United States
Environmental Protection
Agency

STAGE 2 DISINFECTANTS AND DISINFECTION BYPRODUCTS RULE

OPERATIONAL EVALUATION GUIDANCE MANUAL

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Purpose:

The purpose of this guidance manual is solely to provide technical information on completing an operational evaluation as required by the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). This guidance is not a substitute for applicable legal requirements, nor is it a regulation itself. Thus, it does not impose legally-binding requirements on any party, including EPA, States, or the regulated community. Interested parties are free to raise questions and objections to the guidance and the appropriateness of using it in a particular situation. The mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Acronyms

AWWA	American Water Works Association
AwwaRF	American Water Works Association Research Foundation
CCR	Consumer Confidence Report
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CT	Disinfectant Residual Concentration × Contact Time
DBP	Disinfection Byproduct
DBPR	Disinfectants and Disinfection Byproducts Rule
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
ft/sec	feet per second
IESWTR	Interim Enhanced Surface Water Treatment Rule
GAC	Granular Activated Carbon
GIS	Geographic Information System
GWUDI	Ground Water Under the Direct Influence of Surface Water
HAA	Haloacetic Acid
HAA5	The Sum of Five HAA Species
HPC	Heterotrophic Plate Count
IDSE	Initial Distribution System Evaluation
LCR	Lead and Copper Rule
LRAA	Locational Running Annual Average
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
M/DBP	Microbial/Disinfection Byproducts
MG	million gallons
mg/L	milligrams per liter
nm	nanometer
NOM	Natural Organic Matter
OEL	Operational Evaluation Level
ppm	parts per million
SUVA	Specific Ultraviolet Absorbance
SWTR	Surface Water Treatment Rule
THM	Trihalomethane
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes
USGS	United States Geological Survey
UV	Ultraviolet Light
UV_{254}	UV absorption at 254 nm
VOC	Volatile Organic Compound
WTP	Water Treatment Plant
µg/L	micrograms per liter

Glossary

Booster disinfection: the practice of adding disinfectant in the distribution system to maintain disinfectant residual concentration throughout the distribution system.

Combined distribution system: the interconnected distribution system consisting of the distribution systems of wholesale systems and of the consecutive systems that receive some or all of their finished water from those wholesale system(s).

Consecutive system: a public water system that buys or otherwise receives some or all of its finished water from one or more wholesale systems. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

Disinfectant: any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

Disinfectant residual concentration: the concentration of disinfectant that is maintained in a distribution system. Disinfectant could be free chlorine (the sum of the concentrations of hypochlorous acid (HOCl) and hypochlorite acid (OCl^-)) or combined chlorine (chloramines). It is used in the Surface Water Treatment Rule as a measure for determining CT.

Disinfection: a process which inactivates pathogenic organisms in water by chemical oxidants or equivalent agents.

Disinfection byproduct (DBP): compound formed from the reaction of a disinfectant with organic and inorganic compounds in the source or finished water during the disinfection process.

Dual sample set: a set of two samples collected at the same time and same location, with one sample analyzed for TTHM and the other sample analyzed for HAA5. Dual sample sets are collected for the purposes of conducting an Initial Distribution System Evaluation and determining compliance with the TTHM and HAA5 Maximum Contaminant Levels.

Finished water: water that is introduced into the distribution system of a public water system and is intended for distribution and consumption without further treatment, except that treatment necessary to maintain water quality in the distribution system (e.g., booster disinfection, addition of corrosion control chemicals).

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 180 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.

Ground water under the direct influence of surface water (GWUDI): any water beneath the surface of the ground with (1) significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as *Giardia lamblia*, or (2) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH that closely correlate to climatological or surface water conditions. Direct influence should be determined for individual sources in accordance with criteria established by the State. The State determination of direct influence may be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation.

Haloacetic acid (HAA): one of the family of organic compounds named as a derivative of acetic acid, wherein one to three hydrogen atoms in the methyl group in acetic acid are each substituted by a halogen atom (namely, chlorine and bromine) in the molecular structure.

Haloacetic acids (five) (HAA5): the sum of the concentrations in milligrams per liter of the haloacetic acid compounds (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid), rounded to two significant figures after addition.

Locational running annual average (LRAA): the average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

Maximum contaminant level (MCL): the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

Mixing zone: an area in the distribution system where water flowing from two or more different sources blend.

Monitoring site: the location where samples are collected.

Public water system (PWS): a system for the provision to the public of piped water for human consumption, if such system has at least 15 service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system.

Residence time: the time period lasting from when the water is treated to a particular point in the distribution system. Also referred to as water age.

Residual disinfection: also referred to as "secondary disinfection". The process whereby a disinfectant (typically chlorine or chloramine) is added to finished water in order to maintain a disinfection residual in the distribution system.

Secondary disinfection: see definition for "residual disinfection".

State: the agency of the State or Tribal government which has jurisdiction over public water systems. During any period when a State or Tribal government does not have primary enforcement responsibility pursuant to section 1413 of the Act, the term "State" means the Regional Administrator, U.S. Environmental Protection Agency.

Surface water: all water which is open to the atmosphere and subject to surface runoff.

Total trihalomethanes (TTHM): the sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane [chloroform], dibromochloromethane, bromodichloromethane, and tribromomethane [bromoform]), rounded to two significant figures. Note that some publications may use the term “THM4” instead of “TTHM.”

Trihalomethane (THM): one of the family of organic compounds named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

Water age: see definition for “residence time.”

Wholesale system: a public water system that treats source water as necessary to produce finished water and then sells or otherwise delivers finished water to another public water system. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

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1. Introduction

This chapter covers:

1.1 Purpose and Scope
1.2 Who Must Comply with the Operational Evaluation Requirements of the Stage 2 DBPR?
1.3 What Is an Operational Evaluation Level Exceedance?
1.4 What Are the Requirements If the Operational Evaluation Level Is Exceeded?
1.5 When Do the Operational Evaluation Requirements Take Effect?
1.6 Organization of this Guidance Manual
1.7 Additional Resources

The Environmental Protection Agency (EPA) promulgated the Stage 2 Disinfectants and Disinfection ByProducts Rule (DBPR) in January 2006. The Stage 2 DBPR provides for increased protection against the potential risks for cancer and reproductive and developmental health effects associated with disinfection byproducts (DBP). The Stage 2 DBPR establishes maximum contaminant level goals for chloroform, monochloroacetic acid and trichloroacetic acid; maximum contaminant levels (MCLs), based on a locational running annual average (LRAA)[1], for total trihalomethanes (TTHM) and haloacetic acids (HAA5); monitoring, reporting, and public notification requirements based on the TTHM and HAA5 MCLs; and revisions to the reduced monitoring requirements for bromate. The complete Stage 2 DBPR can be found at http://www.epa.gov/safewater/disinfection/stage2/regulations.html.

The Stage 2 DBPR also establishes operational evaluation requirements that are initiated by the TTHM and HAA5 levels found during Stage 2 DBPR compliance monitoring. Compliance with Stage 2 DBPR MCLs is based on the average of four individual quarterly DBP measurements collected at a given location (i.e., LRAA). However, a system that is in compliance with the Stage 2 DBPR MCLs, based on the LRAA, at a location may still have individual (i.e., not averaged) DPB measurements at that location that exceed the Stage 2 DBPR MCLs. EPA and the Stage 2 Microbial/Disinfection Byproducts (M/DBP) Advisory Committee were concerned about these higher levels of DBPs. The Stage 2 DBBR operational evaluation requirements were established to address these concerns.

The Stage DBPR requires systems to conduct operational evaluations, initiated by the operational evaluation levels (OEL) found in Stage 2 DBPR compliance monitoring, and to submit an operational evaluation report to the State. The OELs are determined with an algorithm, described later in this section, based on Stage 2 monitoring results. The OELs initiate a comprehensive review of system operations and act as an early warning for a possible Stage 2 DBPR violation in the following quarter. This early warning allows systems to act to prevent the violation. The Stage DBPR process for initiating an operational evaluation is not based on health effects information. **The operational evaluation requirements of the Stage 2 DBPR are**

[1] The Stage 2 DBPR requires systems to meet an LRAA of 0.080 mg/L for TTHM and 0.060 mg/L for HAA5 at each compliance monitoring location (40 CFR 141.620 (d)).

intended as an indicator of operational performance and to allow systems to take proactive steps to remain in compliance with the Stage 2 DBPR MCLs.

1.1 Purpose and Scope

EPA has developed this manual to provide guidance to water systems on identifying TTHM and HAA5 peaks and conducting operational evaluations to determine the cause(s) of and reduce such peaks, and to assist States in implementing the Stage 2 operational evaluation requirements and in reviewing operational evaluation reports. The specific objectives of this manual are to:

- Describe an OEL exceedance.
- Summarize regulatory requirements for addressing an OEL exceedance.
- Provide guidance for documenting and reporting an OEL exceedance.
- Provide a methodology for identifying the cause of an OEL exceedance.
- Present options available to reduce TTHM and HAA5 concentrations in the distribution system to minimize a future OEL exceedance.

