Naval Facilities Engineering Command

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USER'S GUIDE
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POTABLE WATER QUALITY MANAGEMENT GUIDANCE DOCUMENT

by

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EXECUTIVE SUMMARY

In January of 2006, the United States Environmental Protection Agency (EPA) passed two large pieces of legislation that further protect the treatment and distribution of the nation's drinking water supply: the Long Term 2 Enhanced Surface Water Treatment Rule (LT2) and the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2). The rules build on their predecessors to expand protection from biological contaminants (LT2) and treatment byproducts (Stage 2) for the public.

Prior to the enactment of these rules, Navy drinking water installations already had compliance issues. These included microbiological problems, lead and copper non-compliance, nitrification, and operational issues. But the number one problem for Navy installations has been compliance to the total trihalomethane (TTHM) maximum contaminant level (MCL) as regulated by the Stage 1 Disinfectant and Disinfection Byproduct Rule (24 reports of non-compliances from 2004-2006). Many of these issues are inter-related and can be conflicting. Under continuing pressure to increase treatment to handle microbiological issues, utilities could find themselves further exceeding the legal limits for disinfection byproducts.

The LT2 rule expounds upon the Long Term 1 Enhanced Surface Water Treatment Rule by enforcing additional protection from *Cryptosporidium* and other pathogenic microorganisms and contaminants, ensuring that systems do not compromise disinfection when attempting to decrease disinfection byproducts. The Stage 2 rule addresses high risk systems that may not have adequate protection from disinfection byproducts under the current regulations. The rule requires more stringent monitoring, reporting and sampling and also extends the regulations beyond the primary system to consecutive systems.

Approximately 75 percent of the Navy's installations are consecutive systems. Since in most cases these systems did not have to adhere to disinfection byproducts rules before, the enactment of the Stage 2 brings a new level of sampling and reporting requirements to these systems.

The chief purpose of this document is to provide direction and information for meeting compliance goals of the new rules while maintaining compliance to other Safe Water Drinking Act rules for both primary and consecutive Navy drinking water installations. The major issues for Navy installations are outlined and tabulated with corresponding links for quick access to references and information. Summaries of previous rules and the new rules are included with more details provided in the Appendices. Acceptable and applicable solutions to the major issues for Navy installations are listed and described with links and references for more detailed information. These solutions are the heart of this guidance document.

Solutions are mainly based on whether the drinking water installation is a primary or consecutive system. Both types of systems can review operational or treatment changes, but their specific options are vastly different.

For operational changes, primary systems will want to look at any source water options available to their specific system. Changes can be made in watershed protection measures; in the source water itself (from various sources and / or the blending of these sources); or in the uptake

infrastructure. To optimize their system, primary systems also have the option to simply move their current point of chlorination/disinfection or make adjustments in pH and other chemical parameters depending on the source water pH and temperature. Furthermore, if not already being accomplished, primary systems can utilize enhanced coagulation or softening for better organic carbon removal, which will improve system operations and efficiency.

Primary systems have the far greater advantage in treatment options than consecutive systems. Treatment changes include adding to or replacing chlorine with alternative disinfectants and/or oxidants that form fewer disinfection byproducts than chlorine, such as chloramines, UV, ozone and chlorine dioxide. Other treatment options utilize different types of filtration to remove microbes and disinfection byproduct precursors. Filtration types include GAC, microfiltration, ultrafiltration or nanofiltration.

Because consecutive systems are buying and distributing treated water, their options for operational and treatment changes are limited. However, options are available to assist systems in complying with rules and regulations. Consecutive system operations should consult with the primary treatment facility concerning the water quality and methods of treatment. They can also consult with outside firms for ideas and direction and perhaps have a hydraulic study completed, which would provide information regarding the system's overall condition, and provide data on storage facility issues, water age, flow pattern and velocities, flushing program adequacy, disinfection distribution, and vulnerability locations. Using this information, consecutive systems may choose to alter finished water storage facilities; close off dead-ends and over-sized facilities; and alter and/or install flushing programs, all of which provide means to decrease the water age, which will in turn, improve corrosion, microbiological, nitrification and disinfection byproduct issues. Treatment options that systems may consider employing are booster chlorination and breakpoint chlorination. Booster chlorination restores chlorine residuals in the distribution system and minimizes initial chlorine dosage requirements. Breakpoint chlorination helps minimize microbiological and nitrification issues by occasionally providing disinfection within the distribution system.

The main objective for Navy installations with compliance issues is to decrease their disinfection byproduct formation without compromising disinfection and other treatment actions. Primary systems can make both operational and treatment changes that can affect disinfection byproduct formation in the short and long terms. Consecutive systems can make operational and treatment changes that can reduce exposure of disinfection byproducts to the public. Regardless of the change made, consequences and compromises to disinfection, corrosion, microbiological activity, etc., must be considered. These resulting issues are also discussed within the appropriate sections.

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ACRONYMS AND DEFINITIONS

AL – Action Level – The existence of a contaminant concentration high enough to warrant action or trigger a response. The response depends on the contaminant.

AWWARF – American Water Works Association Research Foundation

ClO_2 – Chlorine dioxide

Consecutive treatment system – Public water systems that buy or otherwise receive some or all of their finished water from another public water system.

Cryptosporidium – A protozoan microbe associated with the disease cryptosporidiosis in man. The disease can be transmitted through ingestion of drinking water, person-to-person contact, or other pathways, and can cause acute diarrhea, abdominal pain, vomiting, fever, and can be fatal.

CT – The product of “residual disinfectant concentration” (C) in mg/L, measured before or at the first customer, and the corresponding “disinfectant contact time” (T) in minutes, i.e., “C” x “T”. If a public water system applies disinfectants at more than one point prior to the first customer, it must determine the CT of each disinfectant sequence before or at the first customer to determine the total percent inactivation or “total inactivation ratio”. In determining the total inactivation ratio, the public water system must determine the residual disinfectant concentration of each disinfection sequence and corresponding contact time before any subsequent disinfection application point(s).

CWS – Community Water System - A public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

DBP – Disinfection byproducts – A compound formed by the reaction of a disinfectant such as chlorine with organic material in the water supply.

EPA – Environmental Protection Agency - http://www.epa.gov/

GAC – Granular Activated Carbon

GAC10 – Granular activated carbon filter beds with an empty-bed contact time of 10 minutes based on average daily flow and a carbon reactivation frequency of every 120 days.

GAC20 – Granular activated carbon filter beds with an empty-bed contact time of 20 minutes based on average daily flow and a carbon reactivation frequency of every 240 days.

Giardia Lamblia – Protozoan in the feces of humans and animals that can cause severe gastrointestinal ailments. It is a common contaminant of surface waters.

GWUDI – Ground Water Under the Direct Influence of Surface Water – Any water beneath the surface of the ground with significant occurrence of insects or other microorganisms, algae, or large-diameter pathogens; and/or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions. Direct influence is determined for individual sources in accordance with criteria established by a state.

HAA – Haloacetic Acids – A group of chemical compounds that are formed along with other disinfection byproducts when chlorine or other disinfectants react with naturally occurring organic and inorganic matter in water.

HAA5 – The five EPA-regulated haloacetic acids: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid.

HRT – Hydraulic Residence Time - The theoretical calculated time required for a small amount of water to pass through a defined entity at a given rate of flow.

ICR – Information Collection Rule

IESWTR – Interim Enhanced Surface Water Treatment Rule

LCR – Lead and Copper Rule

Legionella – A genus of bacteria, some species of which have caused a type of pneumonia called Legionnaires ' disease, which can be found in drinking water.

LRAA – Locational Running Annual Average – The approach set forth in the Stage 2 Disinfectants and Disinfection Byproduct Rule for compliance with the maximum contaminant levels for the two groups of disinfection byproducts (TTHM and HAA5). It is calculated for each monitoring location in the distribution system and averaged over time.

LT1 – Long Term 1 Enhanced Surface Water Treatment Rule

LT2 – Long Term 2 Enhanced Surface Water Treatment Rule

MCL – Maximum Contaminant Level – The maximum permissible level of a contaminant in water delivered to any user of a public system.

MCLG – Maximum Contaminant Level Goal –A non-enforceable concentration of a drinking water contaminant, set at the level at which no known or anticipated adverse effects on human health occur and which allows an adequate safety margin.

MRDL – Maximum Residual Disinfectant Level

MRDLG – Maximum Residual Disinfectant Level Goal

NOM – Natural Organic Matter – Organic matter originating from plants and animals present in natural (untreated or raw) waters.

NPDWR – National Primary Drinking Water Regulations – Set forth by the Surface Water Treatment Rule, these regulations are legally enforceable standards that apply to public water systems. They protect public health by limiting the levels of contaminants in drinking water.

NTNCWS – Non-Transient Non-Community Water System – A public water system that regularly serves at least 25 of the same non-resident persons per day for more than six months per year.

OEL – Operational Evaluation Level – A concentration less than the MCL, but high enough to trigger a response from the system.

Preoxidation – Oxidation in drinking water is the chemical addition of oxygen via chemicals to break down pollutants and organic wastes. Preoxidation is utilizing this process prior to other treatment techniques like coagulation, sedimentation and filtration, for better removal of the contaminant compounds during these later processes.

Plug-flow reactor – A type of reactor in which fluid elements move through the reactor in the same order as they entered, with no intermixing.

Primary treatment system – A system that treats source water as necessary to produce finished water and then delivers finished water to the consecutive system or another public water system.

PWS – Public Water System – A system that provides piped water for human consumption to at least 15 service connections or regularly serves 25 individuals.

Redox reactions – Oxidation-reduction reactions – A family of reactions that are concerned with the transfer of electrons between species.

SDWA – Safe Drinking Water Act

Secchi disk – An 8 inch diameter metal disk painted in alternate black and white quadrants used to measure how deep a person can see into the water.

Stage 1 – Stage 1 Disinfectants and Disinfection Byproduct Rule

Stage 2 – Stage 2 Disinfectants and Disinfection Byproduct Rule

SUVA – Specific UV adsorption – The ratio between UV absorption and the dissolved organic carbon in a water sample. SUVA can be used as a surrogate measurement to characterize the aromatic nature of the dissolved organic carbon.

SW – Surface Water – A water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.)

SWTR – Surface Water Treatment Rule

TCR – Total Coliform Rule

TOC – Total Organic Carbon – The amount of carbon bound in an organic compound.

TTHM – Total Trihalomethanes – Trihalomethanes are a family of organic compounds named as derivatives of methane. They are generally by-products of chlorination of drinking water that contains organic material. Total Trihalomethanes equals the sum of the mass concentrations of chloroform, bromodichloromethane, dibromochloromethane and bromoform in micrograms/L.

1. PURPOSE

This guidance document presents information and materials to help Navy installations meet and maintain compliance with the Stage 2 Disinfectants and Disinfection Byproducts (Stage 2) and Long Term 2 Enhanced Surface Water Treatment (LT2) Rules. The document also serves to address issues resulting from operational or treatment changes related to these rules.

2. SCOPE

2.1. Systems Application

The information in this document applies to all Navy drinking water systems of all sizes, both primary and consecutive. It includes operational and maintenance changes and treatment alternatives.

2.2. Primary Water System

Primary systems are drinking water treatment plants that receive water from untreated or raw sources and treat the water to provide potable water (water that is chemically and microbiologically safe for human consumption), meets all applicable standards; and is distributed to one or more consecutive systems.

2.3. Consecutive Water System

Consecutive Systems are defined in Stage 2 as “public water systems that buy or otherwise receive some or all of their finished water from another public water system”.

3. BACKGROUND AND NAVY COMPLIANCE ISSUES

3.1. Disinfection byproducts

There are a variety of bacteria, protozoa, parasites and viruses naturally occurring in water, some of which can cause illness or health problems if ingested by humans. Some waterborne pathogens are associated with more serious disorders like hepatitis, cancer, ulcers, myocarditis, meningitis, encephalitis or other diseases. Disinfectants are an essential tool in drinking water treatment because of their use to inactivate these disease-causing pathogens.

Historically, chlorine has been used for disinfection, both primary and secondary, and often times, for preoxidation as well. It is relatively effective at inactivating most pathogens, oxidizing iron and manganese, controlling taste and odor, and controlling biological regrowth, while remaining a relatively inexpensive solution. However, chlorine reacts with both natural organic matter (NOM) and inorganic matter present in water to form disinfection byproducts (DBP), which create health concerns ranging from potential carcinogenic behaviors to developmental interferences. DBP compounds became detectable in the early 1970’s with advanced analytical technology, which launched the ever-increasing difficult task of balancing the risk of disinfection byproducts with the need for microbial inactivation.

Disinfection byproducts begin to form as soon as chlorine comes into contact with NOM and continue to form until the reaction is quenched or until either the NOM or chlorine is spent. Disinfection byproduct formation increases with time, meaning that disinfection byproducts will continue to form in the distribution system. Other parameters influencing DBP formation are temperature, pH, NOM characteristics, type of disinfectant, and treatment processes employed.

Rules and regulations governing DBP formation have focused on monitoring and compliance for two sets of compounds: total trihalomethanes (TTHM) and haloacetic acids (HAA). Because these compounds are formed during a reaction between the disinfectant (most commonly chlorine) and NOM (DBP precursors) in the water, they can be largely controlled by two overall approaches. One approach is to reduce the concentrations of organic carbon in the source water before disinfection. The second approach is to utilize disinfectants that are effective at the inactivation of pathogens and microorganisms, but which react much slower or not at all with NOM.

Prior to the enactment of the Stage 2 and the LT2 rules, complying with disinfection byproduct regulations, especially TTHM levels, was already an issue for Navy installations. Many Navy installations reported difficulty complying with Stage 1 TTHM levels. With the recently passed Stage 2 rules, and more specifically, the change to compliance with the locational running annual average (LRAA) (see Section 4.2 for more information) for TTHM and HAA5, noncompliance is expected to become more of a problem.

3.2. Summary of Navy Water Systems

As of 2004, the Navy had 32 primary systems and 96 consecutive systems. Of the 32 primary systems, 22 of them use groundwater as their source and serve approximately 222,000 people, and the remaining 10 systems use surface water as their source, serving nearly 103,000 people. The 96 consecutive systems serve approximately 413,000 people.

Estimated Number of Water Systems Impacted by the Stage 2 D/DBP Rule	
Fiscal Year	Number of Systems
2006	50
2008	23
2009	53
Overseas Systems	21
TOTAL	147

3.3. Common Navy Compliance Issues Related to Disinfection and Disinfection Byproducts

3.3.1. Microbiological Issues

3.3.1.1. Problem Summary

Microbiological issues are one of the most common causes of noncompliance at Navy installations. To comply with the Total Coliform Rule (TCR), systems must sample and report according to the requirements issued and meet the maximum levels established (see Appendix F, Total Coliform Rule). Positive total coliform results can be indicative of a number of issues: nitrification in the distribution system, overgrowth of biofilm in the distribution system, water quality changes, disinfectant degradation, high disinfectant demand, etc. Systems should verify the cause of the positive result prior to making any system changes.

3.3.1.2. Potential Solutions Summary

Potential Solutions		
Solution Name	Brief Description	Document Section
Watershed protection	Protection of source water from agriculture, outfalls and other contaminant forms will help alleviate coliform risks.	5.1.1.1 Long-term watershed protection
Enhanced Coagulation	Enhanced coagulation can provide better organismal removal	5.1.4 Enhanced Coagulation and Softening
Filtration	Micro and ultra filtration can remove microbes down to the size of the micropores.	5.2.2 Micro/Ultra-Filtration

3.3.1.3. Sources of Regulatory and Background Information

Resource Name	Description	Document Section
4.0 Regulations and Navy Policy	Brief overview of the rules and regulations governing drinking water quality and safety.	4. Regulations and Navy Policy
Appendix E	Summarizes the Long Term 1 Enhanced Surface Water Treatment Rule	Appendix E
Appendix F	Summarizes the Total Coliform Rule and provides links for further information.	Appendix F
Appendix G	EPA TCR Quick Fact Sheet	Appendix G
Appendix J	Summarizes the Long Term 2 Enhanced Surface Water Treatment Rule	Appendix J
EPA Web Site	Provides a summary of the rule. Also provides links to reference guides and tools.	http://www.epa.gov/ogwdw/therule.html#Total

3.3.2. Lead and Copper Issues

3.3.2.1. Problem Summary

To comply with the Lead and Copper Rule (LCR) (Appendix H, Lead and Copper Rule), systems must sample and report according to the requirements set forth and meet the maximum contaminant levels established. Navy installations continue to have occasional issues with Lead and Copper Rule noncompliance. The majority of the systems reporting noncompliance are consecutive.

Lead and copper leaching into the drinking water can be an indicator of a variety of problems. While the leaching is caused by a drop in pH, the decrease in pH is what must be studied. Changes in pH are caused by a myriad of things: change in disinfectants or coagulants, system upset, biofilms, nitrification, etc. Systems should determine the cause of the drop in pH before attempting to make system changes.

3.3.2.2. Potential Solutions Summary

Potential Solutions		
Solution Name	Brief Description	Document Section
Inhibit nitrification	Nitrification contributes to a myriad of problems including distribution pipe corrosion and therefore subsequent lead and copper leaching.	Sections: 5.2.5.1 Chloramines 5.3.2 Finished Water Storage Facilities 5.3.3 Flushing 5.4 Consecutive System Treatment Options
Adjust the pH before distribution	Increasing the pH inhibits corrosion in the distribution system.	5.1.3 Adjustments of pH and Temperature
Inhibit biofilm formation	Microbiological activity (which produces biofilm) enhances pH drops and pipe corrosion.	5.3.2 Finished Water Storage Facilities 5.3.3 Flushing 5.4 Consecutive System Treatment Options

3.3.2.3. Sources of Regulatory and Background Information

Resource Name	Description	Document Section
4.0 Regulations and Navy Policy	Brief overview of the rules and regulations governing drinking water quality and safety.	4. Regulations and Navy Policy
Appendix H	Summarizes the Lead and Copper Rule and provides links for further information.	Appendix H
Appendix I	EPA LCR Quick Fact Sheet	Appendix I
EPA Web Site	Provides a summary of the rule. Also provides links to reference guides and tools.	http://www.epa.gov/safewater/lcrmr/compliancehelp.html
EPA Web Site	Provides the Lead and Copper Rule Document	http://www.epa.gov/safewater/lcrmr/index.html

3.3.3. Nitrite and Nitrification

3.3.3.1. Problem Summary

In rare cases, Navy installations have reported nitrate/nitrite noncompliance. However nitrification may become more of an issue with the increased use of chloramines. Nitrite/nitrate can be indicative of environmental or system issues. Runoff from fertilizer use; leaching from septic tanks, sewage; and erosion of natural deposits are all examples of environmental issues that cause nitrate and nitrite readings. However, high nitrite and nitrate can also indicate nitrification in the distribution system. Often times, systems with nitrification problems will also see high coliform counts, a drop in pH, an increase in disinfectant demand, and/or a decrease in disinfectant residual.

Nitrification became a more prevalent problem with the enactment of the Stage 1 Disinfectants and Disinfection Byproducts Rule, when many systems switched from chlorine to chloramines as the secondary disinfectant to help alleviate DBP issues. If there is any residual free ammonia in the system from the chloramination process, nitrification is likely to occur.

Nitrification is an oxidation process by which nitrogen compounds (ammonia in the case of drinking water) are oxidized to nitrite and nitrate. Organisms adapted to performing this function are common in distribution systems with poor circulation or where biofilms on the pipe walls have built up. Problems resulting from nitrification in the distribution system include the degradation of disinfectant residuals, the consumption of dissolved oxygen, an increase in heterotrophic plate counts (which could lead to a violation of the Total Coliform Rule), a decrease in pH, taste and odor issues, and a potential increase in pipe corrosion (and therefore, an increase in metal concentrations in the water and a potential violation to the Lead and Copper Rule).

