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Drinking water security: Overview  
of Canadian and U.S. Strategies

By:

J. Marsalek

NWRI Contribution No. 05-178

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## **Drinking water security: overview of Canadian and U.S. strategies**

J. Marsalek

### **Abstract**

Drinking water systems represent one of the critical infrastructures that are essential for the well-being of the general population. Consequently, risk management strategies need to be applied to these systems to strengthen their safety under exposure to various types of hazards. The process of developing management actions, with respect to new technologies and procedures, can be guided by recent advances in this field, and particularly those produced under the U.S. EPA water security program.

## **NWRI RESEARCH SUMMARY**

### **Plain language title**

Drinking water security: overview of Canadian and U.S. strategies

### **What is the problem and what do scientists already know about it?**

Drinking water systems represent one of the critical infrastructures that are essential for the well-being of general population. Such systems are exposed to various levels of risk for a variety of reasons, including major (natural) disasters, accidents, and acts of extortion or terrorism. Experiences with drinking water system failures during the past five years brought increased attention to these systems, including evaluation of hazards and relative risks of failure, and application of risk reduction measures.

### **Why did NWRI do this study?**

This study is a part of the NWRI Urban Water Management Project activities, designed to address timely issues related to urban water services, including drinking water supply, urban drainage, and wastewater management.

### **What were the results?**

This overview paper summarized the current experience with drinking water infrastructure and its assurance practices in Canada and USA. In Canada, a position paper on this issue has been published, describing a basis for developing a national strategy for infrastructure protection. The guiding principles include awareness, integration, participation, accountability and an all-hazards approach. The development of the US strategy has been completed and it is being implemented. Essential components of the US approach include vulnerability assessment, assessment of the likelihood of system failure (qualitative probability), evaluation of the existing counter or protective measures, analysis of current risks, and development of prioritized plans for risks reduction.

### **How will these results be used?**

The results will serve for protection of the drinking water infrastructure.

# **Sécurité de l'eau potable : survol des stratégies canadienne et étatsunienne**

J. Marsalek

## **Résumé**

Les systèmes d'eau potable constituent une des infrastructures essentielles au mieux-être de la population. Il faut donc appliquer à ces systèmes des stratégies de gestion des risques propres à renforcer leur sûreté s'ils sont exposés à divers types de dangers. Le processus d'élaboration de mesures de gestion, dans le contexte des nouvelles technologies et procédures, peut être guidé par les progrès récents dans le domaine, et particulièrement par les avancées du programme de sécurité de l'eau de l'EPA aux États-Unis.

## **Sommaire des recherches de l'INRE**

### **Titre en langage clair**

La sécurité de l'eau potable : survol des stratégies canadienne et étatsunienne

### **Quel est le problème et que savent les chercheurs à ce sujet?**

Les systèmes d'eau potable constituent une des infrastructures essentielles au mieux-être de la population. Ces systèmes sont exposés à divers niveaux de risque pour toutes sortes de raisons, dont les grandes catastrophes (naturelles), les accidents et les actes d'extorsion ou de terrorisme. Les défaillances des systèmes d'eau potable observées au cours des cinq dernières années ont attiré l'attention sur ces systèmes, particulièrement pour ce qui a trait à l'évaluation des dangers et des risques relatifs de défaillance ainsi qu'à l'application de mesures de réduction des risques.

### **Pourquoi l'INRE a-t-il effectué cette étude?**

Cette étude fait partie des activités du Projet de gestion des eaux urbaines de l'INRE, qui a pour but d'étudier les sujets d'actualité liés aux eaux urbaines, y compris l'approvisionnement en eau potable, le drainage urbain et la gestion des eaux usées.

### **Quels sont les résultats?**

Le présent aperçu résume l'expérience actuelle en matière d'infrastructures d'eau potable et de pratiques de sécurité au Canada et aux États-Unis. Au Canada, un exposé de principe décrivant les fondements d'une stratégie nationale de protection des infrastructures a déjà été publié. Les principes directeurs comprennent la sensibilisation, l'intégration, la participation, la responsabilisation et une approche tous risques. La stratégie des États-Unis est achevée et déjà mise en œuvre. Les composantes essentielles de l'approche étatsunienne sont l'évaluation des vulnérabilités, l'évaluation de la probabilité d'une défaillance du système (probabilité qualitative), l'évaluation des contremesures ou des mesures de protection existantes,

l'analyse des risques actuels et l'élaboration de plans de réduction des risques ordonné par priorités.

