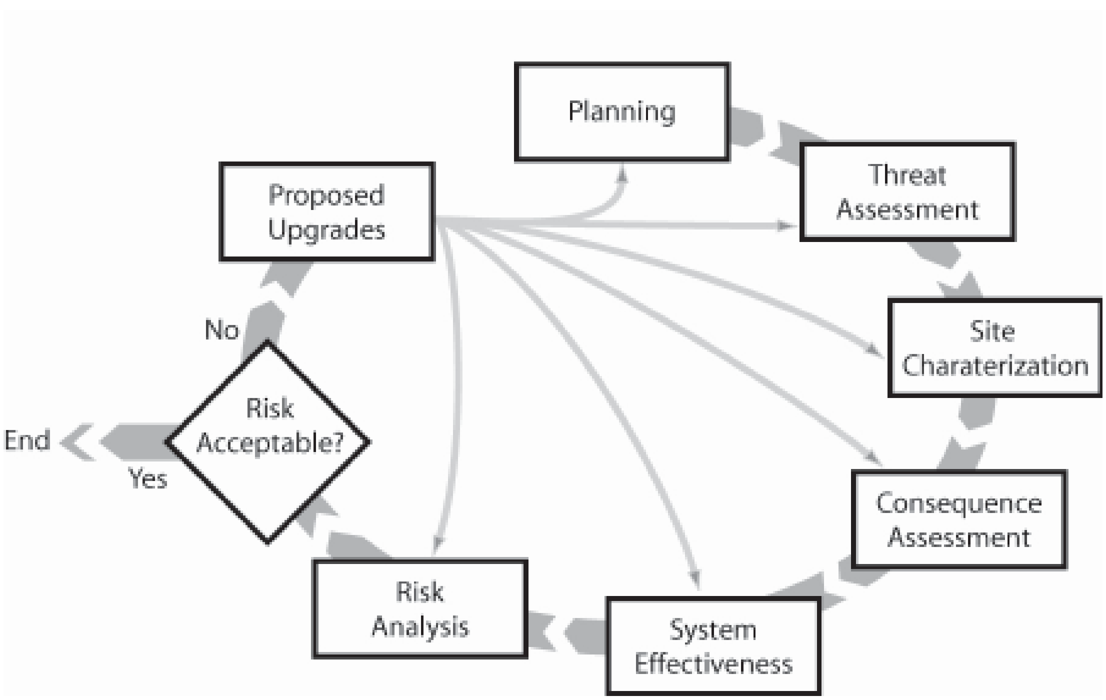

Figure 1. RAM-W™ Process

As stated earlier, the specified threat drives the risk analysis. Therefore, water utilities are faced with a high degree of ambiguity about what the actual threats are while having to undertake risk reduction programs that may cost millions of dollars. Even with the billions of dollars already being spent to improve the security of our nation's water utilities, it is questionable whether or not the utilities will be able to withstand a high-level threat. Much of the utilities' infrastructure resides in the public realm, is broadly distributed, and is very difficult to protect.

The federal government has not defined a threat that can be used as the basis of a security design for the water infrastructure, nor is there agreement in the water community about what threats to consider. Therefore, the water utilities analyzed a multitude of threats and threat levels. Neighboring water utilities often used significantly different threat levels during their risk assessment. The number of adversaries and their projected capabilities will dramatically affect the outcome of the security risk analysis.

Contamination of Water Supplies

One of the least understood threats to the drinking water industry is contamination, particularly in the water distribution system. At the beginning of the program to assess the vulnerabilities of water utilities, very little was known about malevolent water contamination and even fewer analytical tools were available to help understand and analyze the problem. Since 9/11, several groups, including the AwwaRF, the EPA, and the Center for Disease Control, have collaborated to collect and characterize information on contaminants that may pose a significant health threat in drinking water systems. Prioritizing contaminants, developing methods to rapidly detect them, developing a full understanding of contaminant fate and transport, developing estimates for contamination risks to water distribution systems, creating programs for isolating and treating contaminants, and final restoration of clean water supplies are all in their early stages of development.

Sandia has launched an internal research program, with collaborators at EPA, to provide tools for answering many of these important contamination-related questions. This research program will develop numerical tools to probabilistically predict the fate and transport of a variety of potential contaminants and thus facilitate the development of contamination risk maps for water distribution systems. The research program will also help determine optimal sensor locations for detection of contaminants (assuming the appropriate sensors are developed) and develop analytical tools to quickly locate where contaminants were introduced.

Response to Threats

High-security environments often have an on-site response force to deal with malevolent threats. The vast majority of water utilities do not employ such a strategy. Instead, they rely on cooperation from local law enforcement, public health authorities, and other providers of emergency services. This is not an unusual situation within the community of critical infrastructures, but this approach leads to long response times, raising a concern about the level of security provided.

Immediately after 9/11, many metropolitan areas assigned police officers at water utility assets to deter adversaries. Due to budget constraints and a belief that the threat is not as imminent as previously believed, this practice has been largely discontinued.

Recommendations

Based on the experience of applying RAM-W™ to hundreds of water utilities, several improvements could enhance future risk assessments. These improvements include: a refined threat description, complete integration of the water distribution system contamination analysis with the risk assessment, and improved response protocols. Naturally, these recommendations will require resources and time to accomplish.

Because the threat level drives the risk assessment analysis and ultimately, the risk reduction recommendations, the area of threat assessment could be improved. A variety of approaches may be taken, such as the following:

1. Issue a mandatory threat level for all water utilities (minimum standard) to use as the basis for determining which risk reduction upgrades are appropriate
2. Use a graded approach to implementing upgrades based on population served or some other statistic, such as volume of water shipped

3. Water-community-developed threat scenarios that are graded by population
4. Threat levels based on regional or target attractiveness

Whatever threat definition system is chosen, consistency and minimally acceptable threat levels should be created to provide a balanced approach to countering the threat.

The water distribution system has long been known to represent one of the greatest security vulnerabilities. Current challenges include a lack of clear understanding of the fate and transport and consequences of potential contaminants within a water distribution system coupled with generally easy access into the system. To minimize the potential risks from a malevolent contamination attack, it is first necessary to develop computational tools that can predict the fate and transport of contaminants within distribution systems, or more generally, how contaminants might move in a hydraulically complex pipe network. This computational tool must be integrated within a systematic framework (as embodied in RAM-W™), so that a more comprehensive risk assessment can be accomplished. Such a tool (or set of tools) (1) would be capable of determining (in a probabilistic sense) the spread of contaminants within a distribution system, (2) could be used to estimate consequences from such an attack, (3) would be able to identify optimum locations for early-warning sensors, and (4) would be able to identify the source location (point of introduction) in near-real time. Determining the extent of contamination in a water distribution system in real time is essential so that proper actions can be taken to minimize the further spread of the contaminants.

Methodologies for conducting vulnerability assessments should include a framework for cleanup and recovery. The tools to estimate the fate and transport of contaminants within a water distribution system could also play a significant role in developing a methodology for recovery after such an event and could serve as the instrument to integrate both components for the protection of drinking water systems.

Better response protocols are needed in several areas. Response to water contamination events is entirely different than response to an armed attack where the intent is to damage the utility's physical assets. The current research underway to understand the fate and transport of contaminants will help decision makers understand the risk and to develop new response protocols that address that attack before the contamination event. Those protocols must include clean-up processes and placing the system back in service.

Responding to threats may require new approaches that greatly enhance the time an adversary needs to complete a malevolent act. Threats can be countered by storing high-consequence assets underground, limiting the paths an adversary might exploit and thereby creating long task times. For example, pumping stations could be protected better by installing them below grade in protected shelters.

In testimony to the United States House of Representatives Committee on Science entitled "H.R. 3178 and the Development of Anti-Terrorism Tools for Water Infrastructure," Jeffrey J. Danneels of Sandia suggested several alternatives that might provide the improved security desired at a much lower cost than the physical security approaches currently in use. Research dollars should be made available to study alternatives that put final treatment of the water supply closer to the consumer, consider much of the present potable water system as non-potable to decentralize the impact of a potential event, and evaluate the efficacy of creating municipal bottling facilities and other novel approaches that provide the level of security demanded by the water consumer and which may not be achievable through any other means.

Conclusions

Understanding and analyzing the vulnerabilities within the water infrastructure is a very important undertaking. Our government needs to protect one of the most basic assets America has—a clean water supply. Understanding and analyzing the vulnerabilities within the nation's water infrastructure will help us protect the health and safety of our citizens. The efforts completed to date have highlighted several vulnerabilities that will require significant amounts of effort to correct. Within the list of 14 U.S. critical infrastructures listed in HSPD-7, the water infrastructure is probably the most taken for granted. A large investment will be required to provide even minimal levels of security for this important resource. "When is enough, enough?" will be a difficult question to answer and will be debated for years to come.

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References

Awwa Research Foundation. 2002. *Risk Assessment Methodology for Water Utilities (RAM-W™).* 2nd ed. Denver, Colorado: Awwa Research Foundation and Sandia National Laboratories.

Awwa Research Foundation. 2004. *Results from the Water Utility Vulnerability Assessment Lessons Learned Study.* Denver, Colorado: Awwa Research Foundation and Sandia National Laboratories.

Environmental Protection Agency. n.d. *FACTOIDS: Drinking Water and Ground Water Statistics for 2001*. Available at http://www.ngwa.org/pdf/01factoids.pdf.

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Responding to Threats and Incidents of Intentional Drinking Water Contamination

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Both water contamination *threats* and intentional water contamination *incidents* could be designed to disrupt the delivery of safe water to a population, interrupt fire protection, create public panic, or cause disease or death in a population. A water contamination threat occurs when the introduction of a contaminant into the water system is threatened, claimed, or suggested by evidence. A water contamination incident occurs when a contaminant is successfully introduced into the water supply. A water contamination incident may be preceded by a threat, but not always. Both water contamination threats and incidents may be of particular concern due to the range of potential consequences:

1. Creating an adverse impact on public health within a population
2. Disrupting system operations and interrupting the supply of safe water
3. Causing physical damage to system infrastructure
4. Reducing public confidence in the water supply
5. Long-term denial of water and the cost of remediation and replacement.

Some of these consequences would only be realized in the event of a successful contamination incident; however, the mere threat of contamination can have an adverse impact on a water system if improperly handled.

In characterizing any threat, both the *possibility* and *probability* should be considered. A general assessment of the threat of intentional contamination of drinking water indicates that it is possible to cause varying degrees of harm through contamination of the drinking water supply. However, an evaluation of past incidents at drinking water facilities would indicate that the probability of an actual contamination incident is relatively low, but the probability of a contamination threat is relatively high. Many of the apparent security breaches at drinking water utilities that have occurred since 9/11 have been perceived as potential contamination incidents. Although a few threats have been verbal, most have been circumstantial, such as a low-flying airplane over a reservoir or a lock cut from the hatch of a distribution system storage tank. Given the possibility of contamination, many utilities choose to treat these security breaches as potential contamination threats.

Vulnerabilities to intentional contamination exist in all drinking water systems. While it may be possible to improve security at some critical system locations to reduce the level of vulnerability, it is impossible to eliminate all vulnerabilities. Thus, the contamination threat may be most effectively managed through thorough planning, careful evaluation of any specific threats, and implementation of appropriate response actions.

Managing a Contamination Threat

Management of a contamination threat involves: 1) planning for the response prior to an incident, 2) evaluating the credibility of the threat, and 3) implementing appropriate response actions based on available information and the circumstances of the situation. This article provides an overview of the process for managing a contamination threat, while more detailed guidance is available from the *Response Protocol Toolbox: Planning for and Responding to Drinking Water Contamination Threats and Incidents* (EPA 2003a). This toolbox is organized into six modules, which discuss water utility planning (EPA 2003b), water contamination threat management (EPA 2003c), site characterization and sampling (EPA 2003d), sample analysis (EPA 2003e), public health response, and water system remediation and recovery. Additional resources for drinking water security in general may be found at the EPA Water Security Division website (http://www.epa.gov/safewater/security/).

1. Planning a Response to Contamination Threats

Planning is the foundation of making good response decisions. For water contamination threats and incidents, planning takes on a special meaning because of the multitude of potential and/or threatened contaminants, whether they are biological, chemical, or radiological. However, to paraphrase the World Health Organization, it is neither possible nor necessary to specifically plan for attack with all possible contaminants, but increasing preparedness to counter the effects for such an attack by planning and preparation can provide the capabilities to deal with a wide range of possibilities (WHO 2003).

Planning for any type of emergency, including water contamination threats and incidents, begins at the local level. Officials within the utility and local government will have a collective knowledge of the organizations and systems that exist to provide support during an emergency. During this planning, the utility and local or state authorities will need to determine:

1. Who will respond to the initial threat?
2. Who will determine if the threat is possible or credible?
3. Who will evaluate the site and collect samples?
4. Who will perform analyses?
5. Who will make public health decisions?
6. Who will manage remediation and recovery activities?

In many cases, the answers to these questions will not be immediately evident, or may vary with the circumstances of the situation. This is especially true in the case of drinking water contamination threats where it is unclear whether or not the water has been contaminated and presents a threat to public health. Proper planning should establish roles and responsibilities of various parties under a variety of scenarios. There are many planning activities that a drinking water utility can undertake to improve preparedness and the ability to respond effectively to a drinking water contamination threat or incident, and several are briefly described below.

1. <u>Know your water system</u>: This includes documentation of construction, design, operation, and personnel; assessment of vulnerabilities to contamination threats; and identification of critical customers.
2. <u>Update Emergency Response Plans</u>: Many utilities have existing Emergency Response Plans (ERPs); however they may need to be updated to cover terrorist threats, including intentional contamination.
3. <u>Develop Response Guidelines</u>: A set of Response Guidelines (RG) is a streamlined, action-oriented, easy-to-follow document that is intended to support responders and decision officials in the midst of a crisis. An RG might include organizational charts, notification trees, contact information, standard operating procedures, decision trees, and reporting forms among other tools.
4. <u>Establish Structure for Incident Command</u>: The leadership and chain-of-command must be clearly established prior to an actual threat or incident. There is a formal *Incident Command System* that has been adopted by many response organizations (FEMA 2003). Incident Command for drinking water response is intricate because the water utility may be handling the early stages of the threat evaluation, while other parties, such as law enforcement, may be in charge during later stages (EPA 2003b).
5. <u>Develop Information Management Strategy</u>: Timely and accurate information will be key to evaluating the credibility of a threat and taking steps to protect public health as necessary. A system should be in place to manage the flow of this critical information.
6. <u>Establish Communication and Notification Strategy</u>: Predefined communication pathways and notification trees are essential to the effectiveness of any incident command

structure and will help to ensure that important parties are notified at the right time.