The options presented to reduce TTHM and HAA5 concentrations in the distribution system to minimize future OEL exceedances are intended to assist systems in meeting their operational evaluation requirements and to assist States in reviewing operational evaluation reports. **An OEL exceedance requires an operational evaluation meeting specific criteria and reporting of the evaluation to the State, but does not require systems to take corrective actions. The operational evaluation and report will provide valuable information to both the system and the State.** This guidance manual focuses on common surface and ground water and treatment processes that affect formation of TTHM and HAA5. References are provided throughout the document to help you optimize other treatment processes. You should also consider contacting your State to discuss your particular system needs and concerns.

1.2 Who Must Comply with the Operational Evaluation Requirements of the Stage 2 DBPR?

All community water and non-transient non-community water systems that use a primary or residual disinfectant other than ultraviolet light (UV), or that deliver water that has been treated with a primary or residual disinfectant other than UV, must comply with the Stage 2 DBPR MCLs for TTHM and HAA5 and the Stage 2 DBPR operational evaluation requirements. This includes consecutive systems delivering water that has been treated with a primary or residual disinfectant other than UV. If you are one of these systems, you must comply with the operational evaluation requirements of the Stage 2 DBPR if you meet both of the following criteria:

1) You are required to conduct compliance monitoring for the Stage 2 DBPR; and

2) You collect Stage 2 DBPR compliance samples **quarterly**. If you are on annual monitoring, you are not subject to the operational evaluation requirements of the Stage 2 DBPR. If you are required to increase Stage 2 monitoring to quarterly (§141.625), you are also required to meet the operational evaluation requirements.

1.3 What Is an Operational Evaluation Level Exceedance?

The Stage 2 DBPR states that a system exceeds the OEL if one of the following occurs at any compliance monitoring location (40 CFR 141.626(a)):

- TTHM compliance monitoring results for the two previous quarters plus two times the TTHM result for the current quarter, divided by 4, exceeds 0.080 milligrams per liter (mg/L); or

- HAA5 compliance monitoring results for the two previous quarters plus two times the HAA5 result for the current quarter, divided by 4, exceeds 0.060 mg/L.

You can use the formula below to determine if you have an OEL exceedance. Example 1.1 shows how this formula can be used with distribution system TTHM and HAA5 data.

Formula for Determining if You Have an OEL Exceedance

For both TTHM and HAA5 and for each compliance monitoring location, calculate the following:

$$(A + B + (2 * C)) / 4 = D$$

Where:
A = TTHM or HAA5 result for the quarter before the previous quarter (mg/L)
B = TTHM or HAA5 result for the previous quarter (mg/L)
C = TTHM or HAA5 result for the current quarter (mg/L)
D = your **Operational Evaluation Value (mg/L)**

If **D for TTHM** is **> 0.080 mg/L**, you have an **OEL Exceedance**

If **D for HAA5** is > **0.060 mg/L**, you have an **OEL Exceedance**

Example 1.1 Determining If There Is an OEL Exceedance

A system is conducting Stage 2 compliance monitoring at four locations. TTHM and HAA5 data from the previous two quarters (February and May) and the current quarter (August) are presented below.

TTHM Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Value:
	A	B	C	D = (A+B+(2*C))/4
#1	0.065 mg/L	0.074 mg/L	0.087 mg/L	0.078 mg/L
#2	0.064 mg/L	0.072 mg/L	0.084 mg/L	0.076 mg/L
#3	0.068 mg/L	0.075 mg/L	0.093 mg/L	**0.082 mg/L**
#4	0.066 mg/L	0.070 mg/L	0.082 mg/L	0.075 mg/L

HAA5 Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Value:
	A	B	C	D = (A+B+(2*C))/4
#1	0.033 mg/L	0.041 mg/L	0.050 mg/L	0.044 mg/L
#2	0.042 mg/L	0.048 mg/L	0.055 mg/L	0.050 mg/L
#3	0.037 mg/L	0.043 mg/L	0.046 mg/L	0.043 mg/L
#4	0.043 mg/L	0.045 mg/L	0.052 mg/L	0.048 mg/L

In August, the system exceeds the OEL at **location #3** because the TTHM value in column D exceeds the OEL (0.080 mg/L).

1.4 What Are the Requirements If the Operational Evaluation Level is Exceeded?

If the OEL is exceeded, you **must** take the following actions (40 CFR 141.626(b)):

1) Conduct an operational evaluation to determine the cause of the exceedance(s).

2) Submit a written report of the evaluation to the State no later than 90 days after being notified of the analytical result that caused the exceedance(s).

3) Keep a copy of the operational evaluation report and make it available to the public upon request.

An OEL exceedance ***is not*** a violation of the Stage 2 DBPR. However, failure to submit an evaluation report to the State in the required time frame is a violation and requires Tier 3 public notice (as required by the Public Notification Rule). All Stage 2 DBPR compliance monitoring results must be included in the system's Consumer Confidence Report (CCR). There are no additional CCR requirements related to an OEL exceedance unless the system is in violation due to failure to complete and submit an evaluation report.

The operational evaluation must include an examination of system treatment and distribution operational practices that may contribute to TTHM and HAA5 formation including:

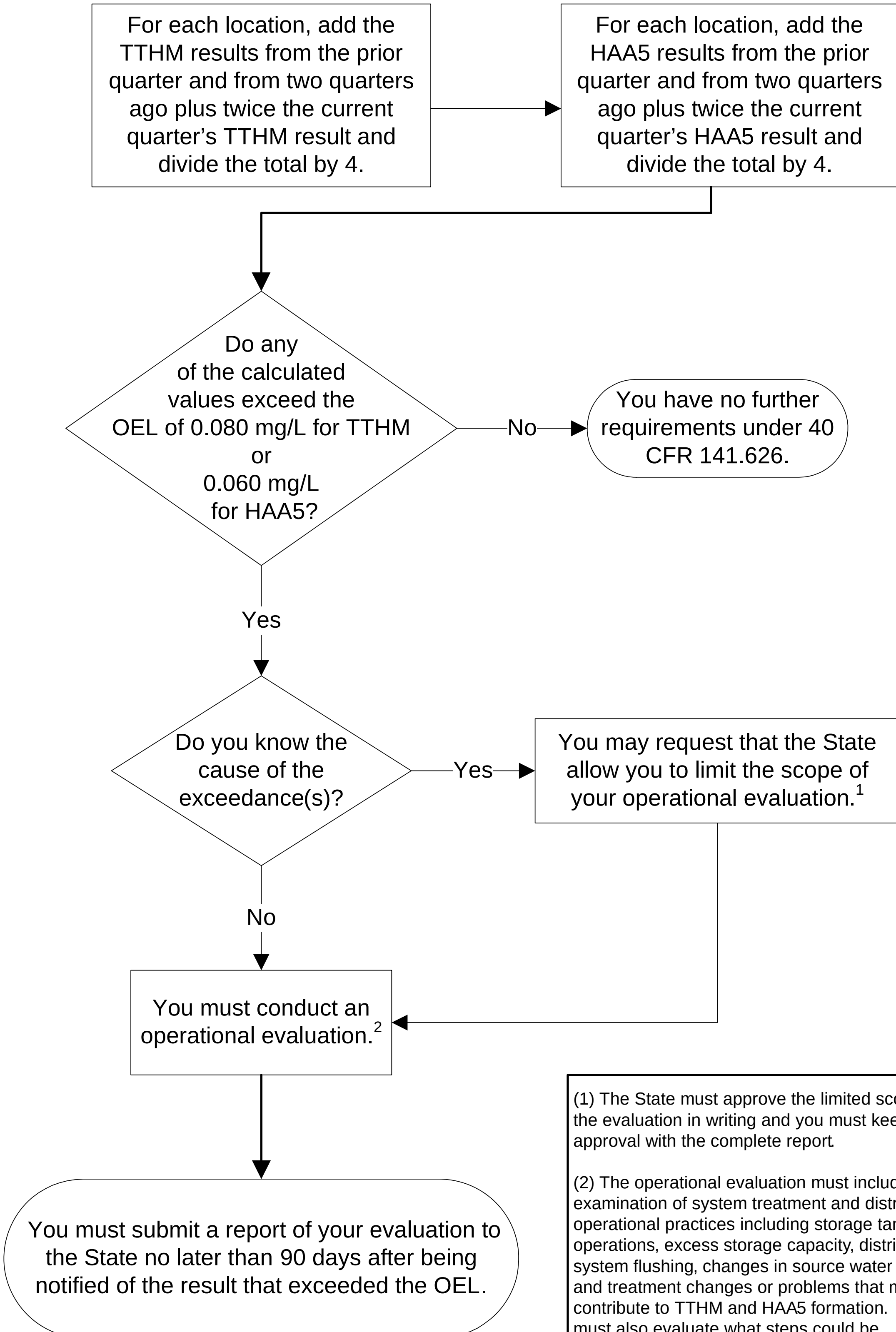
- **Storage tank operations,**
- **Excess storage capacity,**
- **Distribution system flushing,**
- **Sources of supply and source water quality, and**
- **Treatment processes and finished water quality.**

The operational evaluation must also include what steps could be considered to minimize future exceedances (40 CFR 141.626(b)(2)).