**Comment ces résultats seront-ils utilisés?**

Les résultats serviront à la protection des infrastructures d'eau potable.

# DRINKING WATER SECURITY: OVERVIEW OF CANADIAN AND U.S. STRATEGIES

SHORT TITLE: STRATEGIES FOR DRINKING WATER SECURITY

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**Abstract.** Drinking water systems represent one of the critical infrastructures that are essential for the well-being of the general population. Consequently, risk management strategies need to be applied to these systems to strengthen their safety under exposure to various types of hazards. The process of developing management actions, with respect to new technologies and procedures, can be guided by recent advances in this field, and particularly those produced under the U.S. EPA water security program.

**Keywords:** drinking water infrastructure; threats and hazards, vulnerability assessment; risk management, emergency response plan; online monitoring

## 1. Introduction

Failures or impairments of water supply systems have been experienced since ancient times, when such systems have been targeted during armed conflicts. In recent times, water supply systems have been exposed to various levels of risk for a variety of reasons including major disasters (e.g., storms, earthquakes, fires, floods, or explosions), accidents, acts of extortion or acts of terrorism (Halliday, 2003). While the accidental contamination of drinking water may have tragic consequences (e.g., the Walkerton affair, O'Connor, 2002a), its risk can be substantially reduced by adopting the so-called multiple barrier approach ensuring drinking water safety by complementary and redundant safety

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measures (O'Connor, 2002b). However, intentional attacks on drinking water infrastructure pose a much more serious challenge and the associated risks must be managed.

Currently, the risk management for water infrastructure in Canada and USA is conducted under the public safety and emergency preparedness programs, dealing with critical infrastructure protection, emergency preparedness, response and recovery, and related communication and dissemination of information. While these programs generally consider the whole system of critical infrastructures, the discussion in this paper is limited just to the water supply infrastructure.

Following the attacks of September 11, 2001, new programs on infrastructure security have been initiated in the USA by the Department of Homeland Security (DHS) and in the field of water infrastructure, by the U.S. Environmental Protection Agency (U.S. EPA). The main issues addressed include protecting drinking water systems against physical and cyber threats; identifying drinking water threats, contaminants, and threat scenarios; improving analytical methodologies and monitoring systems for drinking water; containing, treating, decontaminating, and disposing of contaminated water and materials; planning for contingencies and addressing infrastructure interdependencies; determining effects on human health and informing the public about risks; and, protecting wastewater treatment and collection systems. Most of the information produced is readily accessible via the Internet, and as documented later, Canadian municipalities use the EPA water security portal for their risk management activities. Currently, there is a high volume of research under way under the EPA collaborative research program (USEPA 2004b, 2004c) and many new advances can be expected.

The main purpose of this paper is to review the current strategies for addressing drinking water security in Canada and the USA and provide key sources of information on these developments.

## **2. Drinking Water Infrastructure**

In designating national critical infrastructures (NCI) to be protected against disasters, terrorism or other hazards, individual countries take different approaches. The resulting NCI lists may include various entries, with the water sector (sometimes separated into drinking water and wastewater systems) being included by almost all countries.

Recently, the Government of Canada issued a position paper on a National Strategy for Critical Infrastructure Protection (PSEPC, 2004), which forms a basis for developing a national strategy for critical infrastructure protection. This strategy includes a number of guiding principles, such as awareness,

integration, participation, accountability, and an all-hazards approach. Within the context of this NATO workshop, the discussion herein focuses just on drinking water, even though it is recognized that various infrastructures are interconnected and the failure of the water supply would impact on other NCIs as well (PSEPC, 2004).

## 2.1. WATER SUPPLY SYSTEM

The water supply system must be understood in its entirety, consisting of water sources (including an intake and piping), water treatment, and water distribution. Indeed, potential threats/attacks concern all these components, even though risks may be different for individual components. The most upstream component represents a raw water source, such as a reservoir, lake, river, stream, or groundwater wells. This is where the water intakes are located and water from these sources is then transported to the water treatment facilities. Water sources are usually public water bodies, which can be easily targeted for disruption. However, an effective attack would require very large quantities of harmful agents and this limits the probability of success of such attacks.

