Trends and Effects of Chloramine in Drinking Water

By Cang Li, Ph.D.

Introduction

Chlorine is the most common drinking water disinfectant and has been extensively used by municipal water treatment plants to inactivate microorganisms, including pathogens that can cause waterborne diseases, such as typhoid, cholera and dysentery. In the early 1970s, free chlorine (as molecular chlorine, Cl_2; hypochlorous acid, HOCl and hypochlorite ion, OCl^-) was found to interact with natural organic matter (NOM) in drinking water supplies to form products known as disinfection byproducts (DBPs), such as trihalomethanes (THMs). Some of these products have been linked to cancer in laboratory animals and may cause other adverse health effects. In tap water, THMs are believed to be responsible for as much as 17 percent of the bladder cancers diagnosed each year in the US. To protect public health, US EPA has established disinfection byproduct regulations (see Table 1).

Best available technology for controlling regulated DBPs

Chloramines refer to three compounds: mono-, di- and tri-chloramine. The most common and effective chloramine used as a disinfectant is monochloramine, an inorganic compound with the formula NH_2Cl. It has been used by water utilities since 1918 (Denver, CO). Chloramine use is closely regulated and the current US EPA maximum contaminant level (MCL) is four mg/L (or ppm). Since chloramine is not commercially available, it must be generated onsite by adding ammonia to drinking water containing chlorine. Because chloramine is a weaker disinfectant compared to free chlorine, it is chemically more stable and remains more effective in the distribution system over a longer period of time. More importantly, chloramine produces much lower levels of DBPs in drinking water. Chloramine is currently considered to be the best available technology for controlling the formation of regulated DBPs. This is why many water utilities have switched to chloramine in order to meet US EPA regulations.

Pros and cons of chloramine use

The choice of chlorine versus chloramine as a secondary disinfectant varies among water utilities based upon their needs. US EPA does not require water utilities to use chloramines, but a state agency or other authority typically has requirements as to which disinfectant should be used. Use of chloramines as a secondary disinfectant has been increasing over the last decade. Although monochloramine has several advantages over chlorine—especially lowering concentrations of regulated DBPs, such as TTHM and HAA5—chloramine-treated water may contain different unregulated DBPs, including nitroamines, iodo-trihalomethanes and iodo-acids. Regardless of free chlorine or chloramine used, the types and concentrations of DBPs vary from each water treatment utility and also from day to day. US EPA and other organizations are currently doing research on the unregulated DBPs.

Using chloramine has some other disadvantages as well, including lead release from metal corrosion (a case in Washington, DC in 2004), biofilms and nitrification. According to US EPA, chloraminated water is safe to use for drinking, cooking, bathing and other household uses. Health authorities recognize, however, that some populations may have chemical sensitivity to chloramines, which could lead to side effects such as skin problems. People with weak immune systems, including transplant patients and people with AIDS, should not drink chloraminated water. Chloramine must be removed prior to use in kidney dialysis machines. Ammonia can be converted by naturally occurring bacteria through nitrification to form nitrite and nitrate that can be harmful to infants. Chloramine can impact the taste of a soft-drink beverage. Chloramine can also

Table 1. US EPA disinfectant byproduct regulations

Contaminant	MCL (mg/L)	Potential health effects	Common sources	Public health goal (mg/L)
Total Trihalomethanes (TTHMs)	0.080	Liver, kidney or central nervous system problems; increased risk of cancer	DBP	N/A
Haloacetic acids (HAA5)	0.060	Increased risk of cancer	DBP	N/A
Bromate	0.010	Increased risk of cancer	DBP	0
Chlorite	1.0	Anemia, infants, young children and fetuses of pregnant women: nervous system effects	DBP	0.8

Table 2. Pros and Cons of chloramine use

Pros		Cons		
Health effect	Secondary disinfection	Health effects	Aesthetic effects	Plumbing/physical/ other effects
Control regulated DBPs	More stable, more effective and longer lasting	Unregulated DBPs, nitrification, skin problems/ chemical sensitivities	Taste and odor	Lead leaching from metal corrosion, rubber hose and gasket degradation, corrosion to food service equipment, and harmful to fish

cause plumbing problems. As mentioned before, chloramines can cause lead leaching from lead pipes, lead soldering and brass plumbing parts. It reacts with ordinary buna-N rubber hoses and gaskets and causes swelling, which may produce black or greasy particles. It may cause pinhole pitting in copper pipes. In restaurant applications, corrosive chloraminated water could cause problems for steamers, coffee/tea machines and ice machines. Furthermore, chloramine is toxic to fish, amphibians and water-based reptiles and marine invertebrates. The pros and cons of chloramine use are summarized in Table 2.