7. Perform Training and Conduct Desk/Field Exercises: Training and practice are essential to the proper application of any emergency plan (e.g., ERP, RG). Desk-top or field exercises that involve all of the key players are a valuable test of the plan.
8. Enhance Physical Security: Enhancements to physical security at sites identified as particularly vulnerable to contamination, or which have been subject to intrusion in the past, may significantly reduce false alarms that would otherwise expend utility resources.
9. Establish a Baseline Monitoring Program: Unusual water quality data or consumer complaints may indicate a potential problem, but only if the results can be compared against an established baseline that accounts for normal fluctuations.

2. *Evaluating a Contamination Threat*

A contamination threat is typically triggered by an occurrence or discovery that indicates the potential for water contamination. Several potential *threat warnings* are summarized in Figure 1. Threat warnings occur on a regular basis if they are monitored; however, the vast majority are due to harmless activity and require no response. Nonetheless, every threat of potential drinking water contamination should be evaluated in order to identify the handful of credible threats that might exist among the large number of threat warnings.

The overall response to a contamination threat is schematically depicted in Figure 2 and indicates two parallel and inter-related activities: the threat evaluation and response actions. A fundamental principle of this process is the concept of expanded response actions as the credibility of the threat increases. This is intended to avoid both under- and over-response to a contamination threat since both have potential adverse consequences to the public. For example, a complete lack of response to a credible threat might put the public at an unacceptable risk of exposure to a harmful contaminant. On the other hand restrictions placed on water usage, such as a notice not to drink the water, in response to a threat that has not been determined to be credible carries its own consequences.

A *threat evaluation* is a process that considers available information about a contamination threat to determine if it is "*possible*," "*credible*," or a "*confirmed*" incident. Each of these stages is depicted in Figure 2 as a decision point and described in more detail below:

1. Stage 1: "Is the threat possible?" A water contamination threat is characterized as "possible" if the circumstances of the threat

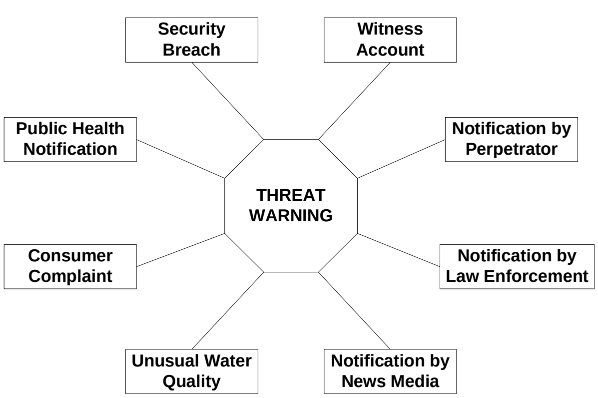

Figure 1. Summary of Threat Warnings

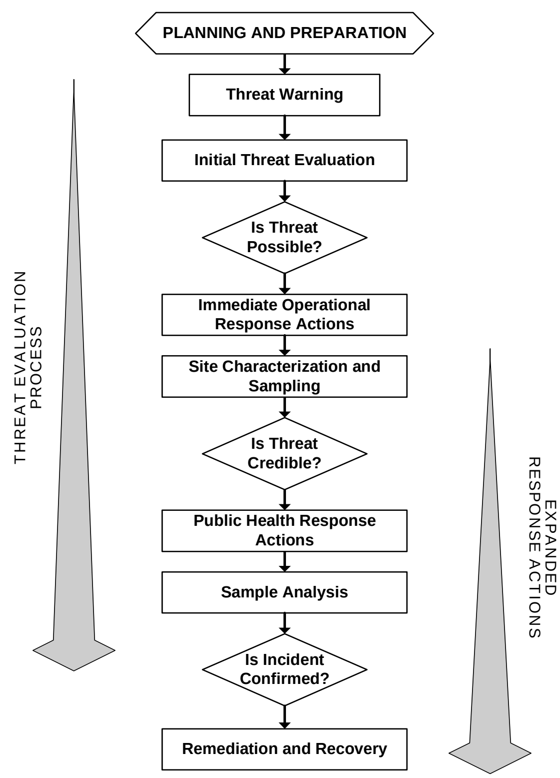

Figure 2. Overview of Response to a Contamination Threat

warning appear to have provided an opportunity for contamination. Response to a "possible" threat might include immediate operational response actions in an attempt to contain the water, and collection of additional information to help establish whether or not the threat is "credible." Site characterization activities are designed to collect additional information to support this determination.

2. Stage 2: "Is the threat credible?" A water contamination threat is characterized as "credible" if information collected during the threat evaluation process (e.g., site characterization activities) corroborates information from the threat warning. The threshold at the credible stage is higher than that at the possible stage, thus more significant response actions might be considered, such as restrictions on public use of the water (e.g., issuance of a "do not drink" notice). Furthermore, steps should be initiated to confirm the incident and positively identify the contaminant.
3. Stage 3: "Has the incident been confirmed?" A water contamination incident is "confirmed" if the information collected over the course of the threat evaluation provides definitive evidence that the water has been contaminated. Response actions at this point include all steps necessary to protect public health, supply the public with an alternate source of drinking water, and begin remediation of the system.

3. Responding to a Contamination Threat

Figure 2 illustrates the elevation of potential response actions as the threat evaluation progresses through the "possible," "credible," and "confirmed" stages. In addition to the results of the threat evaluation, consideration should be given to the potential consequences of the suspected contamination incident as well as the impact of response actions on consumers. The consequences of contamination are a function of contaminant properties (e.g., toxicity, infectivity, persistence in water, etc.), the concentration profile of the contaminant through the system, and the population within the contaminated area. In many cases, it will be difficult to accurately assess the potential consequences since the identity of the contaminant may be unknown and the information necessary to estimate the spread of the contaminant through the system may be unavailable. Nonetheless, even an estimate of potential consequences within a couple orders of magnitude may be useful in making decisions regarding response actions (e.g., are tens or thousands of people potentially affected?).

Various response actions will have different impacts on consumers. For example, immediate operational response actions such as containment may go unnoticed by the public. On the other hand, restrictions on water usage could have a substantial, negative impact on consumers. Consumers may need to find an alternate supply of water for consumption and food preparation. For the most severe restrictions, sanitation and fire fighting may also be adversely impacted.

Early in the response to a contamination threat, before credibility has been established and consequences evaluated, relatively low impact response actions would be appropriate. For example, isolation of a storage tank, reservoir, or small area of the distribution system might be a suitable response to a 'possible' contamination threat. Once a threat has been deemed 'credible' it may be necessary to take steps to limit public exposure. This might involve more extensive isolation, or if the suspect water cannot be contained, it may be necessary to notify the public and place restrictions on water usage (i.e., issue a "do not drink" order). Finally, once a contamination incident is confirmed, all actions necessary to limit exposure and protect public health should be initiated. Furthermore, it will be necessary to arrange for an alternate water supply and begin planning for remediation activities.

Summary

All drinking water systems have some degree of vulnerability to contamination, and analysis shows that it is possible to contaminate drinking water at levels causing varying degrees of harm. Furthermore, experience indicates that the threat of contamination, overt or circumstantial, is probable. Thus, there is a clear need to address the contamination threat. While certain steps may be taken to reduce the vulnerabilities and prevent intentional contamination, it is impossible to completely eliminate this vulnerability, although a utility could spend a lot of resources trying to do so. Instead, it may be more effective to plan for responding to contamination threats that do arise.

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References

Federal Emergency Management Agency (FEMA). 2003a. *IS-195 Basic Incident Command System – EMI Independent Study Program*.Washington, DC: Federal Emergency Management Agency. Available at http://training.fema.gov/EMIWeb/IS/is195.asp.

U.S. Environmental Protection Agency (USEPA). 2003a. *Overview of the Response Protocol Toolbox*. EPA-817-D-03-007. Washington, DC: U.S. Environmental Protection Agency, Office of Water. Available at http://www.epa.gov/safewater/security/pdfs/guide_response_overview.pdf.

U.S. Environmental Protection Agency (USEPA). 2003b. *Water Utility Planning Guide - Module 1*. EPA-817-D-03-001. Washington, DC: U.S. Environmental Protection Agency, Office of Water. Available at http://www.epa.gov/safewater/security/pdfs/guide_response_module1.pdf.

U.S. Environmental Protection Agency (USEPA). 2003c. *Contamination Threat Management Guide - Module 2* EPA-817-D-03-002. Washington, DC: U.S. Environmental Protection Agency, Office of Water. Available at http://www.epa.gov/safewater/security/pdfs/guide_response_module2.pdf

U.S. Environmental Protection Agency (USEPA). 2003d. *Site Characterization and Sampling Guide - Module 3*. EPA-817-D-03-003. Washington, DC: U.S. Environmental Protection Agency, Office of Water. Available at http://www.epa.gov/safewater/security/pdfs/guide_response_module3.pdf.

U.S. Environmental Protection Agency (USEPA). 2003e. *Analytical Guide - Module 4*. EPA-817-D-03-004. Washington, DC: U.S. Environmental Protection Agency, Office of Water. Available at http://www.epa.gov/safewater/security/pdfs/guide_response_module4.pdf.

World Health Organization (WHO). 2003. *Public health response to biological and chemical weapons*: *WHO guidance*, 2nd ed. (Draft, March 2003). Available at http://www.who.int/csr/delibepidemics/biochemguide/en/index.html.

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Water Treatment and Equipment Decontamination Techniques

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In responding to an intentional contamination of a drinking water system, water utility personnel (along with many other entities) will be faced with both providing clean and safe drinking water for their consumers and for cleaning up the contamination. How those two responsibilities are handled will be dictated by the type of contaminating event. For example, if a major ground water aquifer is contaminated, then decontamination of the aquifer may not be possible and treatment of the water from that aquifer would be required before the water could be used. If a storage tank is contaminated, the storage tank could possibly be taken off line. The contaminated water would then be treated prior to disposal and the storage tank decontaminated (cleaned) prior to bringing the storage tank back online.

This summary article will discuss the various water treatment and decontamination techniques that could be used during an intentional contamination event. For this article, water treatment will refer to techniques that would be used to treat the contaminated water and decontamination will refer to the techniques that would be used to clean hard surfaces such as the insides of a pipe or storage tank. Although this article will not discuss specific actions to take during specific events (or specific contaminants), the article provides summary information that will guide water personnel towards the proper treatment techniques.

The basic contaminants that could be used in an intentional attack against a water system could be broken down into chemical (inorganic or organic), microbial (bacteria, protozoan, or viruses), and radiological classes. Various groups have made public lists available (States 2003; CDC 2003). This article will not discuss the merits of those lists, the specific contaminants on those lists, nor attempt to define where or how those contaminants could be introduced into a water system. The discussion contained in this article will start with the assumption that a contaminating event has occurred. Although this article focuses on the basis of an intentional contamination, the same process described here could be used during an unintentional contaminating event. This article will also address some of the knowledge gaps missing in the water treatment and decontamination area that could lead to research needs.

Water Treatment

The various types of water treatment technologies available (or applicable) depend on the type of contaminant and the extent of the contamination. For example, if a storage tank was contaminated with a microbial contaminant that could be inactivated by disinfectant, then proper levels of the disinfectant could be added to the storage tank for the proper length of time and no additional treatment would be necessary. In the case where an inorganic chemical contaminant was introduced into an aquifer, a granular activated carbon water treatment plant might need to be constructed in order to treat the water for very long periods of time. The various typical water treatment practices are described below along with a summary of their capabilities and where they could be used. A full description of the following techniques can be found in the literature (AWWA 1999).

Conventional coagulation/settling/filtration water treatment uses chemical pretreatment to cause particulate material in a water system to form floc that would then be settled out in a sedimentation basin and/or removed by filters. The typical pretreatment chemicals include aluminum or iron coagulants, lime or polymers and the type and amount of chemical depends on the water quality present. This type of treatment is very good at removing particulate matter (including microorganisms), small amounts of various chemical contaminants, and to some extent various radionuclide contaminants. Although this process is very good at removing many contaminants, the process would be difficult to install during an emergency situation. There are some mobile water treatment units that utilize this technology, but those mobile units could not treat large quantities of water. This technology would be (and is) very useful for treating the drinking water for communities that use surface waters for their source water. As an added advantage, this process provides a measure of protection in case their source water becomes contaminated.

One modification to the conventional process is known as direct filtration. In direct filtration, the sedimentation step is eliminated. Source waters that contain low levels of particulate material may be suitable for direct filtration. The types of contaminants removed by direct filtration and the limitations of direct filtration are similar to conventional treatment.

Granular activated carbon (GAC) is an absorption media that can be used to remove many organic contaminants from water. GAC is also effective in the removal of lesser amounts of inorganic contaminants and radionuclides. The GAC is typically placed into a contactor and the water passes over and through the carbon. The contaminants attach themselves to the carbon and are removed from the carbon during reactivation or remain on the carbon for disposal (depending on the contaminant). GAC contactors can be installed quickly and the carbon replaced when it is spent rather than trying to reactivate the carbon. GAC systems are also readily available for smaller applications such as apartment buildings; they are even small enough for houses and single faucets. Thus, during an emergency situation, GAC units could be utilized to treat only the water that was to be used for consumption or to treat all of the water that was being distributed.

One modification to GAC is known as powdered activated carbon (PAC) where instead of the water flowing through a carbon contactor, the PAC is added to the water and then removed by other processes. The types of contaminants removed by PAC are similar to those listed under GAC. PAC is typically used in situations where seasonal (or occasional) contaminantion occurs and the activated carbon is only needed for relatively short times.

Aeration is a process in which high volumes of air are passed through the water in an effort to transfer the contaminant from the water to the air and thus remove the contaminant from the water. There are several types of aeration systems utilized in drinking water treatment and they range from pipes that bubble air into a pool of water, to pressurized, diffused bubble systems, to tower aeration processes. In all cases, the treatment process is to pass air through the water to strip out the contaminant. Aeration techniques are typically used to remove volatile organic contaminants but there are a few radionuclides that can be stripped from water by this process. Aeration systems can be installed in relatively short periods of time and they are adaptable to various sizes of systems. For example, aeration systems have been placed into open-air reservoirs, down single wells or to centrally treat water in a community. One draw back to aeration systems is that the water will have to be re-pumped after aeration to pressurize the system.

There are several treatment technologies that fall under the category of membrane treatment. Those technologies include reverse osmosis, nano-filtration, and micro-filtration. In all three cases, the idea is to pass water through a membrane by pressure while leaving the contaminants on the other side of the membrane and removed from the system in a concentrated waste stream. In drinking water treatment, these three technologies are differentiated by the size of the contaminant that will go through the membrane. Reverse osmosis systems are capable of removing chemicals (inorganic or organic), microorganisms, and radionuclides. Nano-filtration would typically be capable of removing inorganic chemicals, some large organic compounds, and microorganisms. Micro-filtration would only be used to remove the microorganisms.