3.3.3.2. Potential Solutions Summary

Potential Solutions		
Solution Name	Brief Description	Document Section
Operational Options	Describes various source water and other operational changes that can be made in order to inhibit/limit nitrification in the distribution system.	5. Primary System Operational Options
Chloramine optimization	Discusses the use of chloramines and their effect on nitrification and how to optimize their use.	5.2.5.1 Chloramines
Nitrification	Discusses nitrification in more detail.	Under: 5.3.2 Finished water storage facilities

3.3.3.3. Sources of Regulatory and Background Information

Resource Name	Description	Document Section
EPA Web Site	Consumer fact sheet on nitrates and nitrites.	http://www.epa.gov/safewater/dwh/c-ioc/nitrates.html
EPA Web Site	Link to the National Primary Drinking Water Regulations.	http://www.epa.gov/safewater/mcl.html

3.3.4. Operational Problems

3.3.4.1. Problem Summary

In some cases operational issues have resulted in noncompliance. Examples of issues include line breaks that were not properly disinfected and failure to install backflow prevention devices.

3.3.4.2. Information and Resources

Potential Solutions		
Name	Brief Description	Link
Cross-connections and backflow prevention	Briefly describes rule and regulations and links to more information.	5.3.4 Cross-connections and backflow prevention
Guidance Manual for Maintaining Distribution System Water Quality	Identifies water quality degradation that can occur during distribution system operation and maintenance. Recommends operational, maintenance, and design practices that can prevent or minimize water quality degradation.	Guidance Manual for Maintaining Distribution System Water Quality
Guidance for Management of Distribution System Operation and Maintenance	Provides a comprehensive guidance manual for evaluation and operation of a water distribution system for reliability and water quality maintenance. Includes recommendations on topics such as valve maintenance needs, system maintenance needs, system reliability and evaluation, and fire hydrant maintenance schedules.	Guidance for Management of Distribution System Operation and Maintenance

3.3.4.3. Water Age Management Issues and Associated Resources

Issue	Description	Secondary Effects	Document Section(s) Cross
Abandoned Lines	Lines constructed for a purpose that no longer exists and the line was never removed or closed off.	Disinfectant residual degradation; Taste and odor issues; Microbial regrowth / Coliform violations; Nitrification; Increased DBP formation Sedimentation; Biofilm formation; Corrosion.	5.3.1 Consultations and hydraulic studies
Poor System Design	Poor system design can create short circuiting, slow velocities and other water management issues.		5.3.1 Consultations and hydraulic studies 5.4.3 Storage isolation
Oversized Lines	Historically, systems were over-designed to ensure emergency and future needs. Low usage of water in systems with large lines can create long hydraulic residence times and the associated problems.		5.3.1 Consultations and hydraulic studies 5.3.3 Flushing
Storage Over-design	Similar to oversized lines, over-design of storage also creates long residence times and poor water hydraulic, health and aesthetic qualities.		5.3.1 Consultations and hydraulic studies 5.3.2 Finished water storage facilities 5.3.3 Flushing 5.4 Consecutive System Treatment Options
Low Water Velocities	A result of system or storage over-design or of poor design (short-circuiting), low water velocities lead to residual degradation, enhanced microbiological activity, biofilms and increased DBP formation.		5.3.1 Consultations and hydraulic studies 5.3.3 Flushing
System Short-circuiting	A result of poor system design, short-circuiting creates areas of low flow and subsequent issues as described in 'low water velocities'.		5.3.1 Consultations and hydraulic studies 5.3.3 Flushing

3.3.5. Total Trihalomethanes

3.3.5.1. Problem Summary

TTHM exceedances, often an indicator of other underlying problems, are one of the top three issues facing Navy installations today. These problems are often difficult to resolve and in many cases are beyond the direct control of the water system, especially for consecutive systems. Primary system issues contributing to increased DBP formation range from source water contents, natural organic matter type, system configuration and treatment methods employed. Issues specific to the consecutive system can be disinfectant employed, disinfectant concentrations, nitrification issues, pH problems, excessive microbiological growth, biofilm formation, system configuration, hydraulic residence times and excessive storage.

3.3.5.2. Potential Solutions Summary

Potential Solutions		
Solution Name	Brief Description	Document Section
Source water alterations	What is in the source water and how the source water is collected for treatment can affect DBP formation. If the source water has high concentrations of NOM or if the type of NOM is a reactive type, this can enhance DBP formation. If there is a source of organic matter upstream (runoff or a treatment plant or stormwater discharge), this can increase DBP formation. Perhaps the uptake infrastructure is poorly designed or is in a poor position for year-round uptake. Due to the stratification of water, certain layers during certain times of the year can be utilized for uptake.	5.1.1.1 Long-term watershed protection 5.1.1.2 Source water manipulation 5.1.1.3 Uptake infrastructure alterations
Disinfection strategies	Chlorine is the most common form of disinfectant chosen for drinking water treatment. However, chlorine reacts efficiently with NOM to form DBP. Altering the chlorine dosing strategy or changing to an alternative disinfectant can reduce DBP formation.	5.1.2 Moving the point of chlorination 5.2.5 Alternative disinfection strategies

Solution Name	Brief Description	Document Section
Alternative treatments	Aside from alternative disinfectants, there are many alternative treatment strategies being employed to help reduce DBP formation.	5.1.3 Adjustments of pH and temperature 5.1.4 Enhanced coagulation and softening 5.1.5 Presedimentation basin operations 5.2.1 Granular activated carbon 5.2.2 Micro/ultra-filtration 5.2.3 Nanofiltration 5.2.4 Other removal technologies
Consecutive system options	Under the Stage 2 rule, consecutive systems must comply with DBP levels. Though a consecutive system is purchasing treated water, there are options and solutions to help consecutive systems meet their goals. These options range from consulting with primary systems, to valving-off old, abandoned lines and excessive storage, to establishing flushing programs, to providing additional chlorine dosing in the distribution system.	5.3 Consecutive System Operational Changes and Maintenance Options 5.4 Consecutive System Treatment Options

3.3.5.3. Sources of Regulatory and Background Information

Resource Name	Description	Document Section or Link
4. Regulations and Navy Policy	Summarizes the regulations and policy surrounding disinfection byproducts.	4. Regulations and navy policy

Stage 2 Disinfectants and Disinfection Byproducts Rule	Summarizes the EPA issued rule.	4.2 Stage 2 Disinfectants and Disinfection Byproducts Rule
EPA Web Site	Link to the fully-published rule.	http://www.epa.gov/ogwdw/disinfection/stage2/regulations.html
EPA Web Site	Link for compliance help.	http://www.epa.gov/ogwdw/disinfection/stage2/compliance.html

3.3.6. Monitoring and Sampling

3.3.6.1. Problem Summary

Issues related to monitoring and sampling are a common cause of noncompliance at Navy installations. These problems can include both taking samples and required compliance paperwork and reporting.

The various rules set forth by the EPA for drinking water have specific sampling requirements and techniques depending on the system source, type and size. The rules must be reviewed by the water system to determine specific requirements.

3.3.6.2. Sources of Regulatory and Background Information

Potential Solutions		
Solution Name	Brief Description	Document Section (Links)
Regulations and Navy Policy	Section of document summarizing the current rules and links to these rules for further information.	4. Regulations and navy policy
Total Coliform Rule	The Total Coliform Rule sets both health goals and legal limits for total coliform levels in drinking water. The rule also details the type and frequency of testing that water systems must complete.	Appendix F Appendix G http://www.epa.gov/ogwdw/therule.html#Total

Lead and Copper Rule	The Lead and Copper Rule protects public health by minimizing lead (Pb) and copper (Cu) levels in drinking water, primarily by reducing water corrosivity. Pb and Cu enter drinking water mainly from corrosion of Pb and Cu containing plumbing materials.	Appendix H Appendix I http://www.epa.gov/safewater/lcrmr/compliancehelp.html#one
Long Term 2 Enhanced Surface Water Treatment Rule	The purpose of the rule is to reduce disease incidence associated with *Cryptosporidium* and other disease-causing microorganisms in drinking water.	Appendix J http://www.epa.gov/ogwdw/disinfection/lt2/regulations.html
Stage 2 Disinfectants and Disinfection Byproducts Rule	The Stage 2 DBP rule focuses on public health protection by limiting exposure to DBPs, specifically total trihalomethanes (TTHM) and five haloacetic acids (HAA5).	Appendix K http://www.epa.gov/ogwdw/disinfection/stage2/regulations.html

4. REGULATIONS AND NAVY POLICY

Passed by Congress in 1974, and amended in 1986 and 1996, the Safe Drinking Water Act (SDWA) (http://www.epa.gov/safewater/sdwa/index.html) is cornerstone legislation that protects human health by regulating the nation's drinking water supply. It authorized the United States Environmental Protection Agency (EPA) to set national health-based standards to regulate both naturally occurring and man-made contaminants. Today, the EPA, state environmental organizations, and local municipalities and water systems work together to meet the standards and to provide clean, safe drinking water to consumers. In most cases, states have been granted primacy by the EPA, guaranteeing they will follow the national standards or provide more stringent standards. The U.S. EPA continues its involvement by providing direction and public information, collecting and assessing drinking water data, and guiding state drinking water programs. Either the U. S. EPA or the State EPA may impose fines, issue administrative orders or take other legal actions.

Under the SDWA, many rules and regulations have been written by the EPA to create specific guidance and goals for various contaminants deemed harmful to the public (http://www.epa.gov/ogwdw/regs.html). Public water systems (PWS) must comply with these rules as a measure of protection to consumers. The regulations pertinent to this guidance document are described in Table 5.1. Details can be found at the provided links.

Table 4.1 Past and Current Federal Regulations

Year	Regulation	Description	Applicable Systems	MCL	MCLG	Other	Links
1989	Surface Water Treatment Rule	Set MCL, MCLG for harmful contaminants and established NPDWRs. Established the need to maintain a disinfectant residual in distribution system.	SW and GWUDI	N/a	N/a	3-log removal -*Giardia*	http://www.epa.gov/ogwdw/therule.html#Surface
				N/a	N/a	4-log removal-viruses	
1996	Information Collection Rule	Established to help EPA collect data and information for future rules and regulations.	Large PWS	N/a	N/a	N/a	http://www.epa.gov/ogwdw/icr.html
1998	Interim Enhanced Surface Water Treatment Rule	Addressed balance between microbial disinfection and byproduct formation. Established turbidity, storage coverage and sanitary survey requirements.	SW and GWUDI > 10,000 users	N/a	0 for *Cryptosporidium*	2-log removal-*Cryptosporidium*	http://www.epa.gov/ogwdw/mdbp/ieswtr.html
1998	Stage 1 Disinfection / Disinfectants Byproduct Rule	Established MRDL and MRDLG for chlorine, chloramine and chlorine dioxide. Established MCL and MCLG for TTHM, HAA5, chlorite and bromate. Established organic material removal requirements.	CWS and NTNCWS	TTHM-0.08 mg/L	chlorite-0.8 mg/L	MRDL for chlorine and chloramines = 4.0 mg/L	http://www.epa.gov/safewater/mdbp/dbpfr.pdf
				HAA5-0.06 mg/L			
				chlorite-1.0 mg/L	bromate-0.0 mg/L	MRDL for chlorine dioxide = 0.8 mg/L	
				bromate-0.01 mg/L			

Table 4.1 Past and Current Federal Regulations, cont.

Year	Regulation	Description	Applicable Systems	MCL (mg/L)	MCLG (mg/L)	Other	Links
2002	Long Term 1 Enhanced Surface Water Treatment Rule	Enhanced the IESWTR by extending the regulations to all systems using surface water or GWUDI and to any surface water serving < 10,000 users. The other regs of the IESWTR still apply.	SW and GWUDI > 10,000 users and all systems < 10,000 users	N/a	N/a	2-log removal-*Cryptosporidium*	http://www.epa.gov/fedrgstr/EPA-WATER/2002/January/Day-14/w409.pdf
1989	Total Coliform Rule	Targeted and achieved reductions in illnesses associated with water-borne organisms by establishing an MCL and an MCLG on total coliforms. It also established monitoring and sampling requirements.	All PWS	< 5% of samples taken can be positive	0	N/a	http://www.epa.gov/ogwdw/therule.html#Total
1991	Lead and Copper Rule	Limits concentrations of lead and copper exposed to the public. The two main objectives are to reduce corrosivity of distribution system and educate the public.	N/a	N/a	Lead = 0.0 mg/L	AL Lead = 0.015 mg/L	http://www.epa.gov/safewater/lcrmr/index.html
					Copper = 1.3 mg/L	AL Copper = 1.3 mg/L	

The most recent rules passed, the Long Term 2 Enhanced Surface Water Treatment Rule (LT2) and the Stage 2 Disinfectants and Disinfection Byproduct Rule (Stage 2), were promulgated in January 2006. Both of these rules build upon their predecessors, LT1 and Stage 1 respectively, by creating more stringent requirements in an effort to further protect the public. The balance between microbial inactivation and disinfection byproduct formation is becoming more and more difficult. In addition, unlike the LT1 and Stage 1, the LT2 and Stage 2 require compliance from both primary and consecutive systems. Because the Navy's consecutive systems outnumber primary systems by three times, compliance will be an issue.

4.1. Long Term 2 Enhanced Surface Water Treatment Rule

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2) was promulgated to continue to improve the quality and safety of drinking water. Specifically, it provides additional protection from *Cryptosporidium* and other pathogenic microorganisms and contaminants, ensuring that systems are not compromising disinfection in the face of decreasing disinfection byproducts. *Cryptosporidium* is of particular concern because of the number of disease outbreaks caused by it and due to its resistance to traditional disinfection techniques. The LT2 enhances the protection goals set forth by the LT1 rule by enforcing additional *Cryptosporidium* treatment in high risk systems, requiring further provisions to reduce risks from uncovered finished water storage facilities, and enforcing additional precautions be taken to ensure microbial inactivation while systems attempt to decrease their DBP formation. Table 4.1.1 summarizes the requirements for the LT2.

Table 4.1.1 Long Term 2 Enhanced Surface Water Treatment Rule General Information

Initial Monitoring and Sampling Requirements

System Size	Number of Years to Sample	Minimum Samples per Month	Organisms
Large* Filtered PWS	2	1	*Cryptosporidium* *E.Coli* turbidity
Large Unfiltered PWS	2	1	*Cryptosporidium*
Small** Filtered PWS Stage 1	1	1 / every 2 weeks	*E.coli****
***Stage 2-If Lake/Reservoir results = *E.coli* > 10/100mL			*Cryptosporidium*
***Stage 2-If flowing source results = *E.coli* > 50/100mL			*Cryptosporidium*
Small Unfiltered PWS	1-2	2 / month for 1 year or 1 / month for 2 years	*Cryptosporidium*

*Large systems are defined by the LT2 rule as systems serving > 10,000 users.

**Small systems are definied by the LT2 rules as systems serving < 10,000 users.

***For systems using GWUDI must comply with the rules corresponding to the nearest body of surface water.

Bin Classifications

PWS	*Cryptosporidium* concentration (oocysts / L)	Bin Classification
Monitor for *Cryptosporidium*	< 0.075	1
	0.075< conc.< 1.0	2
	1.0 < conc. < 3.0	3
	> 3.0	4
Not required to monitor for *Cryptosporidium*	N/a	1

Treatment Requirements

System Type	Bin Classification	Additional Treatment Requirement for *Cryptosporidium**
All	1	No additional treatment. Must comply with LT1 and IESWTR.
Filtered Systems (conventional, diatomaceous earth, slow sand)	2	1-log
	3	2-log
	4	2.5-log
Direct Filtration	2	1.5-log
	3	2.5-log
	4	3-log
Alternative filtration technologies	all	determined by State
	Level of *Cryptosporidium* (oocysts/L)	
Unfiltered Systems**	≤ 0.01	2-log
	> 0.01 (or if *Cryptosporidium* was not monitored)	3-log

*For Bins 3 and 4 classifications, at least 1-log removal must be achieved by using ozone, ClO2, UV, membranes, bag filtration, cartridge filtration or bank filtration

**All unfiltered systems must also use at least 2 different disinfectants to provide 4-log removal of viruses and 3-log removal of *Giardi lamblia.*

Table 4.1.1 Long Term 2 Enhanced Surface Water Treatment Rule General Information, cont.

Public Notice Requirements

Type of Violation	Public Notice Requirement
Treatment Technique	Tier 2
Monitoring and Testing	Tier 3
Failure to collect 3 or more *Cryptosporidium samples*	Tier 2 Special
Failure to collect *Cryptosporidium* samples according to bin classification	Tier 2

Uncovered Finished Water Storage Requirements

Requirement	Compliance Deadline
Reported	April 1, 2008
1 of 2 choices:	
1. Covered	April 1, 2009
2. Treat all distributed water with 4-log virus, 3-log *Giardia*, and 2-log *Cryptosporidium* removal.	April 1, 2009

EPA Recommended Best Available Technologies

Technology	*Cryptosporidium* inactivation credit
Watershed Control Program	0.5-log
Alternate Source	Requires additional monitoring
Pre-sedimentation with Coagulant	0.5-log
Two-Stage Lime Softening	0.5-log
Bank Filtration	0.5-1.0-log
Combined Filter Performance	0.5-log
Individual Filter Performance	0.5-log
Demonstration of Performance	Site-specific
Bag and Cartridge Filtration	up to 2.0-2.5-log
Membrane Filtration	filter specific
Second Stage Filtration	0.5-log
Slow Sand Filtration	up to 2.5-log
Ozone and Chlorine Dioxide	see Table IV. D-3 and Table IV.D-4 of the LT2 rule
Ultraviolet Light	see Table IV. D-3 and Table IV.D-4 of the LT2 rule

(Table 4.1.1 adapted from

Other requirements included in the LT2 that should be further explored are disinfection benchmarking, reporting requirements and Sanitary Survey requirements. Brief explanations can be reviewed in Appendix J.

The LT2 rule applies to all public water systems using surface water or ground water under the direct influence (GWUDI) of surface water. Table 4.1.2 summarizes the compliance deadlines based on the size and type of system.

Table 4.1.2 Long Term 2 Enhanced Surface Water Treatment Rule Compliance Deadlines Summary

Type of System	**Activity-- Reporting or Providing**	**Dates**				
		PWS Size (users)				
		> 100,000	**100,000 -- 50,000**	**50,000 -- 10,000**	**< 10,000**	
All Systems Serving > 10,000 users	Initial Source Water Monitoring	October 2006	April 2007	April 2008	N/a	
	Bin Classification	April 2009	October 2009	October 2010	N/a	
	Additional *Cryptosporidium* Treatment	April 2012	October 2013	October 2012	N/a	
	Second Round of Source Water Monitoring	April 2015	October 2015	October 2016	N/a	
Filtered Systems	Initial Source Water Monitoring	N/a	N/a	N/a	October 2008	
	Bin Classification	N/a	N/a	N/a	If results > E. coli trigger concentrations, see below. Otherwise, N/a.	
	Additional *Cryptosporidium* Treatment	N/a	N/a	N/a	If results > E. coli trigger concentrations, see below. Otherwise, N/a.	
	Second Round of Source Water Monitoring	N/a	N/a	N/a	October 2017	
					Monitoring Schedule	
					2 x / mo for 1 y	1 x / mo for 2 y
Filtered Systems that Exceed E. coli Trigger Concentrations and <u>all</u> Unfiltered Systems	Initial Source Water Monitoring	N/a	N/a	N/a	April 2010	April 2010
	Bin Classification	N/a	N/a	N/a	October 2011	October 2012
	Additional *Cryptosporidium* Treatment	N/a	N/a	N/a	October 2014	October 2014
	Second Round of Source Water Monitoring	N/a	N/a	N/a	April 2019	April 2019

At the time this document was being produced, several of these and other listed deadlines had passed for PWS serving at least 100,000 people, including: reporting the sampling schedule and sampling location description for source water monitoring; reporting notice of intent to grandfather previously collected *Cryptosporidium* data; reporting intent to provide the maximum *Cryptosporidium* treatment level in lieu of monitoring; beginning the initial source water monitoring; and submitting any information for grandfathering, if applicable. Utilities are strongly encouraged to review the deadlines for upcoming compliance dates.

