TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

DIRECTED ASSISTANCE MODULE NO. 4A

CHLORAMINE DISINFECTION AND DBP CONTROL AT SURFACE WATER TREATMENT PLANTS (SWTPS)

LAST REVISION DATE:
VERSION 8 MAY 2013

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I. Introduction

Background

The recent regulatory trend toward stricter limits on disinfection byproduct (DBP) levels in drinking water has resulted in widespread efforts to develop disinfection strategies that provide the required protection against pathogens while minimizing the formation of DBPs. To accomplish this, many large utilities have made substantial investments in alternate disinfectants such as ozone and chlorine dioxide. Others are evaluating the use of emerging disinfectants such as ultraviolet light. The vast majority of utilities, however, are focusing on chloramination as a disinfection process that is both proven and cost-effective. This has resulted in a growing demand for technical guidance in developing effective chloramination strategies, particularly at smaller surface water treatment plants.

Primary Objective

The primary objective of this module is to provide directed assistance to surface water treatment plants in developing a chloramination strategy that meets minimum disinfection requirements and effectively controls the formation of DBPs.

Plant Applicability

The technical guidance provided in this module is applicable to utilities that are considering the use of chloramination for primary disinfection, as well as utilities that are having problems with existing chloramination processes. The guidance does not consider the expanded capability of plants with disinfection processes that utilize chlorine dioxide, ozone, or ultraviolet light; nor does it address the disinfection byproducts associated with these other processes.

Schedule of Activities

The module consists of 12 hours of directed assistance that is provided during two separate site visits to the treatment plant. During the first visit, the trainer conducts a 4-hour special study to obtain data on DBP formation rates at the plant. During the second site visit, the trainer provides 8 hours of directed assistance to develop a chloramination configuration and process control procedures that are best suited for the specific conditions at the treatment plant. The Schedule of Activities in Attachment 1 provides additional information on the basic activities associated with the module and the time it takes to complete each activity.

Training Provided

The directed assistance provided by this module includes related technical training for the treatment plant staff. After completing the module, the plant staff should be familiar with the procedures for:

1. evaluating potential chloramination configurations based on disinfection credit,
2. evaluating potential chloramination configurations based on DBP formation rates,
3. evaluating operational procedures for controlling the chloramination process, and
4. developing an action plan for implementing an effective chloramination strategy.

II. DBP Formation

As mentioned previously, the objective of this module is to develop a chloramination strategy that meets minimum disinfection requirements and effectively controls disinfection byproducts (DBPs). The first step toward this end is to identify basic information about the type of disinfection byproducts that form and the rate at which the formation takes place.

Chloramination and DBP Formation

The chloramination process, by its very nature, includes a period of free chlorination that occurs after the addition of chlorine and before the addition of ammonia. This period can be as short as several seconds or as long as several hours. As a result, the potential DBPs associated with chloramination are basically the same as those associated with free chlorination: trihalomethanes (THMs) and haloacetic acids (HAAs). For the purpose of this module, the assessment and control of DBPs will focus primarily on THMs, although it may be possible to establish useful correlations with HAAs. Disinfection byproducts associated with the use of other disinfection strategies, such as chlorite created by chlorine dioxide and bromate created by ozone, are beyond the scope of this module and are not considered.

THMs form when free chlorine combines with organic precursors that are present in the source water supplied to the treatment plant. The rate at which this formation takes place is of particular interest because it defines how much, if any, free chlorination can be used to supplement the chloramination process. The THM formation rate depends largely on the type of precursors that are present and the associated THM constituents. For the sake of convenience, THM constituents can be divided into two general groups: chloroform THM and brominated THMs. Chloroform THM, as the designation indicates, consists of chloroform. Brominated THMs include bromoform, bromodichloromethane, and dibromochloromethane.

The distinction between chloroform THM and brominated THMs is useful because the two groups of constituents typically have formation rates that are significantly different. Chloroform THM tends to form more slowly allowing the use of limited or extended periods of free chlorination in the treatment process without creating unacceptable THM levels. Brominated THMs, on the other hand, tend to form more rapidly and may severely restrict free chlorine contact time. In both cases, there are significant implications with respect to the development of an effective chloramination strategy.

DBP Formation Assessment

The maximum contaminant levels (MCLs) for THMs and HAAs established by federal and state drinking water standards are 0.080 mg/L (80 ug/L) and 0.060 mg/L (60 ug/L), respectively. Utilities that are not able to comply with the MCLs must notify their customers of the violation and are subject to enforcement action by TCEQ. Because the assessment of DBP formation in this module focuses primarily on THM levels, the MCL of 0.080 mg/L will be used as a key parameter in developing an effective chloramination strategy.

A couple of issues must be considered in using the MCL of 0.080 mg/L to assess THM formation at a treatment plant. First, the MCL is based on a running annual average of quarterly averages, not on the results from individual quarters. This means it may be possible for a utility to have THM levels above 0.080 mg/L during one or two quarters without actually violating the MCL. This is especially true in cases where THM levels are moderately higher than 0.080 mg/L during the summer months, but much lower during the rest of the year.

Second, the THM MCL is based on the analysis of samples collected from the distribution system, where THM levels tend to be significantly higher than those at the plant due to continuing THM formation.

Although chloramination dramatically reduces THM formation in the distribution system, it does not prevent it altogether. In most cases, THM levels following chloramination increase by 10% or so in the distribution system. For this reason, THM levels below 0.060 mg/L should be targeted at the plant to assure levels below 0.080 mg/L in the distribution system. HAA formation trends in the distribution system are more difficult to predict, and in many cases, actually decrease in the distribution system.

For the purposes of this module, then, DBP formation will be assessed based on whether THM levels below 0.060 mg/L can be maintained at the plant using chloramination. The assessment will focus primarily on the THM levels that occur within the first 15 minutes of free chlorine exposure. It should be emphasized that this approach is designed to evaluate potential chloramination configurations with respect to current regulatory limits for THMs. In practice, however, DBP control efforts should not only assure regulatory compliance, but should target DBP levels that are as low as possible. This is particularly important since regulatory requirements related to DBPs are expected to become even more stringent in the near future.