All of the membrane technologies are such that they can be installed easily and range in size from single faucet application (e.g., home reverse osmosis units) to large-scale applications for treating water for large communities. There are mobile water treatment systems utilized by the military and some of these use membrane technologies to be prepared to remove as many contaminants as possible.

Ion exchange technology is one where water passes over a bed of ion exchange media (typically resin beads). The resin beads have sacrificial chemical groups attached to them such as sulfate, sodium, potassium, hydrogen and others. The chemicals in the water exchange themselves for the chemical group on the resin. Currently, ion exchange systems are utilized for inorganic chemical, radionuclides, and some organic chemicals. Ion exchange systems can be installed easily and are readily available in cartridge systems for small applications, whole house systems (home water softener), commercial size for industrial uses, and full-scale water treatment systems.

Activated alumina treatment is not a common practice in drinking water treatment, but is being used to remove specific inorganic chemicals from some water supplies. The removal process is by both adsorption and ion exchange within the activated alumina. Activated alumina has not been used to remove organics or microorganisms from drinking water.

One of the most common forms of water treatment that would be used during and intentional attack of a water system is the use of a disinfectant. Currently, the most common drinking water disinfectants used are chlorine, chloramines, and ozone. Ultraviolet light is also used to disinfect drinking water. Typically, the drinking water disinfection processes are utilized to inactivate microorganisms, oxidize inorganic chemicals or destroy some organic compounds. The amount and type of disinfectant required is dependant on the water quality, type and number of organisms, and chemical to be oxidized. Disinfectant technologies are probably the easiest technology to implement in an emergency situation. Quantities of disinfectant could be added manually to a storage tank if necessary, the water utility could increase the disinfectant addition at the treatment plant or disinfection equipment could be added in desired locations.

Heat inactivation is the final process to be discussed. During drinking water emergencies, boil water orders are often implemented. Notices are given for individuals to boil their water prior to consumption. This process is only given for microbial problems and should only be given when boiling is thought to be the desired treatment.

In all of the treatment technologies described above, one does need to be aware of the waste products that are generated. In the conventional (and direct filtration) technology, waste sludge is generated that could potentially be very hazardous. The waste sludge in this case would have to be disposed of (or treated) properly. All of the above technologies generate some sort of waste product.

Decontamination Techniques

After an intentional contamination attack on a water system, there is a concern that some of the contaminant could remain on the interiors of the storage tanks, distribution system pipes, or in home fixtures. Decontamination of that infrastructure may be necessary to remove the contaminants from the interiors so that the residual contaminant does not pose a health or aesthetics problem. In most cases, simple flushing of the system with clean water will remove the bulk of the contaminants. Simple flushing may need to increase to high velocity flushing to allow for some physical scouring in addition to clean water rinsing. Processes for doing uni-directional flushing are described in the literature (AWWARF 2003) and care should be taken that the flushing program does not contaminate a clean area accidentally.

In some cases, other decontamination methods may need to be implemented to fully remove the specific contaminant. At this time, there are not definitive measures described for individual contaminants, thus generic decontamination techniques are described.

The disinfection chemicals described in the water treatment section may also play a major role in decontaminating a water system. High levels of disinfectant put into a storage tank (or pipe network) will inactivate many of the organisms that attached themselves to the interior structures. The high levels of disinfectants could also disrupt the normal biofilm in the system that some of the contaminants could hide in and not come out during routine flushing. In many cases, the flushing technique described above will be done at the same time that high levels of disinfectant are added to the flush water.

At this time, little is known about the ability of various surfactants to remove specific contaminants from pipe walls. Other techniques used in drinking water distribution pipe network rehabilitation include pigging and relining. There is also little know about how these techniques could play a role in decontaminating a water system after an intentional attack. (See AwwaRF 2003b for a review of methods to clean the interior of pipes in order to improve bulk water quality.)

Future Work

At the present, the U. S. Environmental Protection Agency's (U. S. EPA) National Homeland Security Research Center (NHSRC) is evaluating specific water treatment and decontamination technologies for various drinking water contaminants. The list of contaminants includes those not normally found in drinking water system and those that could be used in an intentional attack. The information gathered in those projects will be made available to water utilities and those that assist water utilities during an emergency. The data that are considered non sensitive will be published in peer journals or on EPA's web site. For data that are considered sensitive, secure publications and access will be available.

Future research will also be necessary on newly created chemicals and mutated or genetically altered microorganisms. Much of that work will be long term research projects as the specific contaminant is identified.

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References

American Water Works Association (AWWA). 1999. *Water Quality & Treatment*. Denver, Colorado: American Water Works Association.

American Water Works Association Research Foundation. 2003. *Establishing Site-Specific Flushing Velocities.* Denver, Colorado: American Water Works Association.

American Water Works Association Research Foundation. 2003b. *Investigation of Pipe Cleaning Methods.* Denver, Colorado: American Water Works Association.

Centers for Disease Control (CDC). 2003. *Emergency Preparedness & Response*. Atlanta, Georgia: Center for Disease Control.

States, S., et al. 2003. Utility-based Analytical Methods to Ensure Public Water Supply Security. *Journal American Water Works Association* 95(4): 103-115.

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Linking Public Health and Water Utilities to Improve Emergency Response

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Intentional contamination of a drinking water system may be discovered in several ways. If the potential contamination is unannounced or covert, its first indications might be detected by the water utility operating the system or by the public health system. In contrast, if a terrorist group announces a contamination event (or the threat of one), water utilities and the health-care system both may learn about the event simultaneously through such channels as mass media. Various other scenarios are also possible, such as a threat being telephoned to a water utility. In all of these scenarios, water utilities and the public health system must work together to respond to real or threatened contamination of drinking water supplies.

Water Utility and Public Health System Responses to Drinking Water Contamination

If an event involves an obvious security breach related to drinking water, the water utility would likely be the first to uncover the possibility of contamination. Security breaches associated with vandalism such as cutting locks or fences, are not uncommon. However, recent terrorism events and increased awareness of terrorist intentions have highlighted the need to handle these situations differently than in the past. As stated by the Florida Department of Environmental Protection (DEP) in a letter to water plant owners and operators: ". . . we live in a new era. We must be much more vigilant and responsive about the security of our water supply systems to protect the public. Incidents, that in the past may have been viewed as acts of mischief and vandalism, now need to be fully investigated and managed seriously" (Florida DEP 2003a).

One element of managing these situations is informing local and state health departments, and involving them in response efforts. This has not always occurred in a timely manner. For example, in a recent drinking water system security breach in Florida that involved forced entry into water system facilities, 36 hours elapsed between when the utility discovered the problem and when they notified the state health department (WaterTech 2003). Events such as this prompted a change in policy in Florida to require water utilities to notify a designated state emergency response hotline within two hours after any suspicious incident (Florida DEP 2003b).

Health departments need to know about potential drinking water contamination because they may need to be involved in responding to potential contamination incidents. Important elements of a response in the public health system include investigation of any unusual patterns of illnesses, dissemination of guidance to the public to safeguard health, and preparation of treatment for people affected by contamination (Fig. 1). Therefore, water utilities and the public health system must not only communicate but also actively work together to effectively respond to potential contamination events involving security breaches of water system facilities.

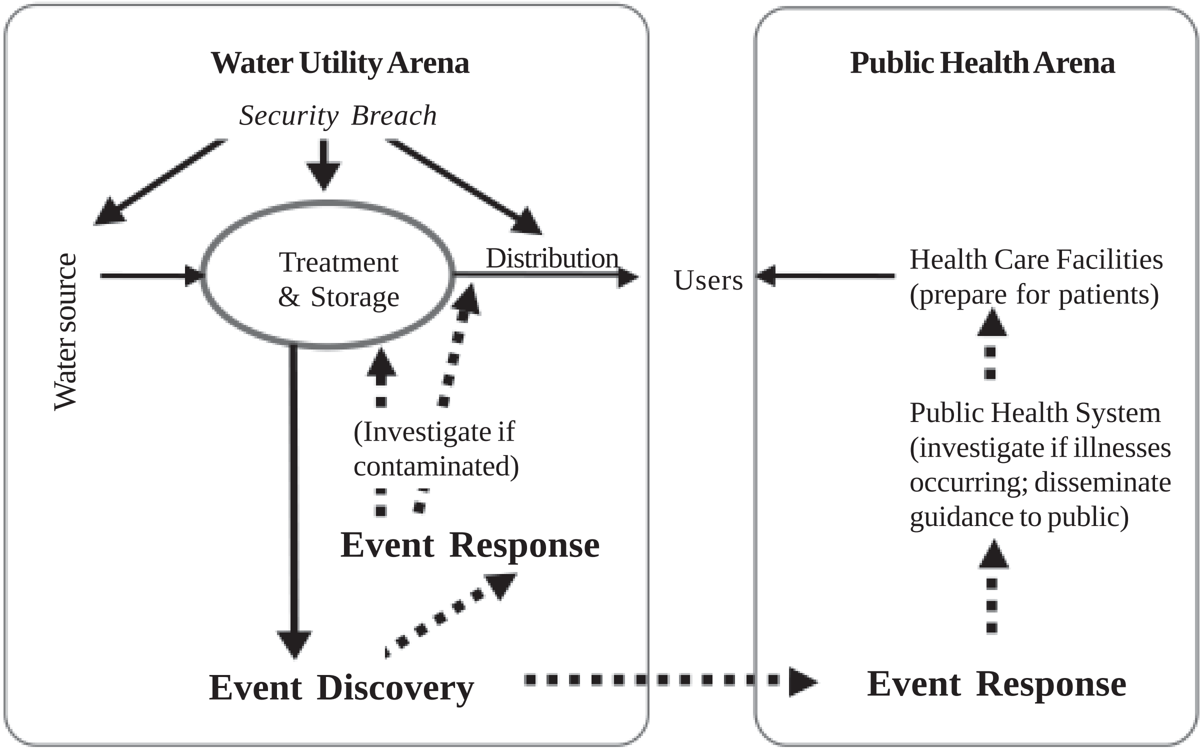

Figure 1. Response to a Water Contamination Event: Detection in Water Utility

Although methods exist for real time detection of some contaminants in drinking water distribution systems, such diagnostic tools are neither well developed for detection of multiple unknown contaminants nor deployed in a widespread manner. Therefore, if contamination does not involve an obvious security breach of drinking water system facilities, the first indication of contamination may be patients seeking medical assistance at health care facilities. The patients themselves may not know what made them sick. However, if multiple patients have similar symptoms, health-care facilities would notify public health agencies, which would begin investigating the cause and source of the illness. In the case of potential drinking water contamination, effective responses will require collaboration between water utilities and public health agencies. Although the public health system may discover the initial contamination, much of the response will take place in the water utility arena, including actions such as identifying likely locations where an agent may have been introduced into the water system, decontaminating the drinking water distribution system, and disposing of contaminated water (Fig. 2).

Although it was naturally occurring, *Cryptosporidium* contamination of the Milwaukee drinking water supply in 1993 provided an example of a contamination event discovered in the public health arena (Centers for Disease Control and Prevention [CDC] 1995). During a heavy rainfall event, *Cryptosporidium* in the city's surface water source passed through the municipal treatment system and into the drinking water distribution system. At that time, the city's drinking water treatment plant was not operating at optimal levels for treatment of *Cryptosporidium*, and high turbidity levels caused by the rainfall as well as cold temperatures contributed to the treatment system's lack of effectiveness against the organism. As people ingested the parasite, many became ill with gastrointestinal symptoms, especially diarrhea. Public health officials discovered the contamination because so many people sought treatment, especially over-the-counter anti-diarrheal medications. However, long-term response to the problem was the responsibility of the water utility who upgraded the drinking water treatment system to make it effective against *Cryptosporidium*.

If a terrorist group announces real or threatened contamination of drinking water in the media or directly to a water utility or public health agency, a solid partnership between water utilities and public

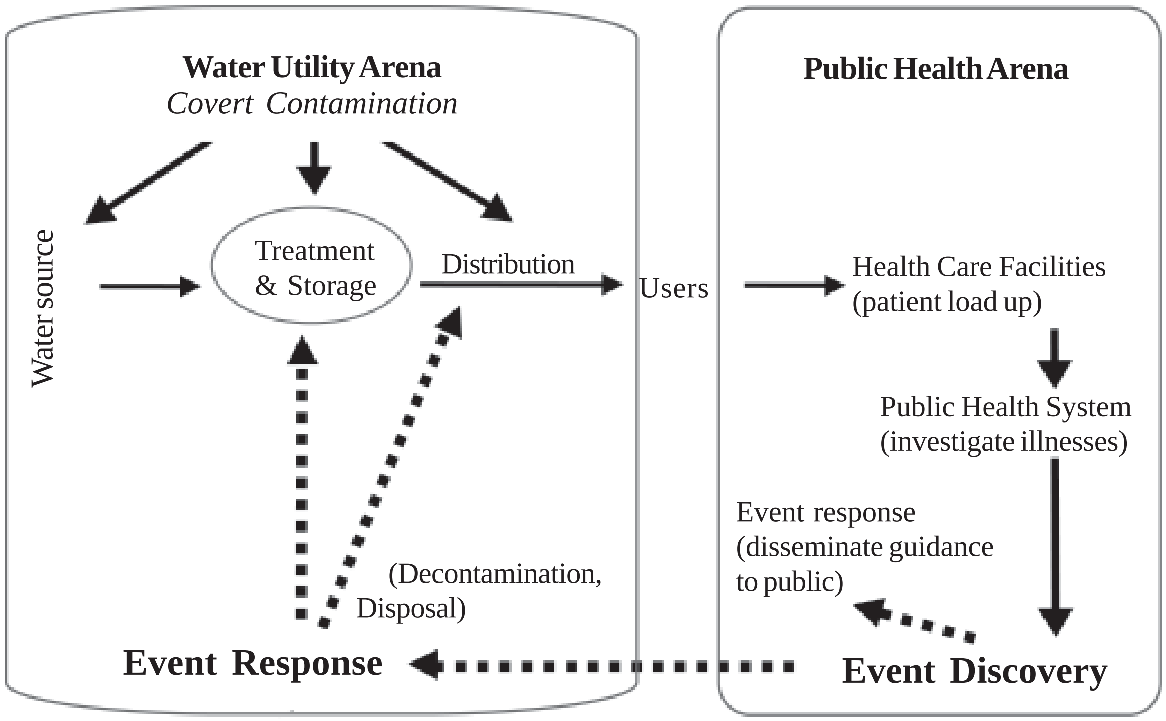

Figure 2. Response to a Water Contamination Event: Detection in Public Health System

health agencies also would be required to deal effectively with the event. To protect the public's health, decisions would need to be made quickly about, for example, whether chlorine is effective against the suspected agent, whether the affected area of the distribution system can be isolated, or whether a boil-water notice should be issued. Public health authorities can often provide credible messages to the public, but will need critical information from water utilities to craft the most appropriate messages. Quickly disseminating information to the public also will be an important element of a response, especially when terrorism may be involved. Confusing and potentially conflicting messages need to be avoided, especially regarding actions the public should take to protect itself, highlighting the need for coordination. Communication problems were an issue for some communities during the widespread electricity blackouts in the Northeastern and Midwestern United States in 2003, when utilities and public health agencies issued boil-water orders with conflicting information. The resulting confusion highlighted the need for better coordination between water utilities and the public health system in responding to emergencies.

