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Water and terrorism

Peter H. Gleick

Pacific Institute, 654 13th Street, Oakland, California, USA. www.pacinst.org. Tel: 510 251 1600. Fax: 510 251 2203. E-mail:pgleick@pacinst.org

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Abstract

The importance of freshwater and water infrastructure to human and ecosystem health and to the smooth functioning of a commercial and industrial economy makes water and water systems targets for terrorism. The chance that terrorists will strike at water systems is real; indeed, there is a long history of such attacks. Water infrastructure can be targeted directly or water can be contaminated through the introduction of poison or disease-causing agents. The damage is done by hurting people, rendering water unusable, or destroying purification and supply infrastructure. More uncertain, however, is how significant such threats are today, compared with other targets that may be subject to terrorist attack, or how effective such attacks would actually be. Analysis and historical evidence suggest that massive casualties from attacking water systems are difficult to produce, although there may be some significant exceptions. At the same time, the risk of societal disruptions, disarray, and even overreaction on the part of governments and the public from any attack, may be high. This paper reviews the history of past attacks on water systems and the most pressing vulnerabilities and risks facing modern water systems. Suggestions of ways to reduce those risks are also presented.

Keywords: Biological warfare; Chemical warfare; Distribution systems; Eco-terrorism; Environmental terrorism; Water and terrorism; Water supply

Introduction

Water is a fundamental resource for human and economic welfare and modern society depends on complex, interconnected water infrastructure to provide reliable safe water supplies and to remove and treat wastewater. This infrastructure is vital for human welfare and economic development and it is vulnerable to intentional disruption from war, intrastate violence and, of more recent concern, terrorism.

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There is a long history of using water as a political or military target or tool, going back over 2,500 years (Gleick, 2004). Water resources and systems are attractive targets because there is no substitute for water. Whether its lack is due to natural scarcity, a physical supply interruption or contamination, a community of any size that lacks sufficient fresh water will suffer greatly. Furthermore, a community does not have to lack water to suffer. Too much water at the wrong time can also lead to death and great damage.

The chance that terrorists will strike at water systems is real but poorly understood by water managers and the public. This paper reviews the history of past attacks on water systems and the most pressing vulnerabilities and risks facing modern water systems. Suggestions for ways to reduce those risks are also presented.

Water infrastructure can be targeted directly or water can be contaminated through the intentional introduction of poison or disease-causing agents. The damage is done by hurting people, rendering water unusable, or destroying purification and supply infrastructure. Some important water facilities, such as dams, reservoirs and pipelines, are easily accessible to the public at various points and there are new worries that computer control systems may be accessible to hacking. Many large dams are tourist attractions and offer tours to the public, while many reservoirs are open to the public for recreational boating and swimming. Pipelines are often exposed for long distances. Water and wastewater treatment plants dot our urban and rural landscape.

What is less clear, however, is how significant such threats are today, compared with other targets that may be subject to terrorist attack, or how effective such attacks would actually be. Analysis and historical evidence suggest that massive casualties from attacking water systems are difficult to produce, although there may be some significant exceptions. At the same time, the risk of societal disruptions, disarray, and even overreaction on the part of governments and the public from any attack, may be high.

As an example of the economic and human chaos even moderate disruption or contamination might cause, an outbreak of *Cryptosporidium* in Milwaukee in 1993 killed over a hundred people, affected the health of over 400,000 more (MacKenzie *et al.*, 1994; Smith, 1994) and cost millions in lost wages and productivity. That outbreak, completely unrelated to terrorism, gives some sense of the vulnerability of modern water systems to similar undetected, intentionally caused, contamination events.

This article will not offer any new information for those hoping to harm water systems and all information used here is derived from open sources and readily accessible materials. The purpose is to identify where productive and protective efforts to reduce risks would be most useful on the part of water managers and planners and to reduce unnecessary fear and worry. Proper and appropriate safeguards can reduce the risks identified here significantly and reduce the consequences should an event occur.

The worry

The typical scenario for a terrorist attack on domestic water supplies involves putting a chemical or biological agent into local water supplies or using conventional explosives to damage basic infrastructure such as pipelines, dams and treatment plants. This is not as straightforward as it sounds. The number of casualties that would result from such an attack depends on the system for water treatment already in place, the type and dosage of poison ingested, individual resistance, the timing of an attack and the speed and scope of discovery and response by local authorities.

Most biological pathogens cannot survive in water and most chemicals require very large volumes to contaminate a water system to any significant degree. Many pathogens and chemicals are vulnerable to the kinds of water treatment used to make it potable for human use. Indeed, the whole purpose of municipal water systems is to destroy biological pathogens and reduce the concentration of harmful chemicals through chlorination, filtration, ultraviolet radiation, ozonation and many other common treatment approaches. Many contaminants are also broken down over time by sunlight and other natural processes. Most infrastructure has built-in redundancy that reduces vulnerability to physical attacks.

Because of these safeguards, one early commentator noted: "it is a myth that one can accomplish [mass destruction] by tossing a small quantity of a 'super-toxin' into the water supply…it would be virtually impossible to poison a large water supply: hydrolysis, chlorination and the required quantity of the toxin are the inhibiting factors" (Kupperman & Trent, 1979).

It is important to note, however, that terrorist attacks that fail to kill or injure large numbers of people may still have important political repercussions by affecting public perception, reducing confidence in institutions and forcing inappropriate political responses. Society reacts differently to natural and human-caused disasters: we often accept large casualties from natural disasters with a degree of sanguinity not matched by our response to intentional acts of violence (Wardlaw, 1989). Terrorism destroys our sense of safety and normality and introduces new and often substantial stress and uncertainty in individuals and communities (Ursano *et al.*, 2003).

Even a plausible public threat has the potential to cause fear and anxiety. The best defenses against such threats are public confidence in water management systems, rapid and effective water quality monitoring, and strong and effective information dissemination. While many water districts and providers have regular mechanisms for communicating with customers, new tools may be valuable in countering the threat of water-related terrorism and ensuring public confidence and calm.

As we have seen in the past several years, responses to the threat of terrorism can often be ineffective or ill-considered. Even governmental and public responses to natural disasters, for which planning – in theory – is well advanced, are often inadequate when actual disasters occur. As a result, the adverse reactions resulting from an intentional effort to contaminate or damage public water systems may be both significant and underestimated. The solution to this must include efforts both to prevent such attacks and to educate the public and media about actual risks and consequences.

Defining terrorism: the context of water systems

As many previous observers have noted, defining "terrorism" is problematic (Hoffman, 1998; Wardlaw, 1989; Schmid, 1997; Martin, 2006) A detailed review of the challenges of defining "terrorism", especially in the context of water systems, is provided by Gleick (2006: Chapter 1). No standard or consistent definition is used by federal or state agencies in the United States, although most follow the form of that adopted by the US Federal Bureau of Investigation (FBI): "the unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives" (US Code of Federal Regulations (28 CFR Section 0.85)). Similarly, Title 22, Section 2656 of the US Code states, "Terrorism means premeditated, politically motivated violence perpetrated against non-combatant targets by sub-national groups or clandestine agents, usually intended to influence an audience."