DBP Formation Data Sources

Information on the type of DBPs that form at a treatment plant, and the rate at which they form, is available from several sources. The annual chemical analysis of the treatment plant effluent provides basic information on the type and levels of THM constituents leaving the plant. Similar information is also available from quarterly monitoring of THM and HAA levels in the distribution system. In some cases, the brominated THM data included in these records provides a general indication of the THM formation rate. However, a THM Formation Rate Study should be conducted to obtain quantitative information on the actual rate at which THM constituents form. Instructions for conducting such a study are provided in Attachment 3.

DBP Formation Data Form

The DBP Formation Data Form provided in Attachment 2 should be used to document information related to DBP formation associated with the treatment process. The form includes provisions for recording DBP data from annual chemical analysis results on the treatment plant effluent, quarterly THM and HAA results on distribution samples, and the results of the THM Formation Rate Study. The completed DBP Formation Data Form and the guidance in this section should be used to complete the second part of the Process Configuration Form in Attachment 5.

III. Disinfection Credit

The disinfection credit provided by the existing plant facilities plays a key role in developing an effective chloramination process. In particular, the treatment process must be evaluated to determine if sufficient detention time exists to meet minimum disinfection requirements with chloramination alone, or if a period of free chlorination is necessary to supplement the chloramination process. To make this determination, an electronic CT Study Template developed by TCEQ is used to calculate the disinfection credit provided by basic chloramination configurations. The template includes a Description Worksheet, T_{10} Details Worksheet, Summary Worksheet, and Calculator Worksheet.

The information necessary to complete the CT Study Template is usually available from the following sources: the current CT Study Approval Letter for the treatment plant, as-built engineering drawings and specifications, a plant schematic showing the location of existing chemical feed points, and information from the plant staff on the worst-case flow rates, temperatures, and pH conditions that occur seasonally.

Description Worksheet

The Description Worksheet in the CT Study Template is used to identify the disinfection zones in the treatment process. In order to assess potential changes to the disinfection process, each component of the treatment process should be identified as a separate disinfection zone. For example, the raw water supply line, clarification process, filtration process, and clearwell storage should be identified as four separate disinfection zones. Additional units such as flocculation basins or transfer wells may also need to be identified as separate zones. Care should be taken to properly identify parallel units that may exist within a single disinfection zone.

T_{10} Details Worksheet

The T_{10} Details Worksheet is used to calculate the T_{10} values for each of the disinfection zones. Information on unit dimensions, baffling factors, and flow rates must be entered to determine the effective volume and T_{10} value for each disinfection zone. This information is usually documented in the CT Study Approval Letter. If not, the data can be obtained from plant drawings or actual measurements.

The T_{10} Details Worksheet is also used to identify the type of disinfectant that will be used in each zone. Initially, the disinfectant in all of the zones should be identified as chloramine since the first configuration to be assessed will be based on chloramination through the entire treatment process. Then, if necessary, the disinfectant in one or more of the zones can be changed to free chlorine to assess other possible configurations.

Summary Worksheet

The information that is entered into the Description Worksheet and the T_{10} Details Worksheet is automatically summarized in the Summary Worksheet of the CT Study Template. Some of the information is also transferred to the Calculator Worksheet.

Calculator Worksheet

The Calculator Worksheet is used to actually calculate the Giardia and viral inactivation ratios provided by a particular chloramination configuration. These ratios must be at least 1.0 in order to meet minimum disinfection requirements. Required log inactivations of Giardia and viruses must be entered, as well as disinfectant residuals, and worst-case flow, temperature, and pH conditions. The required log inactivations for Giardia and viruses are usually 0.5 and 2.0, respectively, although the CT Study Approval Letter should be reviewed to confirm this. Disinfectant residuals through each zone should be estimated at the high end, usually around 2.0 mg/L for free chlorine and 3.0 mg/L for chloramine (as measured by total chlorine). Worst-case flow rate and water quality parameters should be based on seasonal conditions. In most cases, these conditions occur during the summer due to high flow conditions, although there may be cases where worst-case conditions occur during the winter due to low water temperatures.

Disinfection Credit Assessment

Once the data described above has been entered in the CT Study Template, the Calculator Worksheet can be used to assess potential chloramination configurations by entering the appropriate disinfectant types and residuals. In most cases, this assessment focuses on one or two basic configurations. First, the disinfection credit is calculated based on the use of chloramination through all of the disinfection zones under worst case seasonal conditions. If the resulting inactivation ratio is less than 1.0, a second assessment should be conducted based on the use of free chlorination through the filtration process and chloramination through clearwell storage.

CT Study Template Worksheets

Copies of the completed CT Study Worksheets should be printed out to document the results of the disinfection credit assessment. Examples of completed CT Study Worksheets are provided in Attachment 4. The information in the completed CT Study Worksheets should be used to complete the first part of the Process Configuration Form in Attachment 5.

IV. Process Configuration

The chloramination process at a surface water treatment plant is based on the addition of chlorine and ammonia. The physical configuration of the chlorine and ammonia feed points must consider several important issues. To begin with, the chlorine must be added before the ammonia to assure acceptable viral inactivation unless another disinfectant such as ozone or chlorine dioxide is providing equivalent protection. Beyond this, the distance between the chlorine and ammonia feed points, and their relative location in the treatment process, are usually dictated by three considerations: compliance with the minimum disinfection requirements, the rate at which DBPs form under free chlorine conditions, and the need for secondary disinfection benefits such as improved particle formation and algae control.

Minimum Disinfection Requirements

Compliance with the minimum disinfection requirements must be the first consideration in evaluating potential configurations for the chloramination process. A disinfection process that provides effective DBP control without assuring proper inactivation of disease-causing organisms may reduce long-term risks associated with DBP exposure, but increases the short-term risk of waterborne illnesses associated with pathogens.