The water treatment facility is the next component in the water supply system; it is a plant where raw water is treated to the level required by local regulations. Water treatment plants employ chemicals (e.g., chlorine-based disinfectants) which could be used to contaminate water or harm employees. Also these plants often employ Supervisory Control and Data Acquisition (SCADA) computer systems which may be vulnerable to cyber attacks. Furthermore, many of these facilities are automated with minimum staff present on site. Consequently, water treatment plants may be vulnerable to attacks, particularly the final distribution tanks.

The last component is the water distribution system, which transports treated water to individual points of consumption. The quality of water entering the distribution system is generally tested, but the results are known with some delay and the tests performed do not target all chemicals that could be used in an attack. Consequently, the distribution system is also considered fairly vulnerable to attacks. It should be also noted that contamination of drinking water could have an impact on wastewater collection and treatment as well, when disposing of contaminated drinking water.

Welter (cited in Halliday, 2003) listed targets of the North American "events" disrupting water infrastructure, in a descending order of frequency, as drinking water systems (31%), storage facilities (27%), surface sources (8%), water treatment plants (7%), distribution systems (6%), dams (4%), SCADAs (3%), and miscellaneous (4%).

## 2.2. TYPES OF THREATS

In addressing drinking water security, it is important to deal with all hazards, which may include natural disasters, accidents, computer cyber attacks, and deliberate attacks by extortionists or terrorists; such incidents are also referred to in the literature as "major events". In a listing of North American major events involving drinking water infrastructure, Welter (cited in Halliday, 2003) analyzed the attacks with respect to the modes of attack and listed them in the order of descending frequencies as contamination (37% of all events), break-in (29%), use of explosives (7%), hacking (6%), vandalism (6%), and information gathering (3%). Such acts were perpetrated by unknown persons (41%), vandals (19%), terrorists (12%, domestic or foreign), employees (8%), disturbed (6%), and others (4%).

Thus, the available information indicates that any component of the water supply system may be vulnerable to some form of failure or attack, and the most common forms are contamination and break-in. It should be also noted that this list does not include disasters, which also pose significant hazards with respect to safety and security of water supply systems. Examples of such hazards include floods (potentially impacting on water sources, intake structures, and water treatment plants), power failures (impacting on pumping stations and treatment plant operations), and earthquakes impacting on all elements of the drinking water infrastructure.

## 3. Risk Management

The assurance actions of critical infrastructure owners/operators are based on risk management principles. In this approach, a consistent set of criteria is used to identify and rank critical infrastructures and determine the relative levels of risk of their failure. The relative priority of infrastructures is assessed by identifying the impact of their loss on the operation of the respective sector and on other sectors, and the consequence of their loss. Subsequently, owners and operators make decisions about the appropriate level of infrastructure protection (PSEPC, 2004).

The risk management process includes the following three components: (a) developing an understanding and creating awareness of the critical infrastructure and its interdependencies, (b) assuring the critical infrastructure through threat and vulnerability assessments, and threat mitigation; and, (c) managing response and recovery by facilitating cross-sector coordination, response planning, and education and training (PSEPC, 2004). The vulnerability assessment and emergency preparedness planning are particularly important elements of this process and procedures for their preparation have



been developed by, and are available from, the U.S. EPA (USEPA 2002, 2004a). Canadian municipalities are taking advantage of this source of information.

### 3.1. DRINKING WATER INFRASTRUCTURE – VULNERABILITY ASSESSMENT

The main purpose of vulnerability assessment (VA) is to evaluate the susceptibility of the drinking water infrastructure to potential threats and hazards, and identify corrective actions reducing or mitigating the risk of serious consequences from adverse incidents (e.g., vandalism, sabotage, terrorist attack, etc.). VA takes into account the vulnerability of the whole water supply system (water source, transmission, treatment plant, and distribution components) and the risks posed to the surrounding community (USEPA, 2002). The assessment then serves to guide the agency in prioritizing plans for security upgrades, modifications of operations, and policy changes to mitigate the risks and vulnerabilities to the critical assets. VA should be performance-based, i.e., it should result in evaluation of the risk to the water system for the existing situation and for future measures designed to reduce the existing vulnerabilities. While the U.S. VA procedures emphasize adverse actions (USEPA, 2002), in the Canadian approach, consideration of all threats, including those caused by natural disasters, is emphasized (PSEPC, 2004).

