Contamination and Clean-up of a Potable Water Supply System: A Simulation Modeling Approach

Submitted to

Institute for Security Studies
Las Vegas, Nevada

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March, 2009

Acknowledgements: Funding for this study was provided by UNLV Institute for Security Studies (http://iss.unlv.edu/)

Executive Summary

The main objective of this study was to evaluate the impacts of intentional or accidental contamination of a potable water supply system for a typical town in the U.S. Southwest. Different decontamination options were also explored. EPANET, a water supply system simulation model, was used to evaluate contamination and decontamination scenarios. Three types of contaminants were evaluated including (i) inorganic contaminants, (ii) biological contaminants, and (iii) organic toxins.

The following questions were explored: (1) How is the spread of contaminant in the water supply system influenced by the location where the contaminant is introduction? (2) How does a contaminant move through the system under different scenarios when a system has water supply from multiple sources? (3) How does the contaminant spread in the water system when different concentrations of contaminant are introduced in the water supply system? and (4) What are the clean-up times and volume of contaminated water generated in different clean-up scenarios?

Results indicate that system demand and the location of the contaminant with respect to the source feed appear to dictate how far and how fast a contaminant will propagate through the system. Contamination at or closer to the water source impacts larger portions of water system compared to contamination at neighborhood locations. Multiple sources of water supply tend to limit the area of water supply system that will be contaminated compared to a single water supply source.

Sensitivity analysis on the relationship between the contaminant's initial concentration and the contaminated volume shows that there is a threshold concentration and that a contaminant need not be introduced at its maximum soluble concentration in order to be harmful.

Estimates of clean-up time and volume of contaminated water show that the minimal time required (6 hours) and minimum volume of water (2.35 million gallons (Mgal)) contaminated would occur when both taps and fire hydrants are operated. This strategy of opening both taps and hydrants is feasible for contaminants that pose a threat only when water is ingested. If a contaminant is too dangerous to be discharged into a user's home, then flushing through the fire hydrant may present less risk. Decontamination takes 7 hours and generates less contaminated water (1.89 Mgal). Opening taps is less effective (more time consuming) than opening fire hydrants to flush the system.

Based on the results of this study, the following recommendations are made.

- Although general conclusions can be drawn, every water system is unique and should be modeled individually. Water utilities that already have a water system model should modify that model to include contaminant transport. Towns that do not have a water distribution model can use existing drawings of the system layout and water demands to create a model. They can use a similar approach used in this study to understand how water moves in their system and which sources and neighborhood locations are critical. They can evaluate potential actions to be taken in case a contamination incident occurs.

- Water utilities should pay special attention to protecting the water sources (reservoirs, storage tanks), especially the tanks that are located upstream and feed the largest portion of the system.

- Even though contaminating a neighborhood location is less critical, water utilities should pay attention to protecting neighborhood locations that feed hospitals or schools.

- Although the amount of contaminant required to contaminate a larger water system may be difficult to obtain and deploy, small water utilities should not underestimate the potential to contaminate a system because, for most highly toxic chemicals, only a small amount of contaminant is required. If a contaminant is introduced to a neighborhood location using a truck mounted pump the system could be contaminated in a short duration.

- Water utilities should avoid feeding the entire system from one storage tank. Instead multiple smaller tanks should be considered.

- Because of higher flow rates and location, fire hydrants should be used to flush contaminated systems rather than opening taps in homes.

- Water utilities should estimate the volume of water that will be contaminated. With this estimate they should evaluate if their sewer system and storm water system will be able to handle the contaminated volume flushed through fire hydrants. If not, provisions should be made to build temporary storage (e.g. ponds).

- If water is contaminated with a compound that would affect the operation of a waste water treatment plant (e.g. compounds that are toxic to bacteria), then contaminated water would have to be transported by trucks to storage ponds where it could be treated. Even for a small system the number of tuck loads required is very large.

- The U.S. Environmental Protection Agency (EPA) has compiled a list of potential contaminants for water systems. Water utilities should select inorganic, organic and biological contaminants from that list with low contaminant thresholds and run models to prepare for worst case contamination scenarios.

- Water utilities should determine the amount of disinfectant required to clean up the system. This amount is what they would need to procure in a timely manner in case of an incident.

- Water utilities should explore the possibility of decontaminating the system by pH (measure of the acidity or alkalinity of a solution) changes; there are several inorganic contaminants that are less toxic at different pH levels.

- Water utilities should identify the locations (e.g. storage tank or fire hydrant) in the water system where disinfectants or decontaminating compounds should be added to provide for effective clean-up.