4.2. Stage 2 Disinfectants and Disinfection Byproducts Rule

The Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2) was written to supplement the Stage 1 Rule and address higher risk systems that may not have had adequate protection from disinfection byproducts (DBP) under the existing regulations. Updates include more stringent monitoring, sampling, reporting requirements for TTHM and HAA5, and extension of the rule to not only primary systems, but consecutive systems of community and non-transient non-community water systems. The Stage 2 rule also contains MCLG for chloroform, monochloroacetic acid and trichloroacetic acid. Table 4.2.1 lists the various levels and goals for disinfectants and byproducts for the Stage 1 Rule, which are still in effect today. Table 4.2.2 summarizes the major details of the new Stage 2 rule. More information can be reviewed in Appendix K.

Table 4.2.1 MRDLGs, MRDLs, MCLGs and MCLs for Stage 1 Disinfectants and Disinfection Byproducts Rule*

DISINFECTANT RESIDUAL	MRDLG (mg/L)	MRDL (mg/L)	COMPLIANCE BASED ON
Chlorine	4.0 (as Cl_2)	4.0 (as Cl_2)	Annual Average
Chloramine	4.0 (as Cl_2)	4.0 (as Cl_2)	Annual Average
Chlorine Dioxide	0.8 (as ClO_2)	0.8 (as ClO_2)	Daily Samples
DISINFECTION BYPRODUCTS	MCLG (mg/L)	MCL (mg/L)	COMPLIANCE BASED ON
Total trihalomethanes (TTHM)[1]	N/A	0.080	Annual Average
- Chloroform	***		
- Bromodichloromethane	0		
- Dibromochloromethane	0.06		
- Bromoform	0		
Haloacetic acids (five) (HAA5)[2]	N/A	0.060	Annual Average
- Dichloroacetic acid	0		
- Trichloroacetic acid	0.3		
Chlorite	0.8	1.0	Monthly Average
Bromate	0	0.010	Annual Average

*Table copied from EPA website

N/A - Not applicable because there are individual MCLGs for TTHMs or HAAs

*** EPA removed the zero MCLG for chloroform from its National Primary Drinking Water Regulations, effective May 30, 2000, in accordance with an order of the U.S. Court of Appeals for the District of Columbia Circuit.

Table 4.2.2 Stage 2 Disinfectant/Disinfection Byproduct Rule General Information

Affected Systems

Systems using a disinfectant other than UV light

Community	primary
	consecutive
Nontransient-noncommunity	primary
	consecutive

Maximum Contaminant Level Goals

Compound	MCLG (mg/L)
chloroform	0.07
monochloracetic acid (MCAA)	0.02
trichloroacetic acid (TCAA)	0.07

Initial Distribution System Evaluation

To whom does it apply?	all CWS
	consecutive systems
	noncommunity systems > 10,000 users using a disinfectant other than UV
Approaches	standard monitoring
	system specific studies
	40/30 certification

Operational Evaluation Level Requirements

Provides system an early detection method and allows for proactive steps to avoid MCL violations.

If $\frac{Q_1 + Q_2 + 2Q_3}{4} > MCL$, then the system must conduct an operational evaluation

(where Q_1 = quarter before previous quarter measurement of DBP concentration;
Q_2 = previous quarter measurement
Q_3 = current quarter measurement)

Public Notice Requirements

Refer to Stage 1 requirements

Compliance Timelines

PUBLIC WATER SYSTEMS	ACTIONS			
	Submit IDSE monitoring plan, system specific study plan, or 40/30 certification	Complete an initial distribution system evaluation (IDSE)	Submit IDSE Report	Begin subpart V (Stage 2) compliance monitoring
CWS and NTNCWS serving at least 100,000	October 1, 2006	September 30, 2008	January 1, 2009	April 1, 2012
CWS and NTNCWS serving 50,000 - 99,999	April 1, 2007	March 31, 2009	July 1, 2009	October 1, 2012
CWS and NTNCWS serving 10,000 - 49,999	October 1, 2007	September 30, 2009	January 1, 2010	October 1, 2013

Compliance Timelines, cont.

PUBLIC WATER SYSTEMS	ACTIONS			
	Submit IDSE monitoring plan, system specific study plan, or 40/30 certification	Complete an initial distribution system evaluation (IDSE)	Submit IDSE Report	Begin subpart V (Stage 2) compliance monitoring
CWS serving fewer than 10,000	April 1, 2008	March 31, 2010	July 1, 2010	October 1, 2013
NTNCWS serving fewer than 10,000	NA	NA	NA	October 1, 2013

*States may grant up to an additional two years for systems making capital improvements.

EPA Recommended Best Available Technologies

System Types	Size	Technique
Primary	large	GAC10
	small	GAC20
Groundwaters with high TOC	any	Nanofiltration
Consecutive	all	collaboration with wholesalers
	> 10,000	chloramination with hydraulic flowmanagement
	< 10,000	hydraulic flow management

4.3. Navy Policy

The current policy establishing the minimum requirements for Navy installation responsibilities is OPNAVINST 5090.1B “Environmental and Natural Resources Protection Manual” (see link: http://neds.nebt.daps.mil/5090). Chapter 8 of the manual, *Safe Drinking Water Act Compliance Ashore*, describes requirements, policies and responsibilities that Navy drinking water installations need in order to comply with the Safe Drinking Water Act. However, all public water systems must also comply with current, applicable regulations.

5. SOLUTIONS TO MEET AND MAINTAIN COMPLIANCE FOR THE STAGE 2 AND LT2 RULES

5.1. Primary System Operational Options

In many cases, primary systems can make adjustments to existing systems to optimize processes and subsequently decrease disinfection byproducts and help correct other non-compliance issues. Some of these adjustments are simple changes and others require many years of planning and large capital expenditures. Alternatives range from manipulating the source water to making operational changes like moving points of chemical addition.

5.1.1. Source Water Options

By managing the source water feeding drinking water treatment systems, facilities can optimize water conditions for best treatability. Modifications to source water can require large capital expenditures. Reductions in DBP formation can be realized through decreasing some of the total organic carbon (TOC) concentrations, temperatures, and/or organic matter. Reducing TOC concentration and organic matter can also decrease the demand of the raw water, which there by can reduce the disinfectant concentration required for dosing.

5.1.1.1. Long-term watershed protection

Source water can introduce sediment, silt, sand, turbidity, tastes, odor, color and organisms. Combined with treatment methods at the plant, these constituents may undergo reactions that result in byproduct, residual, precipitation, and sedimentation issues. Protection of the source water can provide a simple and less expensive way to reduce compliance issues.

Installations should consider the following when assessing their source waters:

- Precipitation events and run-off;
- Point source discharges, like stormwater drains and other treatment facilities upstream from the drinking water treatment plant source uptake;
- Non-point source discharges from sources like agriculture and construction.

The manual, “Effective Watershed Management for Surface Water Supplies” (see link Effective Watershed Management) provides detailed information regarding watershed management, programs, monitoring and protection. Additional sources are:

- Knappe, D.R.U. et al. 2004. Algae Detection and Removal Strategies for Drinking Water Treatment Plants. AWWARF Report 90971. Project #360.
- Cooke, G.D. and R.H. Kennedy. 2001. Managing drinking water supplies. Lake and Reservoir Management. 17(3): 157-174.

- UFC 3-230-07A, "Water Supply: Sources and General Considerations", http://www.wbdg.org/ccb/DOD/UFC/ufc_3_230_07a.pdf

5.1.1.2. Source water manipulation

Systems with more than one source should consider manipulating or alternating sources depending on the season and the source water characteristics. Waters can be blended if necessary.

5.1.1.3. Uptake infrastructure alterations

Facilities can alter their uptake infrastructure in order to deal with seasonal surface water turnover issues, algal blooms, temporary fluctuations in source water quality, and surface water stratification. Facilities should consider installing multi-level uptake structures that pull water from different water level elevations depending on the season, stratification characteristics and other water quality factors. Systems want to draw water with optimal treatment capacity: waters with low TOC, low turbidity, neutral to slightly alkaline pH, average alkalinity, low sediment concentration, low DBP formation potential, and low pathogen concentrations.

Regardless of whether a drinking water treatment facility chooses to manipulate source waters or uptake infrastructures, the facility should conduct jar testing to discern the impact on the treatment system and the distribution system. Additionally, monitoring programs on source water should be put in place. The following parameters provide the most information regarding treatability:

- Dissolved oxygen;
- Temperature;
- pH;
- secchi disk depth;
- Redox potential;
- Turbidity;
- Alkalinity;
- NOM measured as TOC or SUVA;
- Dissolved iron and manganese concentrations;
- Hydrogen sulfide concentrations; and
- Algal counts.

If the plant is treating groundwater, additional parameters to test and monitor are pH, iron and manganese concentrations, redox potential, and any potential toxic compounds from local contaminant plumes.

Considerations and potential consequences to changing source water:

Issues resulting from changing the source water can be avoided if the proper bench-scale testing is applied. The following are potential changes in raw water quality that systems should consider and address **prior to** making any operational changes.

- Water temperature changes will affect CT calculations and disinfectant and/or coagulation effectiveness. Decreasing temperatures will increase the concentration of disinfectant required and can also decrease the rate of coagulation and subsequently the efficiency of turbidity removal. Review CT requirements and how to calculate CT for individual disinfectants in the LT2 Toolbox Guidance Manual at http://www.epa.gov/safewater/disinfection/lt2/pdfs/guide_lt2_toolbox.pdf.

- Changing the raw water could add new or increased concentrations of contaminants, metals, new types of organic matter, sulfides, etc. Any contaminants must be addressed in the treatment process, the finished water and the waste streams.

- Any changes in pH will affect CT, treatability, DBP formation potential, and distribution system water quality. See section 7.1.3, Adjustments of pH and temperature, for more information.

- Changes in types of organic matter and turbidity levels will affect coagulation and flocculation, filtration, and disinfectant demand. The report, “Natural Organic Matter in Drinking Water: Recommendations to Water Utilities” (see link NOM in Drinking Water Recommendations) provides detailed information on NOM and its sources, characteristics, associated costs, etc.

- Aesthetic quality could be compromised (or even simply changed), which could generate customer complaints.

5.1.2. Moving the Point of Chlorination

Moving the point of chlorination downstream can be an effective and efficient way to reduce DBP formation both during treatment and in the distribution system. This occurs in multiple ways: 1) adding chlorine as late as possible means less time for chlorine and NOM reactions; 2) coagulation and flocculation remove significant amounts of reactive material (DBP precursors); and 3) the removal of NOM creates less demand which requires less chlorine for disinfection (and subsequent residual maintenance in the distribution system).

Typically, chlorine addition points are at the raw water intake for biological growth and nuisance species control, pre-coagulant addition for better coagulation and flocculation (preoxidation), and after sedimentation (post sedimentation) for disinfection, oxidation (of iron and manganese), and taste, odor and color control. Choices for moving the point of chlorination could be:

- Move the entire dose of chlorine to post-sedimentation;
- If chlorine is required pre-treatment for biological growth or preoxidation, decrease the dose to a minimum and re-chlorinate post-sedimentation.
- Choose a different type of oxidant for preoxidation (chlorine dioxide, potassium permanganate, ozone, etc.) and chlorinate post-sedimentation. See "Alternative Disinfectants and Oxidants Guidance Manual" from the EPA website: http://www.epa.gov/safewater/mdbp/alternative_disinfectants_guidance.pdf.

Considerations and consequences of moving the point of chlorination downstream:

- For systems receiving CT credit prior to filtration, moving the point of chlorination downstream will reduce the 'T' (time) factor, thereby, reducing the amount of credit received. Systems can choose to increase the 'C' (concentration) factor or modify the hydraulic conditions to increase the 'T'. Go to http://www.epa.gov/safewater/mdbp/mdbptg.html#ctspreadsheet for tools and information to calculate CT.
- Chlorinating post filtration increases the chances of filter fouling.
- Moving or eliminating chlorine from the front of the treatment system may alter the pH of the water. Systems must determine if other pH control is necessary. See section 7.1.3, Adjustments of pH and temperature, for more information.
- Distribution system MRDL compliance must continue to be met and any customer complaints addressed.
- Reductions in chlorine dose can also change oxidation-reduction potentials in the distribution system, affecting lead and manganese concentrations.

5.1.3. Adjustments of pH and Temperature

Because temperature and pH affect a drinking water treatment system throughout the entire process, bench and pilot scales studies are critical prior to making any operational changes. While temperature is mostly a function of the source water, any operational change, whether it be a change in chemicals, a change in chemical operation or a change in other operations, will have a pH impact on the rest of the treatment system.

Temperature has the following effects:

- Generally, temperature and chlorine have a positive, linear relationship;
- Additionally, temperature and reaction rates of chlorine and NOM (DBP formation) have a positive, linear relationship as well.

- Warmer temperatures may increase microbial activity and demand in the source water or in the treatment systems (primary and secondary), diminishing the ability to dose at lower chlorine concentrations.

Facilities with water sources of higher temperatures can utilize this and decrease their disinfectant dose, as long as they don't compromise disinfection. However, these facilities will also need to account for the increase of DBP formation potential resulting from the higher temperatures. Systems with lower temperatures typically have less DBP formation, despite the higher dose of disinfectant required for CT requirements. For facilities to determine their systems' needs, they should:

- Optimize their CT by utilizing tools furnished at the EPA website (http://www.epa.gov/safewater/mdbp/alternative_disinfectants_guidance.pdf and http://www.epa.gov/safewater/mdbp/mdbptg.html#ctspreadsheet);

- Determine reactivity of NOM in the source water;

- If DBP formation potential is high, systems should consider NOM removal options: e.g., coagulation (see "Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual" from the EPA website: http://www.epa.gov/ogwdw/mdbp/mdbptg.html#coag); oxidation (see "Alternative Disinfectants and Oxidants Guidance Manual" from the EPA website: http://www.epa.gov/safewater/mdbp/alternative_disinfectants_guidance.pdf); filtration, etc.

- Modify or optimize the uptake infrastructure to draw raw water with better treatability. See section 7.1.1.3, Uptake infrastructure alterations, for more information.

More than temperature, the pH will change according to treatment methods and has an enormous impact on process performance. In general,

- Lower pH conditions provides better conditions for disinfection, which allows for lower disinfectant doses;

- Lower pH conditions also inhibit TTHM formation;

- Lower pH conditions favors HAA formation;

- Lower pH conditions favors corrosion;

Furthermore;

- Chlorine addition typically lowers the pH of the water;

- Coagulation also typically lowers the pH of the water.

The AWWARF report "Internal Corrosion" provides a good overview of corrosion and of the effect of pH and corrosion on different types of pipes.

Considerations and consequences of manipulating pH:

- Because a lower pH may increase HAA5 formation, systems should conduct studies to determine the level of HAA5 formation that may result.

- Because lower pH increases corrosion, issues both in the treatment plant and in the distribution system will arise if the pH is not readjusted prior to distribution. Additionally, corrosion of pipes can favor microbial growth, creating TCR issues. The "Revised Guidance Manual for Selecting Lead and Copper Control Strategies" at http://www.epa.gov/safewater/lcrmr/pdfs/guidance_lcmr_ control_stratageis_revised.pdf, discusses issues regarding corrosion as relative to lead and copper and control strategies to remedy the problem.

- Adjusting pH can adversely affect treatment chemistry, coagulation, settling and dewatering processes, and inorganic solubility.

    - Increased levels of iron and manganese may be observed.

    - Recalcification of lime-softened waters (increasing turbidity) may also be noticed.

    - For systems utilizing alum as their coagulant, aluminum carryover should be monitored when running in lower pH conditions.

- Maintenance of disinfectant residuals in the distribution system could be an issue due to the lower doses of chlorine. Re-chlorination after treatment but prior to distribution or booster chlorination in the distribution system can offset this problem.

- Reductions in chlorine dose can also change oxidation-reduction potentials in the distribution system, affecting lead and manganese concentrations.

5.1.4. Enhanced Coagulation and Softening

Under the Stage 1 Rule, TOC removal requirements by enhanced coagulation or enhanced softening were established for systems meeting a certain criteria. (See Appendix D.) But even for systems not required to comply with the enhanced coagulation rules, enhanced coagulation and softening are useful tools to reduce the NOM concentration entering a treatment system, thereby reducing DBP precursors and subsequent DBP formation. Other benefits of enhanced coagulation and softening are the reduction in the demand in the water, allowing lower disinfection doses which could also potentially decrease DBP formation; the decrease in pH, which provides better disinfection effectiveness; and the potential enhanced removal of arsenic and radionuclide.

Systems considering enhanced coagulation or softening must fully evaluate their system, their water and any potential impacts resulting from operational, coagulant, pH or preoxidation changes made. Bench-scale and pilot studies are critical in determining the best method to achieve enhanced coagulation or softening. Several beneficial sources are listed below.

- The EPA produced a comprehensive guide, "Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual" (link: http://www.epa.gov/safewater/mdbp/mdbptg.html#coag) detailing how to assess a system, how to implement changes, potential impacts and mitigation strategies for unwanted impacts.

- The article "Secondary Effects of Enhanced Coagulation and Softening" (Carlson et al. 2000), also provides information.

- The AWWARF report, "Removal of DBP Precursors by Enhanced Coagulation and Lime Softening" is a study showing the benefits and drawbacks for enhanced coagulation and softening on different waters.

Enhanced coagulation is defined by the EPA as a process of improving DBP precursor removal in conventional treatment. Systems often already employ coagulation processes, so taking the extra step to reach enhanced coagulation is often obtained through simple changes in the already existing system. These changes can include:

- Increasing coagulant dose;

- Changing type of coagulant;

- Changing preoxidation strategy (type, dose, etc.);

- Changing the pH of the water.

Considerations and consequences of enhanced coagulation

- If the water contains arsenic and radionuclide and enhanced coagulation is being employed, systems must address their disposal and handling requirements.

- The addition or increase of a coagulant will often decrease the pH of the water. While decreasing pH typically reduces turbidity and TOC, occasionally, a less dense, more fragile floc or a restabilization of particles is created, which can carry over to the filters and cause problems. Turbidity may actually increase resulting in compliance issues.

- Reductions in pH and/or alkalinity, or changes in the chloride to sulfate ratio and/or the NOM concentration can enhance corrosion both in the treatment plant and in the distribution system. Any PWS should monitor and test to ensure proper water quality and protection for both inside the treatment plant and in the distribution system. See Section 5.1.3, Adjustments of pH and temperature, for more information.

- Enhanced coagulation can cause an increase in inorganic compounds (manganese, aluminum, sulfate, chloride and sodium) in the finished water. Testing should be conducted to assess the proper coagulant for a specific water and system.

- Enhanced coagulation increases the settled solids, which increases disposal volumes. Additionally, if there are high concentrations of hazardous contaminants, the PWS may not be allowed to dispose of solids and wastes in sanitary facilities.

Enhanced softening means the removal of DBP precursors through precipitative softening. (Note that two-stage softening plants can achieve additional *Cryptosporidium* removal credit in addition to TOC removal credit. See the section named "Two-stage lime softening" of the Long Term 2 Enhanced Surface Water Treatment Rule, Appendix J, for more information.) Softening is typically practiced by utilities in order to remove calcium and magnesium hardness from the water, but a side benefit to softening is its ability to remove particles and TOC, much by the same mechanism as the coagulation process. The disinfection byproduct precursors are removed through coprecipitation and adsorption processes.

Softening plants typically operate at higher pH levels than most drinking water utilities since calcium carbonate begins precipitation at 9.5 and magnesium hydroxide begins to precipitate at pH levels of 10 and greater. Systems must balance these pH levels with TTHM formation rates, with corrosion potential, and with scale formation (see Section 5.1.3). The process is usually completed in one of three ways:

- by adding lime to remove calcium carbonate,
- by adding lime-soda to remove calcium carbonate and noncarbonated hardness,
- or by adding excess lime to remove both calcium and magnesium.

Membrane softening is a potential alternative to lime softening, although, cost may be a prohibitive factor.