Barriers to Collaboration Between Water Utilities and Public Health Agencies

Local public health agencies and water utilities have not always interacted and collaborated closely. Effective regulations and monitoring requirements have prevented large-scale public health problems in the United States related to drinking water except for occasional failures in disinfection. In addition, many health departments are not involved in the regulation and monitoring of water supplies, especially for larger municipal systems. State environmental management or environmental quality agencies (which generally are not part of state or local health departments) often monitor drinking water systems. Unless a disease outbreak involves water, these groups have little need to interact. Differing technical language used by public health agencies and water utilities also present barriers to effective communication, especially if these groups have not interacted in the past.

Private contractors operating water utilities may be reluctant to engage with local public health entities because disclosure of information may affect the status of their contracts with local government.

Additionally, funding is not targeted to facilitate and maintain relationships between public health agencies and water utilities. Both water utilities and public health agencies have limited budgets and lack resources to get involved with activities outside of their legal mandates.

Promoting Linkages Between Water Utilities and Public Health Agencies

Because of the potential for intentional contamination of drinking water supplies, water utilities and public health agencies are beginning to develop closer relationships. At the federal level, the Environmental Protection Agency (EPA), in conjunction with other federal partners such as CDC, is developing a response protocol toolbox for responding to drinking water contamination threats and incidents. The toolbox contains information to assist both water utilities and public health agencies in emergency responses related to drinking water (EPA 2003).

The Public Health Security and Bioterrorism Preparedness and Response Act (Public Law 107-188) requires drinking water facilities to conduct vulnerability assessments and prepare emergency response plans. Implementing or updating these emergency response plans will increase opportunities for public health agency involvement in planning and responses at the local level. EPA's newly released Response Protocol Tool Box also encourages involvement and inclusion of public health agencies in water utility response plans (EPA 2003). In addition, EPA is organizing water security training sessions to educate water utilities, public health agencies, law enforcement, and local governments about water security issues and the need for increased communication and partnerships. CDC and the American Water Works Association are piloting smaller workshops specifically designed to bring local health department and utility staff together to address problems related to water security.

Public health agencies in several major cities throughout the United States are implementing syndromic surveillance programs designed to detect anomalies in disease patterns through the collection and combination of multiple electronic data sources before confirmed diagnoses are made. Although not specifically designed to detect waterborne events, the data gathered through these sources may help increase the speed at which events are detected and data are analyzed (Mandl et al 2003).

Conclusions and Recommendations

Water utilities and public health agencies need to develop stronger working relationships in order to prepare for potential drinking water contamination events. In some cases, these groups previously have collaborated to address specific problems such as *Cryptosporidium* in water, and those efforts can provide a template for collaboration related to terrorism preparedness, such as in the formation of local task forces (CDC 1997). Continued opportunities to collaborate also should be provided through ongoing training, planning, and joint exercises. For example, tabletop exercises can be useful for both water utilities and public health agencies in identifying gaps in preparedness, communication, and response.

Information sharing between utilities and public health agencies can enhance detection and response. For example, increased complaints to water utilities or public health agencies related to water could indicate a problem when coupled with other public health surveillance data. Cross-referencing information, such as water-distribution maps and locations of illness cases, also could improve responses. However, such sharing would require that agreements be in place to allow for information exchange without compromising confidentiality issues for patients or utilities.

Establishment of formal agreements may help ensure regular exchange between utilities and public health agencies. In some cases, requirements, such as the Florida policy requiring notification of security breaches at drinking water facilities, may need to be mandated. The actual mechanisms will vary among locations, but state and local governments should explore ways to ensure regular communication between these entities.

Some efforts probably will require funding dedicated to maintaining collaboration in planning and preparedness by water utilities and public health agencies. However, such collaboration will help ensure these entities are better equipped and trained to respond to both intentional and naturally occurring drinking water contamination events.

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References

Center for Disease Control (CDC). 1995. Assessing the public health threat associated with waterborne cryptosporidiosis: report of a workshop. *Morbidity and Mortality Weekly Report (MMWR)*. 44(RR-6).

Center for Disease Control (CDC). 1997. *Cryptosporidium and Water: A Public Health Handbook*. Atlanta, Georgia: United States Department of Health and Human Services, Center for Disease Control.

Florida Department of Environmental Protection (FDEP). 2003a. Letter to Plant Owners and Operators, January 23, 2003. Tallahassee, Florida: Florida Department of Environmental Protection.

Florida Department of Environmental Protection (FDEP). 2003b. Division of Water Resources Management, Permitting, Construction, Operation, Maintenance of Public Water Systems, Rule Chapter NO: 62-555, Rule NO: 62ER03-1, January 22, 2003. Tallahassee, Florida: Florida Department of Environmental Protection.

Mandl, K.D., J.M. Overhage, M.N. Wagner, W.B. Lober, P. Sebastiani, F. Mostashari, J.A. Palvin, P.H.Gesteland, T. Treadwell, E. Koski, L. Htwagner, D.L. Buckeridge , R.D. Aller, S. Grannis. 2003. Implementing syndromic surveillance: a practical guide informed by the early experience. *JA Med Inform Assoc*. Electronically published ahead of print Nov. 21, 2003 as doi:10.1197/jamia.M1356. Available at http://www.jamia.org/cgi/reprint/M1356v1.pdf

U.S. Environmental Protection Agency (USEPA). 2003. *Response Protocol Toolbox: Planning for and Responding to Drinking Water Contamination Threats and Incidents, Interim Final–December 2003*. Washington, DC: Environmental Protection Agency.

U.S. Public Law 107-188. 107th Cong., 1st sess., June 12, 2002. *The Public Health Security and Bioterrorism Preparedness and Response Act*.

Water Tech Online. 2003. *Water security breach prompts statewide security order*. Available at www.watertechonline.comNews.asp?mode=4&N_ID=37672

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Safeguarding The Security Of Public Water Supplies Using Early Warning Systems: A Brief Review

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Water distribution systems are vulnerable to aqua-terrorism (terrorism attacks on the water supply) because they are extensive, relatively unprotected, accessible, and often isolated (USEPA 2002, 2003a, Grayman, 2002; Mays, 2004). An emerging activity in the water security arena is developing methods to minimize the public health and economic impacts of a large-scale attack. An intense effort is currently underway to improve analytical monitoring and detection of biological, chemical, and radiological contaminants in drinking water systems as part of the overall effort to secure drinking water supplies (USEPA, 2003b).

One approach for avoiding or mitigating the impacts from contamination of a distribution system is to perform monitoring in the context of an Early Warning System (EWS). At present, federal agencies, academic communities, and private companies are working together to develop practical and effective early warning systems. The goal of an early warning system is to reliably identify low-probability/high-impact contamination events in a distribution system's finished water, or in source water, in time to permit an effective local response that reduces or avoids entirely the adverse impacts that may result from such an event. The core of an EWS is a monitoring technology that, ideally, would detect or screen for a variety of toxic substances or infectious microorganisms (Brosnan 1999; USEPA 2002).

This article briefly reviews the essential elements of an EWS, the relevant plans for developing and implementing an EWS, and the current status and potential for an EWS to ensure the security of drinking water supplies and systems.

The Early Warning System Concept

Though early warning systems are frequently equated with the monitoring instrumentation used to detect contaminants in water, an effective EWS is, in reality, an integrated system for deploying the monitoring technology, analyzing and interpreting the results, and utilizing the results to make decisions that protect public health while minimizing unnecessary concern and inconvenience within a community. Ideally, an EWS should be an integral part of the operation of a water system. It should be able to be used to detect not only intentional contamination, but also contaminants introduced accidentally or as the result or natural occurrences (i.e., dual use capabilities).

A recent American Water Works Association Research Foundation (AwwaRF) study concluded that an effective EWS should include the following components (Grayman et al. 2001):

1. A mechanism for detecting the likely presence of a contaminant in the finished water;
2. A means for confirming the presence of the contaminant, determining the nature of the contamination event and the intensity (concentration) of the contaminant in the drinking water distribution system, and predicting when the contamination will affect the end users;

3. Communication linkages for transferring information related to the contamination;
4. Various mechanisms for responding to the presence of the contamination in the finished waters in order to mitigate its impacts on water users; and
5. An institutional framework, generally composed of a centralized unit that coordinates the efforts associated with managing the contamination event.

Characteristics of Early Warning Systems

The following guidance is provided for utilities that may consider implementing an EWS using existing technologies, or technologies that will likely enter the consumer market within the next few years. As various technologies and systems are considered, one may wish to evaluate how they compare to the characteristics of an ideal EWS, as described in a recent report by International Life Science Institute (Brosnan 1999), as follows: (1) exhibits warning in sufficient time for action, (2) provides affordable cost, (3) requires low skill and training, (4) covers all potential threats, (5) identifies the source, (6) demonstrates sensitivity to quality changes at regulatory levels, (7) gives minimal false positive or negative responses, (8) exhibits robustness, (9) allows remote operation, and (10) functions year-round.

Currently, an EWS with all of these features does not exist. However, there are some technologies that can be used to build an EWS that can meet certain core criteria: (1) provide rapid response, (2) screen for a number of contaminants while maintaining sufficient sensitivity, and (3) perform as automated systems that allow for remote monitoring. Any monitoring system that does not meet these minimum criteria should not be considered an effective EWS. Although an emphasis is placed on these three features, the other issues discussed above cannot be ignored in the design of an EWS. For example, consideration should be given to the rate of false positive/false negative results and method sensitivity when interpreting the results. Furthermore, system costs, sampling rate, and reliability should also be included in the design of an EWS (Grayman et al. 2001, 2004; USEPA 2002).

Design Considerations for an Early Warning System

An Early Warning System should be integrated into the operation of a water system. Therefore, an overall context for decision making relative to EWS may be viewed as one of designing and operating the system to minimize the risks associated with degraded drinking water quality, under various cost and technology constraints. Designing an EWS is not simple because there are many issues and water system characteristics that need to be considered. These EWS design considerations are discussed in various sources (Brosnan 1999; Clark et al. 2004; Foran and Brosnan 2000; Grayman et al. 2001, 2004; USEPA 2002) and are briefly summarized below:

Planning and Communication. Before initiating an early warning monitoring program, the objectives of the program should be defined clearly, and a plan should be developed for the interpretation, use, and reporting of monitoring results. Furthermore, the plan should be developed in coordination with the water utility, local and state health departments, emergency response units, law enforcement agencies, and local political leadership.

System Characterization. The first step in the design of an EWS is to fully characterize the system to be monitored such as the distribution system infrastructure. The system should be characterized with respect to access points, flow and demand patterns, and pressure zones. If not already available, a hydraulic model should be constructed. Finally, system vulnerabilities should be identified and characterized, preferably through a formal vulnerability assessment as described previously by EPA (USEPA 2002). An understanding of each of these characteristics provides the backbone for the proper design and development of an EWS. In addition, system characterization should consider both water demand and water usage patterns.

Target Contaminants. An ideal EWS should be capable of monitoring for all potential contaminants. However, even the most complex array of monitoring equipment cannot detect the entire spectrum of agents that could pose a threat to public health via contaminated water. Thus, the design of an EWS should focus on contaminants that are thought to pose the most serious threat. Many factors may go into this assessment, including: the concentration of a particular contaminant that is necessary to cause harm, the availability and accessibility of a contaminant, the persistence and stability of a contaminant in an aqueous environment, and the difficulty associated with detecting a contaminant in the water. System vulnerabilities and the ability of existing treatment barriers to remove or neutralize specific contaminants should also be considered in the threat assessment.

A challenge in designing an effective EWS is striking a balance between the screening function of the system (i.e., the ability to detect a wide range of contaminants) and specificity (i.e., the ability to positively identify and quantify a specific contaminant). One approach to resolving these conflicting objectives is through *tiered monitoring*. In a tiered approach with two stages, the first stage might provide a continuous, real-time screen for a range of contaminants that could pose a threat to public health, utilizing a broad-based screening technology such as assays designed to detect changes in toxicity. A positive result from the first stage would trigger confirmatory analysis using more specific and sensitive techniques, and a positive result from the confirmatory analysis would trigger a response action. Additional discussions of tiered monitoring are presented elsewhere (Daughton 2001). A common misconception is that the screening stage alone of a monitoring system constitutes an EWS. However, a properly designed EWS should include all elements of a monitoring program necessary to inform the decision making of officials responsible for public health. Thus, confirmatory analyses used to verify a positive result from a screening analysis, and the hydraulic modeling or analysis that determines the sampling locations, should be integrated into the overall design of the EWS.

EWS Technology Selection. Once target contaminants for the EWS have been identified, it is necessary to select a monitoring technology for the particular contaminant or class of contaminants, if one that meets the core requirements of an EWS exists. The monitoring technology should be capable of dealing with complex water matrices. This may require an extraction step to remove the material from the water matrix and/or a concentration step to enhance detection and quantification. Although techniques for isolating, concentrating, and purifying microbial and chemical substances have been developed for many laboratory methods, they may not necessarily be transferable to field deployable monitoring devices. The technology considered for use in an EWS should be evaluated to ensure that all steps of the methodology perform correctly and can detect the target contaminant(s) without excessive interference.

Identifying a field deployable technology with an acceptable methodology is only the first step. Performance of the monitoring technology must also be adequate to meet the data quality objectives of the monitoring program. These data quality objectives should be defined during the design of the EWS and include: specificity, sensitivity, accuracy, precision, and recovery, as well as rates of false positives and negatives. If the monitoring technology cannot meet the data quality objectives, then another technology should be selected. If no technology can be identified that meets the objectives, then either the EWS should not be implemented, or the data quality objectives will need to be revised. If the later approach is taken, it will be necessary to modify the manner in which the results are used to be consistent with revised data quality objectives.