The system may request and the State may allow a limited scope of the operational evaluation if the system is able to identify the cause of the OEL exceedance to the State's satisfaction. The State **must** then approve the limited scope of the evaluation in writing and the system **must** keep the written approval with the completed report. Note that submitting this request **will not** extend the 90 day deadline for submitting the operational evaluation report.

Exhibit 1.1 presents a flow chart with the operational evaluation rule requirements.

Exhibit 1.1 Operational Evaluation Flow Chart (40 CFR 141.626)



(1) The State must approve the limited scope of the evaluation in writing and you must keep that approval with the complete report.

(2) The operational evaluation must include an examination of system treatment and distribution operational practices including storage tank operations, excess storage capacity, distribution system flushing, changes in source water quality, and treatment changes or problems that may contribute to TTHM and HAA5 formation. You must also evaluate what steps could be considered to minimize future exceedances.

1.5 When Do the Operational Evaluation Requirements Take Effect?

The operational evaluation provision of the Stage 2 DBPR applies to compliance monitoring results. The first determination of OELs would be after the completion of your first three quarterly monitoring periods. Thereafter, the determination of OELs would be completed each quarter when new monitoring results are available. The schedule for Stage 2 compliance monitoring is summarized in Exhibit 1.2.

Exhibit 1.2 Effective Dates for Stage 2 DBPR Compliance Monitoring

If you are a system serving:	Begin Compliance Monitoring by:
At least 100,000 people or part of a combined distribution system serving at least 100,000 people (Schedule 1)	April 1, 2012
50,000 - 99,999 people or part of a combined distribution system serving 50,000 - 99,999 people (Schedule 2)	October 1, 2012
10,000 - 49,999 people or part of a combined distribution system serving 10,000 - 49,999 people (Schedule 3)	October 1, 2013
Less than 10,000 people or part of a combined distribution system serving Less than 10,000 people (Schedule 4)	October 1, 2013 for systems *not* conducting *Cryptosporidium* monitoring under 40 CFR 141.701(a)(4). October 1, 2014 for systems conducting *Cryptosporidium* monitoring.

1.6 Organization of this Guidance Manual

This guidance manual is organized as follows:

- Chapter 1 - Introduction: Presents the Stage 2 DBPR requirements for systems that exceed the OEL.

- Chapter 2 - Recommended Approach for Conducting an Operational Evaluation: Describes the required components of the operational evaluation and presents EPA's recommended approach.

- Chapter 3 - Distribution System Evaluation: Provides guidance for evaluating distribution system monitoring data and other operational data to determine if distribution system operations were the cause of the OEL exceedance.

- Chapter 4 - Treatment Process Evaluation: Provides guidance for evaluating treatment plant processes, monitoring data, and other treatment plant operational data to determine if a change in treatment was the cause of the OEL exceedance.

- Chapter 5 - Source Water Evaluation: Provides guidance for evaluating source water monitoring and other operational data to determine if a change in source water conditions was the cause of the OEL exceedance.

- Chapter 6 - Minimizing Future Operational Evaluation Level Exceedances: Summarizes options available to reduce OEL exceedances, including operational changes and distribution system modifications.

Appendix A discusses the fundamentals of DBP formation. Appendices B through E are examples of completed operational evaluation reports.

1.7 Additional Resources

USEPA. 2006. *Initial Distribution System Evaluation Guidance Manual for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule.* EPA 815-B-06-002. Available online at: http://www.epa.gov/safewater/disinfection/stage2/compliance.html

USEPA. 2007a. *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules*. EPA 815-R-07-017. Available online at: http://www.epa.gov/safewater/disinfection/stage2/compliance.html

USEPA. 2007b. *Complying with the Stage 2 Disinfectant and Disinfection Byproducts Rule: Small Entity Compliance Guide.* EPA 815-R-07-014. Available online at: http://www.epa.gov/safewater/disinfection/stage2/compliance.html

USEPA. 2007c. *The Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) Implementation Guidance.* EPA 816-R-07-007. Available online at: http://www.epa.gov/safewater/disinfection/stage2/compliance.html

USEPA. TBD. *Consecutive Systems Guidance Manual (Draft) for the Stage 2 Disinfectants and Disinfection Byproducts Rule.* EPA TBD. Available online at: http://www.epa.gov/safewater/disinfection/stage2/compliance.html

2. Recommended Approach for Conducting an Operational Evaluation

This chapter covers:

2.1 Step 1: Confirm that Data Collection and Analysis Protocols Were Followed
2.2 Step 2: Review DBP Data at Other Sites
2.3 Step 3: Limit the Scope of the Evaluation If the Cause of the OEL Exceedance Is Known
2.4 Step 4: Conduct a Detailed Operational Evaluation
2.5 Step 5: Identify Steps to Minimize Future OEL Exceedances
2.6 Step 6: Prepare and Submit a Report
2.7 Uses of Operational Evaluation Reports

If your system exceeds an operational evaluation level (OEL), an operational evaluation **must** be conducted to determine the cause of the exceedance. A written report summarizing the operational evaluation **must** be submitted to the State no later than 90 days after being notified of the analytical result that exceeded the OEL.

Systems that expect, based on Stage 1 monitoring and Initial Distribution System Evaluation (IDSE) data, that they may have to prepare an operational evaluation report should begin data collection efforts for data that would be needed. Data will be valuable in proactive efforts to avoid OEL exceedances. Systems may also want to review how historical data are collected and saved and how historical data represent current system configuration and operating conditions.

This chapter provides a general approach for systems to follow if they experience an OEL exceedance. The Operational Evaluation Reporting Form on pages 2-2 and 2-3 can be used as a template for the operational evaluation report. While the use of this form is not required by the Stage 2 DBPR, it serves as a guideline for collecting pertinent information needed for the operational evaluation report. Detailed information is needed in the operational evaluation report regarding the location and cause of the OEL exceedance, and what steps could be considered to minimize future exceedances. The questions posed in the report form are designed to help the evaluator identify the causes of the exceedance. There may be additional causes of OEL exceedances that are not listed in this form. If the exceedance continues to occur in the next monitoring period, the evaluator may want to review any “no” and “possibly” answers in this form and conduct a more detailed evaluation.

Examples of completed operational evaluation reports are included in Appendices B through E for a variety of system conditions. Site-specific conditions may warrant a more detailed report than shown in these examples.

Operational Evaluation Reporting Form

I. GENERAL INFORMATION

A. Facility Information

Facility Name: ______________________ PWSID: ______________

Facility Address: ______________________

City: ______________________ State: ______ Zip: ______

B. Report Prepared by:

(Print): ______________________ Date prepared: ______________

(Signature): ______________________

Contact Telephone Number: ______________________

II. MONITORING RESULTS

A. Provide the Compliance Monitoring Site(s) where the OEL was Exceeded.

____

Note: The site name or number should correspond to a site in your Stage 2 DBPR compliance monitoring plan.

B. Monitoring Results for the Site(s) Identified in II.A (include duplicate pages if there was more than one exceedance)

1. Check TTHM or HAA5 to indicate which result caused the OEL exceedance. ☐ TTHM ☐ HAA5
2. Enter your results for TTHM or HAA5 (whichever you checked above).

	Quarter			**Operational Evaluation Value**
	Results from Two Quarters Ago	Prior Quarter's Results	Current Quarter	
	A	B	C	D = (A+B+(2*C))/4
Date sample was collected				
TTHM (mg/L)				
HAA5 (mg/L)				

Note: *The operational evaluation value is calculated by summing the two previous quarters of TTHM or HAA5 values plus twice the current quarter value, divided by four. If the value exceeds 0.080 mg/L for TTHM or 0.060 mg/L for HAA5, an OEL exceedance has occurred.*

C. Has an OEL exceedance occurred at this location in the past?	☐ Yes	☐ No
If NO, proceed to item D. If YES, when did exceedance occur?		
Was the cause determined for the previous exceedance(s)?	☐ Yes	☐ No
Are the previous evaluations/determinations applicable to the current OEL exceedance?	☐ Yes	☐ No

Operational Evaluation Reporting Form

III. OPERATIONAL EVALUATION FINDINGS

A. Did the State allow you to limit the scope of the operational evaluation? ☐ Yes ☐ No

If NO, proceed to item B. If YES, attach written correspondence from the State.

B. Did **the distribution system** cause or contribute to your OEL exceedance(s)? ☐ Yes ☐ No ☐ Possibly

If NO, proceed to item C. If YES or POSSIBLY, explain (attach additional pages if necessary):

____

____

____

C. Did the **treatment** system cause or contribute to your OEL exceedance(s)? ☐ Yes ☐ No ☐ Possibly

If NO, proceed to item D. If YES or POSSIBLY, explain (attach additional pages if necessary):

____

____

____

D. Did **source water quality** cause or contribute to your OEL exceedance(s)? ☐ Yes ☐ No ☐ Possibly

If NO, proceed to item E. If YES or POSSIBLY, explain (attach additional pages if necessary):

____

____

____

E. Attach all supporting operational or other data that support the determination of the cause(s) of your OEL exceedance(s).