Both of these definitions focus on motive – the “furtherance of political or social objectives”. Such motives can also include religious, cultural, economic or psychological factors. Increasingly important, however, is the question of targets. In traditional discussions about terrorism, targets are usually governments, political figures, objects of economic or social significance, or random civilians. But both motives and targets can include environmental and ecological resources such as water and built water systems.

The social and cultural value and importance of water systems also make them attractive targets. By calling attention to the inability of governments to protect vital symbols of civilization, terrorists can raise doubts about controlling authorities. As Thornton (1964) noted: “The relatively high efficiency of terrorism derives from its symbolic nature. If the terrorist comprehends that he is seeking a demonstration effect, he will attack targets with a maximum symbolic value.” There are few natural resources with more symbolic power than water.

Environmental terrorism, eco-terrorism, and environmental warfare

Important distinctions should be made between two different categories: environmental terrorism and eco-terrorism. The focus of this article is on the first of these, but I discuss the second to provide some perspective.

In recent years, US law enforcement agencies have had to deal with a range of concerns and activities increasingly defined as “terrorism” with an environmental or ecological context. For example, in 2006 the FBI announced arrests in several cases of property destruction thought to have been caused by extreme animal rights or groups with “environmental” agendas. Indeed, FBI Director Mueller said one of the Bureau’s “highest domestic terrorism priorities” is prosecuting people who commit crimes “in the name of animal rights or the environment” (Janofsky, 2006). This kind of activity, however, should be considered “eco-terrorism”, not “environmental terrorism” (Schwartz, 1998; Schofield, 1999).

There is an important distinction between the two. The term “environmental terrorism” should exclusively refer to the unlawful use of force against environmental resources or systems with the intent to harm individuals or deprive populations of environmental benefit(s) in the name of a political or social objective. This distinguishes it from “eco-terrorism”, which should only be considered the unlawful use of force against people or property with the intent of saving the environment from further human encroachment and destruction. The professed aim of eco-terrorists is to slow or halt exploitation of natural resources and to bring public attention to environmental issues (see Lee, 1995; Chalecki, 2001). Simply put, environmental terrorism involves targeting natural resources for a political, social or economic objective. Eco-terrorism involves targeting social, political or economic resources for an environmental objective. The former is the subject of this article.

History of water-related terrorism

There is a long history of the use of water resources as both a target and tool of war and terrorism (Gleick, 1993, 2004). Water resources or systems can be used as delivery vehicles to cause violence to a human population. Water supplies can be poisoned; dams can be destroyed to harm downstream populations. Table 1 lists examples from the Water and Conflict Chronology that can be described as terrorism. Even popular culture reflects public interest and concern over these issues. Box 1 lists some popular novels and films that use water-related terrorism in the plot or theme.

Box 1. Environmental terrorism, eco-terrorism, water and popular culture.

Popular culture often portrays terrorism in dramatic ways that either influence perceptions of threats (Jenkins, 2000) or reflect public fears and concerns. Environmental and eco-terrorism involving water have long been included among those threats. Kurt Vonnegut's classic book *Cat's Cradle* (1963) describes an amoral genius who creates "ice-nine" – a chemical that freezes water at room temperature and ends up destroying the world. Edward Abbey's (1975) novel *The Monkey Wrench Gang* and Johnson and Bent's film *Christie Malry's Own Double Entry* featured blowing up dams, poisoning water supplies and attacking resources for political or environmental purposes. Wilson and Leeson's 2002 movie *The Tuxedo* starring Jackie Chan features a power hungry bottled-water mogul trying to destroy the world's natural water supply to force everyone to drink his bottled water. The movie *Batman Begins*, released in 2005, portrayed a terrorist attempt to destroy Gotham by introducing a vapor-borne hallucinogen into the water system and releasing it throughout the city. In early 2006, an independent feature film, *Waterborne*, was released, which follows the fictional aftermath of a bio-terrorist attack on the water supply of Los Angeles. And *V for Vendetta* (2006) features corrupt government leaders contaminating London's water supply to kill people, spread fear and consolidate power.

The recorded history of attacks on water systems goes back 4,500 years ago, when Urlama, King of Lagash from 2450 to 2400 BC, diverted water from this region to boundary canals, drying up boundary ditches to deprive the neighboring city state of Umma of water. His son Il later cut off the water supply to Girsu, a city in Umma. In an early example of biowarfare (or bioterrorism, depending on one's understanding of "states" and "governments" at the time) Solon of Athens besieged Cirrha around 600 BC for a wrong done to the temple of Apollo and put the poison hellebore roots (or rye ergot – reports differ) into the local water supply. This reportedly caused the Cirrhaeans to become violently ill and facilitated the subsequent capture of the city (Eitzen & Takafuji, 1997).

Many of the recorded instances of violence by individuals and non-state groups concerning water focus on perceived inequities associated with water development projects or controversial decisions about allocations of water. Often, marginalized groups faced with the construction of water systems that appropriate local water resources have responded by threatening or attacking those systems. This violence may be related to both absolute deprivation, where access to the most basic of needs is denied to a group or region, and to relative deprivation, where basic needs are met, but water allocations or control are perceived to be unfair or inequitable. Examples of violence related to both absolute and relative deprivation of water can be found in Table 1. In one of the earliest reported acts, an angry mob in New York in 1748 burned down a ferry house on the Brooklyn shore of the East River, reportedly as revenge for unfair allocation of East River water rights (Museum of the City of New York (MCNY), no date). In the 1840s and 1850s, groups attacked small dams and reservoirs in the eastern and central USA because of concerns about threats to health and to local water supplies (Table 1). In a now famous case, between 1907 and 1913, farmers in the Owens Valley of California repeatedly dynamited the aqueduct system being built to divert their water to the growing city of Los Angeles (Reisner, 1993).

Table 1. Water and terrorism chronology[1].

