by Randy Johnson

Disinfectants and Disinfection By-products: the suspicions, the truth and the solutions

In the 1960's a worldwide public health entity decided to study the factors that had most contributed to the dramatic increase in man's life expectancy during the 20th century. The greatest increase in life expectancy had occurred in the United States and Sweden. The study noted many significant contributing factors including better medical care, better diet, education, improved health awareness and others. But the two most significant factors were the chlorination of public drinking water systems and the construction of sanitary sewer systems. The study specifically cited "chlorination" of public water supplies.

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What a revelation this was and what a light it should shine on the importance of the job and responsibilities that water and wastewater system operators perform. The work performed by water and wastewater system operators is essential to providing the quality of life that we are privileged to experience today.

Prior to the introduction of chlorine in drinking water treatment, water borne diseases such as cholera, dysentery and typhoid were commonplace and killed many people. Chlorine was first used, it is believed, to treat public drinking water in 1918 or 1919 in Jersey City, N.J. The chlorination of public water supplies gained widespread use and to this day remains a highly effective and the most practical means to protect the water consuming public from water-borne diseases. Water-borne diseases still kill many people and shorten the life expectancy of those who live in parts of the world that do not chlorinate public water systems or benefit from sanitary sewer systems.

The characteristics that make free chlorine a superior disinfectant also cause it to dissipate during long distribution system resident times.

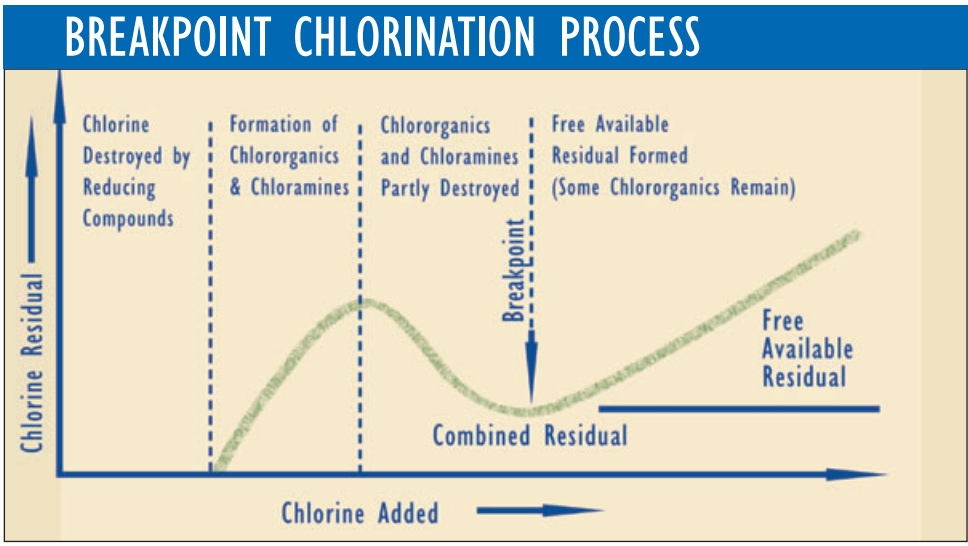

Table 1-A

Recent studies indicate that of all the water disinfection options available today (see Table, 1-B on page 86) chlorination is still the most effective and practical. All forms of chlorination (gas chlorine, sodium hypochlorite and calcium hypochlorite) are effective and economical. From the study of chlorination, we have learned about the breakpoint chlorination process (see table 1-A below). Chlorine is a very reactive chemical and will react with many substances, both suspended and dissolved, found in water. When a small amount of chlorine is added it will be "used up" by reacting with substances such as iron and manganese and effects of environmental conditions such as temperature and sunlight. No chlorine residual will be available. Additional chlorine added may react with organic matter and naturally occurring ammonia to form combined compounds that can be measured as combined residual. While combined chlorine compounds do offer some

disinfecting qualities they are not considered to be acceptable primary (main) disinfecting agents (see table 1-B on page 86). Most systems have fed additional chlorine, which reacts with the combined compounds, destroying some of them. Offensive taste and order can occurs during the period of breaking down chloramines and other compounds. Additional chlorine is then added which reduces the taste and odor problem and forms free chlorine residual. Free chlorine residual is the effective disinfecting agent that has long served the water supply industry and the water consuming public so well. You cannot ensure that disinfection has occurred until a chlorine residual is maintained.

Chlorine protects

A chlorine residual is necessary to be maintained in the water as it travels through the water distribution system to protect consumers from spores. A spore is an inactive (resting) bacteria cell. Spores can be formed in water when bacteria are subjected to conditions not favorable for their existence. The spore stage of a bacteria's life cycle can be described as a "resting" stage and they are not subject to inactivation by disinfecting agents. Spores can then redevelop into active bacteria if conditions become favorable. A chlorine residual is maintained for the purpose of inactivating any spores that try to redevelop and therefore protects water consumers from water borne diseases.