F. If you are unable to determine the cause(s) of the OEL exceedance(s), list the steps that you can use to better identify the cause(s) in the future (attach additional pages if necessary):

____

____

____

G. List steps that could be considered to minimize future OEL exceedances (attach additional pages if necessary)

____

____

____

H. Total **Number of Pages** Submitted, Including Attachments and Checklists: ____________

Overview of Recommended Approach

To fulfill the operational evaluation requirements, EPA recommends that you perform the following steps:

Step 1 Confirm that samples were properly collected, preserved, and analyzed.

Step 2 Review TTHM and HAA5 data at other sites within your distribution system to determine if the exceedance is localized or system-wide.

Step 3 If the cause of the OEL exceedance is known, request approval from the State to limit the scope of the operational evaluation.

Step 4 Conduct a detailed or limited operational evaluation depending on State response in Step 3.

Step 5 Identify steps to minimize exceedances.

Step 6 Prepare the operational evaluation report and submit it to the State.

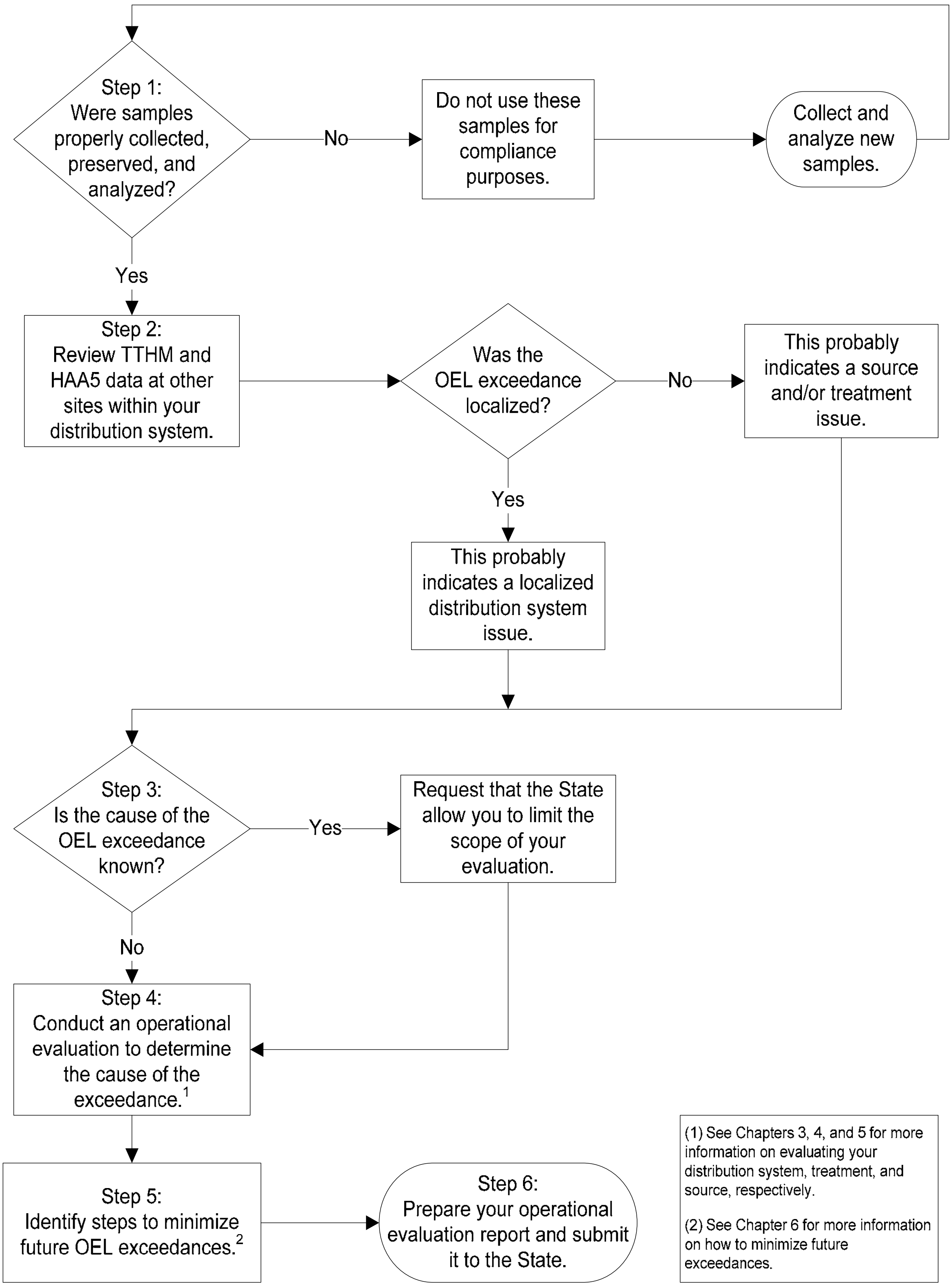
Exhibit 2.1 presents these steps in a flow chart. Each step is described in detail starting in Section 2.1. Additional guidance for Step 4, conducting the detailed operational evaluation, is provided in Chapters 3 through 5. Guidance for Step 5, minimizing future exceedences, is provided in Chapter 6.

Special Considerations for Consecutive Systems

If you are a consecutive system and purchase all of your water, the operational evaluation should focus on the distribution system. Consecutive systems should consider collecting TTHM and HAA5 data at the wholesale connection point (e.g., master meter, intertie, turnout, etc.). This operational data will assist consecutive systems in understanding where DBP formation is occurring. Knowledge of the concentration of these DBPs at the entry point to the system will help assess how they change (i.e., increase or decrease) within the system. This knowledge will assist consecutive systems in identifying the cause(s) of OEL exceedances, in identifying steps that could be considered to minimize future exceedances, and in any needed interaction with the wholesale supplier(s). TTHM and HAA5 can change day-to-day, so taking TTHM and HAA5 samples at the entry point to your distribution system is encouraged at the same time as Stage 2 compliance distribution samples are taken to allow valid comparison of results.

Once you have reviewed your system and identified the cause of the OEL exceedance and the potential for the exceedance to reoccur, you should consider initiating a discussion with the wholesaler about treatment and other alternatives. Refer to the *Stage 2 Consecutive System Guidance Manual* (to be published) for more information on how to communicate with your wholesaler on this issue.

Exhibit 2.1 Suggested Steps for Performing an Operational Evaluation



2.1 Step 1: Confirm that Data Collection and Analysis Protocols Were Followed

Before conducting an operational evaluation, you should ensure that all compliance sample results are accurate. Accurate sample results depend on proper execution of all procedures for sample collection and analysis.

Exhibit 2.2 shows the methods, sample containers, preservatives, dechlorinating agents, storage guidelines, and sample collection guidelines that should be followed when collecting and analyzing TTHM and HAA5 samples. The checklist at the end of this section can be used to ensure that all of the sample collection and storage guidelines were met. You may need to contact your laboratory to ensure that the proper analytical method was used for analysis and that all analytical protocols were followed. Remember, all TTHM and HAA5 samples collected for Stage 2 DBPR compliance must be analyzed by a certified laboratory. Several States control the sampling process. In some States, samples are analyzed by State laboratories. If either of these situations occurs in your State, you should contact the State drinking water program before contacting the laboratory or before filling in the TTHM and HAA5 Sample Collection and Handling Checklist.

If the laboratory has invalidated samples based on holding times being exceeded or other factors, you should not use these sample results for compliance purposes. New samples should be collected and analyzed. In these circumstances, the system should contact the State regarding invalidation and a new sample schedule/date for that quarter.

Before you conduct an operational evaluation you should ensure that all sample collection, holding, and laboratory procedures were followed correctly.