The effectiveness of chloramination in meeting minimum disinfection requirements is a function of the detention time and associated disinfection credit that is possible using the existing plant facilities. For example, if the existing facilities provide sufficient detention time, it may be possible to utilize chloramine disinfection through the entire treatment process. Under these conditions, the chlorine and ammonia are usually added just ahead of the rapid mixing unit at the front of the plant. The chlorine is added slightly upstream of the ammonia to assure acceptable viral inactivation. Also, post-filtration chlorine and ammonia feed points are usually necessary to properly control the chloramine residual supplied to the distribution system.

On the other hand, if the existing treatment facilities do not provide sufficient chloramine contact time to meet minimum disinfection requirements, a limited period of free chlorine contact time may be necessary prior to adding ammonia. In such cases, chlorine is typically added ahead of the filters and ammonia after the filters. Depending on the rate of DBP formation under free chlorine conditions, the chlorine feed point can be moved farther upstream or the ammonia feed point moved farther downstream to increase free chlorine contact time and the associated disinfection credit.

DBP Formation Rate

Assuming the treatment plant facilities provide sufficient capacity to meet minimum disinfection requirements utilizing some form of chloramination, the next consideration in evaluating potential chloramination configurations is the control of DBPs, specifically THMs. The THM formation rate typically dictates the amount of free chlorine contact time that can be allowed, and the associated chlorine and ammonia feed point locations in the treatment process.

For example, source water with rapid THM formation potential can severely limit the use of free chlorine contact time in the treatment process. This is particularly true in the case of brominated THM constituents which, in some cases, can form almost immediately. Moderate THM formation rates, on the other hand, may allow brief periods of free chlorine contact without forming unacceptable DBP levels. Similarly, THM formation rates that are slow may allow extended free chlorine contact time with only nominal DBP formation.

Secondary Disinfection Benefits

In addition to minimum disinfection requirements and the rate of DBP formation, the development of an effective chloramination process should also consider the potential impact on the secondary treatment benefits associated with disinfection. These considerations are related primarily to the impact of reducing or eliminating the use of free chlorine through the treatment process. The most common areas affected are particle formation during coagulation, particle removal during clarification and filtration, and algae control in open treatment basins.

The significance of secondary treatment benefits associated with disinfection depends on whether the benefits are essential to the treatment process, and if so, whether supplemental chemicals can be used to achieve equivalent results. For example, potassium permanganate is often fed in the raw water supply line to improve coagulation, and copper sulfate to control algae growth in the clarifiers. The secondary benefits of disinfection are inherent in configurations that utilize free chlorination or chloramination through most or all of the treatment process. Configurations that limit free chlorination or chloramination to the later stages of treatment (such as the addition of chlorine after the clarification process) do not provide the same benefits, and supplemental chemicals may be necessary if such benefits are essential to the treatment process.

Basic Process Configurations

This module focuses on three basic process configurations that are commonly used to meet minimum disinfection requirements, minimize DBP formation, and support secondary disinfection benefits. These configurations and the issues associated with them are explained in Table 1.

The three configurations are not intended to be exclusive. Plant-specific conditions may allow variations in a particular configuration. For example, if the treatment facilities include a disinfectant contact chamber between the filters and clearwell storage, the free chlorine contact time associated with Configuration B can be extended before ammonia is added. Other conditions that provide similar flexibility include clearwells with enhanced baffling and clearwells that are operated in series rather than parallel. In addition, seasonal changes in source water quality at a plant may dictate the use of more than one configuration over the course of the year.

It is important to note that some plant specific conditions can severely limit or even prevent the use of chloramination as a viable disinfection process. For example, a rapid THM formation rate can prevent the use of free chlorination to provide additional disinfection credit, and insufficient detention time through the treatment process can prevent the use of chloramination alone to meet disinfection requirements. When these two conditions both exist, the plant facilities may have to be modified to provide additional chloramine detention time or alternate disinfectants such as chlorine dioxide or ozone may have to be considered.

Process Configuration Form

The Process Configuration Form included provided in Attachment 5 should be used to identify which of the three basic process configurations is most likely to provide the required disinfection credit, minimize DBP formation, and support secondary disinfection objectives given the specific conditions at the treatment plant. The information documented in the CT Study Worksheets should be used to evaluate the process configurations based on minimum disinfection requirements. The information documented on the DBP Formation Data Form should be used to evaluate the configurations with respect to DBP formation rates. Finally, information provided by the plant staff should be used to evaluate the configurations based on secondary disinfection benefits such as improved particle formation and algae control.

The guidance in this section and the completed Process Configuration Form should be used to identify specific action steps related to process configuration that will be included in the Recommended Action Plan in Attachment 7.

TABLE 1: BASIC PROCESS CONFIGURATIONS

Configuration Description	Configuration A Chloramination with Minimal Free Chlorination	Configuration B Chloramination with Limited Free Chlorination	Configuration C Chloramination with Extended Free Chlorination
Applicable DBP Formation Rate	Rapid DBP formation rate causes high DBP levels in a short period of time	Moderate DBP formation rate allows limited free chlorination without substantial DBP formation	Slow DBP formation rate allows extended free chlorination without substantial DBP formation
Minimum Disinfection Requirements (CT Credit)	Chloramination through the clarifiers, filters, and clearwells	Free chlorination through the filters, and chloramination through the clearwells	Free chlorination through the clarifiers and filters, and chloramination through the clearwells; or free chlorination through the clarifiers, and chloramination through the filters and clearwells
Disinfectant Feed Point Locations	Chlorine followed by ammonia at the raw water supply line prior to the rapid mixing unit	Chlorine at the clarifier effluent, and ammonia at the combined filter effluent	Chlorine at the raw supply line, and ammonia at the clarifier effluent or the combined filter effluent
Secondary Disinfection Benefits (Supplemental Chemicals)	Secondary disinfection benefits are inherent in Configuration A and supplemental chemicals are usually not necessary	Potassium permanganate at the raw water supply line, coagulant aid at the rapid mixing unit, flocculant aid at the flocculation unit, and filter aid ahead of the filters for improved particle formation; copper sulfate ahead of the clarifiers for algae control	Secondary disinfection benefits are inherent in Configuration C and supplemental chemicals are usually not necessary
Distribution Residual Control	Chlorine and ammonia at the combined filter effluent	Distribution residual control is inherent in Configuration B and additional chlorine and ammonia feed points are usually not necessary	Chlorine and ammonia at the combined filter effluent