During the 1970s, studies were performed to determine if by-products formed from the exposure of halogens, such as chlorine, to organic precursors, primarily humic and fulvic acids formed from decomposing plants, were a threat to public health. Suspicions from those studies were that the by-products, trihalomethanes, were possible human carcinogens. While the suspicions still exist today, the continuing studies have not proved conclusive that the by-products, which now also include halo-acetic acids, will cause cancer in humans. The regulatory agencies and the water supply industry have taken a cautious approach to protecting the public by going ahead and establishing standards for the by-products and enacting rules and regulations that establish monitoring and reporting requirements for water supplies.

The disinfection by-product regulations have caused the water supply and treatment industry to take a close look at how water is treated, disinfected and distributed. In order to comply with the regulations some water systems have employed new treatment techniques and new technologies. One common method used to reduce the formation of disinfection by-products is the addition of ammonia to the treatment process. After breakpoint chlorination has been accomplished, ammonia is fed to combine with the residual free chlorine to form chloramines (combined chlorine residual) for the purpose of residual maintenance in the distribution system.

Chloramines are much more stable than free chlorine, much less reactive and will persist for much longer time periods.

The practice of using chloramines for residual

COMPARISON OF POSSIBLE DRINKING WATER DISINFECTION METHODS

Agent	Suitable as Inactivating Agent	Limitations	Suitable as Drinking Water Disinfection Agent
Chlorine	Yes	Effectiveness decreases as pH increases, affected by ammonia or organic nitrogen	Yes
Chlorine Dioxide	Yes	Onsite generation required; interim MCL 1.0 mg/L	Yes
Ozone	Yes	Onsite generation required; other disinfectant needed for residual	Yes
Iodine	Yes	Biocidal activity sensitive to pH	No
Bromine	Yes	Lack of technological experience; activity may be pH-sensitive	No
Chloramines	No	Mediocre bactericide, poor virucide	No*
Ferrate	Yes	Moderate bactericide; good virucide; residual unstable; lack of technological experience	No
High pH conditions	No	Poor biocide	No
Hydrogen peroxide	No	Poor biocide	No
Ionizing radiation	Yes	Lack of technological experience	No
Potassium permanganat	No	Poor biocide	No
Silver	No	Poor biocide; MCL 0.05 mg/L	No
UV light	Yes	Adequate biocide; no residual; use limited by equipment maintenance considerations	No

*Chloramines may have use as a secondary disinfectant in the distribution system in view of their persistence.

Table 1-B

maintenance has long been performed by large water systems that have extensive distribution systems. While those systems would agree that free chlorine is a better disinfectant and offers a higher level of water borne disease protection, the problem is maintaining the residual to the point of use. The characteristics that make free chlorine a superior disinfectant, also cause it to dissipate during long distribution system resident times. Chloramines are much more stable than free chlorine, much less reactive and will persist for much longer time periods. But, those "stable" characteristics render chloramines a much less effective disinfectant.

A case can be made that many water systems are paying the price of using a much less effective disinfectant, in order to comply with the Disinfection By-products Rule. How high of a price is being paid? Studies and monitoring performed on water utilities employing chloramine disinfection protection have revealed some problems with the re-growth of microbes in the distribution system. While this may be cause for concern, it should be noted that none of those re-growths have resulted in water borne disease occurrences. A better, although more costly, solution may reside in improved coagulation and clarification of water prior to addition of a disinfectant. Enhanced or improved clarification and filtration can provide a significant removal of the disinfection by-product precursors,

which can result in the use of superior disinfectants, such as free chlorine, while maintaining compliance with the disinfection by-products standards.

Future KRWA magazine articles and training sessions will continue to address this and related issues. More discussion is needed in the areas of unregulated microbial contaminants, monitoring and analysis procedures and new and improving water treatment techniques and technologies. Kansas Rural Water Association will continue to assist Kansas water utilities to comply with all current and forthcoming rules and regulations while providing the highest water quality possible for their customers.

The 2005 KRWA Conference & Exhibition has numerous sessions on water quality, treatment, analysis, regulations and water well rehabilitations. Board and council members, operators and managers are encouraged to attend. Look for these topics and speakers listed in the sidebar at the right.

KRWA Annual Conference & Exhibition March 29-31, Wichita, Kansas

Tuesday, March 29

- *Enhanced Coagulation and Membrane Filtration Technologies* presented by Michael Kalis of Archer Engineers and Leonard Whiting, Public Water District 7, Cass County, Mo.

Wednesday, March 30

- *Chlorine Dioxide Treatment For Potable Water Systems,* presented by Jeff Dotson, Pureline
- *The Use of Combined Chlorine In Water Treatment*, presented by Pat McCool, Kansas Rural Water Association
- *Simultaneous Removal Of Arsenic, Iron, Manganese, and More,* presented by Ron Rappard, Layne Western Company
- *Regulatory Update For Public Water Supply Systems,* presented by Kelly Kelsey, Kansas Dept. of Health & Environment
- *Advances In Water Quality Disinfection Analysis,* presented by Kevin Menning, Hach Company

Thursday, March 31

- *U.S. EPA Drinking Water Program Update, presented* by Ralph Flournoy, Environmental Protection Agency
- *Public Water Supply Well Rehabilitation,* presented by Terry Alexander and Don Teeters, Alexander Pump & Service