Date	Parties involved	Violent conflict or in the context of violence?	Description
1748	United States	Yes	Ferry house on Brooklyn shore of East River burns down. New Yorkers accuse Brooklynites of having set the fire as revenge for unfair East River water rights.
1841	Canada	Yes	A reservoir in Ops Township, Upper Canada (now Ontario) was destroyed by neighbors who considered it a hazard to health.
1844	United States	Yes	A reservoir in Mercer County, Ohio was destroyed by a mob that considered it a hazard to health.
1850s	United States	Yes	Attack on a New Hampshire dam that impounded water for factories downstream, by local residents unhappy over its effect on water levels.
1853–1861	United States	Yes	Repeated destruction of the banks and reservoirs of the Wabash and Erie Canal in southern Indiana by mobs regarding it as a health hazard.
1887	United States	Yes	Dynamiting of a canal reservoir in Paulding County, Ohio by a mob regarding it as a health hazard. State militia called out to restore order.
1890	Canada	Yes	Partly successful attempt to destroy a lock on the Welland Canal in Ontario, Canada either by Fenians protesting against English Policy in Ireland or by agents of Buffalo NY grain handlers unhappy at the diversion of trade through the canal.
1907–1913	Owens Valley, Los Angeles, California	Yes	The Los Angeles Valley aqueduct/pipeline suffers repeated bombings in an effort to prevent diversions of water from the Owens Valley to Los Angeles.
1965	Israel, Palestinians	Yes	First attack claimed by the Palestinian National Liberation Movement Al-Fatah is on the diversion pumps for the Israeli national water carrier. Attack fails.
1970	United States	No: threat	The Weathermen, a group opposed to American imperialism and the Vietnam war, allegedly attempt to obtain biological agents to contaminate the water supply systems of US urban centers.
1972	United States	No: threat	Two members of the right-wing “Order of the Rising Sun” are arrested in Chicago with 30–40 kg of typhoid cultures that are allegedly to be used to poison the water supply in Chicago, St. Louis and other cities. It was felt that the plan would have been unlikely to cause serious health problems owing to chlorination of the water supplies.
1972	United States	No: threat	Reported threat to contaminate water supply of New York City with nerve gas.
1973	Germany	No: threat	Threat by a biologist in Germany to contaminate water supplies with bacilli of anthrax and botulinum unless he was paid US$8.5 million.
1977	United States	Yes	Contamination of a North Carolina reservoir with unknown materials. According to Clark: “Safety caps and valves were removed, and poison chemicals were sent into the reservoir.... Water had to be brought in.”
1978–1984	Sudan	Yes	Demonstrations in Juba, Sudan in 1978 opposing the construction of the Jonglei Canal led to the deaths of two students. Construction of the Jonglei Canal in the Sudan was forcibly suspended in 1984 following a series of attacks on the construction site.

Continued

Table 1. (*continued*)

Date	Parties involved	Violent conflict or in the context of violence?	Description
1980s	Mozambique, Rhodesia/ Zimbabwe, South Africa	Yes	Regular destruction of power lines from Cahora Bassa Dam during fight for independence in the region. Dam targeted by RENAMO (Mozambican National Resistance).
1982	United States	No: threat	Los Angeles police and the FBI arrest a man who was preparing to poison the city's water supply with a biological agent.
1983	Israel	No	The Israeli government reported that it had uncovered a plot by Israeli Arabs to poison the water in Galilee with "an unidentified powder".
1984	United States	Yes	Members of the Rajneeshee religious cult contaminate a city water supply tank in The Dalles, Oregon, using *Salmonella*. A community outbreak of over 750 cases occurred in a county that normally reports fewer than five cases per year.
1985	United States	No: threat	Law enforcement authorities discovered that a small survivalist group in the Ozark Mountains of Arkansas known as The Covenant, the Sword, and the Arm of the Lord (CSA) had acquired a drum containing 30 gallons of potassium cyanide, with the apparent intent to poison water supplies in New York, Chicago and Washington, DC. CSA members devised the scheme in the belief that such attacks would make the Messiah return more quickly by punishing unrepentant sinners. The objective appeared to be mass murder in the name of a divine mission rather than to change government policy. The amount of poison possessed by the group is believed to have been insufficient to contaminate the water supply of even one city.
1991	Canada	No: threat	A threat is made via an anonymous letter to contaminate the water supply of the city of Kelowna, British Columbia, with "biological contaminates" [sic]. The motive was apparently "associated with the Gulf War". The security of the water supply was increased in response and no group was identified as the perpetrator.
1992	Turkey	Yes	Lethal concentrations of potassium cyanide were reported discovered in the water tanks of a Turkish Air Force compound in Istanbul. The Kurdish Workers' Party (PKK) claimed credit.
1993	Iran	No	A report suggests that proposals were made at a meeting of fundamentalist groups in Tehran, under the auspices of the Iranian Foreign Ministry, to poison water supplies of major cities in the West "as a possible response to Western offensives against Islamic organizations and states".
1994	Moldavia	No: threat	Reported threat by Moldavian General Nikolay Matveyev to contaminate the water supply of the Russian 14th Army in Tiraspol, Moldova, with mercury.
1998	Tajikistan	No: threat	On November 6, a guerrilla commander threatened to blow up a dam on the Kairakkhum channel if political demands were not met. Col. Makhmud Khudoberdyev made the threat, reported by the ITAR-Tass News Agency.

Continued

Table 1. (*continued*)

Date	Parties involved	Violent conflict or in the context of violence?	Description
1998 (1994)	United States	No	The Washington Post reports a 12-year old computer hacker broke into the SCADA computer system that runs Arizona's Roosevelt Dam, giving him complete control of the dam's massive floodgates. The cities of Mesa, Tempe and Phoenix, Arizona are downstream of this dam. No damage was done. This report turns out to be incorrect. A hacker did break into the computers of an Arizona water facility, the Salt River Project in the Phoenix area. But he was 27, not 12, and the incident occurred in 1994, not 1998. And while clearly trespassing in critical areas, investigators concluded that the hacker never could have had control of any dams and that no lives or property were ever threatened.
1998	Democratic Republic of Congo	Yes	Attacks on Inga Dam during efforts to topple President Kabila. Disruption of electricity supplies from Inga Dam and water supplies to Kinshasa.
1999	Lusaka, Zambia	Yes	Bomb blast destroyed the main water pipeline, cutting off water for the city of Lusaka, population 3 million.
1999	South Africa	Yes	A home-made bomb was discovered at a water reservoir at Wallmansthal near Pretoria. It was thought to have been meant to sabotage water supplies to farmers.
1999	Angola	Yes	100 bodies were found in four drinking water wells in central Angola.
1999	East Timor	Yes	Militia opposing East Timor independence kill pro-independence supporters and throw bodies in water well.
1998–1999	Kosovo	Yes	Contamination of water supplies/wells by Serbs disposing of bodies of Kosovar Albanians in local wells. Other reports of Yugoslav federal forces poisoning wells with carcasses and hazardous materials.
2000	Belgium	Yes	In July, workers at the Cellatex chemical plant in northern France dumped 5000 liters of sulfuric acid into a tributary of the Meuse River when they were denied workers' benefits. A French analyst pointed out that this was the first time "the environment and public health were made hostage in order to exert pressure, an unheard-of situation until now".
2000	Australia	Yes	In Queensland, Australia, on 23 April, 2000, police arrested a man for using a computer and radio transmitter to take control of the Maroochy Shire wastewater system and release sewage into parks, rivers and property.
2001	Israel, Palestine	Yes	Palestinians destroy water supply pipelines to West Bank settlement of Yitzhar and to Kibbutz Kisufim. Agbat Jabar refugee camp near Jericho was disconnected from its water supply after Palestinians looted and damaged local water pumps. Palestinians accuse Israel of destroying a water cistern, blocking water tanker deliveries and attacking materials for a wastewater treatment project.

