



Drinking Water Chlorination: A Review of Disinfection Practices and Issues

Courtesy of the Chlorine Chemistry Council/American Chemistry Council

The treatment and distribution of water for safe use is one of the greatest achievements of the 20th century. Before cities began routinely treating drinking water with chlorine (starting with Chicago and Jersey City in 1908), cholera, typhoid fever, dysentery and hepatitis A killed thousands of U.S. residents annually. Drinking water chlorination and filtration have helped to virtually eliminate these diseases in the U.S. and other developed countries.

Meeting the goal of clean, safe drinking water requires a multi-barrier approach that includes protecting source water from contamination; appropriately treating raw water and ensuring safe distribution of treated water to consumers' taps.

During the treatment process, chlorine is added to drinking water as elemental chlorine (chlorine gas), sodium hypochlorite solution or dry calcium hypochlorite. When applied to water, each of these forms 'free chlorine,' which destroys pathogenic (disease-causing) organisms.

Almost all U.S. systems that disinfect their water use some type of chlorine-based process, either alone or in combination with other disinfectants. In addition to controlling disease-causing organisms, chlorination offers a number of other benefits:

- reduces many disagreeable tastes and odors;
- eliminates slime bacteria, molds and algae that commonly grow in water supply reservoirs, on the walls of water mains and in storage tanks;
- removes chemical compounds that have unpleasant tastes and hinder disinfection; and
- helps remove iron and manganese from raw water.

As importantly, only chlorine-based chemicals provide 'residual disinfectant' levels that prevent microbial re-growth and help protect treated water throughout the distribution system.

The challenge of disinfection by-products

While protection against microbial contamination is the top priority, water systems must also control disinfection by-products (DBPs), chemical compounds formed unintentionally when chlorine and other disinfectants react with natural organic matter in water. In the early 1970s, U.S. EPA scientists first determined that drinking water chlorination could form a group of by-products known as trihalomethanes (THMs), including chloroform. U.S. EPA set the first regulatory limits for THMs in 1979. While the available evidence does not prove that DBPs in drinking water cause

adverse health effects in humans, high levels of these chemicals are certainly undesirable. Cost-effective methods to reduce DBP formation are available and should be adopted where possible. However, a report by the International Programme on Chemical Safety¹ strongly cautions:

The health risks from these by-products at the levels at which they occur in drinking water are extremely small in comparison with the risks associated with inadequate disinfection. Thus, it is important that disinfection not be compromised in attempting to control such by-products.

Recent U.S. EPA regulations have further limited THMs and other DBPs in drinking water. Most water systems are meeting these new standards by controlling the amount of natural organic material prior to disinfection.

Drinking water and security: threats to public water systems

Water treatment and distribution systems provide one of the most basic elements of life, a reliable supply of safe

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drinking water. Protecting these critical systems from intentional wrongdoing has always been a concern. For many systems, security measures were primarily designed to protect facilities and equipment from pranks and vandalism. Recently, though, the prospect of a terrorist attack on a water system has forced all water systems, large and small, to re-evaluate and upgrade existing security measures.

Even before the September 11th terrorist attacks on the World Trade Center and the Pentagon, officials recognized water systems as potential terrorist targets.

Since September 11th, water system managers have taken unprecedented steps to improve security at their facilities. With support from federal, state and local governments, water utilities are working to secure their reservoirs, treatment plants and distribution systems from a terrorist attack and to minimize the potential impact if an attack were to occur.

Disinfection and bioterrorism

Disinfection is crucial to water system security, providing the 'front line' of defense against biological contamination. Normal filtration and disinfection processes would dampen or remove the threats posed by a number of potential bioterrorism agents. In addition, water systems should maintain an ability to increase disinfection doses in response to a particular threat.

However, conventional treatment barriers in no way guarantee safety from biological attacks. For many potential bioterrorism agents, there is little scientific information about what levels of reduction can be achieved with chlorine or other disinfectants. In addition, contamination of water after it is treated could overwhelm the residual disinfectant levels in distribution systems. Furthermore, typical water quality monitoring does not provide real-time data to warn of potential problems.²

Protecting chlorine and other treatment chemicals

As part of its vulnerability assessment, each water system must consider its transportation, storage and use of treatment chemicals. These chemicals are both critical assets (necessary for delivering safe water) and potential vulnerabilities (may pose significant hazards if released). For example, a release of chlorine gas would pose an immediate threat to system operators and a large release may pose a danger to the surrounding community. As part of its vulnerability assessment, a water system using chlorine must determine if existing layers of protection are adequate. If not, a system should consider additional measures to reduce the likelihood of an attack or to mitigate the potential consequences.

Possible measures to address chlorine security include: enhanced physical barriers (e.g., constructing secure chemical storage facilities), policy changes (e.g., tightening procedures for receiving chemical shipments), reducing quantities stored on-site or adopting alternative disinfection methods. These options must be weighed and prioritized, considering the unique characteristics and resources of each system.

Water system officials must evaluate the risk-tradeoffs associated with each option. For example, reducing the chemical quantities on-site may reduce a system's ability to cope with an interruption of chemical supplies. Furthermore, changing

disinfection technologies will not necessarily improve overall safety and security.

Conclusion

In response to new regulations, emerging science on microbial contaminants, as well as safety and security concerns related to treatment chemicals, water system managers will continue to evaluate chlorine and other disinfection methods. Despite these challenges, a number of factors indicate that drinking water chlorination will remain a cornerstone of waterborne disease prevention.

Disinfection is unquestionably the most important step in drinking water treatment and chlorine's wide range of benefits cannot be provided by any other single disinfectant. Only chlorine-based disinfectants provide residual protection, an important part of the multi-barrier approach to preventing waterborne disease.

It is uncertain that alternative disinfectants reduce potential DBP risks significantly.¹ All chemical disinfectants produce by-products. Generally, the best approach to control disinfection by-products is to remove natural organic precursors prior to disinfection.^{3,4}

To comply with the forthcoming Long Term 2 Enhanced Surface Water Treatment Rule, some systems with high levels of *Cryptosporidium* in their source water may choose to adopt alternative disinfection methods (e.g., chlorine dioxide, ozone, or UV). However, most water systems are expected to meet disinfection requirements without changing treatment technologies. The U.S. EPA's forthcoming Groundwater Rule, as well as efforts to strengthen Canadian drinking water standards following the *E. coli.* outbreak in Walkerton, Ontario will likely increase the use of chlorination for ground water systems.

World leaders increasingly recognize safe drinking water as a critical building block of sustainable development. Chlorination can provide cost-effective disinfection for remote rural villages and large cities alike, helping to bring safe water to those in need.

References

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About the Council

This article is an abridged version of "Drinking Water Chlorination," a comprehensive review of the disinfection method first produced in 2003 by the Chlorine Chemistry Council/American Chemistry Council. To read a copy of the complete report, visit http://c3.org/chlorine_issues/disinfection/c3white2003.html

The Chlorine Chemistry Council®, a business council of the American Chemistry Council, is a national trade association based in Arlington, Va. representing the manufacturers and users of chlorine and chlorine-related products. Chlorine is widely used as a disease-fighting disinfection agent, as a basic component in pharmaceuticals and myriad other products that are essential to modern life. For more information, contact the council at (703) 741-5583 or visit <http://c3.org>