V. Process Control

An effective chloramination strategy is not limited to the proper location of chlorine and ammonia feed points in the treatment process. A process control program must be developed and implemented to assure that the chloramination process consistently achieves the desired results. This program should assure adequate capability for feeding disinfectant chemicals, identification of an optimum chlorine-to-ammonia ratio, and proper procedures for monitoring and adjusting the chloramination process.

Chemical Feed Facilities

The chemical feed facilities at a treatment plant provide essential physical support for process control efforts by the plant staff. In this respect, the feed equipment that is used to deliver disinfectants and related chemicals must be designed to allow effective dosage control over the full range of expected feed rates and must be able to deliver 50% more than the highest expected feed rate. The feed equipment must also include provisions for determining the chemical feed rate that is being delivered. In the case of gaseous chemicals, this capability is typically provided by a rotometer. For liquid chemicals, the feed pump piping is usually equipped with a calibration cylinder.

The availability of standby disinfectant feed points and monitoring points at critical locations in the treatment process also facilitates process control efforts by providing expanded flexibility. However, it must be emphasized that all such standby points must be properly documented in the most current CT Study approved for the treatment plant.

Chlorine-to-Ammonia Ratio

The chlorine-to-ammonia ratio used by the plant staff to proportion chlorine and ammonia feed rates provides an important benchmark for proper control of the chloramination process. Chlorine-to-ammonia ratios are usually reported using one of two methods. The first method is based on the weight of chlorine to the weight of ammonia. The second method is based on the weight of chlorine to the weight of nitrogen in ammonia. The references and chemical formulas associated with these methods are shown below.

Metho d	**Basis for Method**	**Common Reference**	**Chemical Formula**
1	weight of ammonia	chlorine-to-ammonia ratio	$Cl_2:NH_3$ ratio
2	weight of nitrogen in ammonia	chlorine-to-nitrogen ratio *or* chlorine-to-ammonia nitrogen ratio	$Cl_2:N$ ratio *or* $Cl_2:NH_3$-N ratio

The difference in the two methods is basically the difference between the atomic weight of ammonia (17.0306) and the atomic weight of nitrogen (14.0026). Conversion from one method to the other is as follows:

$Cl_2:N$ x (14.0026) 17.0306) = $Cl_2:N$ x 0.822 = $Cl_2:NH_3$

$Cl_2:NH_3$ x (17.0306) 14.0026) = $Cl_2:NH_3$ x 1.216 = $Cl_2:N$

It is important to understand both reporting methods since both methods are in common use throughout the water industry. For the purpose of this module, however, the chlorine-to-ammonia ($Cl_2:NH_3$) ratio will be used for the sake of consistency.

Chlorine-to-Ammonia Ratio *(continued)*

In theory, a Cl_2:NH_3 ratio of 4.2 :1 is optimum for forming monochloramines (the preferred chloramine species). That means a free chlorine residual of 4.2 mg/L theoretically requires an ammonia dose of 1.0 mg/L to form 4.2 mg/L of monochloramine. In practice, Cl_2:NH_3 ratios are affected by plant specific conditions and usually range from 3:1 to 5:1. Ratios below 3:1 can result in excessive ammonia levels in the distribution system that facilitate nitrification. Ratios above 5:1, on the other hand, can result in the formation of undesirable chloramine species (dichloramine and nitrogen trichloride) that cause objectionable taste and odor problems. Moreover, disproportionately high ratios can lead to breakpoint chlorination resulting in a free chlorine residual and the associated formation of DBPs. As a result, most plants target a Cl_2:NH_3 ratio of 4:1 as a good starting point for effective control of the chloramination process.

Process Monitoring Procedures

Process monitoring activities related to chloramination focus on the collection of information that is necessary to evaluate current process conditions and provide direction for needed adjustments. Such monitoring activities typically include regular determinations of the chlorine and ammonia feed rates, the free chlorine available for the chloramine reaction, and the total chlorine residual, free chlorine residual, and free ammonia residual created by the chloramine reaction.

The chlorine feed rate is monitored to assure that the proper amount of chlorine is available for the chloramine reaction, and the ammonia feed rate is monitored to assure the proper proportion of ammonia with respect to the desired Cl_2:NH_3 ratio.

The amount of chlorine available for the chloramine reaction is usually determined using one of two methods. The first method is based on the free chlorine residual just prior to the addition of ammonia, while the second is based on the chlorine dose at the point of chlorine addition. The first method is preferable because the chlorine that is available for the chloramine reaction can decrease significantly between the point of chlorine addition and the point of ammonia addition. This is especially true under high chlorine demand conditions such as occur through clarifiers and filters (Configurations C and B). However, the second method may have application under very low chlorine demand conditions such as sometimes occur when ammonia is added immediately downstream of chlorine in the raw water line (Configuration A).

The total chlorine residual, free chlorine residual, and free ammonia residual are monitored after the chloramine reaction to confirm that the desired chloramine residual (measured as total chlorine residual) has been achieved, and the free chlorine residual and free ammonia residual leaving the plant are as low as possible (usually less than 0.05 mg/L).

Process Adjustment Procedures

Process adjustment activities related to chloramination consist of actual changes that are made to the chlorine and ammonia feed rates with respect to the desired Cl_2:NH_3 ratio and associated disinfectant residuals. The method for determining the direction and degree of adjustment varies from plant to plant, although the fundamental concepts that are used should be the same.