Alarm Levels and Response. Once the EWS technology has been identified, it is necessary to identify the concentrations at which the agents pose a threat to human health so that alarms can be triggered at appropriate levels. The basis for setting alarm levels will depend on the capability of the EWS employed. It should also be noted that the alarm should be triggered by a combination of events, not a single detection, which may be a false positive. Many responses are possible when an early warning monitoring system triggers an alarm. Responses may include modification to the drinking water system (e.g., shutdown, addition of disinfectants, etc.), notification (e.g., boil water advisory) either to the general public or to target communities or subpopulations, additional data gathering or monitoring, follow-on surveillance and epidemiologic studies, no action, or some combination of these. The type of response will be dependent on the nature of both the threat to and the nature of the drinking water system, including the population it serves. Where an EWS is in place, credibility of the threat may be judged by the performance of the EWS itself, when it is capable of detecting the contaminants included in the threat. Additionally, law enforcement representatives may provide insight into the credibility of the threat (Foran and Brosnan 2002). If a false alarm leads to a decision to issue a notice to the public to stop using the water, public health as well as public confidence could be impacted.

Fate and Transport of Pathogens and Chemicals. Chemical and microbial agents can behave in a variety of ways as they migrate through a water system. Environmental conditions, the presence of oxidants or other treatment chemicals, and the hydraulic characteristics of the system will affect the concentration and characteristics of these agents. If information is available on agent characteristics that affect their fate and transport, it should be factored into the design of an EWS. For example, if a target agent is known to chemically degrade at a certain rate in the presence of free chlorine, it may be possible to use a hydraulic/water quality model of the distribution system to predict the concentration profile through the system. This information, in turn, can be used to design the EWS and select optimal locations for sensors.

Sensor Location and Density. The location and density of sensors in an EWS is dictated by the results of the system characterization, vulnerability assessment, threat analysis, and usage considerations. The size, complexity, and dynamic nature of distribution systems complicate the selection of sensor locations. Proper characterization of the distribution system, including usage patterns, and the location of critical system nodes (e.g., hospitals, law enforcement and emergency response agencies, government facilities, etc.) is necessary to design an effective monitoring network. Due to their complexity and dynamic nature, it may be beneficial to develop a hydraulic model of the system to assist in the placement of sensors (see the paper by Uber et al, in this issue). Other methods are reported in the literature for optimal placement of monitoring stations (Lee and Deininger 1992; Uber et al. 2004). However, even if sensors can be optimally located within a distribution system, there may not be sufficient time to prevent exposure of a portion of the public to the contaminated water. At best, monitoring conducted within the distribution system will provide time to limit exposure, isolate the contaminated water, and initiate mitigation/ remediation actions.

Data Management, Interpretation, and Reduction. The computer system infrastructure of a medium to large water utility typically includes its financial system, Human Resource (HR) system, Laboratory Information Management System (LIMS), Supervisory Control and Data Acquisition (SCADA) system, Computerized Maintenance Management System (CMMS), etc. The financial, HR, LIMS, and CMMS systems are considered to be part of the utility's Information Technology (IT) infrastructure run by a utility or local government IT group on a daily 8-10 hour schedule. Cyber attacks to the IT infrastructure (i.e., a computer-to-computer attack that undermines the confidentiality, integrity, or availability of a computer or the information it stores) may cause significant financial damage and disruption of the utility's internal operations, but they are not expected to cause immediate water supply disruptions. However, cyber attacks on the SCADA system could have an immediate detrimental impact on the water supply (Panguluri et al. 2004)

One of the challenges of a continuous, real-time monitoring system is management of the large amounts of data that are generated. Use of data acquisition software and a central data management center is critical. This will require that individual sensors deployed in the system be equipped with transmitters, modems, direct wire, or some other means to communicate the data to the acquisition and management systems. Furthermore, the data management system should be capable of performing some level of data analysis and trending in order to assess whether or not an alarm level has been exceeded. The use of "smart" systems that evaluate trends and can distinguish between genuine excursions and noise could minimize the rate of false alarms.

A decision will also have to be made regarding the action that is taken when the data management system detects an excursion above the alarm level. At a minimum, the system should notify operators, public health agencies, and/or emergency response officials. If possible, redundant communication should be used (e.g., notifying multiple individuals through multiple routes such as page and fax). In some cases, it may be appropriate to program the data management system to initiate preliminary response actions, such as closing valves or collecting additional samples. However, these initial responses should be considered simple precautionary measures, and public officials should make judgments regarding decisive response actions.

Existing and Emerging Monitoring Technologies

While laboratory technology exists to measure a wide range of substances in the environment, the analytical capabilities of monitors as part of an EWS are more limited. Currently available water quality monitors include physical, chemical, radiological, and microbiological analysis as well as bio-monitoring systems that use living organisms as broad spectrum indicators of changes in water quality. The use of biosensors has to date been limited to chlorine/chloramines-free source waters. Efforts are underway to adapt biosensors so that they can be employed in public water supply distribution systems. References for commercially available rapid or on-line monitoring techniques for the water industry include AwwaRF and CRS PROAQUA 2002; Frey et al. 2000; Grayman et al. 2001.

Some of the more common physical and chemical monitoring methods proposed for use in EWS include simple probes (e.g., turbidity, pH, temperature, odor, conductivity, dissolved oxygen, chlorophyll); relatively simple batch tests (e.g., immunoassays for herbicides), and more advanced monitoring for chemicals (e.g., fluorescence for oils, chromatography for oil and petroleum constituents, volatile organic chemicals and phenols). Some of the primary contaminant surrogates include turbidity, dissolved oxygen, odor, conductivity, and general measures of organic carbon content (e.g., oxidant demand, total organic carbon). However, the parameters that are easily and inexpensively monitored via on-line probes (e. g., temperature, conductivity, pH) provide limited capability for detection of specific contaminants of security concern. Advanced monitors are more expensive and require more maintenance and expertise, but have better capabilities for these applications. Based on recent research in the food and chemical industry, electronic odor sensing technologies ("electronic noses") may be available in the future for use in the analysis of water (Grayman. et al. 2001).

Conventional culture methods for detecting microbial contaminants require a relatively long time period (hours or days) and many tests are specific for a single species or class of organism. As such, these analyses cannot be used as part of an EWS. However, numerous significant recent advances in microbial monitoring and related technology offer increased sensitivity, specificity and/or more rapid analysis, including DNA microchip arrays, rapid DNA probes and PCR, rapid hand-held immunoassays, cytometry, laser scanning, laser fingerprinting, optical technologies, and luminescence (e.g., bio- and chemi-luminescence) (Foran and Brosnan 2000; Grayman et al. 2001; Lee and Deninger 1999; Rose and Grimes 2001; States et al. 2004; Venter 2000). More recently, concentration of water samples by ultra filtration followed by PCR is carried out by Vince Hall at CDC and others (Gelting 2004). Most of these methods are still being developed or were only recently introduced. Their use, however, is likely to increase in the future.

An example of a promising approach for continuous monitoring of water for multiple pathogens is the Automated Pathogen Detection System (APDS) being developed by the Lawrence Livermore National Laboratory. This system traps analytes of interest onto antibodies conjactaed to beads with subsequent identification through fluorescence. While this immune separation assay has been primarily designed for aerosol monitoring, it may be adaptable to pathogen detection in water supplies if the aerosol monitor is replaced with a large volume water concentration system.

In general, while prototype systems for monitoring airborne contamination are in use at various locations around the country, systems for detecting microbial pathogens in drinking waters supplies lag behind.

Research and Development Needs

A number of ongoing research projects of AwwaRF and the Water Environment Research Foundation are investigating rapid and on-line monitoring technologies. Many of the advances in monitoring technologies occur from research in other scientific fields (e.g., the food and beverages industry, analytical chemistry, the sensor industry, and the military), including biosensor and biochip technology, fiber optics, genetically-engineered organisms, rapid immunoassays, microelectronics, and others. Several U.S. government organizations, including the USEPA and the U.S. Army's Joint Service Agent Water Monitor Program, are conducting research on rapid and/or on line monitoring systems for a variety of contaminants.

A number of monitoring technologies and products are available that could potentially serve as a core component of an EWS, and a number of suppliers of conventional monitoring systems have begun to advertise them as water security monitoring systems in the wake of terrorist concerns. However, the performance of these systems has not been fully or independently characterized in most cases. Without basic performance information (e.g., detection limits, sensitivity, selectivity, rate of false positives and false negatives), it will be difficult to interpret monitoring results and derive the information necessary to make appropriate public health decisions.

As promising technologies continue to be developed and brought into the commercial market, there is a need for a mechanism, including field evaluation and testing sites, to verify system performance. Ideally, such testing should be conducted according to a standard protocol by an independent third party, and the subject technology should be evaluated against standardized methods, if available. This would provide water utilities with the data necessary to make informed decisions regarding the implementation of a specific technology in an EWS. EPA has established the Environmental Technology Verification (ETV) Program to provide independent third party testing of environmental monitoring and treatment technologies. Under the Advanced Monitoring Systems Center of ETV, monitoring technologies with the potential to serve as an EWS in water systems will be evaluated, and the reports will be made available to the public.

Conclusions

An early warning system must reliably identify low-probability/high-impact contamination events in distribution systems or source water in time to allow for an effective response. The type of response and the method of communication of the response will depend on the nature of the threat, the capabilities of the EWS itself, and on the characteristics of the affected population. Especially critical is the development of an emergency preparedness plan that guides the responses associated with a signal from the EWS and the communication of actions based on the responses (Foran and Brosnan 2000).

The resources necessary for the development, installation, operation, and maintenance of an EWS will be substantial; therefore, virtually all of the decisions regarding the EWS must be made at the local or regional level.

Implementation of some types of existing monitoring technology will result in a false sense of security since there is no assurance that they are capable of meeting the monitoring objectives. In addition, these systems could result in false alarms that would undermine the effectiveness of a monitoring program and result in a needless expenditure of resources to follow-up on the false positive and false negative results (USEPA 2002).

To ensure the full protection of drinking water, a technology-based early warning monitoring system should be just one component of a comprehensive program to protect the public from the threat of intentional contamination. The program must also include physical, social, and economic steps to prevent the problem, as well as public health monitoring to ensure that early detection of disease will occur if a monitoring system or other steps fail (Brosnan 1999; Foran and Brosnan 2002; USEPA 2002).

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References

AwwaRF and CRS PROAQUA. 2002. Online monitoring for drinking water utilities. Page 425 in E. Hargesheimer, O. Conio, and J. Popovicova (eds.) Denver, CO: *AWWA Research Foundation and American Water Works Association*.

Brosnan, T. M. (ed.) 1999. Early warning monitoring to detect hazardous events in water supplies. *An ILSI (International Life Sciences Institute) Risk Science Institute Workshop Report*. Washington, DC: ILSI Press.

Clark, R. M., N. Adam, V. Atluri, M. Halem, E. Vowinkel, P. C. Tao, L. Cummings, and E. Ibrahim. 2004. Developing an early warning system for drinking water security and safety. Pages 8.01-8.19 in L.W. Mays (ed.) *Water supply systems security*. New York, NY: McGraw-Hill Companies.

Clark, R. N., and R. A. Deininger. 2000. Protecting the Nation's critical infrastructure: the vulnerability of U. S. water Supply Systems. *Journal of Continuous Crisis Management* 8(2): 73-80.

Daughton, C. G. 2001. One proposal for a nation-wide approach to identifying emerging nascent risks:pollutant fingerprint anomalies. Available at http://www.epa.gov/nerlesd1/chemistry/pharma/science-issues.htm

Deininger, R. A., and P. G. Meier. 2000. Sabotage of public water supply systems. Pages 76-80 in R. A. Deninger (ed.) *Security of public water supplies*. NATO Science Series. Dordrecht: Kluwer Academic Publishers.

Foran, J. A, and T. M. Brosnan. 2000. Early warning systems for hazardous biological agents in potable water. *Environmental Health Perspective*. 108(10): 993-995.

Frey, M., L. Sullivan, and E. Lomaquahu. 2000. Practical application of online instruments in *Proceedings of the AWWA Annual Conference and Exhibition*, New Orleans, LA. Denver, CO: AWWA.

Gelting, R. L. 2004. Personal Communication.

Grayman, W. M., R. A. Deninger, and R. M. Males. 2001. Design of early warning and predictive source water monitoring systems. Denver, CO: *AWWA Research Foundation*.

Grayman, W. M., R. A. Deninger, and R. M. Clark. 2002. Vulnerability of water supply to terrorist activities. *CE News* 14:34-38.

Grayman, W. M., R. A. Deninger, R. M. Males, and R. W. Gullick. 2004. Source water early warning systems. Pages 11.01-11.33 in L.W. Mays (ed.) *Water supply systems security.* New York, NY: McGraw-Hill and Companies.

Lee, J. Y., and R. A.Deininger 1992. Optimal locations of monitoring stations in water distribution systems. *Journal of Environmental Engineers*. 118(1): 4-16.

Lee, J. Y., and Deininger, R. A. 1999. A rapid method for detecting bacteria in drinking water. *Journal of Rapid Methods and Automation in Microbiology*. 7:135-145.

Mays, L. W. 2004. Water supply security: an introduction. Pages 1.1-1.12 in Larry W Mays (ed.) *Water supply systems security.* New York, NY: The Mcgrow-Hill Companies.

Panguluri, S., W. R. Phillips, Jr., and R. M. Clark. 2004. Cyber threats and IT/SCADA system vulnerability. Pages 5.01-5.18 in , L.W. Mays (ed.) *Water supply systems security*. New York, NY: McGraw-Hill and Companies.

Rose, J. B., and D. J. Grimes. 2001. *Reevaluation of microbial water quality:Powerful new tools for detection and risk assessment.* Washington, DC: American Academy of Microbiology.

States, S, J. Newberry, J. Wichterman, J. Kuchta, M. Scheuring, and L. Casson. 2004. Rapid analytical techniques for drinking water security investigations. *Journal AWWA* 96:152-164.

Uber, J., R. Janke, R. Murray, and P. Meyer. 2004. Greedy heuristic methods for locating water quality sensors. *Proceedings of the World Water and Environmental Resources Conference*, Salt Lake City, June 27-July1, 2004..

U. S. Environmental Protection Agency. 2002. Baseline threat information for vulnerability assessments of community water systems, Washington, DC.

U. S. Environmental Protection Agency. 2003a. Planning for and responding to drinking water contamination threats and incidents. Washington, DC.

U. S. Environmental Protection Agency. 2003b. Water security research and technical support action plan (draft). Washington, DC.

Venter, S. N. 2000. Rapid microbiological monitoring methods: The status quo in the Blue Pages, *International Water association*, London, UK. Available at http://www.iawq.org.uk.