Chloramine filtration

Chloramine is more difficult to remove from drinking water than chlorine. Products that reduce free chlorine may not be effective to remove chloramines, but products that are known to reduce chloramines will remove free chlorine. Other methods, such as boiling water, allowing water to sit at room temperature and reverse osmosis also do not remove chloramine very effectively from drinking water. Activated carbon filtration systems are widely used to effectively remove chloramine by catalytic conversion. As Dr. Gary Hatch pointed out in *Catalytic Activated Carbons for Dechlorination and Dechloramination: Do they really work and, if so, how?* (*WC&P*, March 2011) some standard carbons and catalytic carbons are more effective for removing chloramines than others. *NSF/ANSI Standard 42* covers chloramine reduction from three ppm to

Figure 1. 2010 map of drinking water treated with chloramine

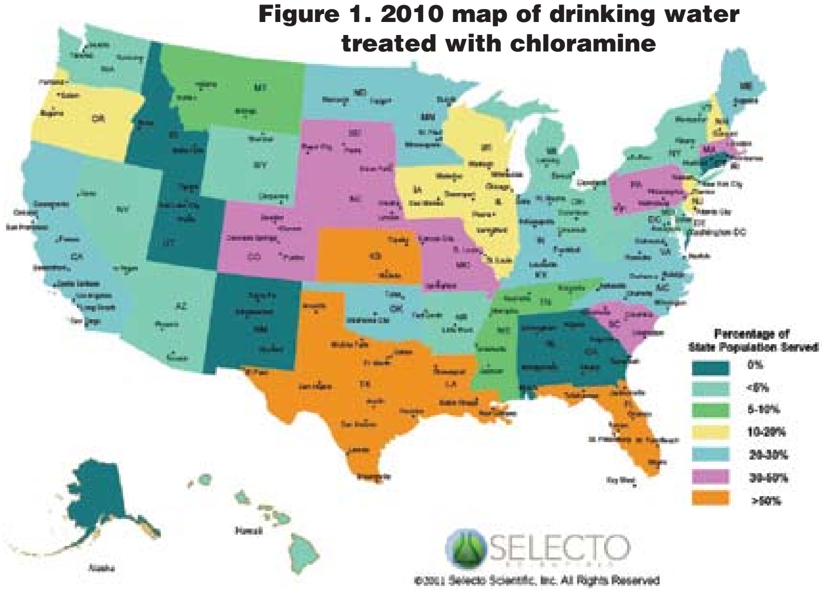

Table 3. Comparison data between 2007 and 2010

	Total water systems			Total states		Population served	
	2007	2010	Change (%)	2007	2010	2007	2010
Nation	944	1,298	+37	36	43	54,083,661	68,397,713
Texas	282	435	+54			11,141,645	12,504,394
Florida	138	197	+43			8,914,118	10,351,719
California	45	54	+20			6,676,183	10,771,907

Table 4. Number of water systems by state and name of cities using chloraminated water from US EPA 2010 data

State	Number of systems	Top cities	State	Number of systems	Top cities	State	Number of systems	Top cities
AZ	2	Phoenix	MD	1	Cumberland	OH	3	Warren
AR	1	Bull Shoals	MA	18	Boston	OK	15	Oklahoma City
CA	54	San Diego, San Francisco, Long Beach	MI	4	Lansing, Flint, Ann Arbor	OR	4	Portland
CO	11	Denver, Aurora	MN	20	Twin Cities	PA	31	Philadelphia, Pittsburgh
DE	1	Bethany Beach	MS	1	Jackson	SC	25	Greenville, Columbia
DC	1	Washington, DC	MO	33	St. Louis, Kansas City	SD	12	Sioux Falls
FL	197	Miami	MT	8	Great Falls	TN	1	Nashville
HI	1	Hilo	NE	4	Omaha, Lincoln	TX	435	Houston, Dallas, Austin
IL	90	Aurora, Belleville	NV	1	Las Vegas	VT	1	S. Burlington
IN	16	Indianapolis	NH	2	Manchester	VA	16	Newport News, Richmond
IA	14	Cedar Rapids	NJ	6	Haworth, Plainfield	WA	4	Spokane
KS	71	Kansas City, Wichita	NY	4	Poughkeepsie	WV	1	Charles Town
KY	7	Louisville, Lexington	NC	58	Raleigh, Durham	WI	9	Milwaukee
LA	80	New Orleans, Baton Rouge	ND	13	Fargo	WY	2	Casper
ME	15	Portland						