Adjustment of the chlorine feed rate is relatively straightforward when the plant staff is using a Cl_2:NH_3 ratio based on the free chlorine residual just prior to ammonia addition. In this case, the chlorine feed rate is simply set to achieve a specific free chlorine residual at a certain point in the treatment process. However, if the plant staff is using a Cl_2:NH_3 ratio based on applied chlorine dose at the point of chlorine addition, the chlorine feed rate is set with respect to the ammonia feed rate.

Process Adjustment Procedures *(continued)*

Adjustment of the ammonia feed rate is more involved and requires information on the type of ammonia being used, the desired $Cl_2:NH_3$ ratio, the chlorine available for the chloramine reaction, and the plant flow rate. In the case of gas ammonia, for example, the ammonia feed rate in lbs/day for a $Cl_2:NH_3$ ratio of 4:1, a free chlorine residual of 2.0 mg/L just prior to ammonia addition, and a plant flow rate of 0.6 MGD is calculated as follows:

$$\frac{2.0 \text{ mg/L} \times 0.6 \text{ MGD} \times 8.34 \text{ lbs/gal}}{4} = 2.5 \text{ lbs/day of Gas Ammonia}$$

In the case of liquid ammonium sulfate (LAS) with a specific gravity of 1.23 and available ammonia of 10%, the ammonia feed rate in mL/min for the same hypothetical plant conditions is calculated as follows:

$$\frac{2.0 \text{ mg/L} \times 0.6 \text{ MGD}}{4 \times 0.10 \times 1.23} = 2.44 \text{ gal/day} \times \frac{3{,}785 \text{ mL/gal}}{1{,}440 \text{ min/day}} = 6.4 \text{ mL/min of 40\% LAS}$$

As previously mentioned, a chlorine-to-ammonia ratio of 4:1 is recommended as a good starting point for effective control of the chloramination process. However, chlorine and ammonia feed rates usually require further adjustment to account for plant specific conditions. In such cases, the adjustments should be made based on the target levels for total chlorine residual, free chlorine residual, and free ammonia residual leaving the plant.

Once the desired chlorine and ammonia feed rates have been determined, the feed equipment must be physically adjusted to actually deliver the proper amount of chemicals to the appropriate point in the treatment process. Adjusting gas chlorine and gas ammonia feed equipment is accomplished by setting the gas rotometer on the desired feed rate in pounds per day. Adjusting liquid chlorine and liquid ammonia feed rates requires a little more expertise in that a calibration cylinder or calibration curve is used to set the feed pump stroke or speed for the desired feed rate in milliliters per minute. More detailed information on calculating chemical feed rates and adjusting chemical feeders is provided in ADirected Assistance Module 2 - Establishing Appropriate Chemical Feed Rates@.

Process Control Form

The Process Control Form included in Attachment 6 should be used to evaluate process control information related to the existing disinfection strategy at the plant. The form includes three parts. The first part of the form focuses on the physical design and features of the chemical feed facilities used to deliver disinfection chemicals at the plant. The second part of the form documents the sampling and testing activities used by the plant staff to monitor the existing disinfection process. These two parts of the form should be completed regardless of whether chloramination is currently in use at the plant.

The third part of the form evaluates the process adjustment procedures that the plant staff use to control the chloramination process, and should be completed only if chloramination is currently in use at the plant. The process adjustment procedures are evaluated in two ways. First, the $Cl_2:NH_3$ ratio reported by the plant staff is compared with the $Cl_2:NH_3$ ratio that is calculated using actual plant conditions. Second, the disinfectant residuals created by the chloramination process are assessed to determine if the target chloramine residual (measured as total chlorine residual) is achieved, and if the free chlorine and free ammonia residuals resulting from the chloramine reaction are as low as possible.

The completed Process Control Form and the guidance in this section should be used to identify specific action steps related to process control that will be included in the Recommended Action Plan in Attachment 7.

VI. Recommended Action Plan

Once the process configuration and process control procedures associated with an effective chloramination strategy have been identified, steps must be taken to assure that the strategy is actually implemented. In an effort to facilitate this effort, a Recommended Action Plan should be developed that identifies the specific action that will be taken, who will be responsible, and the date the action will be completed. The Recommended Action Plan Form in Attachment 7 is provided to allow a mechanism for formalizing the action that will be taken. The form is divided into process configuration issues, process control issues, and a third category for other relevant issues. The following are examples of typical issues in each of these categories.

<u>Process Configuration Issues</u>

Prepare and submit engineering plans and specifications as required for the following changes [1]

Prepare and submit a revised CT Study as required for the following changes [2]

Install new feed equipment for disinfectant chemicals (gas ammonia, LAS, gas chlorine, etc.)
Install new disinfectant application points at ______________________________________
Install bulk storage and containment facilities for disinfectant chemicals
Contract for supply of ANSI certified disinfection chemicals

<u>Process Control Issues</u>

Begin monitoring free chlorine residuals immediately prior to ammonia addition
Begin measuring total chlorine, free chlorine, and free ammonia residuals after ammonia addition
Revise the treatment plant monitoring plan to reflect monitoring changes
Obtain laboratory equipment for measuring free ammonia levels
Develop written procedures for calculating chlorine and ammonia feed rates
Develop written procedures for calibrating and adjusting disinfectant feed pumps

<u>Other Issues</u>

Prepare and submit engineering plans and specifications as required for the following changes [1]

Prepare and submit a revised CT Study as required for the following changes [2]

Install clearwell baffling to increase available chloramine detention time
Re-pipe the clearwells to operate in series and increase chloramine detention time
Modify fixed speed raw water pumping equipment to allow reduced flow rates during winter months
Feed a coagulant aid instead of free chlorine in the rapid mixing basin to improve particle formation
Feed potassium permanganate instead of free chlorine in the raw water line to oxidize manganese
Feed copper sulfate instead of free chlorine in the rapid mixing basin to control algae in the clarifiers
Conduct additional THM Formation Rate Study to evaluate impact of seasonal changes.