Exhibit 2.2 Sampling Requirements of TTHM and HAA5 Analyses

Analyte Group	Analytical Method[1]	Sample Container Material[2]	Preservative/Dechlorinating Agent (Recommended amount)	Storage Guidelines	Sample Collection Guidelines
TTHM	EPA 502.2	40 ml -120 ml screw cap glass vials with PTFE-faced silicone septum	Options: (1) 3 mg $Na_2S_2O_3$/40 mL sample or (2) 3 mg $Na_2S_2O_3$/40 mL sample and immediate acidification using HCl to pH < 2 or (3) 25 mg ascorbic acid/40 mL sample and immediate acidification using HCl to pH < 2. Option 1 may be used if THMs are the only compounds being determined in the sample. Options 2 & 3 require the sample to be dechlorinated prior to the addition of acid.	Keep at 4°C. 14 days maximum hold time[3].	Fill bottle to just overflowing but do not flush out preservatives. No air bubbles. Do not overfill. Seal sample vials with no head space. If ascorbic acid is used to dechlorinate TTHM samples, then the samples should be acidified. Acidification of TTHM samples containing $Na_2S_2O_3$ is required if the samples will also be analyzed for VOCs. In both cases, the pH should be adjusted at the time of sample collection, not later at the laboratory.
	EPA 524.2	40 ml -120 ml screw cap glass vials with Teflon-faced silicone septum			
	EPA 551.1	60 ml screw cap glass vials with PTFE-faced silicone septum	1 g phosphate buffer & NH_4Cl or Na_2SO_3 mixture per 60 mL sample (mixture consists of 1 part Na_2HPO_4, 99 parts KH_2PO_4, and 0.6 parts NH_4Cl or Na_2SO_3. 1g per 60 mL results in a pH of 4.5-5.5 and 0.1 mg NH_4Cl or Na_2SO_3 per mL of sample.)		
HAA5	EPA 552.1	250 ml (approx.) amber glass bottles fitted with Teflon-lined screw caps	0.1 mg NH_4Cl per mL of sample		
	EPA 552.2	50 ml (approx.) amber glass bottles fitted with Teflon-lined screw caps			
	EPA 552.3[4]	50 ml (approx.) amber glass bottles fitted with Teflon-lined screw caps			
	SM 6251 B	40 ml or 60 ml screw cap glass	65 mg NH_4Cl		

[1] (40 CFR 141.131 (b))
[2] Selection of container should be coordinated with the laboratory.
[3] The holding time has been changed to 14 days for all HAA5 samples as a part of the methods update rule.
[4] EPA Method 552.3 has been added as an approved HAA5 method as part of the Stage 2 DBPR.

TTHM and HAA5 Sample Collection and Handling Checklist

Facility Name: ______________________

Checklist Completed by: Date:

Yes	No	
☐	☐	Did you obtain appropriate sample collection vials provided from the laboratory?
☐	☐	Did the sample vials contain the proper preservative and dechlorinating agents?
☐	☐	Was each vial labeled using waterproof labels and indelible ink?
☐	☐	Did each vial contain the following information on the label?
☐	☐	Unique sample ID
☐	☐	System name
☐	☐	Sample location
☐	☐	Sample date and time
☐	☐	Analysis required, if not already on label
☐	☐	Did you remove the aerator from the tap if there was one present?
☐	☐	Did you open the water tap and allow the system to flush until the water temperature had stabilized (usually about 3-5 minutes)?
☐	☐	Did you adjust the flow so that no air bubbles were visually detected in the flowing stream?
☐	☐	Did you slowly fill the sample vial almost to the top without overflowing?
☐	☐	Were you careful not to rinse out any of the preservative/dechlorinating agent during this process?
☐	☐	After the bottle was filled, did you invert it three or four times to mix the sample with the preservative and dechlorinating agents?
☐	☐	If you collected a TTHM sample that requires acidification, did you:
☐	☐	Let the sample set for about 1 minute, allowing the dechlorinating chemical to take effect?
☐	☐	Carefully open the vial and adjust the pH of the TTHM sample to < 2 by adding approximately 4 drops of hydrochloric acid for every 40 mL of sample (amount of acid needed will depend on buffering capacity of sample)?
☐	☐	Recap the vial, and invert three or four times?

TTHM and HAA5 Sample Collection and Handling Checklist

Yes	No	
☐	☐	Did you invert the vial and tap it to check for air bubbles?
☐	☐	If bubbles were detected, did you carefully open the vial and add more sample water using the cap to achieve a headspace-free sample? *Note that air bubbles would more likely lead to a lower level of THMs or HAAs.*
☐	☐	Did you immediately cool the samples to 4°C by placing them in a cooler with frozen refrigerant packs or ice, or in a refrigerator? Samples should be maintained at this temperature during shipping to the laboratory.
☐	☐	Did you complete the Sample Chain of Custody provided by the laboratory and include it with the sample shipment?
☐	☐	Was the sample holding time of 14 days exceeded?
☐	☐	Was the extract holding time exceeded? *EPA Method 551.1: 14 days at a temperature less than -10°C* *EPA Method 552.1: 48 hours at 4°C or less* *EPA Method 552.2: 7 days at 4°C or 14 days at a temperature less than -10°C* *EPA Method 552.3: 21 days for MTBE extraction solvent at -10°C or less* *OR 28 days for TAME extraction solvent at -10°C or less* *Standard Method 6251 B: 21 days at -11°C*
☐	☐	Did the laboratory invalidate the sample?

Notes/Comments

2.2 Step 2: Review DBP Data at Other Sites

You should review TTHM and HAA5 data at other sites within the distribution system to assess whether the OEL exceedance is:

- **System-wide.** If TTHM and HAA5 are increasing proportionally throughout the distribution system, it probably indicates a source and/or treatment issue.

  OR

- **Localized.** This probably indicates a localized distribution issue.

You may be allowed to limit the focus of the evaluation if the cause is known (refer to Section 2.3).

Following are two simple examples that illustrate, respectively, a system-wide and localized OEL exceedance. For more complex systems with multiple water treatment plants, pressure zones, and finished water storage facilities, a hydraulic or water quality model may be needed to determine if the OEL exceedance is a system-wide or localized problem. For example, the case study in Appendix C describes how the system's hydraulic model was used to trace an OEL exceedance to a finished water storage facility.

Example 2.1 System-wide DBP Increases

TTHM and HAA5 monitoring results for three quarters are shown below for a system serving 35,000 people with one surface water treatment plant. In August, the system exceeded the OELs for TTHM and HAA5 at location #1 and for TTHM at location #4. Notice that the TTHM values and most of the HAA5 values are much higher at all monitoring locations in August than in February or May. The system conducted an operational evaluation and determined that high summer temperatures were the cause of the OEL exceedance and distribution system-wide high TTHM and HAA5 values.

TTHM Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Level
	A	B	C	D = (A+B+(2*C))/4
#1	0.032 mg/L	0.050 mg/L	0.121 mg/L	**0.081 mg/L**
#2	0.026 mg/L	0.045 mg/L	0.105 mg/L	0.070 mg/L
#3	0.030 mg/L	0.044 mg/L	0.115 mg/L	0.076 mg/L
#4	0.035 mg/L	0.052 mg/L	0.125 mg/L	**0.084 mg/L**

HAA5 Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Level
	A	B	C	D = (A+B+(2*C))/4
#1	0.020 mg/L	0.034 mg/L	0.095 mg/L	**0.061 mg/L**
#2	0.025 mg/L	0.032 mg/L	0.068 mg/L	0.048 mg/L
#3	0.022 mg/L	0.038 mg/L	0.074 mg/L	0.052 mg/L
#4	0.029 mg/L	0.034 mg/L	0.079 mg/L	0.055 mg/L

DBPR – Disinfection Byproducts Rule
HAA5 – sum of five haloacetic acids
mg/L - milligrams per liter
TTHM – total trihalomethane

Example 2.2 Localized DBP Increase

TTHM and HAA5 monitoring results for three quarters are shown below for a system serving 48,000 people with two surface water treatment plants. In August, the system exceeded the OEL for TTHM at monitoring location #3. Notice that there was not a significant increase in TTHM or HAA5 at any other location. The system conducted an operational evaluation and determined that a tank serving monitoring location 3 was not operated properly during this period and discharged water with unusually high water age.

TTHM Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Level
	A	B	C	D = (A+B+(2*C))/4
#1	0.033 mg/L	0.035 mg/L	0.039 mg/L	0.037 mg/L
#2	0.035 mg/L	0.037 mg/L	0.038 mg/L	0.037 mg/L
#3	0.032 mg/L	0.035 mg/L	0.131 mg/L	**0.082 mg/L**
#4	0.029 mg/L	0.033 mg/L	0.036 mg/L	0.034 mg/L

HAA5 Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Level
	A	B	C	D = (A+B+(2*C))/4
#1	0.020 mg/L	0.025 mg/L	0.022 mg/L	0.022 mg/L
#2	0.024 mg/L	0.028 mg/L	0.029 mg/L	0.028 mg/L
#3	0.018 mg/L	0.022 mg/L	0.010 mg/L	0.015 mg/L
#4	0.026 mg/L	0.023 mg/L	0.028 mg/L	0.026 mg/L

DBPR – Disinfection Byproducts Rule
HAA5 – sum of five haloacetic acids
mg/L - milligrams per liter
TTHM – total trihalomethane

2.3 Step 3: If the Cause of the OEL Exceedance Is Known, Request State Approval to Limit Scope of Operational Evaluation

The system may request that the State allow a limited scope of the operational evaluation if the cause of the exceedance can be identified to the State's satisfaction. The State **must** then approve the use of a limited scope in writing. The system should confirm recordkeeping requirements with the State for the written approval and the completed report. Note that submitting this request will not extend the 90-day deadline for submitting the operational evaluation report.