Yates, D. G., D. O. Pitcher, and M. Beal. 2002. Implementing advanced early warning systems to safeguard public drinking water, in *Proceedings of the AWWA Annual conference and Exhibition,* New Orleans, LA. Denver, CO: AWWA.

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Use of Systems Analysis to Assess and Minimize Water Security Risks

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Drinking water systems are vulnerable to contamination by toxic substances, whether the contaminants are introduced intentionally during a terrorist attack, or unintentionally through accidental cross-connections or backflow incidents. In this paper, we discuss the particular characteristics of distribution systems that make a "systems modeling" approach useful and effective in assessing, preventing, and mitigating water security threats, and we outline the research needed to develop robust models for water security.

Water Distribution Systems and the Water Security Threat

Many characteristics of water distribution systems contribute to a systems-level complexity: the large spatial extent, multiple flow paths, and time and space varying flow rates. Conceptualizing this complexity is fundamental to understanding and minimizing water security risks.

Water distribution systems are spatially complex. Typically, they convey treated water to thousands or millions of customers spread across tens to hundreds of square kilometers through a looped (as opposed to a branched) network of pipes. Thus, there usually exist multiple flow paths between any set of "upstream-downstream" locations, with each path contributing a portion of the flow. Looped systems increase the reliability of the water supply through flow path redundancy, but also complicate network hydraulic and contaminant transport behavior, which is dominated by the network topology and bulk water velocity.

Water distribution systems are also temporally complex. Water usage rates (demands) vary on hourly to monthly time scales. The ratio of peak hour to average system water demand over a one-day period varies from three to six (Haestad Methods, 2003). Most utilities use distribution system storage tanks to equalize demand, thereby economically satisfying the wide range of usage rates. Treated water is pumped to storage at a more-or-less constant rate, and excess demand or supply is accommodated by fluctuating stored volume. Thus, flow rates are time and space varying, and flow directions frequently reverse, corresponding to changes in pumping policy or water usage rates (e.g., storage tanks that were filling begin to drain, and vice-versa).

<u>System Vulnerability and Network Flows.</u> Source waters—rivers, reservoirs, and groundwater supplies—are vulnerable to intentional contamination because they are open and unsecured, and dilution by large flow rates and volumes will likely limit public health effects or require extremely large contaminant volumes. The impact of contamination at the water treatment plant intake or a unit process is also limited by dilution, since maximum flow occurs at the plant, and treatment processes themselves may also create a barrier for some contaminants. Distribution systems may also be vulnerable to intentional contamination, though the level of vulnerability would be system-specific.

Can distribution system flows support high concentrations of contaminants? The following contaminant mass balance equation describes the relationship between the concentration of the introduced contaminant (contaminant source), C_s, the contaminant volumetric flow rate, Q_s, and the distribution system pipe flow rate, Q_p, and diluted (in-situ) concentration, C_p,

$$Q_p C_p = Q_s C_s,\ \ Q_p = Q_s\left(\frac{C_s}{C_p}\right) \text{or} (1)$$

Note that there is an inverse relationship between the pipe flow rate and the pipe concentration. If C_p represents a concentration of health concern for downstream consumers–for example, the concentration such that an average adult drinking one liter has a 50% chance of developing illness (ID_{50}), C_p^{50}, or the concentration at which no adverse effects are expected to be observed (NOAEL), C_p^{NOAEL}, then one can derive contaminant-specific bounds on the pipe flow rates that could deliver such a dose:

$$\min\left(\frac{(Q_s C_s)}{C_p^{50}}\right) \le Q_p^{50} \le \max\left(\frac{(Q_s C_s)}{C_p^{50}}\right) (2)$$

The above bounds should represent reasonable minimum and maximum values, given uncertainty in the various factors, and $C_p^{50} = ID_{50} \times (W/L)$, where W is the assumed body mass in kg and L is one liter.

Pipe flow rate statistics, thus, can be used as a reasonable indicator of the vulnerability of distribution systems to contamination. Figure 1 shows the cumulative frequency of the temporally averaged pipe flow rates for four different operating systems (the plots are truncated at 100 gpm to highlight detail at the smaller flow rates). (These four systems were not subject to any form of pre-screening, and we did not analyze any other systems.) Note that between 60 and 80% of the average pipe flow rates are less than 100 gpm.

If security is a concern, the potential of health impacts from an intentional contamination by a given contaminant can be interpreted by computing the above Q_p^{50} bounds. For a given contaminant, we assumed $0.1 \le Q_s \le 1$ (gpm), $10^9 \le C_s \le 10^{11}$ (cells/L), $10^3 \le ID_{50} \le 10^5$ (cells/Kg) or, for a 70Kg body weight, $7x10^4 \le C_p^{50} \le 7x10^6$ (cells/L), which together yield maximum pipe flow bounds, $14 \le Q_p^{50} \le 1.4x10^6$ (gpm).

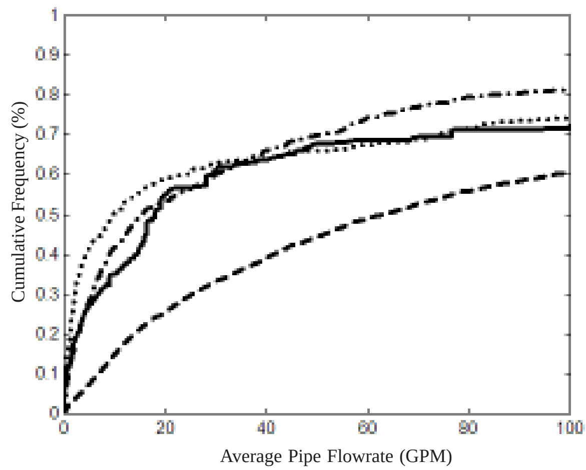

Figure 1. Cumulative frequency of pipe average volumetric flow rates in four distribution systems.

The above pipe flow rate bounds show that, in the worst case, all four distribution systems may be vulnerable to contamination, as the upper bounds on Q_p^{50} are large compared to, say, the 50th percentile values of between 10 and 60 gpm. In this case, there remains a significant fraction (30-60%) of pipes with a flow rate less than the lower bound. We caution that this analysis is rough; it only indicates the potential for significant health consequences without fairly assessing their likelihood or severity.

Storage Tanks, Flow Path Travel Times, and Contaminant Detection. Travel time characteristics in distribution networks affect the transport of contaminants from source to consumer, the robustness of contaminant detection schemes, and the post-detection time window for effective protection of public health. Time series of water quality indices, like those for free chlorine residual shown in Figure 2 reveal the importance of travel time characteristics. Figure 2 shows the variation in free chlorine residual at four distribution system sampling locations at one Midwest utility. These data show that the free chlorine residual can exhibit significant variability on hourly time scales, due in part to the loss of process control at the treatment plant, and in part to the interaction between travel time and chlorine decay kinetics. Chlorine decay kinetics combined with large storage tank residence

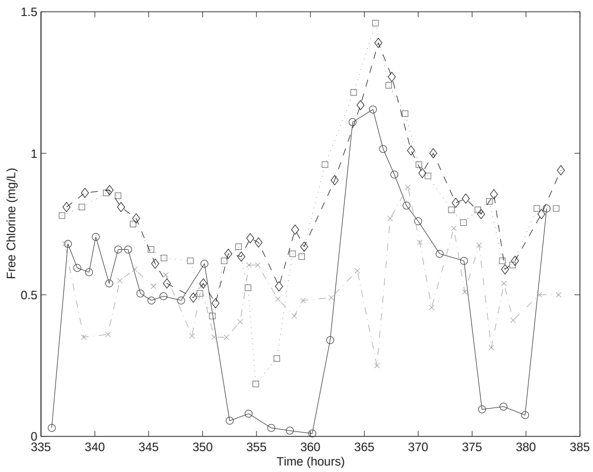

Figure 2. Chlorine concentration variations over time at four regulatory sampling locations in a Midwest utility.

time leads to large free chlorine loss within storage. When such tanks drain as a function of demand variation or system operation, low chlorine residual concentrations sweep across the storage tank service area, and any particular location experiences significant temporal variation in chlorine residual. More precisely, these locations are supplied at different times by distinct sets of flow paths having disparate travel time characteristics: a long travel time set that includes the storage tank, and a short travel time set that excludes it.

A comprehensive understanding of travel time characteristics in typical distribution systems requires system simulation. Here, we simulated "water age" using models of three utility distribution systems. Water age at a location is an integrated measure related to path travel time: it is the volume-weighted average of all travel times, over all paths leading back to a water source (where the age is zero). Typically, water age is simulated as a zero-order reaction with unit reaction rate coefficient. We used this standard approach, but we also prepared simulations where all water in storage used a zero reaction rate coefficient to highlight the role of storage tanks in travel time variation. In this modified approach, any water entering a tank stopped "growing old" until it left the tank and again entered the distribution system.

Water age histograms for the three networks are presented in Figure 3, and graphs of node water age statistics are presented in Figure 4. The latter figure is a scatter plot of water age standard deviation, at each location, versus its median value. These same statistics are also calculated for the water stored in each tank, and they appear as squares to distinguish them from consumer nodes. In each figure, graphs on the left side exclude the effects of storage tanks on travel time, while those on the right correspond to the same network but include the effects of storage.

The water age statistics show consistent trends: storage tanks increase significantly the median water age throughout the network, and dramatically increase water age variability. Indeed, if it were not for storage tanks, the seemingly common perception that distribution systems are relatively static, save for slow (seasonal) fluctuations in water quality, might be close to correct. The large volume of finished water stored in tanks, combined with relatively small replacement rates, leads to high water ages in storage. The contrast between high age water in storage, and low age water delivered from the plant (when tanks are filling), is the source of large variability in water age and travel times.

The water age statistics relate approximately to the time available prior to consumption of contaminated water. A significant fraction of water delivered to consumers—perhaps up to one half of the total—arrives from the source within 24 hours. Yet a significant fraction of water requires days of travel time, due primarily to flow paths that involve storage tanks. These data provide at least order-of-magnitude time constraints on contaminant detection and emergency response. Near complete protection from intentional contamination may require rapid detection and emergency response within hours, but protection of a significant population fraction may still be possible days after contamination. We caution that these observations are a rough guide; in addition to being system specific, they ignore chemical and microbiological processes, proximity of population to contaminant source, disease pathology and treatment, and time varying flow paths and travel times.

Real distribution systems exhibit variability in travel time at all locations, and thus in water quality metrics affected by chemical or biochemical reaction kinetics. A travel time standard deviation on the order of days should be expected within the service area of a storage tank. If not treated carefully, such variability can affect the robustness of contaminant detection systems, specifically the frequency of false positive and negative events. Work on such systems is just

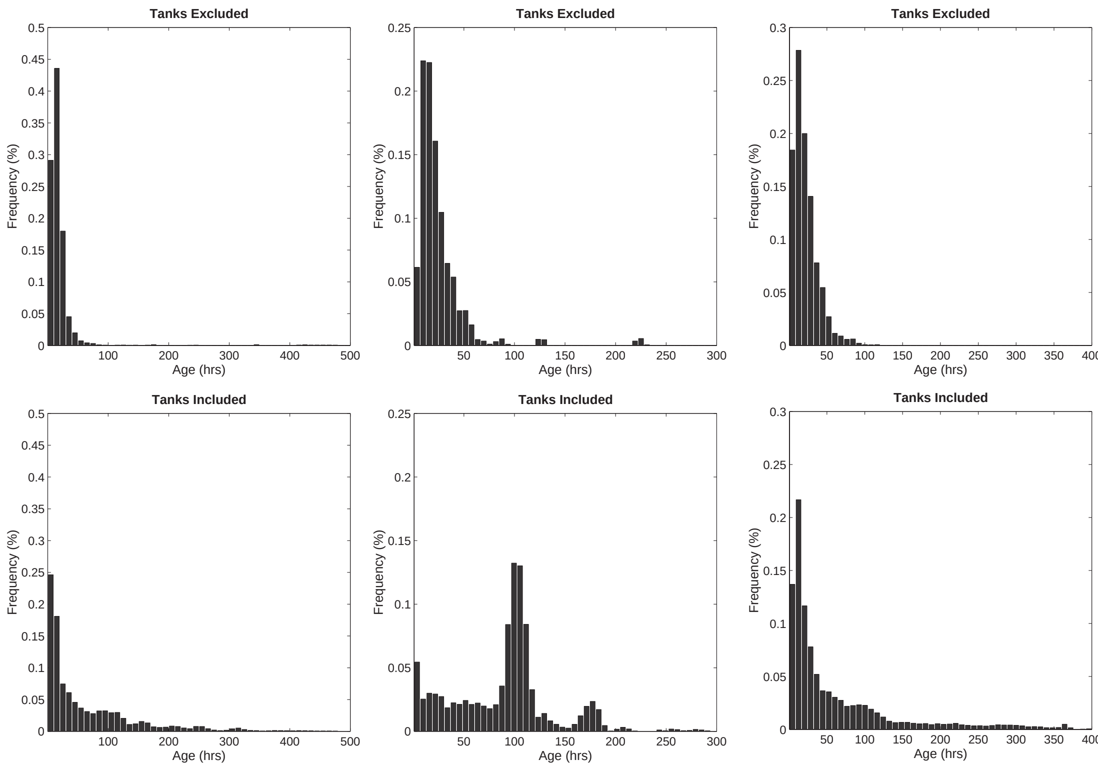

Figure 3. Water age frequency histograms for distribution systems 1 (left), 2 (center), and 3 (right). The travel time impacts of storage tanks are excluded from histograms on the left, and included on the right.