The VA comprises the following elements (USEPA, 2002):

- Characterization of the drinking water system, including its mission and objectives;
- Identification and prioritization of adverse consequences to avoid;
- Determination of critical assets that might be subject to malevolent acts potentially leading to undesired consequences;
- Assessment of the likelihood (qualitative probability) of such malevolent acts from adversaries;
- Evaluation of the existing countermeasures; and,
- Analysis of current risks and development of a prioritized plan for risk reduction.

Brief comments on individual vulnerability assessment elements follow.

#### 3.1.1. *Drinking Water System Characterization*

The most important steps in this process include identifying the drinking water utility customers (e.g., general public, military, industrial, etc.) and the most important facilities, processes and assets needed to achieve the utility's mission

objectives. Specifically, one needs to develop a list of utility facilities, operating procedures, management practices, utility operation (i.e., sources of raw water), treatment processes, storage methods and capacity, chemicals use and storage, and details of the distribution system. In assessing critical assets, important considerations include critical customers, dependence on other infrastructures (e.g., electricity), contractual obligations, points of potential failures (e.g., aqueducts), chemical hazards, and availability of other resources that may affect the criticality of specific facilities (USEPA, 2002).

#### *3.1.2. Identification and Prioritization of Adverse Consequences to be Avoided*

One needs to list all the impacts that would substantially disrupt the system ability to supply safe water, or would impact on the surrounding community. Ranges of consequences or impacts of each eventuality should be identified and might include magnitude of service disruption, economic impacts (replacement of damaged components, revenue losses), number of illnesses or deaths resulting from an event, loss of public confidence in the water supply system, chronic problems arising from specific events, and other types of impacts. Risk reduction recommendations presented later in the vulnerability assessment should address each of these factors (USEPA, 2002).

#### *3.1.3. Determination of Critical Assets Vulnerable to Malevolent Acts*

In this context, the malevolent acts usually considered include physical damage or destruction of critical assets, contamination of water, intentional release of stored chemicals, and interruption of electricity or of other infrastructure interdependencies. The U.S. Bioterrorism Act also specifies the elements that should be included in the review, including: pipes and other conveyance elements; physical barriers; water collection, pre-treatment and treatment facilities; storage and distribution facilities; automated systems utilized in the system operation (SCADAs); the use, storage and handling of chemicals; and, operation and maintenance of such systems (USEPA, 2002).

#### *3.1.4. Likelihood of Malevolent Acts*

At this stage, one needs to identify the possible modes of attack, which would significantly endanger the critical assets. The threats considered will determine, to a great extent, the risk reduction measures to be considered later in the vulnerability assessment process. Other sources of guidance for estimating the probability of major events include local law enforcement agencies, EPA documents, and incident reports reviewing past breaches of security (USEPA, 2002).

### 3.1.5. *Evaluation of Existing Countermeasures*

The first group of considerations deals with capabilities for detection, delay and response, including the existing detection capabilities such as intrusion detection, water quality monitoring, operational alarms, guards, and employee security awareness programs. The current delay mechanisms may include locks and key control, fencing, structure design, and vehicle access checkpoints. Furthermore, the existing policies and procedures dealing with intrusions (both physical or via the cyberspace), system malfunctions, and adverse water quality indications need to be identified and evaluated. This evaluation goes beyond the system identification, it addresses the actual performance. Cyber protection features include protective measures for SCADAs and business related computer information, including firewalls, modem access, Internet and other external connections, and security policies and protocols; and, vendor access rights. Finally, security policies and procedures and compliance records deal with personnel security, physical security, key and access badge control, control of system configuration and operational data, deliveries, and security training and exercise records.