Examples where the OEL exceedance may be known include the following:

- Total organic carbon (TOC) source water and finished water data indicate poor TOC removal across the plant.
- Source water and finished water data indicate a sudden increase in temperature.
- Plant flows were reduced due to lower demand, resulting in a much longer contact time between the chlorine and DBP precursors.
- Predisinfection chlorine feed rates were unusually high.
- OEL exceedance occurs at same location as previous monitoring period for which a cause has been identified but the solution has not yet been implemented.

2.4 Step 4: Conduct Operational Evaluation

The detailed operational evaluation must include an examination of distribution, treatment, and source operational conditions representing the time of the OEL exceedance within the distribution system. If the State approves a limited operational evaluation (see section 2.3 above), it may not be necessary to review all operational conditions. For example, the system may show that the source water quality did not cause the OEL exceedance.

It is important to review data representing all three monitoring periods used to calculate the OEL. It cannot be assumed that the monitoring period with the highest TTHM or HAA5 level "caused" the exceedance. If multiple sources and treatment facilities provide finished water to the distribution system, the operational evaluation can focus on the source(s) and treatment facilities that feed the location where the OEL exceedances occurred. Detailed guidance is provided in subsequent chapters of this report.

> For guidance on identifying the cause of the OEL exceedance, refer to
>
> ***Chapter 3:*** Distribution System Evaluation
>
> ***Chapter 4:*** Treatment Process Evaluation
>
> ***Chapter 5:*** Source Water Evaluation

Each Chapter contains comprehensive checklists that may be useful when evaluating potential causes of the OEL exceedance. Appendix A contains additional information on DBP formation.

For consecutive systems, additional source water and treatment data may be needed from the wholesaler to help identify the cause of the OEL exceedance.

In cases where it is not possible to identify the cause of an OEL exceedance, systems should consider seeking assistance from the State, American Water Works Association (AWWA) and American Water Works Association Research Foundation (AwwaRF) publications, an engineering consultant, or other systems with similar issues.

2.5 Step 5: Identify Steps to Minimize Future OEL Exceedances

As part of the operational evaluation, the system **must** identify steps to minimize future exceedances. Steps may include both treatment and distribution system changes such as improved DBP precursor removal flushing, modified disinfection practices, reduced distribution system residence time, and/or expanded water quality monitoring programs. Chapter 6 contains more information on steps to consider for minimizing future OEL exceedances.

There may be instances where the current system configuration poses limitations in controlling the formation of TTHM and HAA5, particularly for consecutive systems. Consecutive systems should work with their wholesaler on developing an approach for minimizing DBP formation.

For guidance on minimizing future OEL exceedances, refer to

Chapter 6: Minimizing Future Exceedances

2.6 Step 6: Prepare and Submit Report

You **must** submit a written report to the State within 90 days after being notified of the analytical result that caused the OEL exceedance. The written report **must** be made available to the public upon request. The report **must** include the results of examining your distribution, treatment, and source water operational practices that may have contributed to the OEL exceedance. The report **must** also include steps that could be considered to minimize future OEL exceedances.

The form contained at the beginning of this chapter and checklists in Chapters 3, 4, and 5 can be used when preparing your report. You should check with the State regulatory agency to see if any of these or other forms are required as part of the operational evaluation report. Appendices B through E contain example reports using the form and checklists.

2.7 Uses of Operational Evaluation Reports

The operational evaluation provides information that allows systems to act to prevent a violation of the Stage 2 DBPR MCLs. The operational evaluation provides systems with valuable information to evaluate current operational practices (e.g., water age management, flushing, source blending) or in planning system modifications or improvements (e.g., disinfection practices, storage tank modifications, distribution system looping). The operational evaluation will also provide valuable information for use in:

- System capital improvement and planning;
- Preventative maintenance and asset management plans;
- Treatment and distribution operations plans and standard operating procedures; and
- Treatment and distribution system optimization efforts.

State review of operational evaluations will also be valuable for both States and systems in their interactions, particularly when systems may be in discussions with, or requesting approval from, the State for system improvements or modifications. Review of operational evaluations will be valuable for States in reviewing other compliance submittals. The operational evaluation report will also provide valuable information for use in:

- Sanitary surveys and inspections;
- Review of distribution, treatment, or source modifications;
- Review or approval of operations plans or operating permits;
- State optimization efforts; and
- Technical and compliance assistance.

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3. Distribution System Evaluation

This chapter covers:

3.1 System Maintenance
3.2 Changes in System Demand
3.3 Storage Facility Operations
3.4 Booster Disinfection Practices
3.5 References
3.6 Additional Resources

Although a significant portion of TTHM and HAA5 can form during primary disinfection, they can continue to form within the distribution system as a result of continual exposure to disinfectant residuals and extended contact time. TTHM and HAA5 can increase further if precursors contained in pipeline or storage tank sediment come into contact with disinfectant residuals.

This chapter provides guidance on how distribution data and records can be evaluated to determine the cause of the operational evaluation level (OEL) exceedance. The checklist on pages 3-4 and 3-5 can be used to collect information and document the distribution system evaluation. The Stage 2 DBPR does not require the use of this checklist, but you should check with the State regulatory agency to ask if any of these or other forms are required as part of the evaluation report. Items on the checklist are discussed in detail in the applicable sections of this chapter. There may be additional causes of an OEL exceedance that are not included in the checklist.

Before you begin:

- Gather distribution system monitoring and operations data that reflect conditions just prior to and during the time of the OEL exceedance. Types of information that could be useful include:

  - Temperature data;
  - Disinfectant residual data;
  - Pump station and storage facility operating data (e.g., tank level data);
  - System flow and pressure data;
  - Maintenance records (planned and emergency); and
  - Customer complaint records.

  Different systems will have different types of data available to them. Exhibit 3.1 shows the water quality parameters that may be collected by systems using ground water, filtered surface water, unfiltered surface water, and groundwater under the direct influence of surface water (GWUDI). Many systems have water quality monitoring programs above and beyond regulatory requirements to help optimize distribution system operations and finished water quality.

Exhibit 3.1 Distribution System Monitoring Data

Parameter	System Type		
	Ground water	Filtered surface water/GWUDI	Unfiltered surface water/GWUDI
Temperature	Optional	Optional	Optional
Disinfectant residual	Required[1]	Required	Required
Pump records, meter records, and other flow information	Optional	Optional	Optional
Tank operations	Optional	Optional	Optional
Maintenance and operations records (flushing, repairs, replacement, and other)	Optional	Optional	Optional
Customer complaint records	Optional	Optional	Optional

Required = Required data a system should have based on Federal regulatory requirements. Additional monitoring parameters may be required by the State.

Optional = Optional data a system may have for optimization, process control purposes or State requirements.

[1] Ground water systems that disinfect are required to monitor disinfectant residual.

You may wish to obtain historical water quality monitoring data for comparison to data collected at the time of the OEL exceedance to determine if deviations from normal patterns occurred. In particular, evaluate historical temperature and disinfectant residual data for the monitoring site where the OEL exceedances occurred. If water temperature is unusually high or disinfectant residual is unusually low at the location compared to previous years, the site may have experienced longer than normal water residence time. If disinfectant residual is unusually high for that time of year, an increase in finished water residual concentration may be the cause (see Chapter 4 for guidance on treatment process evaluations for OEL exceedances).

Hydraulic models, water quality models or other similar tools may be helpful in conducting this data evaluation. For example, Besner et al. (2001) developed a data integration approach to help identify the causes of water quality variations in the distribution system. Besner emphasizes the need to evaluate system hydraulics data and be aware of operations and maintenance events in the distribution system that can affect water quality. Besner's data integration approach uses Excel spreadsheets, a hydraulic model, and a geographic information system (GIS) program, all tools that are commercially available and familiar to many water system personnel.

- Customer complaint records can be very helpful in identifying a problem with the distribution system that could have contributed to the OEL exceedance. Check records for the following types of customer complaints:

    - **Low pressure.** Reports of low pressure can indicate that a main break or firefighting event occurred. These events can allow old water from tanks, dead ends, or stagnant zones to be drawn into other areas of the distribution system. This water may contain high levels of TTHM and HAA5.

    - **Color.** A sudden change in color may also indicate that sediment or pipe scales have been released into the distribution system. However, systems should be careful when examining color data because source water contaminants such as algae, metals, iron, and sulfur bacteria can also cause color in water.

    - **Odor.** Customer complaints of a strong chlorine odor can indicate that disinfectant concentrations are higher than normal, which may indicate that TTHM and HAA5 levels are also high. Odor complaints may also occur if pipe scales or sediment are disturbed and released into the bulk water.

    - **General Taste and Odor.** Musty, dirty, or stagnant taste and odor could indicate low water use areas or areas where the chlorine residual is low or depleted. The water in these areas of the distribution system may have longer residence times and higher DBPs.

- As recommended in Chapter 2, you should compare TTHM and HAA5 data from different points in the distribution system from the time of the exceedance (See Step 2 in Section 2.2). If OELs were exceeded at only a few locations, you may be able to narrow your focus to monitoring data from those parts of the distribution system. Remember, you **must** obtain State approval to limit the focus of your evaluation.