Table 5. Percentage of population served with chloraminated water

State	Total population	Population served	Percent of population served	State	Total population	Population served	Percent of population served	State	Total population	Population served	Percent of population served
AZ	6,595,778	25,402	0.39	MD	5,699,478	23,600	0.41	OK	3,687,050	992,767	27
AR	2,889,450	2	< 0.01	MA	6,593,587	2,924,485	44	OR	3,825,657	644,009	17
CA	36,961,664	10,771,907	29	MI	9,969,727	380,944	3.8	PA	12,604,767	4,073,407	32
CO	5,024,748	1,877,221	37	MN	5,266,214	1,246,452	24	SC	4,561,242	1,533,833	34
DE	885,122	12,128	1.4	MS	2,951,996	176,342	6	SD	812,383	259,036	32
DC	599,657	500,000	83	MO	5,987,580	2,662,994	44	TN	6,296,254	568,000	9
FL	18,537,969	10,351,719	56	MT	974,989	64,572	6.6	TX	24,782,302	12,504,394	50
HI	1,295,178	12,109	0.93	NE	1,796,619	764,917	43	VT	621,760	17,551	2.8
IL	12,910,409	1,502,923	12	NV	2,643,085	200	0.01	VA	7,882,590	1,939,220	25
IN	6,423,113	1,809,926	28	NH	1,324,575	151,000	11	WA	6,664,195	216,592	3.2
IA	3,007,856	324,317	11	NJ	8,707,739	1,476,814	17	WV	1,819,777	13,767	0.76
KS	2,818,747	1,560,012	55	NY	19,541,453	22,950	0.12	WI	5,654,774	924,789	16
KY	4,314,113	1,170,898	27	NC	9,380,884	2,058,545	22	WY	544,270	50	0.01
LA	4,492,076	2,625,786	58	ND	646,844	187,813	29				
ME	1,318,301	321,116	24	OH	11,542,645	91,883	0.8				

less than 0.5 ppm. Many products have been tested and certified by NSF or WQA.

Water utilities using chloramine

Under the *Freedom of Information Act (FOIA)*, a list of public water utilities that use chloramines as a secondary disinfectant was obtained from US EPA under *HQFOI-00227-11*. Information in the Safe Drinking Water Information System was supplied by primary agencies in compliance with the quarterly reporting requirements. Two reports for 2007 and 2010 were obtained from the Office of Ground Water and Drinking Water. In the 2007 and 2010 reports, information included the water utility name, ID number, telephone number and mailing address. The report also included information about the region, state and population served. Comparison of US EPA chloramine use data for 2007 and 2010, analyzed in terms of number of water utilities and population served, is presented in Table 3. Using the current US population (312 million), about 22 percent of Americans use drinking water containing chloramine.

Nationwide water systems that switched to chloramine in 2010 increased 37 percent compared to 2007. Texas, with the most significant change, showed a 54-percent increase in 2010 compared to 2007, followed by Florida with a 43-percent increase and California with a 20-percent increase. An analysis of US EPA's data in 2010, the number of water systems and the names of cities using chloramine as a disinfectant have been summarized in Table 4. In order to create a map to show where chloraminated drinking water can be found and the area of coverage, state population and not number of water systems was used. Total state populations was retrieved from the US Census Bureau website, www.census.gov; the most current data is from 2009. The percentage of the population served with chloraminated water has been calculated and summarized in Table 5. The percentage of population served for each state has been used to create a map (Figure 1).

Summary

The number of water systems switching to chloraminated water will continue to increase; however, chlorinated water will not be completely replaced by chloramine. Based upon nationwide water quality, Americans using chloraminated water may reach about 40 percent in the future. Texas and Florida are the top two states with more than 50 percent of the population served with chloraminated water.

About the author

Cang Li, Ph.D., is Director of Research and Development/Quality Control at Selecto Scientific, Inc., Suwanee, GA. Since joining Selecto Scientific in 1999, his work has included research and development in water treatment products and purification media. Dr. Li earned a Bachelor of Science Degree in chemistry from Peking University in China, a Master of Science Degree in analytical chemistry from the Chinese Academy of Sciences in Beijing, and his Ph.D. in physical-inorganic chemistry from Boston University in 1991. He was also a post-Doctoral Fellow at the Institute of Paper Science and Technology at Georgia Institute of Technology, and is a member of the American Chemical Society. He holds one US patent, has authored or co-authored 23 articles in scientific journals and has given several technical presentations.

About the company

For more than two decades, Selecto Scientific has provided innovative technologies and advanced products for a host of applications, including water filtration, pharma, biotech, beverage and fuel cells.