Continued

Table 1. (*continued*)

Date	Parties involved	Violent conflict or in the context of violence?	Description
2001	Pakistan	Yes	Civil unrest over severe water shortages were caused by a long-term drought. Protests began in March and April and continued into summer, with riots, four bombs in Karachi (June 13), one death, 12 injuries and 30 arrests. Ethnic conflicts arose as some groups "accuse the government of favoring the populous Punjab province [over Sindh province] in water distribution".
2001	Macedonia	Yes	Water flow to Kumanovo (population 100,000) was cut off for 12 days in conflict between ethnic Albanians and Macedonian forces. Valves at plants on Glaznja and Lipkovo Lakes were damaged.
2001	Philippines	No	Philippine authorities shut off water to six remote southern villages after residents complained of a foul smell from their taps, raising fears Muslim guerrillas had contaminated the supplies. Abu Sayyaf guerrillas, accused of links with Osama bin Laden, had threatened to poison the water supply in the mainly Christian town of Isabela on Basilan island if the military did not stop an offensive against them.
2002	Nepal	Yes	The Khumbuwan Liberation Front (KLF) blew up a hydroelectric powerhouse of 250 kW in Bhojpur District on January 26. The power supply to Bhojpur and adjoining areas was cut off. Estimated repair time was six months; repair costs were estimated at 10 million Rs. By June 2002, Maoist rebels had destroyed more than seven micro-hydro projects as well as an intake of a drinking water project and pipelines supplying water to Khalanga in western Nepal.
2002	Rome, Italy	No: threat	Italian police arrest four Moroccans allegedly planning to contaminate the water supply system in Rome with a cyanide-based chemical, targeting buildings that included the United States embassy. Ties to Al-Qaida were suggested.
2002	United States	No: threat	Papers seized during the arrest of a Lebanese national in Seattle included "instructions on poisoning water sources" from a London-based Al-Qaida recruiter. The FBI issued a bulletin to computer security experts around the country indicating that Al-Qaida terrorists may have been studying American dams and water-supply systems in preparation for new attacks. "US law enforcement and intelligence agencies have received indications that Al-Qaida members have sought information on supervisory control and data acquisition (SCADA) systems available on multiple SCADA-related websites" reads the bulletin, according to SecurityFocus. "They specifically sought information on water supply and wastewater management practices in the US and abroad."
2002	Colombia	Yes	The Revolutionary Armed Forces of Colombia (FARC) detonated an explosive device planted on a German-made gate valve located inside a tunnel in the Chingaza Dam, which provides most of Bogota's water.
2002	United States	No: threat	Earth Liberation Front threatens the water supply of the town of Winter Park. Previously, this group claimed responsibility for the destruction of a ski lodge in Vail, Colorado that threatened lynx habitat.

Continued

Table 1. (*continued*)

Date	Parties involved	Violent conflict or in the context of violence?	Description
2003	United States	No: threat	Al-Qaida threatens US water systems via a call to a Saudi Arabian magazine. Al-Qaida does not "rule out. . .the poisoning of drinking water in American and Western cities".
2003	United States	Yes	Four incendiary devices were found in the pumping station of a Michigan water-bottling plant. The Earth Liberation Front (ELF) claimed responsibility, accusing Ice Mountain Water Company of "stealing" water for profit. Ice Mountain is a subsidiary of Nestle Waters.
2003	Colombia	Yes	A bomb blast at the Cali Drinking Water Treatment Plant killed three workers May 8. The workers were members of a trade union involved in intense negotiations over privatization of the water system.
2003	Jordan	No: threat	Jordanian authorities arrested Iraqi agents in connection with a failed plot to poison the water supply that serves American troops in the eastern Jordanian desert near the border with Iraq.
2003	Iraq	Yes	Sabotage/bombing of main water pipeline in Baghdad. The sabotage of the water pipeline was the first such strike against Baghdad's water system, city water engineers said. An explosive was fired at the six-foot-wide water main in the northern part of Baghdad, according to the chief engineer for the city's water treatment plants.
2003–2004	Sudan	Yes	The ongoing civil war in the Sudan has included violence against water resources. In 2003, villagers from around Tina said that bombings had destroyed water wells. In Khasan Basao they alleged that water wells were poisoned. In 2004, wells in Darfur were reportedly contaminated as part of a strategy of harassment against displaced populations.
2004	Pakistan	Yes	In military action aimed at Islamic terrorists, including Al Qaida and the Islamic Movement of Uzbekistan, homes, schools and water wells were damaged and destroyed.
2004	India, Kashmir	Yes	Twelve Indian security forces were killed by an IED planted in an underground water pipe during "counter-insurgency operation in Khanabal area in Anantnag district".
2006	Sri Lanka	Yes	Tamil Tiger rebels cut the water supply to government-held villages in northeastern Sri Lanka. Sri Lankan government forces then launched attacks on the reservoir, declaring the Tamil actions to be terrorism.

Sources: complete source information for each event is available at www.worldwater.org and in Gleick (2006).

[1] This table is a subset of water-related conflicts reported in the Pacific Institute's Water Conflict Chronology (www.worldwater.org). Only included are those incidents that fall under the broad definition of environmental terrorism, defined here as: "the unlawful use of force against environmental resources or systems with the intent to harm individuals or deprive populations of environmental benefit(s) in the name of a political or social objective". Please remember the caution, described in the text, that one person's "terrorist" is another person's "freedom fighter". As a result, some of these events as "terrorism" will be controversial to some of the parties involved. My objective is not to offend. Also, because of the evolution of the concept of nations and states, I've excluded from this list all water and conflict events before the mid-1700s. I've also excluded numerous development disputes where individuals or sub-national groups take violent action as a result of water disputes, shortages or allocation controversies, i.e. where people fight over water for the sake of water. I note, however, the difficulty of defining "terrorism" (as opposed to military target, tool, or goal or other category) and caution readers to use care in applying these categories.

The first reported attack of the Palestinian National Liberation Movement, Al-Fatah, was in 1965 on the diversion pumps of the Israeli national water carrier (Naff & Matson, 1984) and the region has seen many more examples. In 2001, Palestinians attacked and vandalized water pipes leading to the Israeli settlement of Yitzhar to try to force the Israelis out of the settlement. Around the same time, Palestinians accused Israel of destroying a water cistern, blocking water tanker deliveries and attacking materials for a wastewater treatment project (Israel Line, 2001a,b; ENS, 2001).