Distribution System Evaluation Checklist

System Name: ______________________________

Checklist Completed by: ______________________ Date: ____________

A. Do you have disinfectant residual or temperature data for the monitoring location where you experienced the OEL exceedance? ☐ Yes ☐ No

If NO, proceed to item B. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was the water temperature higher than normal for that time of the year at that location?
☐	☐	Was the disinfectant residual lower than normal for that time of the year at that location?
☐	☐	Was the disinfectant residual higher than normal for that time of the year at that location?

B. Do you have maintenance records available for the time period just prior to the OEL exceedance? ☐ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions:

Yes	No	
☐	☐	Did any line breaks or replacements occur in the vicinity of the exceedance?
☐	☐	Were any storage tanks or reservoirs taken off-line and cleaned?
☐	☐	Did flushing or other hydraulic disturbances (e.g., fires) occur in the vicinity of the exceedance?
☐	☐	Were any valves operated in the vicinity of the OEL exceedances?

C. If your system is metered, do you have access to historical records showing water use at individual service connections? ☐ Yes ☐ No

If NO, proceed to item D. If YES, was overall water use in your system unusually low, indicating higher than normal water age? ☐ Yes ☐ No

D. Do you have high-volume customers in your system (e.g., an industrial processing plant)? ☐ Yes ☐ No

If NO, proceed to item E. If YES, was there a change in water use by a high-volume customer? ☐ Yes ☐ No

E. Is there a finished water storage facility hydraulically upstream from the monitoring location where you experienced the OEL exceedance? ☐ Yes ☐ No

If NO, proceed to item F. If YES, review storage facility operations and water quality data to answer the following questions for the period in which the OEL exceedance occurred:

Yes	No	
☐	☐	Was a disinfectant residual detected in the stored water or at the tank outlet?
☐	☐	Do you know of any mixing problems with the tank or reservoir?
☐	☐	Does the facility operate in "last in-first out" mode?
☐	☐	Was the tank or reservoir drawn down more than usual prior to OEL exceedance, indicating a possible discharge of stagnant water?
☐	☐	Was there a change in water level fluctuations that would have resulted in increased water age within the tank or reservoir?

Distribution System Evaluation Checklist

F. Does your system practice booster chlorination? ☐ Yes ☐ No

If NO, proceed to item G. If YES, was there an increase in booster chlorination feed rates? ☐ Yes ☐ No

G. Did you have customer complaints in the vicinity of the OEL exceedance? ☐ Yes ☐ No

If NO, proceed to item H. If YES, explain.

____

____

____

____

____

H. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the TCR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by the need to maintain a detectable disinfectant residual in your ability to control DBP levels in the distribution system? ☐ Yes ☐ No

If NO, proceed to item I. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

____

____

____

____

____

I. Conclusion

Did the distribution system cause or contribute to the OEL exceedance(s)? ☐ Yes ☐ No ☐ Possibly

If NO, proceed to evaluations of treatment systems and source water. If YES or POSSIBLY, explain below.

____

____

____

____

____

3.1 System Maintenance

Maintenance records are useful supplements to distribution system monitoring data. Although monitoring data can show fluctuations in temperature, disinfectant residual, and other factors that contribute to TTHM and HAA5 formation, maintenance records can reveal short term, physical distribution system changes that can influence TTHM and HAA5 formation but may not be identified through monitoring.

Data Analysis

Systems should examine maintenance records for any activities that may have affected disinfection practices or flow in the areas where OEL exceedances occurred. Systems should examine records of both planned maintenance, such as tank cleaning and flushing, and unplanned maintenance, such as repairing a broken pipe.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from system maintenance activities include:

- **Line breaks.** Line breaks can cause a pressure drop and change the pattern of flow through the distribution system. As a result, older water from stagnant zones may be drawn into other areas of the distribution system where water use is higher. **What to check:** Review maintenance records and determine if a main break occurred in the vicinity of the OEL exceedance.

- **System isolation for repairs.** Frequently, system maintenance work is accompanied by the closure of valves to isolate sections of the distribution system. This changes the flow patterns in surrounding areas of the distribution system, which can potentially cause stagnant water with high DBP levels to flow into areas of the distribution system serving customers. Also, after repair work is completed, the repair crew may fail to open all the valves that were closed due to construction work, which can create artificial dead ends. **What to check:** Review maintenance records and determine if an event, such as a main repair, occurred that resulted in a valve being closed. Also, check valves in the vicinity of the OEL exceedance to assess if a valve is closed that should typically be open. Review customer complaint records to see if anyone reported discolored water in the vicinity of the OEL exceedance.

- **Disinfection of pipe after repair/replacement.** Disinfection of new or repaired distribution system piping is typically accomplished using a highly concentrated (> 25 ppm) chlorine solution. Failure to properly flush a section of new or repaired pipe before placing it into service can introduce excessive amounts of chlorine to the distribution system and result in short-term spikes in TTHM and HAA5 concentrations. **What to check:** Check maintenance records to determine if a section of pipe was replaced or repaired in the area near where an OEL exceedance occurred.

- **Storage tank cleaning and disinfection.** Storage tanks are cleaned periodically. During this cleaning process, sediment can be disturbed and released into the distribution system. This sediment can react with residual disinfectants to form TTHM and HAA5. Storage tanks should be disinfected after any maintenance activities. If disinfection is not conducted properly, water containing high concentrations of chlorine can be released into the distribution system. **What to check:** Review maintenance records and determine if a storage facility was cleaned in the vicinity of the OEL exceedance. Check customer complaint records for reports of a chlorinous odor.

- **Flushing.** Flushing can cause the release of pipe scales and sediment into the water column. Organic matter can be present in these scales and sediment that can react to form TTHM and HAA5. Flushing can also result in a reversal of flow in the vicinity of the OEL exceedance, potentially causing older water to be delivered to an area for a limited time. **What to check:** Review maintenance and other operational data and determine if a flushing or other event occurred in the vicinity of the OEL exceedance. Check customer complaint records for reports of discolored water.

Flushing the distribution system.

- **Breakpoint chlorination to address nitrification.** Some systems that chloraminate periodically use breakpoint chlorination to control nitrification or biofilm growth in the distribution system. DBP formation can increase during these periods. **What to Check:** If your system practices breakpoint chlorination, review operating records to determine if breakpoint chlorination was used prior to or during the OEL exceedance.

3.2 Changes in System Demand

It is important to understand how the hydraulic design of the system and system operation affect TTHM and HAA5 formation. High water residence time in the distribution system can lead to higher TTHM and HAA5 concentrations. High residence times can be the result of low system demand overall, or can occur locally, particularly in dead ends or stagnant zones. System operators should understand "…the amount of water being used, where it is being used, and how this usage varies with time." (National Research Council 2006) With this knowledge, system operators can estimate water ages for various parts of the system and can modify operations to minimize water age.

A dead end may be the result of distribution system piping configuration (e.g., the actual end of a long pipe with few connections) or valving configuration (e.g., a closed valve that prevents flow from one area to another). Stagnant zones are created when water flow from opposing directions meets at a location where there is little or no water demand. There is no net water movement in any direction in that particular location and, therefore, fresh water cannot flow to a stagnant zone from other areas. A hydraulic model may allow you to estimate residence times and identify stagnant zones.

Data Analysis

Systems should review pump and meter data to determine if demands were lower than normal, resulting in high distribution system residence times. It may also be helpful to review hydraulic model results or other data to identify dead ends or stagnant zones near the vicinity of the OEL exceedance. Water quality data should be reviewed from sites in the vicinity of the OEL exceedance. Decreased disinfectant residual and high temperatures may be water quality indicators of high water residence time.

Systems should use caution when using disinfectant residual data to assess water residence times. Disinfectant residual decay is highly dependent on local distribution system conditions including piping materials, corrosion and conditions inside the pipe, microbiological activity, water temperature, level of disinfectant demand, and accumulation of sediment.

Causes

The primary causes of excessive residence times that can lead to increased TTHM and HAA5 formation include:

- **Low system demands.** An overall reduction in system demand can increase residence time throughout the distribution system. Also, reduced water demand from a high-volume industrial water user can have a large impact on water residence time in a specific area. In the summer, demand may be lower during rainy periods due to lower outdoor water use. **What to check:** Review pump and meter data to determine if water demand was low. Check demands for high-volume industrial customers. Check disinfectant residual data throughout the system compared to finished water levels to determine if there was a larger than normal decrease in residual levels.

- **Dead ends and stagnant zones.** If your Stage 2 monitoring site is near a dead end, residence time may be unusually high in this area. If two sources of water supply the area in which the OEL exceedance occurred, a stagnant zone could be occurring at or near the monitoring site. **What to check:** Review system operating data, perhaps with the use of a hydraulic model, to identify dead ends or stagnant zones within the vicinity of the OEL exceedance. Check disinfectant residual data to determine if levels at the site were unusually low at the time of the exceedance compared to previous years, indicating longer than normal residence times in that area.