Considerations and consequences of precipitative softening

- Systems must test to choose a disinfectant for softening plants to limit the potential negative impacts of the disinfectant.
- Providing additional contact time for CT requirements under higher pH conditions may be necessary.
- TTHM formation rates can actually increase in higher pH waters (see Section 5.1.3 for more information regarding pH changes).
- Bromide is not removed when softening. The ratio of bromide to TOC increases during precipitation, which increases the percentage of brominated byproducts.
- As the finished water pH level increases, the chemical adjustments (addition of acid) required to lower the pH to an optimal level increase as well.
- Sludge production increases as lime dose increases.

- Calcium carbonate and magnesium hydroxide form different floc particles, which settle differently. Precipitating both in the same softening process can be difficult.

5.1.5. Presedimentation Basin Operations

For systems with existing presedimentation basins, optimizing the basins can provide a mechanism for DBP precursor removal. The EPA defines presedimentation basins as basins that raw water passes through prior to the main treatment process (which typically consists of coagulation, flocculation, disinfection, etc.), allowing larger particles to settle out and providing a means to buffer against spikes in turbidity and particulate matter. (There is the possibility of receiving 0.5-log removal *Crtyptosporidium* with presedimentation basin operations. See the section named "Pre-sedimentation with coagulant" of the Long Term 2 Enhanced Surface Water Treatment Rule, Appendix J, for more information.)

Enhancing presedimentation basins can be accomplished by:

- increasing contact time via baffling;
- or adding coagulant for particulate removal.

Considerations and consequences of pre-sedimentation basin operations

- Decreased flow can encourage algal growth, which can actually add to the NOM content of the water and subsequently increase DBP formation, produce taste and odor issues or interfere with the other treatment processes. Alternative disinfectants or basin covers can be utilized in the basin to address these issues.
- Settled solids can be difficult to remove if the basin is not properly equipped. Either two basins or proper removal equipment should be considered.

5.2. Primary System Treatment Options

There are a wide variety of alternative treatment technology options available for primary drinking water installations to consider in their quest to reduce DBP formation. Many of the technologies are suitable for a wide range of waters. When choosing the treatment, installations should consider impacts surrounding the treatment and the specific installations. The advantages of alternate treatment technologies can be obscured by problems not initially or clearly identified.

- While alternative disinfectants form fewer TTHM and HAA, they may also produce other regulated disinfectant byproducts.
- Identifying process controls and successes for some of the uncommon and less studied technologies is difficult.
- Some technologies may not have the oxidation or disinfection capabilities as needed.
- Water quality significantly affects the performance of many of the treatment technologies.

- Installations must consider the existing infrastructure, materials, energy, labor, cost and impact on other treatments and processes.

5.2.1. Granular Activated Carbon

Manufactured from carbon containing materials (coal, wood, etc.) and heated to create more surface area, granular activated carbon (GAC) functions primarily as an adsorbent for organic matter, but can provide a means for some microbial removal.

Most relevant to the Stage 2 rules, GAC can be operated as a DBP precursor removal technique. However, utilizing GAC has other benefits as well. Because taste and odor compounds are often organic, GAC will remove these compounds. Additional *Cryptosporidium* removal credit can be received for using GAC. See the section IV. D. 12 in the LT2 Rule (link: http://www.epa.gov/safewater/disinfection/ lt2/index.html).

GAC can be utilized pre- or post-disinfection depending on the needs of the system and the water quality. Used pre-disinfection, GAC could be utilized as a biologically active filter, which is very efficient at removing aqueous organic carbon. However, as a biological filter, the GAC will encourage heterotrophic bacterial growth which can lead to biofilm formation or nitrification. Additionally, biological growth will decrease the life of the GAC between regenerations. Used post-disinfection, GAC targets the remaining organic matter in the water and removes taste and odor compounds. However, disinfectants react quickly with GAC, resulting in both rapid disinfectant residual degradation and GAC depletion. Chlorine dioxide will react with GAC to form chlorate, which can further react to form chlorite, a regulated DBP. The use of chloramines prior to GAC treatment can encourage nitrification in the distribution system. Thorough assessments of the water and treatment process should be assessed before installing GAC treatment.

Considerations and consequence of implementing GAC

Besides the impacts assessed when determining the disinfectant addition point and its relation to GAC, there are other considerations governing the use and placement of GAC.

- Saturated GAC will release compounds if compounds with a greater affinity are introduced to the GAC. This is called chromatographic peaking or breakthrough and can result in recontamination or increase in TOC. Remedies include adjusting pH after the GAC and increasing regeneration frequency.

- Especially when first installed, GAC will release carbon fines into the water and can interfere with subsequent treatment processes downstream. Placement of the GAC and/or maintenance activities can alleviate the problem.

5.2.2. Micro/Ultra-Filtration

Low-pressure membrane technologies, micro- and ultra-filtration (MF/UF) remove all particulate matter larger than the pore size of the membrane. Their usage reduces microbe concentrations and can reduce organic matter concentrations as well, thereby reducing disinfectant demand and doses and subsequently disinfection byproducts. MF membranes typically operate at lower pressures and have larger pore sizes than UF membranes. The two types of membranes can be used together in series where the MF would provide pre-filtration to the UF membrane. MF/UF systems are easily installed and are highly automated.

MF and UF membranes remove bacteria and *Cryptosporidium* and *Giardia* cysts. If these membranes undergo proper testing, they can provide additional *Cryptosporidium* removal credit. See the section named "Membrane Filtration" of the Long Term 2 Enhanced Surface Water Treatment Rule, Appendix J, for more information.

For a general overview of membrane filtration and how it can be utilized to comply with the LT2 rule, see the "Membrane Filtration Guidance Manual at http://www.epa.gov/ogwdw/disinfection/lt2/pdfs/guide_lt2_membranefiltration_final.pdf. In addition, the AWWARF report "Integrated Membrane Systems" (Schippers et al. 2004) provides guidance on the selection, design, and operation of an integrated membrane system for removing microbiological contaminants and DBP precursors. This report must be ordered from the AWWARF website. Contact Ken Kaempffe for more information: ken.kaempffe@navy.mil. An additional AWWARF report titled "Integrating Membrane Treatment in Large Water Utilities" also provides information and issue solutions surrounding membrane treatment in large utilities.

Considerations and consequences of installing micro and/or ultra-filtration

- Organic matter, iron, manganese and carbonate deposits will create membrane fouling. The membranes will have to be cleaned, though pretreatment can extend the time between cleanings.
- Membranes produce reject streams and backwash water which will either require recycling or disposal. Wastewater volumes are typically greater for systems utilizing membranes.
- Membranes are a different technology to operate and monitor than other common treatment techniques, therefore, they require further training and instruction for operators.

5.2.3. Nanofiltration

Similar to MF/UF, nanofiltration is a membrane process that removes particles larger than its pore size. However, its pore size and operating pressures fall below that of UF and reverse osmosis. It too can be utilized for additional *Cryptosporidium* removal credit. (See the section named "Membrane Filtration" of the Long Term 2 Enhanced Surface Water Treatment Rule, Appendix J, for more information.) Like the MF/UF technologies, nanofiltration can also function to decrease DBP formation by reducing disinfectant demand, microbial concentrations, and DBP precursors.

Because of nanofiltration's smaller pore size, it removes nearly all of the organic matter and particulates in water, including dissolved organic matter. It also removes bacteria, protozoa and viruses. The systems typically operate optimally in lower pH levels and periodic cleaning of the membrane is required. To maximize the technology, it is best operated after pretreatment in order to remove as many of the fouling compounds as possible. Most of the issues and disadvantages of nanofiltration are based on its very small pore size, which increases the likelihood of fouling.

In addition to the references listed in the micro- and ultra-filtration section (5.2.2), the AWWARF report, "NOM Rejection by, and Fouling of, NF and UF Membranes" discusses the details of NOM and the related fouling of NF and UF membranes.

Considerations and consequences of nanofiltration

- Membrane fouling increases operation pressures, decreases efficiency, reduces membrane life, and increases backwashing requirements. All of these issues increase operating expenses.
- Nanofiltration generally reduces the pH and softens the water, which could lead to increases in corrosivity in the distribution system. Secondary disinfection may be affected as well. Readjustment of pH and/or alkalinity may be necessary. See section 5.1.3 for more information regarding pH changes.
- Nanofiltration of groundwater may allow the passage of hydrogen sulfide. PWS may utilize aeration to remove sulfide or carbon dioxide and raise oxygen levels to oxidize sulfide to sulfate. Adding an oxidant may provide the same benefit.
- Like MF and UF, nanofiltration has a reject stream and requires backwashing, which increases the overall volume of wastewater produced. However, due to the pore size (and unlike MF/UF), the reject stream could potentially have salts, metals and soluble organic compounds, resulting in more difficult and costly disposal.
- Nanofiltration typically requires a larger volume of water treated per day to serve the same numbers as conventional treatment.
- Similar to MF/UF, nanofiltration operations are a new and different technology to operate and require additional training.

5.2.4. Other Removal Technologies

Other removal technologies available for LT2 compliance are bank filtration, filter performance, bag and cartridge filtration, second stage filtration, and slow sand and diatomaceous earth filtration (see "EPA Recommended Best Available Technologies" of the Long Term 2 Enhanced Surface Water Treatment Rule, Appendix J, for more information.). And while these technologies are designed to remove pathogens, often times, they can enhance DBP reductions as well. Most of the technologies are easy to install and operate. However, facilities must always first consider the following issues: hydraulics, clogging and fouling, backwash and sludge disposal issues, and inorganic compound problems. Additional information regarding these technologies can be found in the following reports:

- Evaluation of Riverbank Filtration as a Drinking Water Treatment Process
- Manual of Design for Slow Sand Filtration

5.2.5. Alternative Disinfection Strategies

Primary systems have the option to employ disinfectants other than chlorine. Systems can optimize oxidation and disinfection with alternatives, still meet disinfection requirements and reduce DBP formation. However, PWS must address the consequences of changing the disinfectant. The EPA Guidance Manual, "Alternative Disinfectants and Oxidants Guidance Manual" (http://www.epa.gov/safewater/mdbp/alternative_disinfectants_guidance.pdf) and the AWWARF report titled " ""Effect of Changing Disinfectants on Distribution System Lead and Copper Release—Part 1-Literature Review" discusses these issues and how they affect Lead and Copper Corrosion, providing a guide to disinfection strategy impact. The EPA manual provides significant detail to alternative disinfectants and their chemistry specific to the disinfection or oxidation process, generation, primary uses and points of application, DBP formation, pathogen inactivation and disinfection efficacy, the status of analytical methods for residual monitoring, and operational considerations.

5.2.5.1. Chloramines

Since the Stage 1 rule was promulgated in 2000, chloramine, as a potentially inexpensive and easy method to control DBP formation, has become the secondary disinfectant of choice. Many Navy consecutive systems already receive chloraminated water from their local municipalities instead of water with free chlorine.

Added as a secondary disinfectant, chloramines significantly reduce the reaction of chlorine with NOM, thereby reducing DBP formation. They also inhibit regrowth of microbial life in the distribution system, and have been shown to penetrate biofilms better than chlorine. Additionally, chloramine residuals in the distribution system are generally easier to maintain.

Chloramines are formed through reactions of ammonia with chlorine, typically forming three different species whose ratios depend on the pH of the water and the relative proportion of chlorine to ammonia. Of the three species, monochloramine is considered the most effective for drinking water purposes.

Disinfection byproduct formation when using chloramines is governed by the initial contact time between the primary disinfectant and NOM, the type of primary disinfectant employed, and the type of DBP precursor material in the water. The most common treatment utilization of chloramines is adding chlorine for a certain amount of contact time to achieve primary disinfection, and following that by the addition of ammonia to quench any free chlorine residual and achieve secondary disinfection. (For CT requirements, visit http://www.epa.gov/safewater/mdbp/alternative_disinfectants_guidance.pdf. For more information regarding optimizing DBP control under chloramination, see the AWWARF report, "Disinfection Byproduct Control During Chloramination".) Systems that do not use chlorine for primary disinfection must add it prior to or at the same time as the ammonia if using chloramines as the secondary disinfectant.

Considerations and consequences of employing chloramination

- As a less effective disinfectant than free chlorine in the inactivation of most microorganisms, chloramines are usually used only as a secondary disinfectant. A separate disinfectant must be used prior to secondary disinfection. More information on the use and implementation of chloramines can be found in the AWWARF reports, "A Guide for the Implementation and Use of Chloramines" and "Optimizing Chloramine Treatment".

- Factors affecting chloramines effectiveness are:
    - contact time—long residence times result in lower residuals, potential biological regrowth, and nitrification;
    - chloramine dosage—low doses can result in the same issues as long residence times;
    - point of ammonia application—pre-filter application can enhance nitrification in the filter and in the distribution system;
    - pH should be optimized based on the system's water quality and conditions—see Section 5.1.3 for more information;
    - temperature—as pH, temperature should be optimized based on present conditions;
    - total organic carbon—reducing the carbon concentration in any system will decrease demand, nitrification, residual degradation and DBP formation;
    - chlorine to ammonia ratio—optimizing this ratio prevents free ammonia in the distribution system and subsequent nitrification;
    - reactivity rates of DBP precursors—precursors with fast reaction rates will result in high DBP concentrations during disinfection (if chlorine is employed), negating the use of chloramines;
    - mixing and dispersion—adequate mixing and dispersion provides better treatment;
    - distribution system configuration—significantly impacts residence time and subsequent disinfectant residuals.

Systems should consider all of these factors prior to making any treatment changes. Table 4 lists the optimal values for some of these parameters.

Table 4.	
Parameter	Target Value
pH	7.5 -- 9.0
Temperature	20 -- 25 °C
Chlorine : Ammonia	3:1 -- 5:1
Precursor material reaction rates	slow

- There are several types of ammonia that can be utilized to form chloramines and each type requires precautionary measures:

  - ammonia - reactions with high concentrations of chlorine can form an explosive mixture of trichloramines;
  - ammonium gas - can be toxic if released in high doses; and
  - ammonium sulfate - is less toxic, but it is more expensive and must be kept very dry to avoid feed problems.

- The use of chloramines can increase the risk of nitrification. See Section 5.3.2 for more information. Nitrification will decrease chloramine residuals and can eventually lead to an increase in heterotrophic plate counts and possible violations of the TCR.
- Blending chloraminated water with chlorinated water can cause a number of issues, including: unnecessary breakpoint chlorination and subsequent loss of disinfectant residual; taste and odor issues due to the formation of dichlor- and trichor- amines; and excess free chlorine resulting in increased DBP formation.
- Chloramines (and chlorine) are ineffective at inactivating *Cryptosporidium* cysts.
- Chloramines added prior to a GAC filter can cause nitrification in the filter and subsequently, in the distribution system.
- Ozone use prior to chloramination has been shown to destabilize the chloramine residual in the distribution system (Wilczak et al. 2003).
- Chloraminated water is toxic to dialysis patients and fish. Chloramines must be removed before water is used for dialysis machines, fish tanks, or before water is discharged to the environment. Chloramines are more expensive to remove or neutralize than chlorine.

5.2.5.2. Ozonation

Typically generated on site, ozone is a powerful oxidant and disinfectant whose effectiveness is independent of pH. It can be employed for oxidation, pre-oxidation, or disinfection depending on the needs of the system. The manual, Ozone in Drinking Water Treatment: Process Design, Operation, and Optimization, published in 2005 by the American Water Works Association, provides a compiled resource for existing ozone system managers and managers considering ozone as an alternative option.

- For disinfection, it is effective at the inactivation of the broad spectrum of pathogens in drinking water: viruses, bacteria, *Giardia*, and *Cryptosporidium*.
- For oxidation, it will oxidize DBP precursors, iron, manganese, arsenic, and taste and odor compounds for better removal during coagulation and sedimentation. Ozone does not chlorinate NOM, therefore chlorinated DBP are not formed.
- If utilized as a primary disinfectant, systems can lower their overall chlorine dose, also reducing DBP formation.

Considerations and consequences for Ozone use

- Ozone does react with bromide to form bromate, a regulated DBP and it can react with organic matter in the presence of bromide to form other brominated compounds. However, these reactions will only continue to occur as long as ozone is present, and as a highly volatile compound, reaction times are relatively short and formation will not continue into the distribution system. Systems with bromide concentrations in their source water should research further ozone as an option.

- Ozone corrosion resistant materials should be utilized anywhere ozone may come into contact.

- Though overall DBP formation is reduced when ozone is used as the primary disinfectant and chlorine as the secondary, a higher percentage of chloroform may form.

- Ozonation oxidizes organic matter into smaller more bioavailable molecules, which could increase microbial issues in the distribution system.

- As a volatile compound that reacts very quickly, ozone does not provide a residual. Secondary disinfection with chlorine, chloramines, etc. is required.

- Ozonation introduces oxygen into the water which can enhance aerobic microbiological growth and increase corrosion. Biofiltration prior to secondary disinfection and the distribution system will help.

- Ozonated organic matter, depending on the organic matter's constituents, can form taste and odor compounds (e.g., aldehydes).

- Ozone bubbles can bind in the filter and reduce filter performance and backwashing techniques.

- As an advanced technology, ozone treatment requires proper operator training.

5.2.5.3. Ultraviolet light

As a physical process which will not form chemical DBP, and because it is effective at inactivating *Giardia* [cysts] and *Cryptosporidium* [oocysts], ultraviolet light (UV) is a viable option for primary disinfection for many water treatment facilities. Not dependent on temperature or pH, UV's disinfection mechanism is its ability to damage the genetic material in microbial pathogens. They cannot reproduce, therefore ending the life cycle and their ability to be infective. Effectiveness of disinfection is based on light intensity employed.

Considerations and consequences for UV use

- Lamp failures and any times of inoperation or sub-specification operation result in poor disinfection or no disinfection at all. Constant monitoring is imperative to ensure disinfection.

- Turbidity, natural organic matter, inorganics and other particulates can interfere with UV operation and effectiveness. Pre-filtration, preoxidation and point of UV disinfection should be considered.

- High UV doses are required for virus inactivation.

- UV disinfection does not provide a residual in the distribution system. Secondary disinfection is required.

- As an advanced treatment technique, UV operation requires more extensive training.

The EPA provides a manual, "Ultraviolet Disinfection Guidance Manual" (see link at http://yosemite.epa.gov/water/owrccatalog.nsf/065ca07e299b464685256ce50075c11a/a4533395e90b100885256d63006cd4df!OpenDocument) providing information for UV use, design, installation and operation. The AWWARF report, "Integrating UV Disinfection Into Existing Water Treatment Plants.pdf" provides additional information for systems considering UV as an alternative disinfection option.

5.2.5.4. Chlorine dioxide

As a strong oxidant, chlorine dioxide (ClO_2) has increased in popularity over the last few years. It produces relatively low concentrations of TTHM and HAA compounds, while remaining effective in bacterial and viral inactivation, *Giardia* inactivation and even some *Cryptosporidium* inactivation. Its main drawback in use is the established MRDL of 0.8 mg/L ClO_2 and the 1.0 mg/L MCL for chlorite, a byproduct of the oxidation reaction of chlorine dioxide.

Chlorine dioxide is a highly volatile compound, especially in warm or UV light conditions, and it is more soluble with decreasing temperatures. Because of its instability, it is generated on site and should be stored in cold and dark areas. It does not oxidize NOM by the same mechanisms as chlorine and therefore does not form the same chlorinated and regulated TTHM and HAA5 compounds. ClO_2 oxidizes many taste and odor compounds and can possibly oxidize arsenic, iron, manganese and sulfides. The use of ClO_2 can also help minimize nitrification potential in the distribution system.

One of the most comprehensive guides on ClO_2 and its use, The Chlorine Dioxide Handbook (Gates 1997) provides detailed information on its generation, application, and DBP formation. The AWWARF Report, Impact of Chlorine Dioxide on Transmission, Treatment, and Distribution System Performance, provides research and case studies on the effect in treatment and in the distribution system of utilizing ClO_2 as part of primary treatment.

Considerations and concerns for the use of chlorine dioxide

- ClO_2 has better disinfection capabilities for *Giardia* and *Cryptosporidium* than chlorine or chloramines. However, due to the limits on chlorite and subsequent ClO_2 dosing, achieving more than 0.5-log inactivation for *Cryptosporidium* is unlikely.