### 3.1.6. *Analysis of Current Risks and Development of a Prioritized Plan for Risk Reduction*

In this step, the above listed information (3.1.1-3.1.5) is analyzed to determine the current levels of risk. The operator should then determine whether the existing risks are acceptable, or risk reduction measures should be pursued. If the latter option is chosen, the recommended measures should measurably reduce risks or consequences, e.g., by reducing vulnerability or improving deterrence, delay, detection, and/or response capabilities. Both short and long-term solutions should be considered; security improvements should be considered in conjunction with other planned improvements (USEPA, 2002). In the multiple barrier approach (O'Connor, 2002b), some system redundancies may both reduce vulnerabilities and improve water supply system operation.

Strategies for reducing vulnerabilities fall into three categories – (a) Sound business practices, which are the policies, procedures, and training designed to improve the overall security culture; (b) System upgrades including changes in operations, equipment, processes and infrastructure that make the system safer; and, (c) Security upgrades improving capabilities for detection, delay or response (USEPA, 2002).

The vulnerability assessment document is used for preparing Emergency Response Plans (ERP), as demonstrated in the following section for small to medium size communities.

#### **4. Emergency Response Plans (example for small to medium size communities)**

An emergency response plan (ERP) describes the actions taken by operators of a municipal water supply system in response to major events, which include credible threats, or indications or acts of terrorism, major disasters or emergencies caused by storms, wind storms, ice storms, fires, floods, earthquakes or explosions, and catastrophic incidents with extraordinary levels of casualties, damage, and disruptions. Before preparing an ERP, vulnerability assessments should be prepared and first responders and ERP partners be identified. Consultations with local and territorial (state or provincial) agencies are recommended to secure their advice and cooperation. ERP has eight core elements, which are briefly described below on the basis of US EPA recommendations for small to medium communities (3,300 < population < 100,000) (USEPA, 2004a).

##### **4.1. WATER SUPPLY SYSTEM SPECIFIC INFORMATION**

During major events, basic technical information for the water supply system should be readily available to staff, first responders, contractors/vendors, the media and others. Thus, such information needs to be assembled during the vulnerability assessment and identified in the ERP. The level of technical documentation reflects the complexity of the water system. Typically, this information includes the municipal water supply system identification; administrative contact persons; population served; service connections; distribution and pressure boundary maps; overall process flow diagrams; site plans and facility "as built" engineering drawings; operating procedures and system descriptions, including those for SCADA systems and process control systems operations; communication system operations; staffing rosters; chemical handling and/or storage facilities; and, release impact analyses (USEPA, 2004a).

##### **4.2. WATER SUPPLY UTILITY ROLES AND RESPONSIBILITIES**

To fulfil responsibilities of the water supply utility, an Emergency Response Lead (ER Lead) and Alternate Lead need to be designated, and must be reachable on a 24-hour basis. The lead will be responsible for evaluating the incoming information, managing resources and staff, and deciding on appropriate response actions. The lead also coordinates response efforts with first responders (USEPA, 2004a).

#### 4.3. COMMUNICATION PROCEDURES: WHO, WHAT AND WHEN

Good communications are essential during emergencies. Consequently, one needs to maintain internal and external notification lists and provisions should be made for an efficient and fail-safe form of communications during major events. The internal notification list includes the ER Lead and Alternate, ER team members, and utility management. The external list focuses on first responders who may be drawn from local, state and national agencies (police, fire protection, emergency committees, etc.). Finally, one also needs to communicate with the public and media. For this purpose, it is best to name an official spokesman, who may be someone external to the municipal water supply utility. Draft press releases and public water restrictions notices can be prepared in advance. In such communications, emphasis is placed on message clarity, accuracy, and ease of understanding (USEPA, 2004a).

#### 4.4. PERSONNEL SAFETY

Protecting the health and safety of the water supply utility staff as well as of the surrounding community is a key priority during emergencies. In safety considerations, one needs to consider evacuation planning, evacuation routes and exits, assembly areas and shelters, accountability, training and information, emergency equipment and administering first aid. There are many sources of additional information on these procedures (USEPA, 2004a).