Rivers and water supply infrastructure such as reservoirs can be especially vulnerable to this type of terrorism, since they are publicly accessible in many places. In July 1999, engineers discovered an unexploded bomb in a water reservoir near Pretoria, South Africa. The bomb, which had malfunctioned, would have been powerful enough to deprive farmers, a nearby military base and a hydrological research facility of water (Pretoria Dispatch Online, 1999). In 2000, a simulated terrorist attack on the Lake Nacimiento Dam caused some local panic in central California until the media was belatedly notified that the situation was merely a disaster preparedness drill (Gaura, 2000).

Motives for such attacks can be economic as well as political. In July 2000, workers at the Cellatex chemical plant in northern France dumped 5000 liters of sulfuric acid into a tributary of the Meuse River when they were denied workers' benefits. Whether they were trying to kill wildlife, people, both or neither is unclear, but a French analyst pointed out that this was the first time "the environment and public health were made hostage in order to exert pressure, an unheard-of situation until now" (Christian Science Monitor, 2000).

More recently, a series of events in India, Pakistan, the Persian Gulf and the Middle East have reaffirmed the attractiveness of water and water systems as targets for terrorists in a wide range of unrelated conflicts and disputes. The major water pipeline to Baghdad was attacked in 2003. The same year, Al-Qaida threatened US water systems in a call published in a Saudi Arabian magazine: "Al-Qaida does not 'rule out. . .the poisoning of drinking water in American and Western cities'" (Associated Press, 2003; Waterman, 2003). In 2004, twelve Indian security forces were killed by an explosive device planted in an underground water pipe during a "counter-insurgency operation in Khanabal area in Anantnag district" (TNN, 2004). In an unusual twist to this problem, the United States responded to a Palestinian attack on US diplomatic personnel in the Middle East by canceling plans for a water-development project in the Gaza Strip (Associated Press, 2004).

Vulnerability of water and water systems

Infrastructure attacks

The most traditional form of water-related terrorism involves physical attacks on water infrastructure – specifically water-supply dams and pipelines. One such attack might target a large hydroelectric dam on a major river or a major water supply system for a city. Terrorists equipped with a relatively small conventional explosive might not be able to cause serious structural damage to a massive dam, which is, after all, usually a giant block of rock, earth or concrete. But the adverse consequences of a major dam failure make the risk worth both assessing and reducing. A major dam failure can kill thousands of people and even more modest damage might interrupt power generation or affect some other important water-system operation.

Some natural disasters involving water infrastructure offer insights into the risks of water-related terrorism. In 1975, the Banqiao and Shimantan dams on tributaries of the Huang He (Yellow) River in China failed in sequence, contributing to the subsequent destruction of dozens of lower dams and the deaths of 85,000 people (Yi, 1998). The famous Johnston Flood of 1889 killed more than 2,200 people when the collapse of a poorly built dam sent a massive wall of water through the poor steel town of Johnston, Pennsylvania. At least 400 people died in California in 1928 when the Saint Francis dam failed in San Francisquito Canyon. Worldwide, millions of people live in the floodplains below large dams and reservoirs. In addition to the potential loss of life, there are also secondary impacts including water quality problems, loss of freshwater supply and hydroelectric power, damage to property and commercial fisheries, and recreation losses.

While many municipal water systems are built with redundancy and backup systems, others have particularly vulnerable points, such as single large pipelines, pumping plants or treatment systems. The bombing of the major water pipeline entering Baghdad in 2003 highlights such vulnerabilities (Tierney & Worth, 2003).

A more modern infrastructure concern is the use of remote computers to attack valves, pumps and chemical processing equipment though computer-based controls. If a group or individual could gain control over the automated operations of water facilities, water supplies or quality could be seriously compromised. These control systems were typically developed with no attention to security. As a result, many of the supervisory control and data acquisition (SCADA) networks used by water agencies to collect data from sensors and control equipment "may be susceptible to attacks and misuse" (Heilprin, 2005).

There is growing recognition of this risk (Littleton, 1995). In 1990, the United States issued National Security Decision Directive 42, which states in part:

> *Telecommunications and information processing systems are highly susceptible to interception, unauthorized access and related forms of technical exploitation as well as other dimensions of the foreign intelligence threat. The technology to exploit these electronic systems is widespread and is used extensively by foreign nations and can be employed, as well, by terrorist groups and criminal elements. (National Security Directive, 1990).*

These risks are more than academic and theoretical. In Queensland, Australia, on 23 April 2000, police arrested a man for using a computer and radio transmitter to take control of the Maroochy Shire wastewater system and release sewage into parks, rivers and property. This is one of the first documented cases of cyber-terrorism in the water industry (Gellman, 2002). Fears that Al-Quaida were seeking information on SCADA systems materialized in 2002: "US law enforcement and intelligence agencies have received indications that Al-Qaida members have sought information on supervisory control and data acquisition (SCADA) systems" (McDonnell & Meyer, 2002; MSNBC, 2002).

Chemical and biological attacks

Of growing concern is the risk of chemical and biological attacks on water systems. This type of attack is often portrayed as follows. Terrorists introduce water-soluble biological or chemical contaminants into a publicly accessible city water supply. In the best-case scenario, the contaminant is detected as it enters the water treatment plant and the plant is shut down while the contaminant is neutralized. This can result in interruption of potable water service to the city and a “boil water” alert for city residents. In the worst-case scenario, the contaminant is undetected and people begin to get sick, panic ensues and health and economic damages soar.

Chemical and biological attacks on water may not be as easy as often portrayed. In order to be effective as a tool of water-related terrorism, a chemical or biological weapon must be:

- (Weaponized: it must be produced and disseminated in quantities sufficient to have the intended effect.
- (Appropriate for water dissemination: it must be viable, dissolvable, stable and transportable in water.
- (Infectious, virulent or toxic: it must be effective at causing illness or death, with no widespread immunity in the target population.
- (Effective over time and treatment: it must maintain its effectiveness in water long enough to reach and affect humans and it must not be negated by standard water treatment systems likely to be in place.

According to easily available open literature, a wide range of chemical and biological agents could be used in water. Table 2, described in a recent US Environmental Protection Agency (EPA) review of water-related threats, should be considered illustrative of the relevant contaminant classes. As noted, some of these substances are only likely to be found in military stockpiles; others may be produced by sub-national terrorist groups; others may have more mundane industrial or even household applications (US National Research Council 1995; Hickman, 1999; US EPA 2003a). All the listed agents have strengths and weaknesses, especially in their usefulness as weapons for use in water. These details will not be described here.

While some of the biological and chemical contaminants listed in Table 2 have been produced for military use, military-grade chemical weapons are far more difficult to produce, handle and disseminate. Commercial chemicals that are commonly produced, distributed and used throughout the world are more likely to be used by terrorists to contaminate water supplies. Of particular concern are pesticides and related chemicals used to kill insects, rodents and plants. These include organophosphate pesticides, chlorinated pesticides and rodenticides. Organophosphates affect the nervous system, as do organochlorine pesticides. Rodenticides like sodium fluoroacetate, strychnine and thallium sulfate are all capable of incapacitating or killing humans in appropriate doses (Hickman, 1999).