- The chlorite MCL is 1.0 mg/L, so ClO_2 dosage should be set based on the approximate 70 percent conversion rate of ClO_2 to chlorite.

- Transport of ClO_2 is very hazardous: on-site generation is required.
- Aggressive daily monitoring of ClO_2 and chlorite are required and often monitoring techniques are more challenging than simply monitoring for chlorine residuals.
- Monthly compliance to chlorite levels is required at three sampling locations.
- As an advanced treatment technique, ClO_2 requires more training and skills in treatment operators.
- ClO_2 can produce its own taste and odor issues.

5.3. Consecutive System Operational Changes and Maintenance Options

Historically, drinking water system designers and engineers planned for over-sized pipes and storage facilities in order to cope with population growth, future water needs, and fire fighting and emergency capacities. (See Impacts of Fire Flow for more information regarding the impacts of fire flow on distribution systems.) Other factors contributing to water age and long detention times are abandoned lines, poor system design, slow water velocities, system short circuiting, and supply sources going on and off-line. Long detention times result in loss of disinfectant residual, taste and odor issues, microbial regrowth, nitrification, and increased disinfection byproduct formation. Low flow also increases sediment accumulation, which serves as both habitat and protection for microorganisms.

The majority of disinfection byproduct problems affect consecutive systems (as opposed to primary systems) since typically the compounds are formed over time. The Navy has far more consecutive systems than primary and most Navy non-compliance to drinking water regulations is associated with these systems. With the new Stage 2 rules, these systems need guidance and methods to address all of their non-compliance problems, especially with disinfection byproducts. Options for consecutive systems used to be considered limited, but with more knowledge, analysis and technologies, consecutive systems have operational, maintenance-related and treatment-related alternatives.

5.3.1. Consultations and Hydraulic Studies

Installations should consult with hydraulic experts and engineers and possibly consider a hydraulic study. Consultations and hydraulic modeling can provide information required to:

- Assess a system’s current condition;
- Locate and size storage facilities;
- Determine how to reduce water age;
- Modify operations when blending source waters;
- Modify flow patterns and velocities;
- Install or modify flushing programs;
- Alter disinfectant addition rates at booster stations;
- Locate new, ideal addition points for disinfectants;
- Minimize consumer exposure to disinfection byproducts; and
- Assess system vulnerability and risks to outside contamination.

5.3.2. Finished Water Storage Facilities

Oversized lines and pipes and excess finished water storage facilities create stagnant areas in the water system. In order to improve the conditions of finished water storage facilities and therefore, the overall conditions of the distribution system, PWS can focus on reducing hydraulic residence time (HRT) by looking to the following options:

- Mix the storage facility by;
    - increasing inlet momentum
    - changing inlet configuration
    - installing mixing devices
    - increasing fill-time.
- Utilize tank turnover by;
    - increasing water level fluctuation
    - increasing draw-downs between fill and draw cycles
    - convert tank to plug flow reactor.
- Install or improve flushing program(s);
- Loop dead-ends;
- Change valve settings;
- Take excess storage facilities off-line;
- Replace over-sized pipes;
- And utilize blow-offs.

The following AWWARF reports present details on retention time, the issues surrounding it and methods to combat it:

- Managing Distribution System Retention Time I
- Managing Distribution System Retention Time II

Advantageous results

Reducing the HRT in the distribution system has the following advantages:

- Eliminates stagnant zones, which in turn, eliminates areas that are conducive to increased microbial growth.
- Reduces DBP formation.
- Enables systems to maintain disinfectant residuals while possibly dosing with lower concentrations of disinfectant.
- Can reduce corrosion and nitrification, which can reduce the possibility of violations to the TCR and LCR.

Considerations

- Management techniques such as pipe replacements, loop installations, and mixer installations are often times capital improvement projects and can be expensive.
- Any changes in distribution operations will cause temporary re-suspension of any sediment present in the system.
- If blow-offs, flushing techniques or decommissioning efforts are employed; disinfected water will require proper neutralization and disposal.
- Decommissioning storage facilities decreases available water for user-demand and emergencies.
- Flushing programs result in water waste, an added expense and a concern for water scarce areas.

Nitrification

Systems that switch to chloramines as a secondary disinfectant will often see a rise in nitrification issues because ammonia is being added to the water. If the ratio of chlorine to ammonia is not optimized, free ammonia will be available for the bacteria. All systems experiencing nitrification problems should assess their distribution system for causes and changes that could lead to the problem. Review Section 5.2.5.1 and the AWWARF report, "Nitrification Occurrence and Control in Chloraminated Water Systems". The following is an informational guide to assist systems in addressing the issue.

- Consecutive system managers should collaborate with their wholesalers! Questions to ask wholesalers can be:
    - Are they protecting the source water from agricultural runoff or other concentrated nitrogen and ammonia sources?
    - Are they implementing any organic removal?
    - If the wholesaler is chloraminating before distribution, are they optimizing the chlorine to ammonia ratio to minimize free ammonia in the system?

  - What is their pH, alkalinity and dissolved organic carbon concentrations in the water and are they in an ideal range? The following table lists common parameters and their optimal range to avoid nitrification.

Parameter	Optimum Range
pH	7.5 – 9.0
Alkalinity	> 40.0 mg/L
Total chlorine	≥ 2.0 mg/L
Free ammonia	≤ 0.1 mg/L
Average chloramine residual	≥ 2.6 mg/L
Nitrite	≤ 0.01 mg/L
Nitrate	≤ 0.05 mg/L
HPC	≤ 500
$\frac{chlorine}{ammonia}$	$\frac{5Cl_2}{1NH_3-N}$ *

*Kirmeyer et al. 1993.

  - Does the wholesaler or has the wholesaler considered performing periodic chlorine burns to inactivate nitrifying bacteria?

- Consecutive systems can utilize booster chlorination or breakpoint chlorination in the distribution system to regain the proper chlorine to ammonia ratio and/or to inhibit microbial growth. However, the potential for increased DBP levels does become an issue with booster chlorination and break-point chlorination. See the AWWARF reports titled "Maintaining Distribution Residuals through Booster Chlorination" and "Nitrification Occurrence and Control in Chloraminated Water Systems" for more information.

- If the source water to the consecutive system is a blend, the sources should be assessed and research should be completed to assess chlorine and ammonia concentrations from all source waters and the resulting concentrations after blending.

- Any seasonal changes in source waters should be evaluated. The AWWARF report "Seasonal Chlorination Practices and Impacts to Chloraminating Utilities" provides more information and guidance.

- Long residence times lead to residual degradation and the subsequent increased chance of nitrification. See Sections 5.3.1, 5.3.2, 5.3.3, and 5.4 Consecutive System Treatment Options for more information.

- Water with high demand degrades chloramine and chlorine residuals more quickly, creating more conducive environments for biological regrowth. Primary systems should review Section 5.2.4 for more information, and consecutive systems should collaborate with their wholesalers and/or optimize chloramine/chlorine addition.

- Facilities should be aware that warmer water temperatures enhance nitrification. Review Section 5.1.3 for information.

- Distribution system flushing programs (see Section 5.3.3) can often lessen the conditions that enhance nitrification.

- For systems with an increase in corrosion, adding a corrosion inhibitor can be an option. Example corrosion inhibitors are carbonate containing chemicals, orthosilicates and polysilicates, orthophosphates and polyphosphates and zinc, and all can be added individually or in a combination.

5.3.3. Flushing

Flushing programs can be a temporary or permanent process for distribution systems to maintain water quality. In general, flushing serves one or a combination of the following purposes: 1) scour and clean the distribution system pipes; 2) remove loose deposits and sediments from the system; and 3) remove stagnant water. Removing stagnant water enables systems to restore disinfectant residuals to distant parts of the system, reduce DBP formation, reduce taste and odor complaints, reduce biological regrowth and nitrification, and inhibit the formation of biofilms. Different flushing strategies include spot flushing, stagnant area flushing, and scheduled system-wide flushing. Flushing methods include conventional flushing, unidirectional flushing and continuous blow-off.

The Journal of American Water Works Association published the following article, "Unidirectional Flushing" (Antoun, E. N., Dyksen, J. E., and Hiltebrand (1999)), detailing specifics on establishing flushing programs. Appendix A of the "Consecutive Water System Guidance Document for Navy Installations" (see link UG-2034-ENV Jan 1999 (Guidance Document)) details the description and benefits of a successful unidirectional flushing program. The AWWARF report, Establishing Site Specific Flushing Velocities, provides a detailed study on specific flushing velocities and includes a section of recommendations for systems.

5.3.4. Cross-connections and Backflow Prevention

Cross-connections are defined as points where non-potable water and potable water come into contact. Backflow is the act of non-potable water flowing into the drinking water supply because of low system pressure or high pressure on the side of non-potable water. Most state and primacy agencies require cross-connection and backflow prevention programs.

As required by the OPNAVINST 5090.1B, Navy water systems are required to carry-out cross-connection controls and backflow prevention programs. See the "Consecutive Water System Guidance Document for Navy Installations" (see link https://www.denix.osd.mil/denix/DOD/Working/SDWASSC /sdwassc.html) for more details.

5.4. Consecutive System Treatment Options

Consecutive systems do have a few treatment options to consider for optimization of their distribution systems. Consideration should be given to primary water treatment, distributed water quality, design of distribution system and feasibility in operations and maintenance.

5.4.1. Booster Chlorination

Primary systems are tasked with adequate disinfection requirements, residual maintenance requirements, disinfection byproduct limits and taste and odor control. If treatment is only done at the water treatment plant, all of these objectives must be met simultaneously. Booster chlorination in the distribution system provides the means for primary systems to meet their inactivation goals without dosing to meet residual requirements. Lowering the dose in the primary treatment system and rechlorinating in the distribution system will decrease overall DBP concentrations.

The AWWARF report, "Maintaining Distribution System Residual Through Booster Chlorination", provides detailed information on the benefits of booster chlorination as well as guidance and technical assistance on design and implementation of systems. To optimize booster chlorination, systems should consider performing a hydraulic study. Familiarity of the system is vital in order to assess areas of biggest concern, residence times, demand, flow, optimization of disinfectant and most beneficial points of application.

5.4.2. Breakpoint Chlorination

Breakpoint chlorination, the process of adding chlorine to chloraminated systems until all present ammonia is oxidized and all that remains is free chlorine, can be used to control nitrification, biofilm and other issues, like taste and odor control. The AWWARF report, "Nitrification Occurrence and Control in Chloraminated Water Systems" discusses the use of breakpoint chlorination for the control of nitrification, its most common use.

5.4.3. Storage Isolation

Storage isolation can mean downsizing oversized mainlines, abandoning mainlines, or taking storage tanks off-line. The AWWARF report "Managing Distribution System Retention Time to Improve Water Quality Phase I" discusses these options briefly as means to control water age management. Section 5.3.1., Consultations and hydraulic studies, can help a PWS determine the feasibility of taking any storage facilities off-line. Considerations include emergency needs; daily, weekly, monthly and annual demand; future requirements; etc.

5.4.4. Recirculating Chlorine-Feed System

Recirculation systems in storage facilities function to mix water to a more homogenous state, providing a consistent water quality. A chlorine feed system can be added in order to maintain disinfectant residuals. Maintaining Water Quality in Finished Water Storage Facilities has sections discussing recirculation considerations and requirements and recirculation system design.

6. CASE STUDIES

Case Study #1

Full Scale System Assessment to Address High Disinfection Byproducts

SUBASE Kings Bay

Kings Bay, GA

This case study demonstrates how a utility assessed their current conditions, consulted with an engineering firm, and decided on future capital improvements to address high DBP concentrations in the distribution system in order to comply with the Stage 2 Rule.

Introduction

SUBASE Kings Bay (SKB), located adjacent to the coast of Georgia about 40 miles north of Jacksonville, FL, currently operates a 1.2 MGD softening water treatment plant that treats groundwater. The influent is a combination of water from three different wells less than 3 miles apart. The water is typically very hard (> 300 ppm calcium and magnesium), but has a low average TOC (1.9 mg/L). Typical water quality parameters for the raw well water are presented in Table 6.1.1:

Table 6.1.1 Average water quality parameter values for SUBASE King's Bay.

Parameter	Average value
TOC	1.9 mg/L
DOC	1.5 mg/L
pH	7.48
Alkalinity	155 mg/L
Total hardness	310 mg/L
Temperature	24.2 C
TTHM formation potential	85 µg/L

HAA5 formation potential	27 µg/L
Operating flow	1.2 mgd
Capacity flow	2.5 mgd
Disinfectant type	chlorine
Disinfectant dose	61 GPD
# NOVs	2*

*In past 18 months

Treatment Process

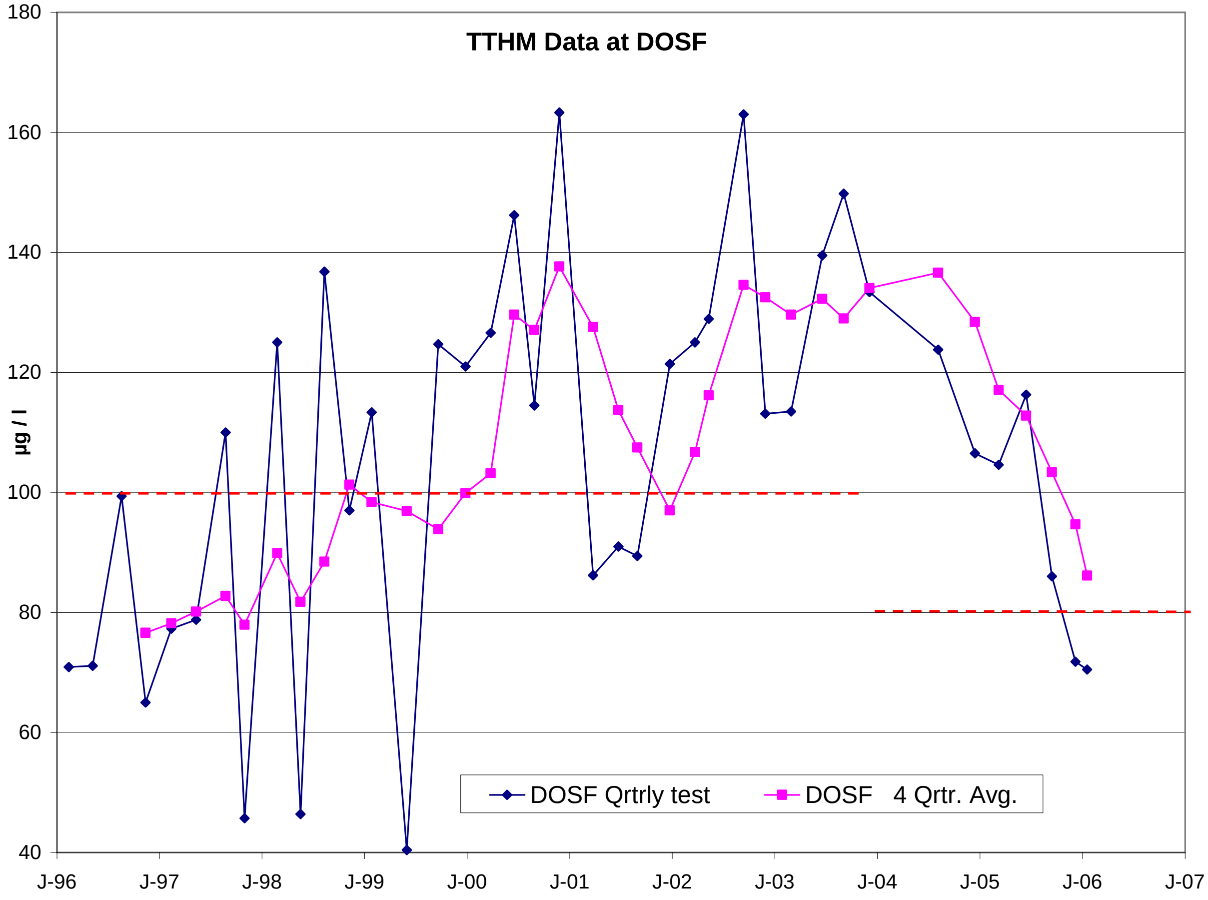
SUBASE King's Bay is an approximately eight to ten square mile (7000 acre) base. The daily supply needs are drawn from three wells no more than three miles apart that feed off the Floridan Aquifer and deliver water to approximately 7000 consumers. The water is extremely hard with values greater than 300 ppm as calcium and magnesium, and with a TOC of approximately 1.9 mg/L. Average operating flow is 1.2 MGD, but the system has a flow capacity of 2.9 MGD.

Raw water is softened to a pH of 11 with caustic soda and then neutralized with carbon dioxide to recarbonate. Through this process, mostly calcium and some magnesium precipitate out, resulting in a hardness of approximately 80 ppm. After the water is softened, it is chlorinated and distributed. The distribution system has approximately 70 miles of lines and 6 million gallons of storage in large mains and storage tanks. Additionally, a chlorine booster station is used to maintain the residual.

Issue

SUBASE King's Bay has received two NOVs for high disinfection byproducts, specifically TTHM levels. While the HAA5 concentrations remain within regulation limits, the TTHM concentrations, under the Stage 1 rule, consistently flirt with the legal limit (80 ug/L). Some of the sample points stay within the MCL, but others reported exceed 100 ug/L. Under the Stage 1 Rule where values were averaged across the distribution system, most of the time, the installation could remain within regulation limits. However, under the new regulations (Stage 2) and the LRAA requirements, those points exceeding the MCL could create a situation where the installation will violate the rule on a regular basis. Figure 6.1.1 shows the fluctuating, and often high concentration values for TTHM as reported from the location denoted as DOSF—a distant point on the distribution system fed by a one-mile 16-inch main and a few thousand-yard 12-inch main. Note that around June of 2000, the values consistently were reported outside regulation limits.

Figure 6.1.1 TTHM concentrations at location DOSF.



The high TTHM concentrations can be attributed to two separate and distinct issues: distribution system detention times and the reactivity of the NOM.

Both a contributing factor to high TTHM concentrations and a separate issue, SKB's detention times are critical. The installation would like to have better water age management. The system was over-designed for a storage capacity of 6 million gallons, far more than required. AH Environmental, Inc. (AH) calculated the current emergency water needs at 1,010,000 gallons (AH, 2006). Furthermore, water turnover has decreased significantly in the past 20 years due to the transitioning of home-based ships to other bases. Fewer ships mean fewer recipients which results in less water usage and turnover. All of these factors create long detention times in the distribution systems.

The raw water for the SKB drinking water treatment system also has a higher than usual content of sulfide, chloride, and bromide, with bromide being the most reactive. This creates a situation where the reaction of the NOM with chlorine is extremely rapid; therefore the majority of the disinfection byproducts are formed in a short time period.

Utility's Past and Present Action Plan

As the numbers continued to increase and rise above regulation limits, SUBASE King's Bay water utility began to study means to correct their TTHM issues in 2002-2003. Studies showed that the reactivity of the raw water organic matter was extremely high (85 µg/L for TTHM). Additionally, it was understood that the system was designed and constructed 20 years ago with a large storage capacity volume located in tanks and oversized mains. Many of the lines had not been maintained since construction. As a first step, in June of 2004, the utility changed from chlorine gas to a hypochlorite solution, and while this allowed for better dosing uniformity, no improvements on TTHM levels were observed. In the fall of 2004 and through early 2005, the large mains were cleaned using scouring pigs, but again, no improvements were seen. In late 2004, SUBASE King's Bay began to flush portions of their distribution system as an interim solution. No formalized flushing plan was put in place, but somewhat routinely, operators would flush various locations of the system. This was the first effective method in lowering the TTHM concentrations. However, a couple of million gallons of water per month were being flushed with as much as 50,000 gallons per day at some of the dead ends. While this improved the TTHM concentrations temporarily and the utility was able to avoid further NOVs in the fourth quarter of 2005, the volume of water usage per day was staggering.