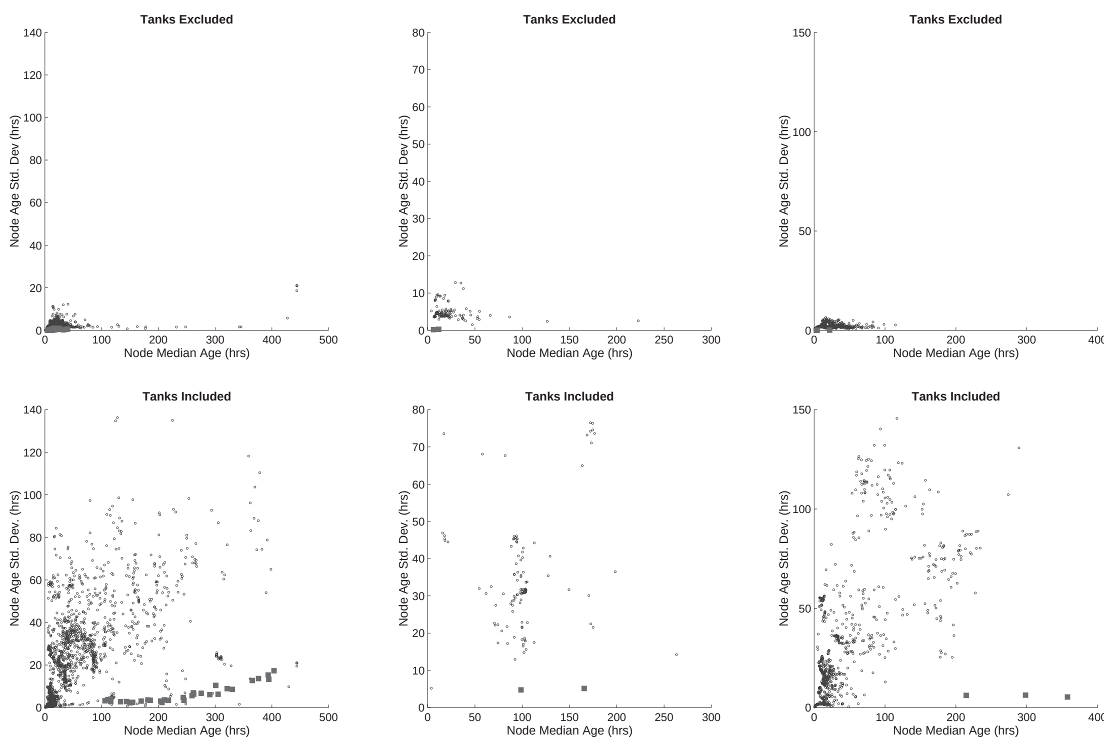

Figure 4. Node water age standard deviation (Ó^{2}) vs. median (m) for distribution systems 1 (left), 2 (center), and 3 (right). The travel time impacts of storage are excluded from plots on the left, and included on the right.

beginning, but one straightforward approach involves on-line sensors that measure broad water quality indices, coupled with simple statistical measures of signal excursions from the expected value. Indeed, one existing sensor that could be used measures free chlorine, relying on its sensitivity as a sentinel to distribution system contamination. The large variation in normal free chlorine residual may, however, require large signal excursion thresholds to avoid false positives, and it may also reduce the effectiveness of such simple statistical warning alarms.

The Role of Systems Analysis and Simulation in Safeguarding Water Supplies

Systems analysis and simulation enable an integrated analysis of the distribution system, bringing the spatial and temporal complexities together into a flexible modeling framework. Systems analysis can be used to understand the interdependencies of these complexities, and thus to aid decision-making in the operations of the system, and in the emergency response to contamination incidents. Network hydraulic models coupled with water quality models can be used to simulate threat scenarios to assess the potential impacts of contamination, and to design and pre-plan for mitigation strategies.

To adequately simulate water security contamination scenarios, many improvements to current modeling capabilities are needed. These improvements fall in two categories: improvements to the basic models and algorithms and improvements to application methods. Algorithms are needed that better reflect the following physical and chemical processes: mechanisms behind contaminant adherence to pipe walls; contaminant interactions with disinfectant residuals, disinfectant byproducts, and corrosion products; particles and biological agents transport ; and the true time-dependent flow characteristics (Uber 2004a). In addition, basic research is needed to gain a better understanding of biofilms and their role in protecting contaminants from disinfection.

Application to Networks. In the post-9/11 environment, vulnerability assessments of water utilities are considered highly sensitive and are not widely shared. Distribution system networks may contain specific information that should not be in the public realm. (For a general discussion of securing publicly available geospatial data, see Baker, 2004.) For researchers to improve modeling capabilities, however, it is essential for them to have access to a broad variety of network data. There are at least two solutions to this problem. First, methods could be developed to transform networks visually so that they cannot be readily identified. Second, a database of "prototype" networks could be fabricated, adequately reflecting the hydraulics and water quality characteristics of real systems, but not representative of any single existing system.

Probabilistic Applications for Quantifying System Vulnerability. Because one cannot predict the behavior of terrorists, an assessment of the vulnerability of a drinking water system to intentional contamination must consider a large number of possible threat scenarios, or a threat ensemble (Murray 2004). These scenarios may include factors such as the type of contaminant, the concentration and quantity of the contaminant, and the location of contaminant introduction. System vulnerability then is based on an assessment of the entire threat ensemble. It is not obvious, however, what constitutes a sufficient ensemble. How can one determine the minimal number of scenarios that should be simulated to obtain an accurate assessment of a system's vulnerability to contamination?

A probabilistic analysis (e.g. Monte Carlo) of the threat ensemble facilitates an understanding of the likely impacts of a contamination event, such as human health impacts (e.g., injury, disease, illness, death), economic impacts (e.g., costs to the water utility, interdependent industry and infrastructure, and medical costs), and environmental impacts (e.g., long-term remediation). Accurate and up-to-date models need to be developed for estimating each of these impacts. There is a lack of reliable data on the behavior of certain contaminants in water, including chemical and biological warfare agents, and their impacts on humans from ingestion or other exposure routes. For contagious diseases, dynamic models of disease transmission must be developed to assess impacts accurately.

Applications for Assessing and Mitigating Threats. Table 1 shows the results of the probabilistic application of a hydraulic and water quality model to three distribution systems to estimate the likely health impacts from a terrorist contamination of a water distribution system. For each network, between 100 and 1,500 scenarios were simulated. Though the contaminant was the same for each scenario, other parameters were varied to reflect the uncertainty in the execution of the contamination. For each scenario, a 55-gallon drum of contaminant was introduced into the system, resulting flow paths and exposures were analyzed, and statistics were generated and examined. The contaminant was assumed to behave like a tracer and to be resistant to chlorine residuals, or to quickly deplete the residuals.

Preliminary results show that this approach has the potential to help water utilities assess the contaminants to which they are most vulnerable, identify the most vulnerable regions of their distribution systems, and select the most appropriate mitigation strategies for their system. The results in Table 1 show that the same scenario applied to various networks can have quite different outcomes, thus the unique physical and flow-dependent features of each distribution system weigh heavily on health outcomes. However, the simulations show that "on average" a low percentage of the population will be severely impacted by contamination events (1-17%). If particular nodes are protected, the vulnerability of the entire system can be dramatically reduced.

Applications for Contaminant Monitoring, Detection, and Warning. Early warning systems consisting of online sensors, remote communication devices, and data analysis tools are thought to hold great promise in protecting drinking water supplies from contamination. Probabilistic applications can be used to simulate early warning system responses to contamination and to test real-time early warning system components under realistic conditions. Algorithms can be developed to optimize the location of sensors to achieve various goals, such as the minimization of public health impacts (Uber 2004b). Many basic questions about the feasibility of early warning systems remain unanswered and realistic simulations of early warning systems would help to optimize their design and to determine how long a utility has to respond after detection of the contamination.

Such systems level models could ultimately serve as emergency response simulators that could train and test operators in their ability to rapidly respond to contamination events. Applications of models could also be used to design intervention strategies, such as the closure of valves to isolate portions of the network, or the superchlorination or decontamination of pipes. Improved models would enable the more accurate prediction of the spread of contaminant as well as its decay due to chlorine residual or treatment/decontamination.

Summary and Conclusions

Because drinking water systems are vulnerable to intentional contamination by terrorists and to accidental contamination from cross-connections, their contamination is becoming an increasing concern. In this paper, the spatial and temporal complexities of distribution systems that make them particularly vulnerable to contamination are presented and discussed. In addition, the utility of a systems modeling approach in assessing, preventing, and mitigating water security threats is discussed. Research needs for better models and application capabilities are highlighted.

Table 1. Results from Monte Carlo analysis of three water distribution systems showing the average percentage of the population receiving a non-zero contaminant concentration or an LD50 concentration at the service connection. The last column lists the worst case exposure scenario.

Network/Population	Avg % Received Nonzero Dose	Avg % Received Concentration of Concern	Worst Case Received Concern Concentration of Concern
1 (< 10,000)	99%	17%	54%
2 (> 100,000)	75%	1%	4%
3 (>100,000)	60%	1%	6%

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References

Baker, John et al. 2004. *Mapping the Risks: Assessing the Homeland Security Implications of Publicly Available Geospatial Information.* The RAND Corporation.

Haestad Methods. 2003. A*dvanced Water Distribution Modeling and Management.* Waterbury, CT: Haestad Press.

Murray, Regan, Robert Janke, and Jim Uber. 2004. The Threat Ensemble Vulnerability Assessment Program for Drinking Water Distribution System Security. Proceedings of EWRI Congress, Salt Lake City, UT. June, 2004.

Uber, James, Lewis Rossman, and Feng Shang. 2004. Extensions to EPANET for the fate and transport of multiple interacting chemical or biological components. Proceedings of EWRI Congress, Salt Lake City, UT. June, 2004.

Uber, Jim, Robert Janke, Regan Murray, and Philip Meyer. 2004. Greedy Heuristic Methods for Locating Water Quality Sensors in Distribution Systems. Proceedings of the EWRI Congress, Salt Lake City, UT. June, 2004.

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Wastewater Security

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If one were to ask the "man or woman in the street" about security and water quality, it is likely that he or she would be able to explain on some level the potential danger associated with contamination of the drinking water supply. Indeed, even before the tragic events of September 11, 2001, President Clinton issued Presidential Decision Directive PDD 63, which designated the water infrastructure along with several other classes of infrastructure as "critical." The U.S. Environmental Protection Agency (EPA) was designated as the lead agency for the water sector and is responsible for developing plans to improve water infrastructure security. The significance of potential vulnerabilities to wastewater infrastructure are less immediately obvious but potentially as catastrophic. This article explains the basis of security concerns for wastewater infrastructure, discusses current practices in the area of wastewater vulnerability assessment and mitigation, and highlights efforts to expand the knowledge base of this emerging area.

Background

Contingency planning for extreme events has long been standard practice for designers and operators of wastewater and stormwater infrastructure. For decades, good practices have required consideration of the potential impact of severe natural events, including floods, hurricanes, blizzards, and earthquakes. These possibilities have been included both in wastewater and stormwater infrastructure design and in emergency preparedness and disaster response planning. The potential consequences of vandalism and employee misconduct may also have been considered. Today, there is a new focus of concern: the possible effects of intentional acts by domestic or international terrorists.

As a result, forward thinking wastewater systems are assessing and mitigating their vulnerabilities to this new area of concern. These systems are, however, challenged by the fact that water and wastewater security is an emerging area of practice that has evolved over just the last two years. Fortunately, rapid progress has been made in expanding the knowledge base required to secure wastewater infrastructure. The EPA, water and wastewater associations, utilities, and other institutions have worked together to identify and address areas of need. In many cases, practices and tools from other sectors for which security has been a long-term concern are being adapted to water and wastewater security. Finally, focused research is being used to fill data gaps and address wastewater-specific issues.

This is, nevertheless, an area of challenge for owners and managers of wastewater infrastructure. Currently, the assessment and mitigation of vulnerabilities is voluntary. Unlike water systems, wastewater and stormwater systems are not facing mandatory requirements (see below). Wastewater systems are, however, faced with other legal requirements and other pressures, including the challenges associated with maintaining aging infrastructure that also requires substantial investments. As a result, water and wastewater utility managers must balance external demands for security measures with the internal resources to develop and finance improvements.

Overview of Wastewater Treatment Systems

Wastewater infrastructure consists of the collection, conveyance, sewer, and treatment system. The collection system is comprised of a network of pipes, conduits, structures, devices, and appurtenances for the collection, transportation, and pumping of wastewater. Some of the underground structures, particularly those intended to contain stormwater following heavy rainfall, can be quite large. While much of the collection system is underground, some essential components (e.g., pumping equipment) are above ground. There are three basic types of sewers: sanitary, storm, and combined. Sanitary sewers contain domestic, commercial, and industrial wastewater, which is conveyed to the treatment plant. Storm sewers contain only stormwater and other runoff, which usually goes directly to a water body, such as a river or stream. Combined sewers are typically located in older metropolitan areas and are used to collect both wastewater and stormwater, which is conveyed to the treatment plant. Typically wastewater and stormwater flows through the collection system under gravity or a combination of gravity and pumping, depending on topographic conditions.

Figure 1 shows the sequence of the unit processes used at a typical wastewater treatment plant in the United States. During preliminary treatment, the first step in the process, large debris and a varied assortment of undesirable solids (e.g., grit, sand, and rags) and other components are removed using screens, shredding devices, grit removal systems, and possibly chemical addition. Preliminary treatment is followed by primary treatment (sometimes termed primary clarification), where gravity is used to separate and remove suspended and floating material. In the secondary treatment phase, biological treatment is used to decrease the concentration of dissolved, colloidal, and suspended organic material in the wastewater. The most common process, the activated sludge process, utilizes aerated biological reactors or tanks containing an established mixed population of microorganisms in the presence of oxygen and trace amounts of

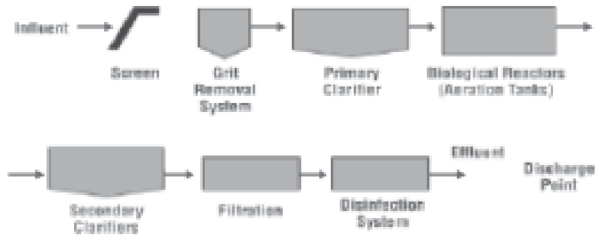

Figure 1 Flow Diagram for Wastewater Treatment Plant

nutrients for treatment. Secondary treatment also involves secondary clarification, where solids generated by the process are removed and sent to solids handling. The liquid separated by this clarification step may be subject to further chemical, physical, or biological treatment (advanced treatment) and will very likely be disinfected to destroy pathogenic organisms before discharge. The most common disinfection agent is chlorine. Other systems use sodium hypochlorite, ultraviolet radiation (UV) or ozonation. Because the solids settled or otherwise removed during wastewater treatment are unstable and contain pathogenic organisms, they must be treated before disposal. This solids treatment is also a multi-step process. The first two steps are thickening (volume reduction by removal of water using a variety of processes and equipment) and stabilization (anaerobic or aerobic biological processing or chemical treatment to decrease levels of volatile materials and pathogens). Dewatering, composting, or thermal drying follow. The solids are then disposed of by either burial in a landfill, beneficial reuse (e.g., as a soil amendment), or incineration.

Assessing Wastewater System Vulnerabilities

On June 12, 2002, President Bush signed the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (PL 107-188) into law. This Act requires community water systems serving populations of greater than 3,300 to conduct and submit to EPA vulnerability assessments and to develop or upgrade emergency response plans. All of these water systems were required to assess and report on their vulnerabilities by June 2004. Although legislative initiatives have been introduced (e.g., S. 1039, The Wastewater

Treatment Works Security Act), there is currently no mandatory requirement that these be conducted.