Several inorganic chemicals are also widely available and potential threats to water systems, including various forms of arsenic and cyanide. Both are soluble in water and can be lethal. Hickman (1999) discusses the challenge posed by a material like sodium cyanide (NaCN) for a small water system. Sodium cyanide is relatively plentiful and accessible because of use in the mining and metals industry. It is an odorless white salt, which is stable and highly soluble in water.

A conference, Early Warning Monitoring to Detect Hazardous Events in Water Supplies, held in May 1999 in Reston, Virginia, concluded that terrorist use of bio-weapons can, under some circumstances, pose a significant threat to drinking water. While most biological warfare agents were developed for the purpose of aerial dissemination, some can be effective if digested, and some of these are stable and soluble in water. There are two main types of biological threats: pathogens and toxins. Pathogens are live organisms, including bacteria, viruses and protozoa. Toxins are chemicals that are derived from biological processes (Valcik, 1998). Table 3 shows a subset of known biological threats to water supplies including at least four that were reported in the public literature to have been

Table 2. Chemical and biological contaminants of water: classes, availabilities and restrictions.

Class	Examples (not exhaustive)	Sources	Limited access?
Microbiological contaminants			
Bacteria	*Bacillus anthracis, Brucella* spp.*, Burkholderia* spp.*, Campylobacter* spp.*, Clostridium perfringens, E. coli* O157:H7, *Francisella tularensis, Salmonella typhi, Shigella* spp.*, Vibrio cholerae*	Naturally occurring, microbiological laboratories, state-sponsored programs	Yes for select agents
Viruses	Caliciviruses, Enteroviruses, Hepatitis A/E, Variola	Naturally occurring, microbiological laboratories,[1] state-sponsored programs	Yes for select agents
Parasites	*Cryptosporidium parvum, Entamoeba histolytica, Toxoplasma gondii*	Naturally occurring, microbiological laboratories[1]	No
Inorganic chemicals			
Corrosives and caustics	Hydrochloric acid, sulfuric acid, sodium hydroxide	Retail, industry	No
Cyanide salts or cyanogenics	Sodium cyanide, potassium cyanide, amygdalin, cyanogen chloride, ferricyanide salts	Supplier, industry (esp. electroplating)	Yes
Metals	Mercury, lead, osmium, their salts, organic compounds and complexes (even those of iron, cobalt, copper are toxic at high doses)	Industry, supplier, laboratory	Yes[2]
Non-metal oxyanions, organo non-metals	Arsenate, arsenite, selenite salts, organoarsenic, organoselenium compounds	Some retail, industry, supplier, laboratory	Yes[3]
Organic chemicals			
Fluorinated organics	Sodium trifluoroacetate (a rat poison), fluoroalcohols, fluorinated surfactants	Supplier, industry, laboratory	Yes
Hydrocarbons and their oxygenated and/or halogenated derivatives	Paint thinners, gasoline, kerosene, ketones, alcohols, ethers (e.g. methyl *tert*-butyl ether or MTBE), halohydrocarbons (e.g. dichloromethane, tetrachloroethene)	Retail, industry, laboratory, supplier	No
Insecticides	Organophosphates (e.g. Malathion), chlorinated organics (e.g. DDT), carbamates (e.g. Aldicarb) some alkaloids (e.g. nicotine)	Retail, industry, supplier (varies with compound)	Yes
Malodorous, noxious, foul-tasting, and/or lachrymatory chemicals[4]	Thiols (e.g. mercaptoacetic acid, mercaptoethanol), amines (e.g. cadaverine, putrescine), inorganic esters (e.g. trimethylphosphite, dimethylsulfate, acrolein)	Laboratory, supplier, police supply, military depot	Yes
Organics, water-miscible	Acetone, methanol, ethylene glycol (antifreeze), phenols, detergents	Retail, industry, supplier, laboratory	No
Pesticides other than insecticides	Herbicides (e.g. chlorophenoxy or atrazine derivatives), rodenticides (e.g. super-warfarins, zinc phosphide, α-naphthyl thiourea)	Retail, industry, agriculture, laboratory	Yes

Continued

Table 2. (*continued*)

Class	Examples (not exhaustive)	Sources	Limited access?
Pharmaceuticals	Cardiac glycosides, some alkaloids, antineoplastic chemotherapies, anticoagulants (e.g. warfarin). Illicit drugs such as LSD, PCP and heroin.	Laboratory, supplier, pharmacy, some from a natural source	Yes
Chemical warfare agents			
Chemical weapons	Organophosphate nerve agents (e.g. sarin, tabun, VX), vesicants, [nitrogen and sulfur mustards (chlorinated alkyl amines and thioethers, respectively)], Lewisite	Suppliers, military depots, some laboratories	Yes
Biotoxins			
Biologically produced toxins	Biotoxins from bacteria, plants, fungi, protists, defensive poisons in some marine or terrestrial animals. Examples include ricin, saxitoxin, botulinum toxins, T-2 mycotoxins, microcystins	Laboratory, supplier, pharmacy, natural source,[5] state-sponsored military programs	Yes
Radiological contaminants			
Radionuclides	Does not refer to nuclear weapons. Radionuclides may be used in medical devices and industrial irradiators (cesium-137 iridium-192, cobalt-60, strontium-90). Class includes both metals and salts.	Laboratory, state sources, waste facilities	Yes[2]

Source: modified from US EPA, 2003 a,b and US NRC, 1995.

[1] The quantity of bacteria, viruses or parasites needed for widespread contamination of a water system is not typically available in a typical clinical laboratory, although the seed cultures could be available. For viruses, vaccine production-grade volumes would be needed, requiring special equipment and facilities, perhaps with state sponsorship.

[2] Availability may be commercially limited for the more toxic materials, especially the heavy metals, which can be quite expensive. Iron and copper are readily available, but not usually in soluble (bio-available) forms.

[3] Availability of arsenicals and selenium compounds in the retail sector has been reduced owing to environmental regulations, but such products can occasionally be found as part of older inventories of merchandise. Supplies of such materials may generally be too small to cause concern.

[4] This grouping includes riot-control agents and other mucous membrane irritants.

[5] The quantity available from laboratories, suppliers and pharmacies needed for widespread contamination of a water system is typically not available from these sources. Many biotoxins that occur naturally would need to be purified or prepared to be of significant concern to water, which could make production beyond the capabilities of most individuals or small groups.

Table 3. Biological pathogens considered to be water threats.