In the mean time, in May of 2005, SUBASE King's Bay hired AH Environmental, Inc. as a consulting firm to assess the system and the TTHM issue. Under the recommendation and direction of AH, the utility established a formal flushing plan in October of 2005 and with time, three automated flush points were put in place in different locations throughout the distribution system. They automatically open in approximately 30 minute intervals. The steady decrease in TTHM values starting in January of 2005 is depicted in Figure 6.1 and represents the benefits of this flushing program.

With the TTHM concentrations under control, SKB approved the completion of a hydraulic study by AH to further assess the current treatment methods being employed. The study confirmed the validity of the flushing techniques and methods already in place and additionally suggested taking a 0.75 MG tank and a 1 MG tank off-line to decrease the storage capacity of the system. In addition, AH recommended reconfiguring parts of the system to decrease short-circuiting, and valving off old lines to eliminate dead-ends and to decrease the overall capacity of the system. As a test, AH also recommended enhanced softening—increasing the pH to 11.3 to precipitate the magnesium (in addition to the calcium) and then neutralizing with sulfuric acid and carbon dioxide to return the pH level to 8 – 8.5 and the hardness to less than 20 mg/L, thereby, in theory, decreasing the overall TTHM formation potential. SKB valved off the 1 MG tank and minimized the level of a 400K gallon tank to decrease the storage capacity of the system and they completed the reconfigurations and eliminations of dead-ends. Improvements in overall ease of operation of the system and in TTHM levels were observed. Enhanced softening was tested, but TTHM formation potential was actually noted to increase.

To address the reactivity of the NOM, AH continued their work on the next level by performing pilot studies utilizing nanofiltration, GAC and/or forms of softening. Six different scenarios were tested:

- aerated raw water / cation exchange softening / anion exchange softening;

- recarbonated water with tripolyphosphate addition / granular activated carbon adsorption;
- filtered water / anion exchange softening;
- recarbonated water without tripolyphosphate addition / granular activated carbon adsorption;
- aerated raw water / anion exchange softening / filtration;
- and non-aerated raw water / nanofiltration.

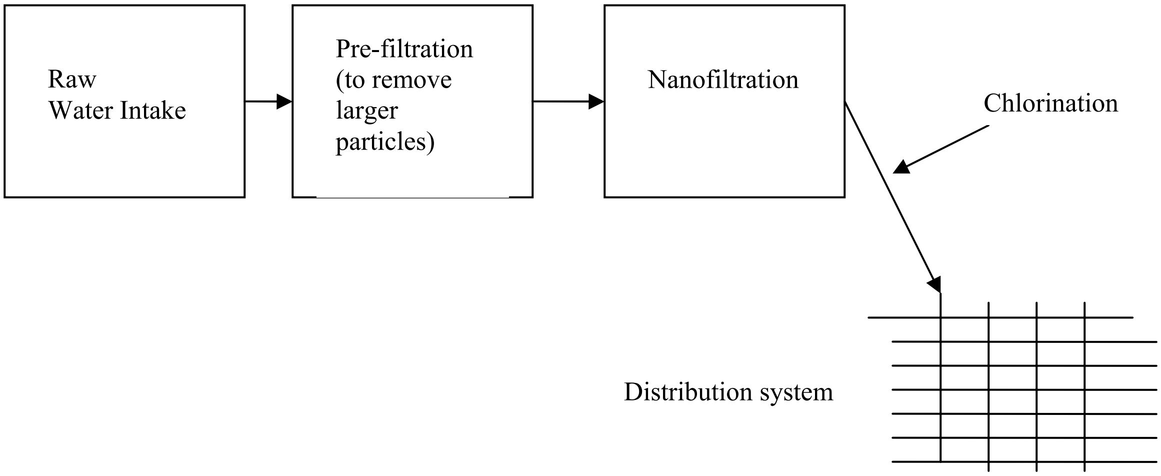
The best results were derived from nanofiltration and granular activated carbon adsorption.

SKB analyzed the installation costs and the life-time usage costs of both technologies. Due to the extreme hardness of the water, they have determined that despite the initial capital costs, the over-life maintenance costs of 100 percent nanofiltration are more attractive. Other advantages of this type of system are:

- the ease of automation of nanofiltration systems;
- the less mess, less hands-on maintenance of the systems;
- the fact that nanofiltration inherently softens the water, eliminating the need for the addition of chemicals to soften the water, as is currently done; and
- the likelihood that nanofiltration will also meet future, more stringent disinfection byproduct rules.

The future SUBASE King's Bay water treatment system configuration is depicted in Figure 6.1.2.

Figure 6.1.2 Flow chart for future SUBASE King's Bay treatment system.



Results of Action Plan

SUBASE King's Bay has been able to prevent further NOVs through their flushing program. However, this is an interim solution as significant volumes of water are wasted.

Remaining Issues

SKB continues to have large quantities of storage volume with low usage. However, additional ships scheduled to base there will help water turnover.

The installation of a nanofiltration system is a large capital investment requiring congressional appropriations. SKB expects to see the funding for the project in the FY 2008 or FY 2009 budget. Until then, the utility will have to continue their strict flushing plan to adhere to the regulations. However, because of the size of the system, compliance to the Stage 2 rule is not required until October 2013. And states can grant up to a two year extension for systems making capital improvements.

Case Study #2

Full Scale System Assessment to Address High Disinfection Byproducts

MCAS YUMA

Yuma, AZ

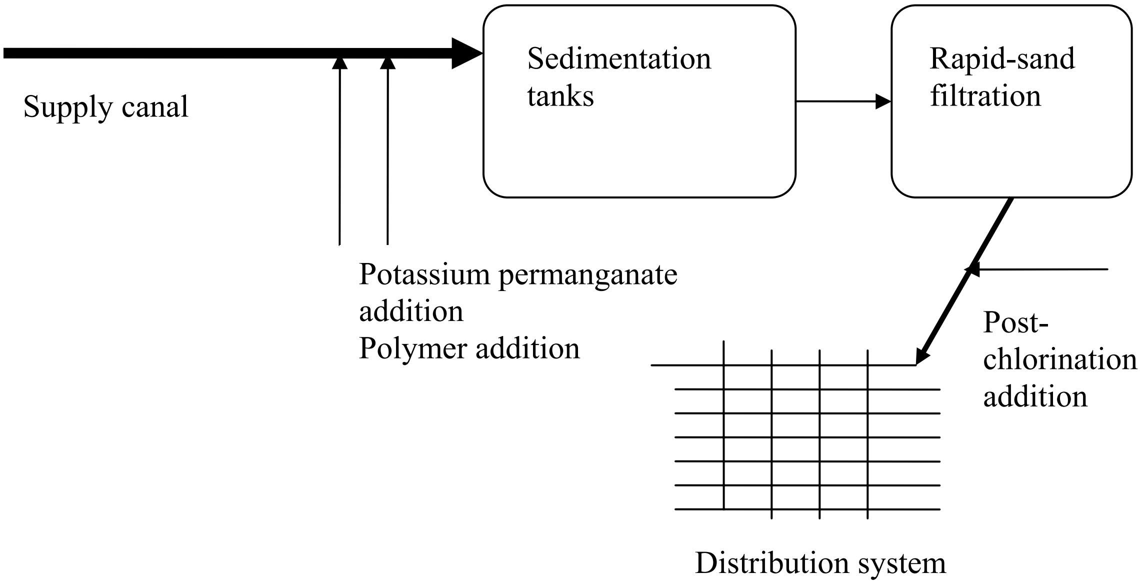
Introduction

Southwest of Yuma, AZ, the five square mile Marine Corps Air Station Yuma (MCAS Yuma) is home to several squadrons, groups and companies. The base houses and employs approximately 6,324 users and is served by a 4.7 MGD sedimentation and filtration treatment plant. The majority of the influent to the plant is supplied by the Yuma Mesa Irrigation and Drainage District supply canal through an agreement with the US Department of Interior, Bureau of Reclamation. A well is also used in conjunction with the main surface water supply blending at a rate of 1/3 to 1/2 with the surface water. During annual canal shutdown and inspection, the water supply comes entirely from the groundwater well. And if the well flow is insufficient, the base has an informal agreement with the City of Yuma to receive their water.

Treatment Process

The MCAS Yuma water treatment plant is supplied by an open, concrete supply canal, which delivers water from reservoir storage created by the Imperial Dam. The treatment plant was built in the mid-1940s as a lime-softening plant and has since been upgraded and expanded several times. The treatment system has not been used as a lime softening plant since the 1950s. Typically, water treatment is conducted as depicted in Figure 6.2.1.

Figure 6.2.1. MCAS Yuma Water Treatment System Configuration.



The raw water comes from the supply canal and potassium permanganate is added for algae control, and polymer is added for better settling. The water flows into three-3 MG sedimentation tanks and after the water is settled, it moves through rapid-sand filtration and is then chlorinated for primary and secondary disinfection. The distribution system consists of approximately 23 miles of lines ranging from three to 16 inches and two storage tanks (one 0.5 MG ground level tank and one 0.5 MG elevated tank).

Typical flows are 1 MGD during the winter months and 3 MGD during the summer months due to irrigation demands. Average water quality parameters are listed in Table 6.2.1.

Table 6.2.1 Water quality parameter values at MCAS Yuma.

Parameter	Average value
TOC	3.5 mg/L
DOC	
pH	8.4
Alkalinity	150 mg/L
Total hardness	420
Temperature Range	13.o to 25.4°C
TTHM formation potential	Not available
HAA5 formation potential	Not available
Operating flow	1 - 3 MGD
Capacity flow	4.7 MGD
Disinfectant type	chlorine
Preoxidant dose	N/a
Disinfectant dose	

Issue

MCAS Yuma exceeded the MCL for TTHM in two quarters of 2005. Due to the number of users, the installation is only required to sample from one point (a point expected to result in the highest TTHM formation) in the distribution system. However, under an approved sampling plan, MCAS Yuma has averaged that one point with three other points in the system, which allows them to remain within regulatory limits most of the time. This approach is appropriate for the Stage 1 rule; however, under the passage of the Stage 2 rule and the requirement of the LRAA, the installation will no longer be able to average across the distribution system. The sample point of most concern will likely create the potential to exceed TTHM regulatory limits on a more consistent basis.

Utility's Past and Present Action Plan

Over time, MCAS Yuma has made improvements and upgrades to the system to deal with age-related issues and water quality issues. In the past two years, the head works were replaced, the sedimentation and backwash recycling basins were replaced, an air scour surface-wash system was added to the filters, a SCADA system was installed for partial automation of the treatment plant, and a standby generator was installed.

More specifically aimed at TTHM exceedances, the water utility has made some alterations in configurations and operations over the past few years. They increased their flushing to help decrease TTHM concentrations. To draw water from the sedmentation basins, floating weirs were installed. This moved the intake from the bottom of the basin, where sediments can be a problem, to the top. They installed better chlorine control for better dosing; and finally, the utility designated a1.5 mile 8"section of the distribution system as fire protection only and now supplies the users with bottled drinking water.

Most recently, MCAS Yuma hired CH2MHill as a consultant to evaluate their water and plant operations. The overall evaluation is in progress, but CH2MHill has recommended three options.

1. Rehabilitating the existing plant into an advanced coagulation facility.
2. Change the existing filters to include granulated activated charcoal.
3. Add additional granulated activated carbon filters to be used when TTHM levels our high.

Results of Action Plan

The Environmental Department funded the Water Plant Initial Study and CH2MHIll provided MCAS Yuma with eight short term recommendations, 5 which have been implemented. The recommendation for disinfection by-product control was to implement chloramination. This recommendation was later rejected after further research found that the use of chloramines during the extreme Arizona summer heat would cause nitrification in the distribution system. A number of long term recommendations were also provided with potential future implementation. The Water Plant Initial Study contract had an option built in for additional evaluation of the long term recommendations. CH2MHILL completed the Water Treatment Alternatives Evaluation Report which gave several options on rehabilitating the WTP with comparative construction cost assumptions. The options have not been implemented. Funding is always a problem. New information was presented on the possibility of using chlorine dioxide, and currently funding is being pursued to do an additional study to further evaluate its use.

Remaining Issues

Because the recommendations implemented are not correcting the TTHM issues, MCAS Yuma must continue to search for solutions. Studies demonstrating the use of alternative disinfectants, especially chlorine dioxide, will be imperative to determine the utility's best option. Furthermore, no matter the change, significant capital funds will be required.

Case Study #3

A Regional Approach for Handling Drinking Water Treatment Issues

Introduction

The NAVFAC MIDLANT (Hampton Roads IPT) region consists of one primary and nine consecutive water systems, serving approximately 85,000 users. In 2000, the majority of these systems were converted to chloramines by the wholesaler to help alleviate issues with disinfection byproducts. By 2004, significant increases in total coliforms were observed; up from 14 reported positives in 2003 to 46 region-wide in 2004. Table 1 provides a basic overview of the treatment systems.

Table 1.

System	Primary Source	Primary Treatment	Secondary Treatment
Cheatham Annex	City of Newport News	Conventional	Chloramines
Craney Island			
Dam Neck Annex*	City of Norfolk	Conventional	Chloramines
Lafayette River Annex			
Naval Air Station Oceana*	City of Norfolk	Conventional	Chloramines
Naval Amphibious Base Little Creek*	City of Norfolk	Conventional	Chloramines
Naval Station Norfolk*	City of Norfolk	Conventional	Chloramines
Naval Support Activity Norfolk			
Naval Support Activity Northwest	Groundwater (Yorktown Aquifer)	Greensand Filtration	Chlorine
Naval Weapon Station Yorktown	City of Newport News	Conventional	Chloramines

Norfolk Naval Shipyard	City of Portsmouth	Conventional	Chloramines

*Water is treated at the Moores Bridges Water Treatment Plant in Norfolk.

Investigation

NAVFAC launched a region-wide investigation to determine the cause of the significant increase in total coliform positives. A number of potential causes were studied: potential sampling or laboratory issues; any common problems among all of the systems; possibility of inadequate disinfection; inefficient and incorrect water program management; over-adequate or aged system design; possibility of biofilm formation; potential internal building piping degradation; and possible municipal source water contamination.

Results of Investigation

The only consistent trend observed was the seasonal increase of positive coliforms. Typically, coliform positives increased during the warmer months. Otherwise, no common thread or particular issue could be identified.

There were concerns of whether the sampler could affect the results or whether the laboratories conducting the analyses were accurate and reliable. It was determined that multiple samplers had taken the positive samples and no trend could be concluded. Correct sampling procedures were also verified. Additionally, the laboratories were found to be reliable and effective. All quality control procedures were sufficient. It was concluded that the results of the positive samples were accurate.

Chlorine and chloramine residuals were reviewed to try and correlate low residual concentrations to increased positive coliforms. While the majority of the positive samples still tested for chlorine residuals greater than 1 mg/L, all of them tested at less than 2 mg/L. Concentrations greater than 2 mg/L have proven more effective at the inactivation of pathogens. Therefore, the lower chlorine concentrations are a concern.

Ineffective or incorrect procedures regarding daily water operation procedures could provide a means to positive coliform sample results. Any trends connected with line breaks and cross-contamination, new connections, backflow prevention devices, and valve operations were studied. No correlations could be observed between line breaks and the positive coliform results. In fact, the utilities have in place and carry-out standard operating procedures for disinfection during repairs and installations. There were concerns whether new connections could be added without going through the proper permitting and disinfection procedures, but it was determined that utilities have adequate permitting programs in place that are implemented as required. Furthermore, a backflow prevention program has operating procedures requiring annual certification, alleviating any concerns of backflow pulling in outside contamination. There were, however, no formal operating procedures for valve operations. But the studied showed that the majority of the program managers utilize good engineering practices and no correlations between valve operations and positive coliform results could be deduced.

Flushing

System design capacities to number of user ratios were studied to determine if over-sized distribution systems are lending to decreased chlorine residuals, low and ineffective turnover rates in storage facilities, increased nitrification and biofilm formation and therefore, subsequent positive coliform results. It was determined that Norfolk Naval Shipyard (NNSY), Saint Juliens Creek Annex (St J), Naval Weapon Station Yorktown, and Cheatham Annex (CAX) were all designed with greater demand than is currently used and could be a contributing factor to the increase in the positive samples.

In addition to over-sized systems, chloramine usage can also increase the likelihood of nitrification and biofilm formation. Because of the use of chloramines in the systems in addition to low flow and sporadic flow conditions, these issues are of particular concern. No additional testing has been completed regarding either condition, but investigators suspect these issues as causes of the recent increase in positives.

Concern for aged and deteriorating piping, which can cause pitting and biofilm formation that harbors pathogens, prompted investigators to study the overall conditions of the piping. Many of the pipes were found to be old and/or cast iron. Utilities are either replacing them on an as-needed basis, or having to put repairs in the capital budget. Like system design, this is a potential factor in the increase in total coliform positive results.

As a last possible contamination source, investigators inquired with the wholesalers and primary treatment systems to determine any source water contaminations and/or other distribution system positives. Most of the public utilities either practiced spot flushing, unidirectional flushing, or free chlorine burn-offs. The utilities had few issues with coliform positives, but regardless, it was determined that better communication between the primary and consecutive systems concerning planned flushing, burn-offs, repairs, changes in treatment, etc. would help the consecutive systems plan and prepare for changes in water quality and the subsequent issues.

Corrective Actions to Date

Overall, as a last possible contamination source, investigators inquired with the wholesalers and primary treatment systems to determine any source water contaminations and/or other distribution system positives. Most of the public utilities either practiced spot flushing, unidirectional flushing, or free chlorine burn-offs. The utilities had few issues with coliform positives, but regardless, it was determined that better communication between the primary and consecutive systems concerning planned flushing, burn-offs, repairs, changes in treatment, etc. would help the consecutive systems plan and prepare for changes in water quality and the subsequent issues.

Specifically, systems with the most significant issues employed aggressive flushing programs and techniques in 2006 to combat the high coliform counts. Spot flushing is used in particularly hot areas. Future and more long-term engineering solutions such as tank isolation and line replacements are being reviewed and implemented as appropriate and as funds are available.

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APPENDICES

Appendix A--Surface Water Treatment Rule

Under the 1989 Surface Water Treatment Rule (SWTR), maximum contaminant level goals (MCLG) were set and National Primary Drinking Water Regulations (NPDWR) were established for all public water utilities using surface water or ground water under the direct influence of surface water (GWUDI). MCLG for *Giardia lamblia,* viruses, and *Legionella* were set at zero, and the NPDWR placed enforceable maximum contaminant levels (MCL) on particular contaminants deemed as harmful. They also described ways to treat the water to remove any contaminants. Unfiltered systems were required to comply by 1991 and filtered systems by 1993. Specifically, the SWTR required:

- maintenance of a disinfectant residual in the distribution system;
- 3-log inactivation for *Giardia* and 4-log removal for viruses;
- combined filter effluent turbidity performance standards; and
- raw water quality standards and source water protection for unfiltered systems.

In 1996, added amendments further enforced legislation recognizing other important drinking water components such as: source water protection for all systems; operator training; water system funding; and public knowledge.

The SWTR can be further reviewed at http://www.epa.gov/ogwdw/therule.html#Surface.

Appendix B--Information Collection Rule

Promulgated in 1996, the Information Collection Rule was established to enable the EPA to collect data and treatment information from water installations to better evaluate current issues and trends. Reported data included the occurrence of pathogens including *Cryptosporidium*, *Giardia*, and viruses, and the occurrence of DBPs and water quality parameters that impact the formation of DBPs. With this information, the EPA could make reasonable and applicable changes to the SWTR if the need arose, and assess the need for new, future regulations (EPA 1996).

For further detailed information, the rule can be viewed in its entirety at http://www.epa.gov/fedrgstr/EPA-WATER/1996/May/Day-14/pr-20972DIR/pr-20972.txt.html.

Appendix C--Interim Enhanced Surface Water Treatment Rule

The December 1998 Interim Enhanced Surface Water Treatment Rule (IESWTR) was enacted to address the balance between microbial disinfection and byproduct formation. It applied only to systems utilizing surface water and systems utilizing GWUDI serving 10,000 people or more. The rule's most significant attributes included:

- an MCLG of zero for *Cryptosporidium*;
- a 2-log removal requirement for filtered systems for *Cryptosporidium*;
- turbidity standards and monitoring requirements;
- storage cover requirements; and
- sanitary survey requirements for all systems. (EPA 1998).