IMPORTANT

[1] *Plans and specifications prepared by a Licensed Professional Engineer must be submitted to TCEQ for review and written approval prior to making any significant changes to the treatment process. Examples of significant changes include the installation of new chemical feed equipment, the construction of bulk chemical storage facilities, and the modification of clearwells to increase detention time.*

[2] *Revised CT Studies must be submitted to TCEQ for review and written approval prior to*

activating any new facilities that will change the existing disinfection process at the plant.

ATTACHMENT 1

SCHEDULE OF ACTIVITIES

DIRECTED ASSISTANCE MODULE NO. 4
CHLORAMINE DISINFECTION AND DBP CONTROL

Schedule of Activities

First Site Visit	
Time	Activity
1:00 p.m. - 1:30 p.m.	Equipment Setup (30 minutes)
1:30 p.m. - 4:30 p.m.	THM Formation Rate Study (180 minutes)
4:30 p.m. - 5:00 p.m.	Sample Preparation and Shipping (30 minutes)

Second Site Visit	
Time	Activity
8:30 a.m. - 9:00 a.m.	Introductions and Overview (30 minutes)
9:00 a.m. - 10:00 a.m.	Plant Tour (60 minutes)
10:00 a.m. - 10:15 a.m.	Break (15 minutes)
10:15 a.m. - 10:45 a.m.	DBP Formation Data (30 minutes)
10:45 a.m. - 11:45 p.m.	Disinfection Credit (60 minutes)
11:45 p.m. - 12:45 p.m.	Lunch (60 minutes)
12:45 p.m. - 1:45 p.m.	Process Configuration (60 minutes)
1:45 p.m. - 2:45 p.m.	Process Control (60 minutes)
2:45 p.m. - 3:00 p.m.	Break (15 minutes)
3:00 p.m. - 4:00 p.m.	Recommended Action Plan (60 minutes)
4:00 p.m. - 4:30 p.m.	Wrap Up and Questionnaires (30 minutes)

ATTACHMENT 2

DBP FORMATION DATA FORM

DIRECTED ASSISTANCE MODULE NO. 4
CHLORAMINE DISINFECTION AND DBP CONTROL

DBP FORMATION DATA FORM

The purpose of this form is to document information related to the type and formation rate of disinfection byproducts, specifically THM constituents.

I. THM Levels in the Treatment Plant Effluent

Collect the following information on THM levels in the treatment plant effluent from the Annual Chemical Analysis Reports over the past four years.

Date	Total THM	Chloroform THM	Brominated THM

II. DBP Levels in the Distribution System

Collect the following information on the maximum TTHM and HAA5 levels in the distribution system over the past four quarters.

Date	Maximum TTHM	Chloroform THM	Brominated THM	Maximum HAA5

III. Results from THM Formation Rate Study

Enter the results from the THM Formation Rate Study, if one was conducted.

Time (minutes)	Total THM	Chloroform THM	Brominated THM
1			
2			
5			
10			
15			
20			
30			
60			
120			
240			
360			

Refer to Attachment 3 for note on time constraints related to 120, 240 and 360 minute samples.

ATTACHMENT 3

INSTRUCTIONS FOR CONDUCTING THM FORMATION RATE STUDY

DIRECTED ASSISTANCE MODULE NO. 4
CHLORAMINE DISINFECTION AND DBP CONTROL

Instructions for Conducting THM Formation Rate Study

Objective:

To provide a real time evaluation of the rate at which THM constituents form when the source water supplied to the treatment plant is dosed with free chlorine.

Preparation:

Confirm that the utility has made arrangements for analytical services with an approved laboratory.
Confirm availability of the equipment and materials needed to conduct the study.
Determine the sampling sequence that will be used in the study.

Note: A typical sampling sequence includes eight duplicate samples collected at 1, 2, 5, 10, 15, 20, 30, and 60 minutes. Sampling events representing longer elapsed times of 120, 240, and 360 minutes are not recommended unless the THM formation rate is unusually slow, and the data is needed to evaluate the use of extended free chlorination. In most cases, a sample should also be collected (without preservation) to determine the maximum THM potential of the source water. If recycling is practiced at the plant, it is also useful to collect a sample from the recycle stream for THM analysis.

Equipment and Materials:

Laboratory equipment and reagents for high-range measurements of free chlorine residuals
THM sample vials (duplicate vials for each sampling event)
Jar test stirrer
One 2-liter jar with a sample port
Pipets (10 mL)
Volumetric flask (1,000 mL)
Liquid sodium hypochlorite (6% available chlorine)
Deionized water
5-gallon bucket
Shipping materials (laboratory forms, sample labels, plastic bags, shipping forms, ice chest, ice, tape)

Procedure:

Add 25 mL of 6% liquid bleach to 975 mL of deionized water.
1 mL of this solution in a 2-liter jar equals a chlorine dosage of approximately 0.85 mg/L.
Fill a 2-liter jar with the untreated source water supplied to the plant.
Set the jar on the stirrer and mix at a moderate speed (100 rpm).
Dose the jar with 1 mL of the prepared chlorine solution, and purge the sample port.
Sample the jar after two minutes of exposure and measure the free chlorine residual.
Add a second 1 mL dose of chlorine solution, purge the sample port, and measure the free chlorine residual.
Continue adding 1 mL doses until a free chlorine residual of approximately 3.0 mg/L is achieved.

Thoroughly rinse out the 2-liter jar and refill it with untreated source water.
Set the jar on the stirrer and mix at a moderate speed.
Add the chlorine dose necessary to produce a free chlorine residual of approximately 3.0 mg/L.
Turn the stirrer off and purge the sample port on the jar. (No subsequent purging is necessary.)
Collect THM sample sets according to the desired sampling sequence.
Label each sample set and prepare the necessary analysis request forms.
Seal the sample sets in plastic bags, pack the bags in ice, and seal the ice chest.
Prepare the shipping forms, and ship the ice chest and analysis request forms to the approved laboratory.