There are unique security concerns related to wastewater and stormwater infrastructure, and a specific vulnerability assessment methodology has been developed to address these concerns. This methodology, the Vulnerability Self Assessment Tool or (VSAT™), is a software program developed by the Association of Metropolitan Sewerage Agencies (AMSA). It provides a structured approach for utilities to assess vulnerabilities and identify countermeasures to reduce risks. The methodology was subsequently adapted for combined water and wastewater utilities and is available free. More information is available at www.vsatusers.net. The Water Environment Federation (WEF) has been conducting free training workshops on conducting vulnerability assessments with this tool. Information on these sessions is available at www.wef.org/watersecurity.

Vulnerability assessment methodologies for the water/wastewater sector are now well-established. In addition to VSAT™, some wastewater utilities are utilizing RAM-W (Risk Assessment Methodology–Water), which was developed by Sandia National Laboratories and the American Water Works Association Research Foundation (AwwaRF), to conduct vulnerability assessments. Combined water/wastewater utilities and stand alone wastewater utilities of various sizes are working to identify and prioritize security concerns, conduct vulnerability assessments, and develop security plans.

In the past, vulnerability assessments have typically been used for facilities such as nuclear or chemical plants where the physical assets are usually centralized and have likely been laid out with security concerns in mind. Wastewater and stormwater physical infrastructure are often highly dispersed geographically which presents challenges for ensuring their protection. Furthermore, concerns regarding collection systems can involve their potential to provide unrestricted access to government buildings, financial centers, hospitals, and other sensitive targets. Large diameter gravity sanitary, storm, or combined sewers could be accessed via manholes, inlets, or overflow structures.These systems are large enough to allow individuals using them to pass undetected beneath city streets. Another specific concern relates to the potential for destruction that could occur if highly flammable or explosive substances are introduced into the wastewater collection system of a major metropolitan area. The level of destruction that has resulted from accidental releases has been significant, including destroying streets and buildings within the vicinity of the explosion. Historical accounts of accidental releases of flammable or explosive materials being deposited into wastewater systems substantiate the potential for widespread devastation from an intentional act.

There are specific concerns related to the wastewater treatment as well as collection systems. Interruption of the wastewater treatment process, for example, by the introduction of substances toxic to the microorganisms in the treatment process, can shut down treatment for some time, potentially causing sewer backups and/or overflows. This can lead to widespread environmental and public health impacts, with subsequent economic impacts and an erosion of public confidence.

For drinking water systems, contamination water has been identified as the highest priority important security concern, and it is the subject of a considerable amount of research and development. Much of this research is focused on "early warning systems." Early warning systems will be designed to rapidly detect contamination events in drinking water systems, with the goal of avoiding or significantly reducing the most serious consequences of such an event. The concerns for intentionally introduced toxic substances in wastewater systems are different in many ways than those for drinking water systems and offer a unique set of detection challenges. However, there are certain parallels between the reliable detection of intentionally introduced toxics in wastewater and drinking water systems that will provide mutual benefits through continued research and development. The benefits of research and development on early warning of potentially disruptive toxic occurrences in wastewater systems will be improved process control both in "routine" operations, and in the event of a terrorist attack.

Hazardous chemicals used and stored at wastewater treatment plants could be used by terrorists or vandals in acts of sabotage. Chlorine can be of particular concern, and some systems in sensitive locations have elected to discontinue its use. However, a recent survey conducted by the WEF does not suggest that this practice is widespread. Nearly 300 wastewater treatment plants in the US responded to the survey conducted in late 2003, and about 40% reported using chlorine gas for disinfection. About one third of respondents indicated that they were considering a change in disinfection practices. Of these facilities, over 60% cited regulatory or safety concerns as the reason, while only 5% cited security concerns as the main reason for a change (WEF 2004).

The information technology systems of wastewater utilities may also prove to be vulnerable. Most modern facilities include supervisory control and data acquisition (SCADA) systems–many designed to completely replace manual operation of a facility. Hacking into these systems could be used to cause overflows or interrupt treatment processes causing back-ups. The Water Environment Research Foundation (WERF) is responding to these concerns with a project to provide guidance to utilities on how to secure and protect computerized and automated systems using currently available technologies to sense and correct security breaches. Initial findings from this work should be available to wastewater utilities in early 2005.

Identifying and Prioritizing Threats To Wastewater Systems

As more wastewater utilities have begun to perform vulnerability assessments, the need for guidance on which threats to consider during this process has been identified. This type of guidance has been available to water utilities for some time. EPA, under the direction of Congress, developed a Baseline Threat Document that provides water utility security teams with a way to identify the most relevant threats for their facility. EPA emphasizes that the document was not designed as an exclusive list of threats for a utility to consider and that the utility team should meet regularly with law enforcement personnel, public health agencies, and other stakeholders in the community to develop a site-specific threat listing for their vulnerability assessment. Nevertheless, water systems have found the guidance valuable and wastewater utilities are seeking a similar resource. EPA and WEF are working jointly to develop similar guidance for wastewater utilities. This guidance should be available late in 2004.

Reducing Vulnerabilities

Many utilities have found that changing operational practices can be a very cost-effective way of decreasing vulnerabilities. This requires training to build awareness and reinforce good practices such as consistent use of employee/contractor badges, pass codes, locks, and so forth. Rigorous chain-of-custody procedures should be used for the acceptance of chemical deliveries. Employees should be trained to identify and respond to suspicious behavior or to recognize indications of the presence of biological or chemical contamination. All employees should be aware of the existence of the facility's emergency response plan and what they should do in the event that it is activated. Regular drills and tabletop exercises can be helpful, and liaison with local emergency responders is essential. Some wastewater utilities are reaching out to local law enforcement personnel who may be unfamiliar with the nature of the operations and materials at the site. USEPA Region 1 has developed a poster and a visor card that water treatment facilities can use to educate their local police and the tips provided via these products may also be helpful for wastewater systems. (Copies of these materials can be obtained at http://www.epa.gov/safewater/security/flyers/index.html. Samples of materials useful for public outreach and for distribution to the news media are also available at this address.) It is important that every facility identify a single, trained spokesperson to communicate to the media should an event occur. Messages must also be coordinated with public health authorities to ensure that the information disseminated to the public is consistent and clear.

Wastewater systems are becoming aware of the need to locate and secure critical business documents and records, including "as-built" drawings, procurement records, legal documents, and a detailed contact list of customers and employees. Some of these records may be deemed sensitive in nature, and access to them will be controlled. Others may prove to be essential in ensuring a utility keeps running in the face of a threat. These "knowledge base assets" need to be organized and securely maintained. In some cases, copies should be made and kept off-site.

Other Areas of Development

Wastewater utilities have unique concerns related to the disposal of residues from the cleanup of chemical, biological, or radiological incidents. Wastewater systems may be asked to accept decontamination residues or contaminants may be washed into wastewater or stormwater systems by storm events or by emergency-response personnel during an incident. Treatment plant managers are seeking guidance on how to treat or dispose of these residues. EPA is working with AMSA to develop guidance for wastewater utilities on the safe handling and disposal of contaminated wastes. These contaminated wastes could result from a direct attack on the wastewater system or from a contamination/decontamination event on another target in the system's service area. The guidance will better prepare wastewater utilities to effectively address worker safety, impacts on their treatment systems (including biosolids), and public health and environmental concerns. Progress on this study will be reported at http://www.amsa-cleanwater.org/advocacy/security/.

The Water Environment Research Foundation is working on a number of projects some of which are in collaboration with AwwaRF. The projects cover a range of issues, including guidance to utilities on how to interact with the public, develop contingency plans, or evaluate "hardening" options (physical security measures). Other projects address specific technological applications, such as methodologies and technologies to identify, screen, and treat chemical, biological, and radiological contaminants in wastewater. The previously mentioned guidance for utilities on securing computerized and automated systems also is a collaborative effort of WERF and AwwaRF.

Finally, designers and managers of wastewater treatment systems have expressed a strong need for peer-reviewed information on best security practices for wastewater and stormwater system design, operation, maintenance, retrofit, and upgrade. Water Environment Federation (WEF) is developing consensus guidance materials that address how to include security and emergency response considerations into the design, construction, operation, and maintenance of wastewater collection and treatment facilities and stormwater systems. Considerations regarding minimizing effects of natural disasters are also being addressed, and this guidance will help systems of all sizes lower security risks and improve emergency response. Size-appropriate approaches and cost considerations will be identified to address specific security concerns. It is anticipated that a draft will be available late in 2004. WEF is working on this project in partnership with the American Water Works Association (AWWA), which is focusing on developing similar guidance materials for water utilities and the American Society of Civil Engineers (ASCE), which, in turn, is focusing on "methodologies and characteristics," such as contaminant and flow modeling.

The wastewater/stormwater security guidance materials will reflect a consensus evaluation of sound security-related practices. Examples of design considerations to be addressed include system redundancy and back-up, location and hardening of mission-critical assets, and design of hazardous materials storage/handling systems. Operations and maintenance guidance will also cover a wide range of issues from employee screening and training; working with the public; coordination and outreach with local emergency response personnel; use of sensing and detection equipment, etc. Some of these measures, though considered in the context of security and emergency response requirements, will also have a positive impact on facility performance. For example, as previously mentioned, use of advanced sensing technology may allow for more effective process control as well as an enhanced capability for the early detection and identification of toxic substances. Special emphasis is being given to identifying and developing measures that will have "multiple benefits" as a means to increase the likelihood that utilities will invest in security enhancements. Once the project is complete, the three project partners (ASCE, AWWA, and WEF) will consider developing consensus industry standards based on the guidance materials.

Research Needs

The current efforts described here should go a long way toward making wastewater systems more secure and better prepared for a variety of adverse circumstances. Both EPA and WERF have undertaken efforts to identify additional security needs faced by wastewater systems. In 2002, EPA initiated a process to identify drinking water and wastewater research and technical support security needs. EPA's process relied on stakeholder input from the outset and resulted in a final "action plan" in early 2004. WERF conducted a wastewater security symposium in the summer of 2003 that produced a prioritized research agenda that also was published in early 2004. Both the EPA and WERF efforts identified a very similar set of research needs. The top two needs identified by WERF are development of security-related design standards for wastewater and stormwater facilities, and guidance on the safe handling of contaminated materials and treatment residuals. Efforts to address these concerns are already underway. The other highest priority needs identified by WERF include: addressing interdependencies with other critical infrastructures that could adversely affect wastewater systems; demonstration of ways to detect contaminants of concern in wastewater systems; and information on physical security measures for wastewater systems.

Conclusions

While the issue of security is new to the wastewater sector, experience dealing with the impacts of natural disasters and accidents on these vital treatment systems has helped prepare utility managers to cope with this new issue. Awareness of the issue of security is growing, though managers must balance competing pressures for scarce resources within their systems. New tools that are being developed and research that is being advanced have and will continue to strengthen the basis for sound decision-making.

Author Bio and Contact Information

Eileen J. O'Neill is Managing Director for Technical and Educational Services with the Water Environment Federation. In this capacity she oversees WEF staff with responsibility for the technical content of WEF conferences, workshops, and training courses; surveys of municipal and industrial practice; training materials including in print, video, CD-ROM, and web formats; and technical support to WEF's committees. Dr. O'Neill oversees various projects in the areas of utility management and security. She has almost 25 years experience and holds a B.S. in Soil Science from the University of Newcastle-upon-Tyne (UK) and a Ph.D. in Soil Science from the University of Aberdeen (UK) and undertook a postdoctoral traineeship in Environmental Toxicology at the University of Wisconsin at Madison. Her area of interest is the fate and transport of contaminants in the environment.

Alan Hais is a Senior Environmental Engineer with EPA's National Homeland Security Research Center. Mr. Hais serves as the EPA headquarters coordinator for water and wastewater security research, and has the lead for EPA research on wastewater security and physical security of water systems. Mr. Hais has more than 30 years experience with EPA's water programs. He has served in various technical and management positions, specializing in municipal wastewater treatment technologies and standards, drinking water regulations and ambient water quality criteria. Mr. Hais also worked for the District of Columbia on the design and operation of the Washington's Blue Plains Wastewater Treatment Plant. He received bachelors and master's degrees in civil/environmental engineering from the University of Maryland and is a registered Professional Engineer.

References

Water Environment Federation. 2004. Disinfection Process Survey Summary, *Water Environment & Technology* 16(7).

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Robert A. Young is a resource and agricultural policy economist with over 40 years of applied research, teaching and consulting experience. He received degrees in Agriculture (1954) and Agricultural Economics (1958) from the University of California (Davis) and an Agricultural Economics doctorate from Michigan State University (1963). Young was on the faculty at the University of Arizona and then for two years was a visiting staff member at the nonprofit research organization Resources for the Future, Inc. in Washington, DC. Since his retirement in 1992 after 22 years as a full-time Colorado State University Agricultural Economics faculty member, Young has carried on his university research and outside consulting activities. He continues to focus on: methods for economic evaluation of proposed public policies for investments in, and allocation of, water supplies and water quality improvements; concepts and methods for valuation of nonmarketed water-related goods and services; and developing interdisciplinary approaches to the modeling of water policy issues. He is the author or co-author of numerous articles, monographs, reports and conference papers.

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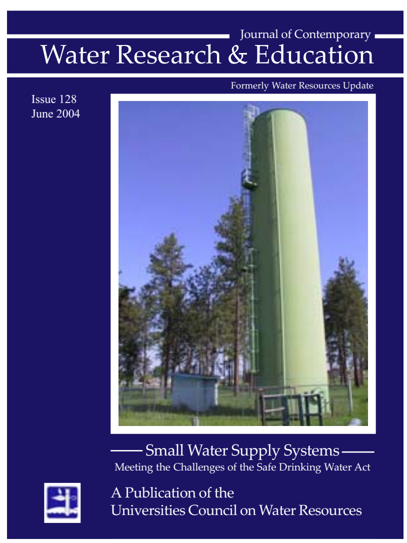

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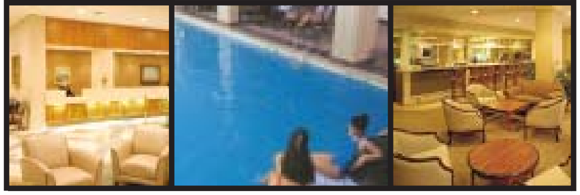

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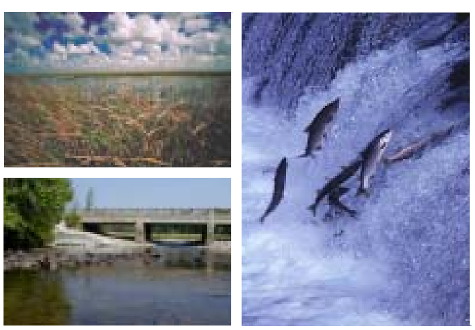

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