Summaries of the rule, in addition to the PDF version, can be reviewed at http://www.epa.gov/ogwdw/mdbp/ieswtr.html.

Appendix D--Stage 1 Disinfection/Disinfectant Byproduct Rule

Promulgated in 1998 as a part of the 1996 Amendments to the SDWA, the Stage 1 rule, combined with the IESWTR, was the rule that solidified the need for a balance between microbial pathogens and DBP. The rule applied to all community water systems (CWS) and all non-transient non-community water systems (NTNCWS) that treat water with a chemical disinfectant for either primary or secondary disinfection. Compliance deadlines were January 2002 for systems using surface water as a source and GWUDI systems serving at least 10,000 people; and January 2004 for all ground water systems, surface water systems and GWUDI systems serving fewer than 10,000 people.

The rule established maximum residual disinfectant level goals (MRDLG) and maximum residual disinfectant levels (MRDL) for chlorine, chloramine and chlorine dioxide. In addition, the rule established MCLG and MCL for total trihalomethanes (TTHM), five of the haloacetic acids (HAA5), chlorite and bromate. Total trihalomethanes and HAA5 were chosen by the EPA as indicator compounds of unregulated or unidentified chlorinated byproducts because they are produced from treating source water (most commonly with chlorine or chloramines) from varied water qualities. Controlling them, will in turn, control other chlorinated byproducts. Table D.1 is a summary of the level limits for the disinfectants and disinfection byproducts.

Table D.1 MRDLGs, MRDLs, MCLGs and MCLs for Stage 1 Disinfectants and Disinfection Byproducts Rule*

DISINFECTANT RESIDUAL	MRDLG (mg/L)	MRDL (mg/L)	COMPLIANCE BASED ON
Chlorine	4.0 (as Cl_2)	4.0 (as Cl_2)	Annual Average
Chloramine	4.0 (as Cl_2)	4.0 (as Cl_2)	Annual Average
Chlorine Dioxide	0.8 (as ClO_2)	0.8 (as ClO_2)	Daily Samples
DISINFECTION BYPRODUCTS	MCLG (mg/L)	MCL (mg/L)	COMPLIANCE BASED ON
Total trihalomethanes (TTHM)[1]	N/A	0.080	Annual Average
- Chloroform	***		
- Bromodichloromethane	0		
- Dibromochloromethane	0.06		
- Bromoform	0		
Haloacetic acids (five) (HAA5)[2]	N/A	0.060	Annual Average
- Dichloroacetic acid	0		
- Trichloroacetic acid	0.3		
Chlorite	0.8	1.0	Monthly Average
Bromate	0	0.010	Annual Average

*Table copied from EPA website

N/A - Not applicable because there are individual MCLGs for TTHMs or HAAs

*** EPA removed the zero MCLG for chloroform from its National Primary Drinking Water Regulations, effective May 30, 2000, in accordance with an order of the U.S. Court of Appeals for the District of Columbia Circuit.

Additionally, systems using surface water or GWUDI and conventional filtration are required to meet organic removal requirements. Required removal levels are listed in Table 2.2. The organic material is measured as total organic carbon (TOC) and removal can be achieved by enhanced coagulation or enhanced softening unless the system meets alternative criteria (EPA 1998b).

Table D.2 Required Removal of Total Organic Carbon by Enhanced Coagulation and Enhanced Softening for Subpart H Systems Using Conventional Treatment

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0-60	>60-120	$>120_2$
>2.0-4.0	35.00%	25.00%	15.00%
>4.0-8.0	45.00%	35.00%	25.00%
>8.0	50.00%	40.00%	30.00%

For further detailed information regarding the Stage 1 rules and requirements, the rule can be viewed in its entirety at http://www.epa.gov/safewater/mdbp/dbpfr.pdf

Appendix E--Long Term 1 Enhanced Surface Water Treatment Rule

Published in 2002, the Long Term 1 Enhanced Surface Water Treatment Rule extended the IESWTR regulations to all systems utilizing surface water or ground water under the direct influence of surface water (GWUDI) and to any system that supplied drinking water to fewer than 10,000 users. Like the IESWTR, it required 99 percent (or 2-log) removal of *Cryptosporidium*, enhanced filtration, turbidity measurements, microbial inactivation benchmarking, finished water storage coverage, and compliance to updated watershed control requirements by unfiltered systems (EPA 2002).

For further detailed information, the rule can be viewed in its entirety at http://www.epa.gov/fedrgstr/EPA-WATER/2002/January/Day-14/w409.pdf

Appendix F--Total Coliform Rule

Coliform are a large group of usually harmless bacteria that reside in the digestive tracts of mammals. Their presence, however, can be indicative of disease-causing organisms, and therefore, they are often used as indicators of pathogenic organisms in drinking water. A test resulting in positive coliforms can signify troubles in the source water, in the treatment process or in the distribution system (EPA 2001b).

Promulgated in June 1989 and currently still in effect today, the Total Coliform Rule targeted and achieved reductions in illnesses associated with water-borne organisms by establishing an MCL and an MCLG on total coliforms. The rule requires all public water systems (PWS) to monitor for the presence of coliforms in their distribution systems. It also modified the existing testing requirements by requiring testing for fecal coliforms and *Escherichia coli*, and by requiring the use of sample siting plans and sanitary surveys for systems collecting fewer than five samples per month. Sampling frequencies depend on system size (EPA 2001b). "A Quick Reference Guide" (EPA 2001b) can be viewed at the included link. In general, the rule presents the following sampling requirements:

- samples must be collected at sites representing the entire distribution system and pre-determined by sample siting plans;
- samples must be collected throughout each month at regular intervals (except groundwater systems serving less than 4900 persons, who can collect all samples on the same day);
- monthly sampling requirements are based on population (see Appendix G);
- reduced monitoring frequencies are available based on water source and users (see Appendix G);
- positive samples require repeat sampling (see Table F.1 for resampling requirements); and
- any positive test must be further tested for fecal coliforms and *Escherichia coli*;

In the event of an MCL violation, the violation must be reported to the state by the end of the next day and the public must be notified within 14 days. For an acute MCL violation, the state requirements are the same, but public notification must occur within 72 hours.

More information regarding the TCR can be reviewed at http://www.epa.gov/ogwdw/therule.html#Total.

Table F.1 Total Coliform Rule Regulations

System Type	Type of Violation	Regulation	Violation Result
All	MCLG	0	None
Systems sampling over 40 times / month	MCL	No > 5% samples can be +	Additional three samples* must be taken immediately tested within 24 hours, and five additional routine samples must be taken the following month.
Systems sampling less than 40 times / month	MCL	No > 1 sample can be +	Additional three samples* must be taken immediately tested within 24 hours, and five additional routine samples must be taken the following month.
If one of three additional samples are +	MCL	No additional samples can be +	Samples must be tested for *Escherichia* coli and fecal coliforms.
If analysis shows + above the MCL for fecal coliforms and *Escherichia* coli	Acute MCL	--	Immediate action and notification.

*Locations for resampling are described in Appendix G

Appendix G--Lead and Copper Rule

Through corrosion of drinking water pipes, lead (Pb) and copper (Cu) can be released into drinking water supplies. The ingestion of lead has long been associated with various health issues, including neurological damage, altered physical development and blood chemistry, and cardiovascular problems. Increased levels of copper can cause stomach and intestinal distress, liver and/or kidney damage, and can further complicate Wilson's disease (a condition in which the body retains copper) in genetically predisposed people (EPA 2004).

Promulgated in June 1991, the Lead and Copper Rule (LCR) protects public health by limiting concentrations of lead and copper in drinking water. The main two elements of the rule are to reduce corrodibility of the water (thereby reducing lead and copper concentrations leached into the water) and to educate the public. The EPA established action levels (AL) (not violations, but concentrations requiring further monitoring, corrosion control treatments, source water treatment, public education, and/or lead service line replacement) for the two contaminants. These levels have been set at 0.015 mg/L and 1.3 mg/L for lead and copper, respectively. The MCLG are 0.0 mg/L and 1.3 mg/L respectively. The 2000 Minor Revisions were adopted to improve implementation and reporting, but did not change any of the level requirements (EPA 2004).

Sampling requirements are based on users served and risk of Pb or Cu contamination. The required number of sample sites ranges from one to 100. All systems must sample every six months unless qualified for a reduced Pb/Cu tap monitoring schedule. Large systems must also complete water quality parameter (WQP) monitoring, and medium and small systems must complete WQP monitoring in the event of AL violation. WQP monitoring entails the following testing: pH, alkalinity, calcium, conductivity, orthophosphate, silica and temperature. WQP monitoring is utilized to determine water corrosivity and to identify the most appropriate corrosion control treatment (CCT). Further information and requirements can be found at the following link: "Lead and Copper Rule: A Quick Reference Guide" (EPA 2004). Additional information can be reviewed at http://www.epa.gov/safewater/lcrmr/compliancehelp.html.

Appendix H--Long Term 2 Enhanced Surface Water Treatment Rule

General

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2) was promulgated to continue the improvement of water quality and safety of drinking water. The full length version can be reviewed at http://www.epa.gov/safewater/disinfection/lt2/index.html. Specifically, it aims to enforce additional protection from *Cryptosporidium* and other pathogenic microorganisms and contaminants, ensuring that systems are not compromising disinfection in the face of decreasing disinfection byproducts. *Cryptosporidium* is of particular concern because of the number of disease outbreaks caused by it and due to its resistance to traditional disinfection techniques. The LT2 enhances the protection goals set forth by the LT1 rule by enforcing additional *Cryptosporidium* treatment in high risk systems, requiring further provisions to reduce risks from uncovered finished water storage facilities, and enforcing additional precautions be taken to ensure microbial inactivation while systems attempt to decrease their DBP formation.

Affected Water Systems

The LT2 rule applies to all public water systems (PWS) using surface water or ground water under the direct influence (GWUDI) of surface water. Compliance timelines, monitoring and sampling requirements, and treatment requirements are based on the number of users for a system and the type of system.

Compliance requirements

In general, the LT2 rule requires PWS to carry out certain activities within a set time frame. These activities include: conducting an initial source water monitoring program on a pre-defined schedule; determining a treatment bin classification; providing additional treatment for *Cryptosporidium* if applicable; reporting disinfection benchmarks before making any significant changes; reporting the use of and treating of any effluent from uncovered finished water storage facilities; and conducting a second round of source water monitoring after 6 years of initial bin classification. The EPA has broken down the compliance deadline requirements according to system size and the type of facility. The deadlines for the major goals are listed briefly in Table 4.1.2 of Section 4.1. For more specific information, review IV. G. of the Long Term 2 Enhanced Surface Water Treatment Rule; Final Rule at http://www.epa.gov/safewater/disinfection/lt2/index.html.

In general, systems serving greater than 10,000 users will conduct two years of source water monitoring. When completed, they will have six months to report their treatment bin classification. If necessary, additional *Cryptosporidium* treatment must be provided within three years. And a second round of monitoring will be required within six years of the initial bin classification.

Filtered systems serving fewer than 10,000 shall monitor source water for *E. coli* for one year, beginning 30 months after the rule is effective. If results exceed the trigger *E. coli* concentrations, the systems must prepare for *Cryptosporidium* monitoring within the next six months after the initial monitoring period is over and monitor for *Cryptosporidium* within 48 months of the rule's promulgation.

All unfiltered systems serving 10,000 or less shall monitor for *Cryptosporidium* within 48 months of the rule becoming effective. Compliance with *Cryptosporidium* treatment requirements for all systems serving less than 10,000 must be completed within 8.5 years of the rule's inception. And all second round monitoring must begin within 11.5 years.

Monitoring and Sampling Requirements

Monitoring and sampling requirements vary according to system size and type of operation. The rule requires all PWS using surface water or GWUDI to monitor their source water to determine an average *Cryptosporidium* level. These results determine the extent of *Cryptosporidium* treatment and the classification bin that the system will fall into. Bin classification determines treatment requirements. Source water samples must be collected prior to any treatment or chemical addition or prior to any recycled filter backwash addition.

Filtered systems serving greater than 10,000 users ('large' PWS) shall monitor for *Cryptosporidium*, *E. coli* and turbidity for two years. Small, filtered systems (serving fewer than 10,000) shall monitor for *E. coli* for one year. If *E. coli* levels exceed specified 'trigger' values, then the system shall monitor *Cryptosporidium* for an additional one to two years depending on sampling frequency. All unfiltered, small systems shall monitor for *Cryptosporidium* for one to two years, depending on the sampling frequency.

Large Filtered PWS

Filtered systems serving more than 10,000 users must sample for *Cryptosporidium*, *E. coli* and turbidity at least monthly, but can sample more often as long as sampling is evenly spaced throughout the monitoring period. Systems sampling over twice per month shall utilize a separate, less conservative calculation to determine bin classification.

Large Unfiltered PWS

Large, unfiltered systems must also sample at least monthly for two years, but only for *Cryptosporidium*. More frequent sampling is allowed, but does not change the bin classification.

Small Filtered PWS

Small, filtered systems must initially sample and screen for *E. coli* once every two weeks for one year. The results of this analysis direct the system's next phase of sampling. For systems utilizing lakes or reservoirs, a system must start analyzing for *Cryptosporidium* if the annual mean concentration of *E. coli* was 10 *E. coli* per 100 mL or greater; and for systems utilizing flowing water sources, if the annual mean concentration was 50 *E. coli* per 100 mL. Systems utilizing GWUDI must comply with the *E. coli* level rules corresponding to the nearest body of surface water. If there is no surface water near, then the system must comply with *E. coli* levels as stated for lakes and reservoirs. Systems can elect to skip testing for *E. coli* and simply test for *Cryptosporidium* as long as written notice is delivered to the State three months prior to the sampling start.

States can approve alternative indicator organisms besides *E. coli* and they can approve different *E. coli* trigger concentrations. Approvals must be in writing and the variations must assure better determination of whether a system will exceed microbial limits.

Systems required to sample for *Cryptosporidium* must choose one of two schedules. Either testing can be done twice per month for one year, or sampling can be done once per month for two years. Regardless of sampling schedule, all systems are required to meet *Cryptosporidium* treatment compliance deadlines.

Small Unfiltered PWS

All unfiltered systems serving fewer than 10,000 customers must monitor for *Cryptosporidium*. Systems can either sample twice per month for one year or once per month for two years. Regardless of frequency chosen, all systems are required to meet *Cryptosporidium* treatment compliance deadlines.

Treatment Requirements

Filtered Systems

The LT2 rule requires filtered systems of any size to provide more treatment for *Cryptosporidium* if their source waters are determined to have higher concentrations of the organism. Systems are classified in one of four ‘bins’ depending on the results from monitoring and sampling. Treatment requirements are based on the assigned bin number and the type of filtration system an installation utilizes. A Bin 1 classification requires any and all systems to provide no additional treatment, though they must continue to comply with the rules as instituted in the LT1 rule and the IESWTR. Conventional systems or systems employing diatomaceous earth filtration or slow sand filtration must provide an additional 1-log treatment for Bin 2 classification, 2-log treatment for Bin 3 classification, and 2.5-log treatment for Bin 4 classification. For systems utilizing direct filtration, additional treatment requirements are 1.5-log, 2.5-log or 3-log removals, respectively. And for systems employing any alternative filtration technologies (for example, membranes, bag filters or cartridge filters), additional treatment requirements are determined by the State based on the credit the State awards to a particular technology.

Bin 2 classifications can meet the *Cryptosporidium* additional treatment requirements by using any or any combination of the microbial tool box options. For Bin 3 and 4 classifications, at least 1-log of the additional removal treatment must be achieved by using ozone, chlorine dioxide, UV, membranes, bag filtration, cartridge filtration or bank filtration. Overall treatment requirements must be met by using at least two disinfectants.

Unfiltered Systems

All unfiltered systems that use surface water or GWUDI are required to provide additional *Cryptosporidium* treatment. The additional treatment requirements depend on the results of the monitoring and sampling phase. If the level of *Cryptosporidium* is less than or equal to 0.01 oocysts/L, then the required *Cryptosporidium* inactivation is 2-log. If the level is greater than 0.01 oocysts/L or if *Cryptosporidium* was not monitored, then 3-log inactivation is required.

Finally, unfiltered systems must use at least two different disinfectants to provide 4-log removal of viruses, 3-log removal of *Giardia lamblia*, and 2- or 3-log inactivation of *Cryptosporidium*. Each of the two disinfectants must achieve total inactivation required for one of the target pathogens by itself.

Public Notice Requirements

The LT2 rule establishes several different public notice requirements depending on the type of violation. For violations of treatment technique, a Tier 2 public notice is required. For violations regarding monitoring and testing procedures, a Tier 3 public notice is required. And if a system fails to collect three or more samples, a Tier 2 special public notice must be provided. Violations for sampling and monitoring will continue until the State is satisfied with a revised schedule that includes missed samples. Failure of a system to collect required *Cryptosporidium* samples for its bin classification requires that the PWS provide a Tier 2 public notice. Violations will continue until a revised schedule is approved.

Uncovered Finished Water Storage Requirements

Systems utilizing finished water from an uncovered storage facility (defined by the EPA as “a tank, reservoir, or other facility used to store water that will undergo no further treatment to reduce microbial pathogens except residual disinfection and is directly open to the atmosphere” (January 2006a)) are required by the LT2 rule to do two things. First, an uncovered storage facility must report their use of the said facility before April 1, 2008, and then provide the following treatment before April 1, 2009: either cover the storage facility, or treat all water distributed directly to consumers with 4-log virus removal, 3-log *Giardia lamblia* inactivation and 2-log *Cryptosporidium* inactivation.

Disinfection Benchmarking

In order to protect against increasing possibilities of compromising disinfection while reducing disinfection byproducts, the LT2 rule requires disinfection benchmarking prior to making any significant changes to a system’s disinfection practice. Significant changes include moving the point of disinfection, changing the disinfectant, changing the disinfection process, or making any changes designated significant by the State. Disinfection benchmarking requires systems to develop a disinfection profile for *Giardia lamblia* and viruses, and requires systems to calculate their actual disinfection benchmark. The disinfection profile entails documenting the log inactivation levels for one year by recording treatment plant parameters such as disinfectant residuals, contact times, temperatures and pH. The disinfection benchmark is calculated by determining the month with the lowest log inactivation, which becomes the critical period and therefore the benchmark for comparison after the change has been made.

Reporting Requirements

The LT2 rule presents several requirements for reporting the source water monitoring results for *Cryptosporidium*, *E. coli* and turbidity. All systems must report within the first 10 days of the month following the sample month. PWS or certified labs must keep all results for at least 36 months after bin classification has been established. For systems serving greater than 10,000 customers, sampling schedules and monitoring results for the initial source water monitoring must be submitted to the EPA electronically. For systems serving less than 10,000 customers, systems must submit their sampling schedules and monitoring results directly to the State. All systems must submit the requirements for the second round of monitoring to the State.

The reporting requirements for *Cryptosporidium* are identifying the PWS ID, the facility ID, the sample collection point, the sample collection date and the sample type. The results must be reported as sample volume filtered in liters, to the nearest 0.25 L; whether or not 100 percent of the filtered volume was analyzed; and the number of oocysts counted.

For systems collecting *E. coli* and turbidity data, the reporting requirements are identifying the PWS ID, the facility ID, the sample collection point, and the sample collection date. In addition, the analytical method number and method type must be reported, as well as the source water type and the results of the sample, reported in *E. coli* / 100 mL. The turbidity result must also be included.

Sanitary Survey Requirements

The LT2 rule describes requirements that PWS must follow when responding to deficiencies called out in Sanitary Surveys conducted by the EPA. First, systems must respond to reported deficiencies within 45 days, describing how and when the deficiencies will be addressed. Then, PWS must correct the deficiencies as outlined in the sanitary survey according to the approved schedule. (Deficiencies are defined by the LT2 rule as ‘a defect in design, operation, or maintenance, or a failure or malfunction of the sources, treatment, storage, or distribution system that EPA determines to be causing, or has the potential for causing the introduction of contamination into the water delivered to consumers’) (EPA 2006a)).