#### 4.5. IDENTIFICATION OF ALTERNATE WATER SOURCES

The planning of alternate supplies requires a good understanding of the water supply system and of the available alternate sources. One needs to plan for both short-term and long-term outages, depending on the type of emergency. Where "boil water" notices suffice to address the problem, there is no need for alternate water sources. The next level is a "do not drink" order; in this case, the water may still be suitable for sub-potable uses not involving ingestion. The most restrictive is the order "do not use", which may eliminate even the use for fire fighting. Possible short-term alternate water supplies include bottled water, bulk water provided by certified water haulers, inter-connections to nearby municipal water systems, and water from unaffected wells (sources). Dealing with long-term outages is much more challenging. Quite often the only solution is a replacement of the entire component of the water supply system, e.g., of the water source, treatment plant, or the distribution system (USEPA, 2004a).

#### 4.6. REPLACEMENT EQUIPMENT AND CHEMICAL SUPPLIES

The ERP should identify equipment that can lessen the impact of a major event on public health and drinking water supply. Towards this end, one should maintain an inventory of replacement equipment, spare parts, chemical supplies, and information on mutual-aid agreements with other municipal water supply utilities (USEPA, 2004a).

#### 4.7. PROPERTY PROTECTION

Protection of municipal water supply facilities, equipment and vital records is important for restoring operations after major events. Thus, the plan must include measures and procedures to be taken, in order to secure and protect the utility property following major events. This may include "lock down" procedures, access control procedures, establishing a security perimeter, evidence protection, and securing building/facilities against forced entry (USEPA, 2004a).

#### 4.8. WATER SAMPLING AND MONITORING

Water sampling and monitoring is needed to determine whether the drinking water is fit for public consumption, following a major event. Typical considerations include identifying sampling procedures, obtaining sample containers, determining the quantity of required samples, identifying who is responsible for collecting and transporting samples, confirming laboratory capabilities and certifications, and interpreting monitoring or laboratory results (USEPA, 2004a).

### 5. Addressing Contamination Threats: Online Contaminant Monitoring

One of the most common major events experienced by water supply utilities is water contamination by various agents (Halliday, 2003). One way of detecting water contamination is by online monitoring, which was examined in the recently published 'Interim Voluntary Guidelines for Designing an Online Monitoring System' (ASCE et al., 2004). A brief summary of these guidelines follows and is used to demonstrate the challenge of dealing with drinking water contamination.

When determining whether to use an Online Contaminant Monitoring System (OCMS), the utility should go through the risk assessment procedures outlined earlier under the vulnerability assessment and emergency response planning documents. In this process, one would consider all practical points of

contaminant insertion, identify the insertion points of highest criticality (affecting the largest population), choose those which are most readily accessible to attackers, postulate a set of contamination threats, and estimate the consequences. Where the cost of OCMS is justified, one would follow with implementing such a system, which should meet the following objectives: (a) Provide an early warning with sufficient lead times to take corrective measures, (b) indicate the location and travel of the contaminant needed to design appropriate responses, (c) "identify" the contaminant and its conceivable concentration to inform the medical community, (d) provide information on the normal operating characteristics of the system, and (e) support or supplement the existing surveillance activities (ASCE et al., 2004).

There are many lists of potential contaminants of drinking water and their concentrations, which are available on the Internet (e.g., from EPA or Centers for Disease Control and Prevention, CDC), or from proprietary sources. Instrumentation for early detection of drinking water contaminants is rapidly developing, but it is not yet at the state of meeting "ideal" performance parameters (States et al., 2004). Thus, it is required to use one tier of instruments to detect contamination events and provide information on locations of contaminant occurrences, and the second tier involving laboratory techniques is needed to measure specific contaminants (ASCE et al., 2004). Among laboratory techniques, preference is given to rapid analytical techniques, such as rapid immunoassays, rapid enzyme tests, polymerase chain reaction, field-deployable gas chromatograph-mass spectrometry, and acute toxicity screening methods (States et al., 2004). This two-tier strategy assumes that contaminants in water may change some measurable properties of the water and reveal their presence through these surrogate measurable parameters. The types of changes possibly caused by contaminants include changes in chemical composition of water, including carbon or other elements; changes in pH, reduction-oxidation potential and conductivity; changes in optical properties; changes in biological makeup of water; and, changes in mechanical and acoustic properties of the water.