Pathogen	Type	Weaponized	Stable in water	Chlorine tolerance
Anthrax	B	Yes	2 years spores	Spores resistant
Brucellosis	B	Yes	20–72 days	Unknown
C. perfringens	B	Probable	Common in sewage	Resistant
Tularemia	B	Yes	<90 days	Inactivated, 1 ppm, 5 min
Shigellosis	B	Unknown	2–3 days	Inactivated, 0.05 ppm, 10 min
Cholera	B	Unknown	Yes	"Easily killed"
Plague	B	Probable	16 days	Unknown
Q Fever	R	Yes	Unknown	Unknown
Hepatitis A	V	Unknown	Unknown	Inactivated, 0.4 ppm, 30 min

Source: modified from Valcik (1998).
B – bacteria; R – rickettsia; V – virus.

produced as biological weapons. Table 4 shows known biological toxins that pose a water threat, including three known to have been turned into weapons. Both tables also describe the ability of chlorine – commonly used in municipal water systems – to neutralize these toxins or pathogens. Less information is available on how these threats may be affected or neutralized by some of the newer, non-chlorine based water-treatment systems including advanced filtration, ultraviolet disinfection and ozonation.

In 1970 (sometimes dated "early 1970s"), the US radical group the Weather Underground reportedly attempted to blackmail a homosexual officer at the US Army's bacteriological warfare facility in Fort Detrick, Maryland, into supplying organisms that could then be used to contaminate urban water supplies (Mullins, 1992; Berkowitz *et al.*, 1972, citing the *New York Times* of 21 November 1970). According to one source, the terrorists apparently succeeded in gaining the cooperation of the officer in question but "This plot was discovered when the officer requested issue of several items unrelated to his work" (Purver, 1995). Another reported incident was the arrest by Los Angeles police and FBI agents of a man "who was preparing to poison the city's water system with a biological poison" (Livingstone, 1982).

Individual and groups have been known to plan and carry out chemical attacks on water systems in the belief that they can be effective. A few cases of actual chemical contamination of water

Table 4. Biological toxins considered to be water threats.

Toxin	Weaponized	Stable in water	Chlorine tolerance
Botulinum toxin	Yes	Stable	Inactivated at 6 ppm, 20 min
T-2 mycotoxin	Probable	Stable	Resistant
Aflatoxin	Yes	Probably stable	Resistant
Ricin	Yes	Unknown	Resistant at 10 ppm
Staph enterotoxins	Probable	Probably stable	Unknown
Microcystins	Possible	Probably stable	Very resistant at 100 ppm
Anatoxin A	Unknown	Inactivated in days	Unknown
Tetrodotoxin	Possible	Unknown	Inactivated, 50 ppm
Saxitoxin	Possible	Stable	Resistant at 10 ppm

Source: modified from Valcik (1998).

supplies, or confirmed plans to conduct such attacks, have been reported in the open literature. In 1972, a right-wing, neo-Nazi group known as the "Order of the Rising Sun", "dedicated to creating a new master race", acquired 30–40 kg of typhoid bacteria cultures to use against water supplies in Chicago, St. Louis and other midwestern cities (Kupperman & Trent, 1979; Purver, 1995). According to Ponte (1980), those arrested had "in their possession detailed plans for dumping the deadly germs into the water supplies". It is likely that typhoid bacteria, even if introduced into an urban water supply, would have been destroyed by normal chlorination (US Office of Technology Assessment, 1991).

In a case of criminal extortion, in 1973 a German biologist threatened to contaminate water supplies with bacilli of anthrax and botulinum unless he was paid a financial ransom US$8.5 million (Jenkins & Rubin, 1978; Kupperman & Trent, 1979). The Israeli government reported in 1983 that it had uncovered a plot by Israeli Arabs to poison the water supply of the city of Galilee with "an unidentified powder" (Douglass & Livingstone, 1987). In 1985, federal law enforcement authorities discovered that The Covenant, the Sword and the Arm of the Lord (CSA) – a survivalist group in the Ozark Mountains of Arkansas – had acquired a drum containing 30 gallons of potassium cyanide. Their goal was to poison water supplies in New York, Chicago and Washington in the belief that this would make the Messiah return more quickly by punishing unrepentant sinners (Monterey Institute for International Studies (MIIS), 2004).

A chemical poisoning attempt was reported in March 1992 when lethal concentrations of potassium cyanide were found in the water tanks at a Turkish Air Force base Istanbul. The Kurdish Workers' Party (PKK) claimed credit (Chelyshev, 1992). The media reported that proposals were made at an early February 1993 meeting of fundamentalist groups in Tehran, under the auspices of the Iranian Foreign Ministry, to poison the water supplies of major cities in the West "as a possible response to Western offensives against Islamic organizations and states" (Haeri, 1993).

Responding to the threat of water-related terrorism

No easy estimate of the true risk of water-related terrorism is possible. The fact that there are numerous examples of actual and planned attacks on water systems in the past suggests that the risk is real. What is more challenging is evaluating both the probability of future attacks and their consequences – the separate components of calculating risk. In the absence of any definitive assessment of risk, however, it is vital to both understand vulnerabilities and to put in place measures to reduce those vulnerabilities and ultimately the overall risk. This can be done by reducing the probability of water-related terrorism, the consequences of an attack should one occur, or both.

Addressing the probability requires a wide range of actions, from reducing the fundamental motivation for terrorist attacks (not addressed here) to limiting the vulnerability of water resources and systems through selective and focused efforts of protection and detection. Addressing the consequences of attacks requires putting in place an array of responses suitable for different kinds of events. This can include responses like rapid repair teams to fix infrastructure, the development of redundant delivery and treatment systems, and preparing the health system promptly to detect and treat water-related illnesses.

Denying physical access

Perhaps the most fundamental action that can be taken to protect water systems is to limit or deny physical access to vulnerable points. Sometimes this may be as easy as locking gates or buildings, or reducing public access to sensitive locations. As examples of new activities put in place since September 11 2001, the Coast Guard increased patrols in the area of Chicago's water intakes from Lake Michigan. New York City increased the number of daily water samples it takes. California has reduced access to some dams and pumping plants and blocked off some roads close to water reservoirs. Many water agencies have stationed guards at "critical sites" (Center for Defense Information, 2002).

Among the recommendations for reducing the physical risk to infrastructure are:

- (Facilities (treatment plants, reservoirs, dams, storage facilities, pumping plants, intake facilities and control systems) should be identified and inventoried. Physical access to those most critical to operations, or most vulnerable to attack, should be controlled.
- (Access to water distribution maps and facility plans should be controlled when there is a clear security risk.
- (Lighting, surveillance cameras and motion detectors should be installed in appropriate places.
- (To prevent hacking, supervisory control and data acquisition systems (SCADA) for monitoring and controlling water should not be connected to the Internet or should be connected to appropriate electronic security, firewalls and passwords.
- (On-site water treatment chemicals should be kept in secure facilities and they should be inventoried on a regular basis.