EPA Recommended Best Available Technologies

The EPA specifies a variety of best available treatment technologies (BAT) to help comply with the LT2 rule and additional *Cryptosporidium* treatment requirements (referred to as the microbial toolbox). (Toolbox guidance manuals can either be located at the EPA website, http://www.epa.gov/safewater/, or can be acquired from EPA’s Safe Drinking Water Hotline.) Filtered PWS in Bin 2 can use any of or any combination of the listed BAT to meet their treatment requirements. PWS in Bins 3 or 4 must achieve at least 1-log removal by using either an approved disinfectant or some form of physical removal (membranes, bag filtration, cartridge filtration or bank filtration). Most of the treatments listed have an assigned treatment credit towards *Cryptosporidium* inactivation, but States can award other treatment credits through a “demonstration of performance”. Compliance with the State is achieved by first reporting the initial design criteria and results, then submitting a monthly report showing the operations criteria and their results. Systems that do not demonstrate the required treatment credit will receive a treatment technique violation. Details of all of the techniques can be reviewed in part IV D of the LT2 Rule http://www.epa.gov/safewater/ disinfection/lt2/index.html. A summary is included here.

Watershed Control Program

The watershed control program has a 0.5 log inactivation credit for *Cryptosporidium* inactivation. In order to receive and maintain the credit, PWS must perform a set of tasks. They must first notify the State their intention to use the program two years prior to the required compliance date, and then they must submit a proposed watershed control plan one year prior to the required treatment compliance date. In order to maintain the credit, PWS must submit an annual watershed control program status report to the State, notify the State prior to making significant changes, and perform and submit a watershed sanitary survey at the same frequency or more as the requirements for regular sanitary surveys to the State. Elements required in a watershed program are defining the area of contamination, identifying sources of contamination, assessing possible control measures, and developing an action plan. The Toolbox Guidance Manual incorporates watershed management into its guidance text. It provides information on effectiveness of control measures and reports on case studies of watershed control management.

Alternate Source

Under State approval, some States may use additional source water monitoring results for an alternative treatment plant intake location or intake operational strategy. Intake is defined as the works or structures where water is diverted from the source into a treatment plant. Changing the intake location or managing the timing or level of withdrawal can help reduce *Cryptosporidium* levels. The requirements for this option include monitoring both the existing plant intake(s) and the alternative intake or operational strategy, monitoring according to the existing bin classification and bin classification deadlines, and submitting the alternative source monitoring results to the State complete with detailed description. If the State approves a bin classification under the alternative source monitoring results, the PWS must relocate the intake or change the operational intake by deadlines specified by the State.

Pre-sedimentation with Coagulant

Pre-sedimentation is a process completed before primary clarification and filtration where a coagulant is added and the water is allowed to settle in order to remove gravel, sand and other particulate material. Under the pretense that the process removes some particulates, the EPA has established a 0.5 log *Cryptosporidium* removal credit for this process if systems meet the following requirements: all flow to the treatment plant must pass through the pre-sedimentation process; coagulant must be continually added to the process; and either the turbidity must have at least a 0.5 log mean reduction or micron-sized particulate material must have at least a 0.5 log mean removal. Additionally, the *Cryptosporidium* sampling point used for monitoring must be upstream of the pre-sedimentation process.

Two-Stage Lime Softening

Lime softening is a process utilized in drinking water treatment where lime (and other chemicals) is added to remove hardness through precipitation. Specifically in two-stage softening, the chemical addition and the precipitation occur in two separate, sequential processes prior to filtration. Drinking water systems can receive 0.5 log *Cryptosporidium* treatment credit if they meet the following conditions: the chemical addition and precipitation do occur in two separate steps prior to filtration; and both steps treat the entire source water flow.

Through the chemical addition and precipitation processes, particulates flocculate and settle, enabling the removal of them, including *Cryptosporidium*. Further removal is accomplished downstream through clarification and filtration.

Bank Filtration

Bank filtration is a process where surface water is forced through a river bank or bed(s) to mimic or enhance natural infiltration, and then the water is recovered by pumping wells. The infiltration action removes microorganisms and other particles. If the process is prior to a filtration plant, the system is eligible for *Cryptosporidium* treatment credit (depending on the ground water flow path (0.5-log for 25 feet and 1.0-log for 50 feet)) under certain conditions. The conditions to meet are: the wells are located in granular (sand, clay, silt, and rock fragments, pebbles or larger, and minor cement) aquifers; the wells must be horizontal or vertical; and turbidity must be monitored once every four hours while the process is in operation.

Systems can elect to apply to the State for treatment credit using bank filtration through the demonstration of performance process. The study must follow a State-approved protocol, incorporate the *Cryptosporidium* removal data; and include sampling from the production wells and the monitoring wells. The State can award greater than 1.0-log *Cryptosporidium* credit if the demonstration of performance supports it.

Combined Filter Performance

Public water systems utilizing conventional or direct filtration can receive an additional 0.5-log *Cryptosporidium* treatment credit if the turbidity level of the combined filtered water is less than or equal to 0.15 NTU in at least 95 percent of the measurements taken each month. Turbidity is used as an indicator for measuring removal of particulate matter and microorganisms. Systems using other types of filtration, e.g., slow sand, diatomaceous earth, membranes, bag or cartridge filtration are not eligible because these types of filtration remove *Cryptosporidium* by different mechanisms.

Individual Filter Performance

Targeting low turbidity in individual filters should provide additional protection from microbial pathogens, so PWS can receive an additional 0.5-log treatment credit for individual filter performance. Systems are required to take turbidity samples every 15 minutes. In order to receive the credit, the filtered water turbidity for each filter must be less than or equal to 0.15 NTU in at least 95 percent of the measurements recorded each month, and no individual filter can have a measured turbidity greater than 0.3 NTU in any two consecutive samples taken 15 minutes apart. If a system receives credit for individual filter performance, they automatically receive credit for combined filter performance. As combined filter performance, individual filter performance is not applicable to systems utilizing other filtration systems.

Demonstration of Performance

Public water systems may choose to conduct a demonstration of performance to establish a *Cryptosporidium* treatment credit higher than the prescribed credit, or to establish a *Cryptosporidium* treatment credit for a treatment process not listed in the microbial toolbox. The credit must be based on a site-specific demonstration of *Cryptosporidium* removal efficiency and the demonstration must follow a State-approved protocol. The State must approve the demonstration in written notification and can designate monitoring and treatment criteria. If credit is received through a demonstration of performance, the PWS is not eligible for any other prescribed treatment credit.

Bag and Cartridge Filtration

As a viable option for smaller systems, *Cryptosporidium* treatment credit of up to 2.0-log for an individual bag and 2.5-log for two or more bag or cartridge filters operated in series can be received. Bag and cartridge filtration are processes utilizing porous media that remove particulate matter larger than 1 micrometer. Bag filters are non-rigid, fabric material housed in a pressure vessel. The direction of flow is from the inside out. Cartridge filters are more rigid, also under pressure and the flow is from the outside in.

To establish treatment credit, the filters must be challenge tested. The test must be conducted on full-size filters that must match the filters that will be used in the treatment process. The testing includes measuring the removal of *Cryptosporidium* or a surrogate, and the method must quantify the type of particulate measured. Monitoring should be conducted in 3 phases: within two hours of start-up; when the pressure drop is between 45 and 55 percent; and when the pressure drop has reached 100 percent. Log removal values (termed LRV_{filter}) should be calculated. During the testing, the filters should operate at full design flow to reach the maximum design pressure drop. The $LRVs_{filter}$ for each filter are used to determine the removal efficiency for the product. The credit is the removal efficiency minus a 1.0-log safety factor up to a maximum of 2.0-log treatment credit for a single filter and the removal efficiency minus 0.5-log safety credit up to a maximum of 2.5-log treatment credit for filters in series.

Membrane Filtration

Membrane filtration is a pressure or vacuum driven separation process which typically removes particulate matter larger than 1 micrometer. Removal credit for membrane filtration processes is obtained by establishing removal efficiencies through challenge testing and sensitivities through direct integrity testing. The direct integrity testing must also be conducted periodically to verify the system integrity, and indirect integrity monitoring must be continuously conducted during membrane use.

Challenge testing must be conducted on either a full-scale module or small-scale model of the membrane filter that the PWS will use. *Cryptosporidium* or a surrogate that is removed no more efficiently must be monitored and the chosen particulate must be quantifiable. The LRV is calculated based on the removal efficiency. Testing must be conducted under representative hydraulic conditions under maximum flux and maximum design process recovery. In addition to the LRV, a quality control release value (QCRV) must also be calculated.

The direct integrity testing is completed to identify any leaks and must demonstrate a removal efficiency equal to or greater than the removal credit awarded to the process. Continuous indirect integrity monitoring involves continuous testing of the filtrate, every 15 minutes, to verify water quality.

Second Stage Filtration

Second stage filtration is defined by the LT2 rule as granular media filtration that follows a first stage granular media filtration. Public water systems can receive 0.5-log removal credit for second stage filtration if it is second stage filtration, the first stage filtration follows coagulation, 100 percent of the flow must be treated by both filtration processes and the state has approved the treatment credit. Credit will not be applied under this term if it is bag filters, cartridge filters, membranes, or slow sand filters. Nor can PWS receive additional credit for both second stage filtration and filter effluent turbidity based on levels following second stage filtration.

Slow Sand Filtration

Slow sand filtration typically involves passing raw water through a bed of sand at very low velocities. It is effective at removing particulate matter and systems can receive a 2.5-log *Cryptosporidium* credit if the filter is placed after primary filtration. Additionally, a disinfectant residual must exist in the water entering the slow sand filter, 100 percent of the flow must be treated, and the process must be State approved

Ozone and Chlorine Dioxide

Shown to be effective for disinfecting *Cryptosporidium,* ozone and chlorine dioxide can be utilized to meet additional *Cryptosporidium* treatment requirements. The water temperature, disinfectant contact time, and residual disinfectant concentration must be measured at least once per day. The values measured are used to determine the log inactivation utilizing Table IV.D-3 and Table IV.D-4 of the LT2 rule. Disinfectants can be used in sequence and the log removals can be figured for each one.

Ultraviolet Light

Ultraviolet light (UV) can also be used to comply with *Cryptosporidium* treatment requirements (in addition to existing *Giardia lamblia* and virus treatment requirements). PWS using UV can achieve credit by operating reactors validated to achieve the required UV dose and monitoring the reactors to demonstrate operation with those conditions. Dose requirements for log credit are listed in Table IV.D-5 of the LT2 rule.

Appendix I--Stage 2 Disinfectant/Disinfection Byproduct Rule

The Stage 2 Disinfectant and Disinfection Byproducts Rule (Stage 2) supplements the Stage 1 Rule to address higher risk systems that may not have adequate protection from disinfection byproducts (DBP) under the existing regulations. The Stage 2 rule contains MCLG for chloroform, monochloroacetic acid and trichloroacetic acid. It also includes revisions to the monitoring requirements for bromate and changes to the monitoring, reporting and public notification requirements for TTHM and HAA5. The MCL for DBP covered in the Stage 1 rule (TTHM, HAA5, chlorite and bromate) do not change; however, the Stage 2 rule now regulates both primary and consecutive PWS that are community and nontransient noncommunity water systems. The rule is designed to address the formation of disinfection byproducts without compromising microbial disinfection.

Affected Water Systems

Drinking water installations potentially required to comply with the Stage 2 are community and nontransient noncommunity water systems, both primary and consecutive, that utilize a primary or secondary disinfectant other than ultraviolet light. This includes industry and Federal, State, Local, and Tribal governments.

Maximum Contaminant Level Goals

Maximum Contaminant Level Goals (MCLG) are set to guard the public from adverse health effects. The Stage 2 rule establishes MCLG for chloroform and two of the haloacetic acids: monochloroacetic acid (MCAA) and trichloroacetic acid (TCAA). The MCLG for chloroform is set at 0.07 mg/L, and for MCAA and TCAA, it is set at 0.02 mg/L and 0.07 mg/L, respectively.

Consecutive Systems

The Stage 2 rule specifically addresses compliance by consecutive systems in order to provide the same protection to users as those whose water supply falls under the Stage 1 rule. The EPA defines consecutive systems as public water systems that receive all or part of their distributed finished water from another water system. Finished water is water that requires no further treatment except that which to maintain a disinfectant residual or provide other water quality maintenance. The rule includes monitoring, compliance scheduling and other requirements specifically aimed at consecutive systems.

Consecutive systems are required to meet the same TTHM and HAA5 standards as wholesale and primary systems. They must use specified analytical methods, and complete associated monitoring, reporting, and public notification requirements. Under the Stage 2, they must comply with the monitoring requirements and the maximum residual disinfectant levels for chlorine and chloramines.

Initial Distribution System Evaluation

In order to locate the areas of highest DBP concentrations for monitoring under Locational Running Annual Average (LRAA) requirements, the EPA, through the Stage 2 rule, is requiring all systems to complete an Initial Distribution System Evaluation (IDSE). This requirement applies to all CWS, consecutive systems, and to large noncommunity water systems serving at least 10,000 people that utilize a disinfectant other than ultraviolet light. Systems serving 500 users or less are not required to complete an IDSE if they have the appropriate TTHM and HAA5 data.

Systems have three approaches for meeting the IDSE requirements: standard monitoring, system specific studies, or 40/30 certification. Under the standard monitoring requirements, systems will prepare and submit a monitoring plan for review and then, monitor their distribution system for one year following the approved plan. The frequency and number of samples is based on system size and source water type. A system may also choose to conduct a system specific study, which is based on system monitoring studies and system hydraulic monitoring. A study plan must be completed and approved first. The third approach available to systems is 40/30 certification. Under this choice, systems must certify that all compliance samples taken during a pre-specified period had TTHM and HAA5 concentrations less than 0.040 mg/L and 0.030 mg/L, respectively, and that there were no TTHM or HAA5 violations during the same period. Specific requirements for all three approaches are defined in Section IV, F of the Stage 2 Compliance Dates, from the Stage 2 Disinfectants and Disinfection Byproducts Rule; Final Rule (http://www.epa.gov/fedrgstr/EPA-WATER/2006/January/Day-04/w03.pdf).

All systems are required to monitor for the IDSE during the peak historical month for DBP levels or water temperatures. Frequencies and locations for monitoring are described in Table IV, G-1 of the Stage 2 Rule, p. 426 (http://www.epa.gov/fedrgstr/EPA-WATER/2006/January/Day-04/w03.pdf).

Compliance Requirements

The Stage 2 rule lists three major activities that have compliance timelines: IDSE completion; Stage 2 monitoring locations determination; and Stage 2 MCL compliance. The deadlines are based on system size, except for consecutive systems, which are required to follow the same timetables as the largest system in the combined distribution system. Table IV,E-1—IDSE and Stage 2 Compliance Dates, from the Stage 2 Disinfectants and Disinfection Byproducts Rule; Final Rule (http://www.epa.gov/fedrgstr/EPA-WATER/2006/January/Day-04/w03.pdf), p.415, presents the timelines for IDSE planning, monitoring and submission requirements; standard monitoring and/or system specific study requirements; IDSE report submission requirements and compliance monitoring requirements. Figure IV, E.-1—Final Stage 2 DBPR and LT2ESWTR Implementation Schedule, p. 416 (http://www.epa.gov/fedrgstr/EPA-WATER/2006/January/Day-04/w03.pdf), shows the timeline relationships between the Stage 2 and LT2 rules.

Monitoring and Sampling Requirements

As opposed to calculating a system-wide annual average for TTHM and HAA5 concentrations, the Stage 2 Rule requires all systems, including consecutive systems, to use the LRAA to determine compliance to the MCL 0.08 mg/L and 0.06 mg/L, respectively. That is, installations must average their results from one location over time.

The sampling location points are determined based on the Initial Distribution System Evaluation (IDSE) if the system conducted standard monitoring or a system specific study. Systems receiving 40/30 certification or a very small system waiver, and NTNCWS serving less than 10,000 can base monitoring locations on existing Stage 1 results. The locations are determined by arraying the results from the IDSE and Stage 1 compliance monitoring. Frequencies are based on system size. Table IV G-2 of the Stage 2 rule (http://www.epa.gov/fedrgstr/EPA-WATER/2006/January/Day-04/w03.pdf) lists the frequencies and locations. As in the Stage 1 Rule, data must be reported within 10 days of end of the quarter and data results must be retained for 10 years.

Compliance Determination

Compliance is achieved when the LRAA is less than or equal to the MCL. If an MCL in a quarter is exceeded, the system is not in immediate violation, but quarterly sampling must be increased. If the LRAA exceeds an MCL for four quarters, then the system is out of compliance.

Evaluation Level Requirements

To address high levels of DBP that exceed the MCL in a single quarter, despite the overall system being in compliance annually, the Stage 2 Rule establishes operational evaluation requirements. Each system will be required to determine if they exceeded an operational evaluation level (OEL), a concentration less than the MCL, but high enough to trigger a response from the system. It will provide the system an early detection method and allow for proactive steps to avoid future MCL violations. The rule calls for systems to conduct operational evaluations and report them to the State. Operational evaluations are initiated by the OEL, which is determined by the system's Stage 2 compliance monitoring results. For each monitoring location, systems should use the following formula to determine their OEL:

If $\frac{Q_1 + Q_2 + 2Q_3}{4} > MCL$, then the system must conduct an operational evaluation

(where Q_1 = quarter before previous quarter measurement;

Q_2 = previous quarter measurement;

Q_3 = current quarter measurement.)

The operational evaluation includes systems investigating current treatment and distribution practices to determine a culprit for high DBP levels. A report must be submitted within 90 days of exceeding the operational evaluation level.

Public Notice Requirements

No changes were made from the language in the Stage 1 Rule regarding public notice requirements for TTHM, HAA5 or TOC.

Bromate

The Stage 2 Rule does not change the bromate values established by the Stage 1 Rule for the MCL (0.010 mg/L) or the monitoring point (entrance to the distribution system). The one change made was the criterion for a system utilizing ozone. If a system is using ozone, they may qualify for reduced bromate monitoring if low levels of bromate (as opposed to bromide as described in the Stage 1 Rule) are shown.

EPA Recommended Best Available Technologies

The EPA is required by the Safe Drinking Water Act to specify best available technologies (BAT) to help systems comply with the MCL of the various rules. If systems are unable to meet the MCL after employing the recommended BAT, they may apply for a variance. General variances may be granted to systems of any size that cannot comply with the MCL because of their source water. In this case, a compliance schedule and any additional control measures must be prescribed and the variance cannot result in any risk to public health. Small system variances can be issued to small PWS (those serving fewer than 10,000) if it is determined that the system cannot afford to comply or that the terms of the variance will ensure protection of public health.

The EPA lists three BAT, for systems that treat their own source water, to help comply with the Stage 2 Rule and specifically, comply with the TTHM and HAA5 LRAA MCL. For larger systems, GAC10 (granular activated carbon filter beds with an empty-bed contact time of 10 minutes based on average daily flow and a carbon reactivation frequency of every 120 days) is recommended for precursor removal. For smaller systems, GAC20 (empty bed contact time of 20 minutes and a carbon reactivation frequency of every 240 days) is recommended. The third recommendation, nanofiltration (NF), using a membrane with a molecular weight cutoff of 1000 Daltons or less, would generally suit ground waters with high TOC values.

The techniques discussed for primary systems are not relevant to consecutive systems because the technologies' success is based on precursor removal. Furthermore, GAC is not a cost-effective tool for removing DBP and nanofiltration has only been shown to be moderately effective at removing DBP. Overall, the best compliance technique for consecutive systems is collaboration with the wholesalers. But the EPA also lists chloramination with management of hydraulic flow and storage for systems that distribute to at least 10,000 people and simply management of hydraulic flow and storage for systems that distribute to fewer than 10,000 people. Managing the hydraulic flow and residence time of a distribution system will also manage chloramine residuals and reduce DBP concentrations and nitrification.