Health Risks Associated with Cross-connections in Drinking Water Supply

By Kelly A. Reynolds, MSPH, PhD

In June 2000, experts convened at a workshop related to the assessment of drinking water distribution systems and conditions known to compromise water quality between the time of municipal treatment and the point of use. At this meeting, key issues identified were: 1) microbial growth and biofilms, 2) cross-connections and backflow, 3) intrusion, 4) corrosion and aging infrastructure, 5) decay of water quality over distribution system residence time, 6) contamination during infrastructure repair and replacement, 7) nitrification, 8) covered storage and 9) permeation and leaching.[1] (For each of these topics, an issue paper was drafted and reviewed at a subsequent workshop held in March 2002. In this month's On Tap, we will explore the topic of cross-connections and backflow, which is reportedly the cause of the majority of waterborne outbreaks associated with municipal drinking water distribution.)

Problem identification

Cross-connections are points in the drinking water distribution system where untreated water from the external environment can come into contact with treated water sources within the piped distribution system. Examples include customer service connections in residential or commercial plumbing systems, such as institutional, industrial or firefighting equipment. Even garden hoses can serve as a transitory connection, allowing back-siphonage of unwanted contaminants into potable water.

Backflow events are simply when the flow of water is reversed. Instead of flowing out, the water flows into the otherwise closed system. This typically occurs following a loss of pressure in the system where the created vacuum literally draws in external water. Back-siphonage events commonly occur, given inconsistent use-patterns, periodic system maintenance (flushing, pipe replacement), main breaks or emergency water use (i.e., hydrant use by fire fighters). Similarly, back-pressure events occur when a connection is made to the distribution system where the external supply maintains a higher pressure than the inside system, causing a reverse flow. This can occur in high-rise buildings where the weight of the piped water creates a back-pressure source.

In the US, there are approximately one million miles (1.6 million kilometers) of water distribution networks with more than 13,000 miles (20,921 kilometers) of new pipes installed each year.[2] A quarter of the distribution pipes in the US are considered in poor condition. This fact is supported by a continual increase in the number of main breaks per year, which is estimated to exceed 237,000. Even small systems serving less than 500 consumers report an average of 1.3 main breaks per year. That number increases to 488 for systems serving more than 500,000 people.[3] (A study of North American water utilities found that nearly 30 percent of cross-connections resulted in bacterial contamination.[4])

Cross-connection contamination events are recognized as a problem nationally where no single state is exempt. Activities of routine maintenance, such as pump repair, hydrant flushing and valve replacement, also presents a risk. (According to a Centers for Disease Control (CDC) survey, cross-connections and back-siphonage caused the majority (51 percent) of outbreaks linked to the distribution system from 1971-2000 and sometimes as much as 78 percent.[1]) These events are thought to be responsible for as much as 95 percent of the cases of illness, however. The CDC further recognizes that only a small percentage of contamination events are actually reported. Thus, the true public health burden from cross-connections and back-siphonage is unknown.

Health risks

Human health risks from contaminated cross-connections and back-flow events are varied and could include anything in the environment that has the potential to be introduced, either accidentally or via an intentional attack. Every connection poses a risk. Education is important to inform the public of the risk of external conditions around areas where cross-connections exist.

One case study involved a professional exterminator who left a garden hose submerged in a barrel of chlordane pesticide, a known neurological toxicant and suspected carcinogen. Following a routine service interruption, the chemical was siphoned into the system, exposing consumers.[1] (Stories abound of contamination events from industrial applications, pesticides, metals and nitrates.) Several fatalities involved back-siphonage from a hospital air conditioning system's water holding tank into dialysis machines.[5]

Biological contaminants are also a concern. Cross-connections with sewer lines or submersion of pipes in untreated water sources, reclaimed water supplies or other wastewater sources (hospitals, mortuaries, farms, etc.) provide substantial risk. Outbreaks have been reported from *Shigella, Salmonella, E. coli, Campylobacter,* Cyanobacteria, noroviruses, *Giardia* and others. An outbreak causing more than 2,000 illnesses in an Arizona state park occurred following a back-pressure event from a tree bubbler system that contaminated the potable water supply.[6]

Contamination sources are most commonly associated with commercial sites, followed by homes with individual connections and industrial sites. Health outcomes, both acute and/or chronic, range from mild skin infections to severe gastroenteritis and death depending on the type, concentration, frequency and duration of exposure.

Preventative measures

Given the magnitude of the risk from cross-connection contamination, controlling these events is important for public health. Monitoring system pressure change is paramount in predicting vulnerabilities and can be done relatively easily and even passively, but pressure changes are common and do not always lead to exposure to harmful contaminants. Direct, routine monitoring for contaminants is generally not practical due to cost, poor sensitivity and long reporting/response times. The first indicator of a back-flow incident tends to be consumer complaints of taste, odor or color changes. At that point, at least some consumers have likely been exposed.

Chlorine residual is frequently utilized to maintain the microbial integrity of piped water but may not be concentrated enough to offer adequate protection to the end user. Various distribution factors further impact chlorine residual concentration and efficacy, including pipe corrosion, biofilm and residence time.

Assessing the potential for contamination can help to drive the level of preventative measures needed. Facilities with highly hazardous contaminants and potentials for cross-connection contacts would need a more diligent management plan. Physically separating potable and non-potable water sources is one option for control (i.e., creating distance between sewer and water lines or air gaps between faucets and non-potable supplies)

Back-flow events can be prevented by eliminating cross-connections where possible and installing back-flow prevention devices. These devices can be installed at the facility/household inlet or at specific connections throughout a facility but must be maintained to guard against fouling and wear. The ability of consumers to bypass or remove these devices, however, creates a difficult situation to monitor or control. Minimally, states should ensure back-flow prevention devices at various water-service connection points where they do have control.

Municipalities are responsible for the quality of the delivered water and thus most states require inventory and monitor the use of back-flow devices. The specific requirements and enforcement actions vary, however. Education and enforcement for cross-connection control and back-flow prevention may be performed by municipalities, plumbing/building code authorities or health departments. US EPA provides guidance to owners/operators of small water systems on how to establish a best-practice approach to cross-connection control but the reality is that adverse events continue to occur.[7,8]

Conclusion

The unpredictable nature of back-flow events from a variety of potential sources, including individual homes or terror threats, creates a vulnerability in our drinking water distribution system that is most effectively controlled at the point of use. POU filtration and purification systems provide a best practice approach for risk reduction that adds consistency to statewide variability.

References

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