Often, however, this approach is not possible, given the vast exposed length of pipelines or aqueducts, or the public uses of lakes, reservoirs, rivers and land. As a result, limiting physical access is an important, but not sufficient approach.

Detection and protection challenges

Unlike more traditional weapons used by terrorists, water-related threats pose some special challenges in the areas of detection and response. As noted above, an attack on a water system may be done surreptitiously through the introduction of a chemical or biological agent. In this case, unless immediate publicity is an objective of the attack, the first evidence may be increased incidences of sickness and death. Identifying the nature of the illness, the source of the contamination and then identifying and quantifying the specific threat could take a substantial amount of time.

New security measures – such as more extensive monitoring of pipelines, water supplies or more guards at power plants – will be expensive and mean higher costs for consumers. Nevertheless, it seems clear that some such measures will be required. In 2002, the US Congress passed the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (the Bioterrorism Act), which President Bush signed into law on 12 June 2002. Among other things, the Bioterrorism Act established requirements that community water systems serving more than 3,300 individuals perform a system-specific vulnerability assessment for potential terrorist threats, including intentional contamination (http://www.epa.gov/safewater/security/community.html). This sort of assessment, if properly done, can provide valuable information for planning and protection.

Early warning systems (EWS)

"Early warning" monitoring systems can help to identify contamination events early enough to permit an effective response. An EWS must be reliable: it should minimize the potential for significant numbers of both false negatives (missing a true event) and false positives (reporting a false event). It must be easy to install and operate, provide continuous monitoring and result in rapid notification of an event. Continuous monitoring reduces the likelihood that contamination events will be missed. The development of standard monitoring systems would reduce cost, permit sharing among users and facilitate repair and replacement (Foran & Brosnan, 2000).

New and developing technologies are being developed rapidly to detect pathogens in real time, both in source water and water distribution systems (US EPA, 2005). Included among these technologies are DNA microchip arrays (Betts, 1999a), immunologic techniques (Betts, 1999b), microrobots (Hewish, 1998) and a variety of optical tools, molecular probes and other techniques (Pelley, 1999; Sobsey, 1999).

Such technology would be useful for a wide range of purposes, including regular water-quality monitoring at municipal systems, but wide development and dissemination of such systems is moving forward slowly. Most of these technologies are not yet commercially available, nor have they been tested in large drinking water systems. Some organizations are now working to improve both available technology and knowledge about tools useful for detection and response. The American Water Works Association (AWWA), for example, offers seminars on these topics for water managers. In 2003 and 2004, the US Environmental Protection Agency published a series of guides for water utilities to help them identify and respond to contamination attacks (US EPA, 2003b). Similarly, in 2003 the World Health Organization updated and released a comparable international planning document (WHO, 2003).

Public and governmental responses

It is extremely unlikely that physical barriers, early warning systems and other preventative measures will be adequate to prevent all attacks. It is also possible that threats alone will trigger reactions. A threat to a drinking water system, whether real or a hoax, may cause as much of a problem as an actual terrorist act. As a result, it is vital to develop tools and advanced plans to respond to both real and threatened events.

Responses may include public advisories, temporary shutdown of the system, identification and use of alternative water supplies, chemical and biological treatment and disinfection, additional data gathering or monitoring, epidemiologic studies, health interventions or some combination of these actions. Responses to actual events will depend on the nature of the attack, the population affected and characteristics of the water system itself.

A key component to the success of any response will be the advance preparation of a process or plan that provides guidelines for all appropriate stakeholders, including water users, emergency responders and law enforcement agencies, water utility staff and community leaders and local media. Such a plan should be considered part of comprehensive emergency planning for a variety of threats to public health, both waterborne and non-waterborne.

There is already extensive experience of emergency response plans developed in different communities, although recent experience with Hurricane Katrina has revealed gaping holes in those plans. The US Environmental Protection Agency, American Water Works Association, American Society of Civil Engineers, US Federal Emergency Management Agency, the National Infrastructure

Protection Center of the Federal Bureau of Investigation and the Emergency Management and Emergency Preparedness Office of the US Health and Human Services all offer some guidelines for water plans and some effort has been made to develop post-event responses (Simon, 1997; Macintyre *et al.*, 2000; Waeckerle, 2000; US EPA, 2003a,b; American Water Works Association, 2006). Local, regional and national planning, however, are still inadequate.

Water security policy in the United States

Even prior to 11 September 2001, analyses were prepared evaluating the risks and threats of terrorism (see, for example, Gilmore Commission, 1999, 2000). The focus of US security policy, however, underwent a fundamental shift in 2001, toward domestic security and challenges. Title IV of the Bioterrorism Act of 2002 pertains to drinking water security and safety requiring vulnerability assessments and emergency response plans for most community water systems. Water systems must certify to the Administrator of the Environmental Protection Agency (EPA) within six months of the completion of the vulnerability assessment that they have completed an emergency response plan. According to the EPA in February 2006, all large- and medium-size systems had completed their assessments; 97% of small systems had completed assessments (Johnson, personal communication, 6 February 2006). No separate information is available on the adequacy or comprehensiveness of the assessments, or whether actual response plans have been put in place.

In early 2006, the US EPA announced a new effort called the WaterSentinel Initiative to design, deploy and evaluate a water contamination warning system. This program was called for by the Homeland Security Presidential Directive 9, which charges the EPA to develop surveillance and monitoring systems to provide early detection and awareness of water contamination events. HSPD-9 also directs the EPA to develop a network of integrated federal and state water testing laboratories (US EPA, 2006).

Conclusions

There is a long history of water-related violence and conflicts, including what must be categorized as environmental terrorism targeting water resources and infrastructure. The threat of future attacks is real, and the plans for responding to such attacks appear to be inadequate. The actual risks of serious human health consequences are less clear, given the complex nature of our developed water systems, protections already put in place to identify and eliminate biological and chemical contaminants and the attractiveness and vulnerability of other targets.

These protections must be strengthened in areas where clear risk assessments indicate high vulnerability, especially where critical infrastructure is exposed or where rapid monitoring can provide time for effective response. It is vital that sensitive water systems be protected through a combination of improved physical barriers, more extensive real-time chemical and biological monitoring and treatment and the development of smart and integrated response strategies at all levels.

Among the best defenses against terrorist threats to water systems are public confidence in water management systems, rapid and effective water quality monitoring, and strong and effective information dissemination. New tools for communicating with water users may be valuable in countering the threat of water-related terrorism and ensuring public confidence and calm. Such tools will also have value during natural disasters and accidents.

It is equally important, however, that the risks not be exaggerated, so that limited financial resources can be spent efficiently and effectively, and so that the public is not made fearful of risks that are low or manageable. The best approaches will require careful assessment of both the probability and the consequences of attacks. By evaluating both, it will be easier to identify vulnerabilities and put in place appropriate and measured responses to those vulnerabilities.

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