ATTACHMENT 4

EXAMPLES OF COMPLETED CT STUDY TEMPLATE WORKSHEETS

DIRECTED ASSISTANCE MODULE NO. 4

CHLORAMINE DISINFECTION AND DBP CONTROL

Example of Completed Description Worksheet

EXAMPLE OF COMPLETED T_{10} DETAILS WORKSHEET

EXAMPLE OF COMPLETED SUMMARY WORKSHEET

Example of Completed CT Calculator Worksheet

ATTACHMENT 5

PROCESS CONFIGURATION FORM

DIRECTED ASSISTANCE MODULE NO. 4
CHLORAMINE DISINFECTION AND DBP CONTROL

The purpose of this form is to identify which of the three basic process configurations described in Table 1 is most likely to meet minimum disinfection requirements, minimize DBP formation, and provide secondary disinfection benefits given the specific conditions at the treatment plant.

- A Chloramination with Minimal Free Chlorination
- B Chloramination with Limited Free Chlorination
- C Chloramination with Extended Free Chlorination

I. Minimum Disinfection Requirements

Identify the preferred process configuration(s) based on whether chloramination alone provides all or only part of the required disinfection credit. For example, if sufficient chloramine disinfection credit is available to completely satisfy minimum disinfection requirements, circle AABC@ under AComplete@. If not, circle ABC@ under APartial@.

Required Disinfection Credit Provided by Chloramination Alone	Complete	Partial
Chloramination Configuration(s)	A B C	B C

NOTE: Multiple configurations are listed in order of preference with regard to lowest potential for DBP formation.

II. DBP Formation Rate

Identify the preferred process configuration(s) based on the THM formation rate and the type of clarification facilities. For example, if the plant has conventional sedimentation and a rapid THM formation rate, circle AAB@ in the first box below ARapid@.

THM Formation Rate (based on 0.060 mg/L)	Very Rapid [1] (< 5 min)	Rapid [2] (5 - 15 min)	Moderate (15 - 120 min)	Slow (120 - 360 min)	Very Slow (> 360 min)
Chloramination Configuration(s) w/ Conventional Sedimentation	A	A B	A B	A B	A B C
Chloramination Configuration(s) w/ Solids Contact Clarification	A	A B	A B	A B C	A B C
Chloramination Configuration(s) w/ High-rate Clarification [3]		B	B C	B C	B C

[1] *If the THM formation rate is very rapid, and Configuration A does not provide the required disinfection credit, the plant facilities will have to be modified to provide additional chloramine detention time or an alternate disinfection strategy will have to be considered. Also, if the THM formation rate is so rapid that unacceptable THM levels form instantaneously, an alternate disinfection strategy will have to be considered.*

[2] *If the THM formation rate is at the low end of the rapid range (5 minutes), and Configuration A does not provide the required disinfection credit, and Configuration B requires more than 5 minutes of free chlorination to provide the required disinfection credit, the plant facilities will have to be modified to provide additional chloramine detention time or an alternate disinfection strategy considered.*

[3] *Configuration A is typically not an option for high-rate clarification processes such as those utilized in Trident, Roberts, and Actiflow designs because there is not enough chloramine detention time to meet minimum disinfection requirements.*

III. Secondary Benefits of Disinfection

Identify the preferred chloramination configuration(s) that are common to Parts I and II based on whether secondary disinfection benefits are essential or optional. Secondary disinfection benefits are related primarily to improved particle formation and algae control. Such benefits are usually inherent in Configurations A and C, but not in Configuration B.

Secondary Benefits Essential [1]		Secondary Benefits Optional [2]
Chloramination Configuration(s) without Supplemental Chemicals	Chloramination Configuration with Supplemental Chemicals	Chloramination Configuration(s) Regardless of Supplemental Chemicals
A C	B	A B C

[1] *If secondary disinfection benefits are essential to the treatment process, and the preferred configurations common to Parts I and II include Configurations A or C, circle AAC@ in the first column to indicate that supplemental chemicals are not necessary to provide secondary benefits. If the preferred configurations common to Parts I and II are limited to Configuration B, circle AB@ in the second column to indicate that supplemental chemicals are necessary to provide secondary benefits.*

[2] *If secondary disinfection benefits are considered optional, circle AABC@ in the third column to indicate that all three chloramination configurations are viable alternatives, regardless of whether supplemental chemicals are used or not.*

IV. Chloramination Configuration

Identify the chloramination configuration that is best suited for meeting the regulatory requirements related to disinfection credit and DBP control, and for supporting secondary disinfection benefits. In the case of Configuration B, indicate whether supplemental chemicals are necessary to provide secondary disinfection benefits.

Best Chloramination Configuration	A	B	C
Supplemental Chemicals Required		Yes / No	

Attachment 6

Process Control Form

Directed Assistance Module No. 4

Chloramine Disinfection and DBP Control

Process Control Form

The purpose of this form is to document physical and operational aspects of the current disinfection process at the plant.

I. Chemical Feed Facilities

Collect the following information on the chemical feed facilities related to the disinfection process, including the facilities used to provide secondary disinfection benefits.

Feed Point Location	Feed Point Status (active or standby)	Chemical Product (gas Cl_2, LAS, etc.)	Max. Capacity (lb/day, gal/day)	Measurement Device

II.Process Monitoring Procedures

Collect the following information related to the monitoring procedures for disinfectant feed rates and residuals.

Monitoring Point Location	Parameter	Frequency	Testing Method	Measured Level

PROCESS CONTROL FORM *(continued)*

III. Process Adjustment Procedures

Collect the following information related to process adjustment procedures for existing chloramination processes.