Potential locations of instruments are in source water, end of water aqueducts, treatment plants, finished water reservoirs, and various locations in distribution systems – early, mid and end points. Each of these sites has advantages and disadvantages, which need to be considered when selecting instrument locations. In general, it is recommended to monitor the following water characteristics: flow/pressure, temperature, pH, conductivity, residual chlorine, turbidity, oxidation-reduction potential (ORP), ammonia, nitrate, chloride, toxic materials (e.g., by a toximeter), and radiation (alpha, beta and gamma) (ASCE et al., 2004). This general list may be modified in specific situations.

Data from online instruments need to be analyzed to identify presence and location of contamination, determine the time to tap, eliminate false negatives and minimize false positives, provide timely information to decision makers, and as much as possible, identify the contaminant and its class and concentration profile, and assess public health risk. Towards this end, instrument data are used in conjunction with computer models of the system, automating the process as much as possible. Besides the common water supply and distribution models, the analysts also need diagnostic/analytical programs, which address such issues as contamination scenarios with a range of insertion events from short insertion pulses to long-term bleeds and filter out background noise to enable extraction of the contamination signal. Furthermore, modellers need to develop a catalogue of pulse characteristics and study signatures of both benign events as well as the historical events, which produced negative impacts. Other uses of modelling analysis include choosing the locations for placing instruments, response planning, design/upgrade of water systems, identification of contamination locations (e.g., by back-tracking contamination to the sources), and confirmation of positive events. A number of suitable models are available on the market (ASCE et al., 2004).

After compilation of contamination data at a central facility, alarms are provided to bring such data to the attention of decision-makers, who then evaluate the situation and take appropriate actions, including issuing advisories, contacting officials, directing utility staff and contacting media. For data transmission and other essential communications, there is a need for a communication system that is reliable, effective and secure.

Next step in this procedure is the response to a contamination event, designed to minimize the exposure of the public while providing additional time to evaluate the nature and severity of contamination. In these actions, water utilities are guided by the EPA Response Tool box (RPTB) (USEPA, 2003), or using additional guidance available from the National Response Plan. The final considerations in designing the OCMS are interfacing with the existing surveillance systems and operations, maintenance, upgrades and exercise of the system (ASCE et al., 2004).

## **6. Ongoing EPA Water Security Research**

The field of drinking water security is rapidly evolving, with many research projects currently under way. Some key research and technical support issues addressed under the EPA program include identification and characterisation of threats to water systems, development of methods for detecting and monitoring contaminants in water, development of rapid screening technologies for contaminant identification, refinement of detectors and early warning systems



for water systems, enhancement of models for contaminant transport in pipes, testing and evaluation of sensors and biomonitors, fate and transport of contaminants in water, treatment or inactivation of water contaminants, improvement of decontamination and disposal techniques, establishing contingency planning and infrastructure backup procedures, improved assessment of risks to the public due to water contamination, enhancing risk communication and information sharing concerning threats or attacks, and providing training and exercises which enhance preparedness and response (USEPA, 2004b, 2004c). Progress on various research projects can be obtained from the National Homeland Security Research Center (NHSRC) at <http://www.epa.gov/nhrc>, or in an Internet-based catalogue with publicly available EPA products at <http://www.epa.gov/watersecurity>.

## 7. Conclusions

Water infrastructure is critical to the well-being of the society and consequently, the risk of its failure or malfunctioning has to be managed for all forms of hazards and threats, including terrorist attacks. Recognizing high costs of drinking water infrastructure protection and relatively low levels of success of past attacks, a rational plan for water infrastructure protection needs to be developed. The first step is the vulnerability assessment considering all hazards, followed by evaluating the risks, and developing response measures presented in an Emergency Response Plan. Good guidance for water security enhancement planning can be obtained from various publicly accessible sources, including those provided by the U.S. EPA and the Department of Homeland Security. The ongoing cooperative research involving government agencies, professional associations and the private sector provides rapid development of new technologies and forms of technical support. Implementation of the current expertise in water security in practice should substantially reduce the risk posed to drinking water infrastructure and ensure the well-being of citizens served by these systems.

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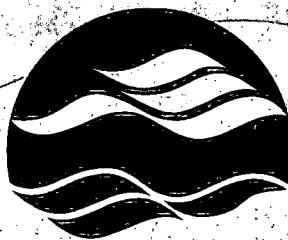
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