Applied Disinfectant Dose		Measured Disinfectant Residual			
Applied Cl_2 Dose before NH_3 [1]	Applied NH_3 Dose [2]	Free Cl_2 Residual before NH_3 [3]	Total Cl_2 Residual after NH_3 [4]	Free Cl_2 Residual after NH_3 [5]	Free NH_3 Residual after NH_3 [6]

[1] Calculate and record the applied chlorine dose in mg/L before the point of ammonia application using the applicable formula:

Gas Chlorine Feed Rate (lbs/day) **or** *Liquid Chlorine Feed Rate (gal/day) x Specific Gravity x Cl_2 Concentration*

Plant Flow Rate (MGD) x 8.34 *Plant Flow Rate (MGD)*

[2] Calculate and record the applied ammonia dose in mg/L at the point of ammonia application using the applicable formula:

Gas Ammonia Feed Rate (lbs/day) **or** *Liquid Ammonia Feed Rate (gal/day) x Specific Gravity x NH_3 Concentration*

Plant Flow Rate (MGD) x 8.34 *Plant Flow Rate (MGD)*

[3] Measure and record the free chlorine residual in mg/L immediately before the point of ammonia application.

[4] Measure and record the total chlorine residual in mg/L after the point of ammonia application.

[5] Measure and record the free chlorine residual in mg/L after the point of ammonia application.

[6] Measure and record the free ammonia residual in mg/L after the point of ammonia application.

$Cl_2:NH_3$ Ratio Calculation Method		$Cl_2:NH_3$ Ratio based on Applied Cl_2 Dose		$Cl_2:NH_3$ Ratio based on Free Cl_2 Residual	
NH_3 Weight [7]	Cl_2 Component [8]	Reported [9]	Calculated [10]	Reported [11]	Calculated [12]

[7] Indicate whether the $Cl_2:NH_3$ ratio used by the plant staff is based on the weight of ammonia or the weight of nitrogen.

[8] Indicate whether the $Cl_2:NH_3$ ratio used by the plant staff is based on the applied chlorine dose or the free chlorine residual.

[9] Record the $Cl_2:NH_3$ ratio reported by the plant staff based on the applied chlorine dose.
If necessary, convert from Cl_2:N to $Cl_2:NH_3$ using the following formula:

$Cl_2:N \times 0.822 = Cl_2:NH_3$

[10] Calculate the actual $Cl_2:NH_3$ ratio based on the applied chlorine dose.

Applied Chlorine Dose (from 1 above)

Applied Ammonia Dose (from 2 above)

[11] Record the Cl_2:NH_3 ratio reported by the plant staff based on the free chlorine residual. If necessary, convert from Cl_2:N to Cl_2:NH_3 using the following formula:

$$Cl_2{:}N \times 0.822 = Cl_2{:}NH_3$$

[12] Calculate the actual Cl_2:NH_3 ratio based on the free chlorine residual.

$$\frac{\text{Free Chlorine Residual (from 3 above)}}{\text{Applied Ammonia Dose (from 2 above)}}$$

ATTACHMENT 7

RECOMMENDED ACTION PLAN FORM

DIRECTED ASSISTANCE MODULE NO. 4

CHLORAMINE DISINFECTION AND DBP CONTROL

RECOMMENDED ACTION PLAN FORM

I. Process Configuration Issues

Describe the action steps related to facilities and equipment that should be taken to implement an effective chloramination process at the plant.

Description of Action Step	By Whom	By When

II. Process Control Issues

Describe the action steps related to process control that should be taken to implement an effective chloramination process at the plant.

Description of Action Step	By Whom	By When

III. Other Issues

Describe the action steps related to any other issues that should be addressed to implement an effective chloramination process at the plant.

Description of Action Step	By Whom	By When

ATTACHMENT 8

PLANT QUESTIONNAIRE

DIRECTED ASSISTANCE MODULE NO. 4

CHLORAMINE DISINFECTION AND DBP CONTROL

PLANT QUESTIONNAIRE

CHLORAMINE DISINFECTION AND DBP CONTROL

(to be completed by plant staff who participated in training activities)

Plant Name: ____

Overall Evaluation:

® Strongly Agree   © Agree   ™ No Opinion   ∑ Disagree   ⎛ Strongly Disagree

The DAM agenda accurately described the materials and activities that were covered.	®©™∑⎛
The technical aspects of the DAM activities were appropriate for the participants.	®©™∑⎛
The DAM activities were reasonably timed and covered the right amount of information.	®©™∑⎛
The participant handouts were understandable and helpful in completing DAM activities.	®©™∑⎛
The DAM adequately covered the evaluation of disinfection credit.	®©™∑⎛
The DAM adequately covered the evaluation of DBP formation rates.	®©™∑⎛
The DAM adequately covered basic chloramination configurations.	®©™∑⎛
The DAM adequately covered chloramination process control procedures.	®©™∑⎛
The on-site training approach enhanced the learning experience.	®©™∑⎛
The electronic CT Study Template was a convenient tool for evaluating disinfection credit.	®©™∑⎛
The THM Formation Rate Study demonstrated useful techniques for evaluating DBP levels.	®©™∑⎛
The Action Plan will encourage implementation of necessary changes at the plant.	®©™∑⎛
The DAM will help us comply with disinfection and DBP requirements.	®©™∑⎛
The DAM was exactly what we needed.	®©™∑⎛
Our water system would be willing pay for this kind of training.	®©™∑⎛

Specific Suggestions:

What could we change in the agenda to improve it?

What did we not explain well enough for you to understand?

Questionnaire continues on the back

PLANT QUESTIONNAIRE (CONT.)

CHLORAMINE DISINFECTION AND DBP CONTROL

Plant Name: ____

What areas did we spend too much time on?

What areas did we spend too little time on?

What are some other issues where you feel more training is needed?

What other comments or suggestions do you have?

Name (optional): ____

Inside back cover
Revision history:
Created MAY 1, 2005
Versions 2-7 various
Revised: V8 May 6, 2013

Back cover