3.3 Storage Facility Operations

Configuration and operation of storage facilities has a significant impact on water age in the areas "downstream" of the storage tank. In general, storage facilities can impact TTHM and HAA5 formation by increasing residence time for the water as a whole, discharging water with very high residence times from stagnant zones in the tank. If bottom sediments are stirred up as the water is discharged from the storage facility, the water may have elevated levels of DBP precursors.

If the storage facility is operated such that water level fluctuations are small and turnover of the water is infrequent, the stored water age can be high. Storage facilities are sometimes oversized to provide water under emergency circumstances. One disadvantage of this design approach is that a much smaller volume of water is needed under normal operations. The longer the water is in contact with a disinfectant, the more likely TTHM and HAA5 will form.

Storage tank configuration and operation can significantly affect DBP levels.

The mixing characteristics of storage tanks are impacted by the inlet/outlet piping configuration, inlet momentum, temperature, and duration of drain/fill cycles. For example, common inlet/outlet piping and oversized inlet piping that results in low inlet velocity are potential causes of poor mixing in storage facilities.

A common problem occurs when tanks operate in "last in–first out" mode, meaning that the freshest water in the tank is the first to be discharged during a drain cycle. During periods of higher than normal demand when drain periods are extended, these tanks may discharge water from the upper regions of the tank where water age is substantially (e.g., several days or weeks) higher than water in the lower regions of the tank. If a system has one or more poorly mixed storage tanks, areas receiving the stored water from those tanks may occasionally have high DBP concentrations.

The presence of sediment in the tank may result in higher TTHM and HAA5 levels. Organic matter in the sediment can react with disinfectants in the water, resulting in increased concentrations of TTHM and HAA5.

Data Analysis

If the OEL exceedance occurred in the area downstream of a storage tank, you should evaluate tank circulation, turnover, and drawdown levels. Examine pump on/off cycles and associated tank levels. A methodology for evaluating storage tank mixing characteristics is presented in *Water Quality Modeling of Distribution System Storage Facilities* (Grayman et al., 2000). Also check maintenance records for the last tank cleaning and inspection. Infrequent draining and cleaning can result in the presence of sediment in storage facilities.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from storage tank operations include:

- **Discharge of stagnant water.** During periods of higher than normal demand when the storage facility is drained to a lower level than usual, water that had previously stagnated in poorly mixed hydraulic zones in the tank may be discharged into the distribution system. **What to check:** Review tank configuration and operations to identify potential stagnant zones. You may also want to evaluate disinfectant residuals and temperatures at different levels and locations to help determine if there are stagnant zones within a tank. Review tank level records to determine if a tank was drawn down to unusually low levels, allowing water from stagnant zones to enter the distribution system.

- **Increased residence time.** Increased residence times can result if water in the storage facility is turned over infrequently. **What to check:** Check tank operating levels and system demands to determine if excessive residence time occurred prior to the OEL exceedance. Check temperature and disinfectant residual data for water discharged from the storage facility. Loss of a disinfectant residual and/or increased temperature may be water quality indicators of high water residence time.

- **Sediment in tank.** The presence of sediment may contribute to higher TTHM and HAA5 formation. **What to check:** Check system maintenance records to determine the last time the tank was drained and cleaned. You may also wish to inspect the tank and determine if sediment is present.

- **Breakpoint chlorination to address nitrification.** Some systems that chloraminate periodically use breakpoint chlorination to control nitrification or biofilm growth in tanks. DBP formation can increase during these periods. **What to Check:** If your system practices breakpoint chlorination, review operating records determine if breakpoint chlorination was used prior to or during the OEL exceedance.

3.4 Booster Disinfection Practices

Booster disinfection is used by some systems to maintain a disinfectant residual in sections of a distribution system that might not otherwise maintain a residual. When properly controlled and coordinated with the treatment plant disinfection process, booster disinfection can be used to reduce average distribution system TTHM and HAA5 concentrations. To accomplish this, the disinfectant dose applied at the plant should be minimized to reduce TTHM and HAA5 formation while maintaining the necessary residual in the distribution system prior to the boosting station. The booster disinfectant dose is then added to maintain a residual to the end of the system. The booster disinfection feed system needs to be maintained in working, calibrated order in order to prevent an overfeed that introduces too much chlorine into the distribution system and increases DBP levels.

Data Analysis

Review the distribution system disinfectant residual data during the time period that would have most impacted TTHM and HAA5 levels at the time and location of the OEL exceedance. It may be helpful to review historical distribution system disinfectant residual data and compare it to residual data collected during the period leading up to the OEL exceedance. It is also helpful to evaluate disinfection feed practices at booster disinfection facilities.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from a problem with booster disinfection include:

- **Sudden increase in booster chlorination feed rates.** A malfunction or poor calibration of a booster chlorination feed pump could cause overdosing of chlorine. **What to check:** Review booster chlorination feed rates during the time period that would have most impacted TTHM and HAA5 levels at the time and location of the OEL exceedance. Verify that chemical feed pumps are delivering chemicals at set rate (i.e., perform a "pump catch").

3.5 References

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Grayman, W. M., L. A. Rossman, C. Arnold, R. A. Deininger, C. Smith, J. F. Smith, and R. Schnipke. 2000. *Water Quality Modeling of Distribution System Storage Facilities*. Denver: AwwaRF and AWWA.

National Research Council. 2006. *Drinking Water Distribution Systems: Assessing and Reducing Risks*. Washington D.C.: The National Academies Press.

3.6 Additional Resources

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4. Treatment Process Evaluation

This chapter covers:

4.1 Predisinfection
4.2 Presedimentation
4.3 Coagulation/Flocculation
4.4 Sedimentation/Clarification
4.5 Filtration
4.6 Primary Disinfection
4.7 Recycle Practices
4.8 Secondary Disinfection
4.9 References
4.10 Additional Resources

This chapter provides guidance on how treatment processes can be evaluated to determine the cause of an operational evaluation level (OEL) exceedance. Different systems will have different types of data available to them – Exhibit 4.1 shows the water quality parameters and operational data that ground water systems, filtered surface water systems, and unfiltered surface water systems may be collecting on a regular basis for regulatory purposes and/or for treatment process control. Systems are encouraged to expand water quality monitoring programs above and beyond regulatory requirements to help optimize treatment processes. Consecutive systems that purchase all water may want to obtain this data from the wholesaler to help identify the cause of the OEL exceedance.

The checklist on pages 4-4 through 4-7 can be used to collect information and document treatment process evaluations. The Stage 2 DBPR does not require the use of the checklist, but you should check with your State regulatory agency to see if any of these or other forms are required as part of the evaluation report. Items on the checklist are discussed in detail in applicable sections of this Chapter. There may be additional causes of OEL exceedances that are not identified in the checklist. Note that treatment plant processes (including recycle practices) are organized according to the order in which they are typically configured in a conventional plant.

Exhibit 4.1 Treatment Plant Monitoring Data

Parameter	System Type[1]		
	Ground water	Filtered surface water/GWUDI	Unfiltered surface water/GWUDI
Raw water TOC		Required[4], Optional	Optional
Predisinfectant and other pretreatment feed rates	Optional	Optional	Optional
Coagulant/polymer feed rates	Optional	Optional	
Other chemical feed rates for pH or alkalinity adjustment to improve coagulation	Optional	Optional	
Settled water turbidity		Optional	
Combined and individual filter effluent turbidity		Required[2]	
Particle counts		Optional	
Primary disinfectant concentration	Optional	Required	Required
Temperature[3]	Optional	Required	Required
pH[3]	Optional	Required	Required
Flow[3]	Optional	Required	Required
Finished water TOC		Required[4], Optional	Optional
Finished water TTHM, HAA5, pH, temperature, DOC, SUVA, color		Optional	Optional
Disinfectant concentration at entry to the distribution system	Required (if using chlorine dioxide)	Required	Required

Required = Required data a system should have based on Federal regulatory requirements. Additional monitoring parameters may be required by the State.

Optional = Optional data a system may have for optimization, process control purposes or State requirements.

[1] Consecutive systems may wish to obtain some of the information in the table from their wholesaler.

[2] Only conventional and direct filtration systems are required by the Surface Water Treatment Rule (SWTR) to monitor individual filter effluent turbidity.

[3] Temperature, pH, and flow must be measured to determine microbial inactivation credit (CT).

[4] Only conventional filtration systems are required by the Stage 1 DBPR to monitor alkalinity and TOC in the source water.

Before you begin:

- You should have a good understanding of the time of travel from the treatment plant to the distribution system monitoring locations to determine the relevant period of treatment process data.

- Review finished water data collected prior to the OEL exceedance to help focus the evaluation. Key parameters to review may include:

  - DBP precursors levels (TOC), specific ultraviolet absorbance (SUVA), dissolved organic carbon (DOC), bromide);
  - TOC characteristics (hydrophobic and hydrophilic fractions);
  - pH;
  - Temperature;
  - Turbidity;
  - Disinfectant concentration; and
  - TTHM and HAA5.

  Compare the current finished water data to historical data taken during the same time frame in past years. Increases in one or more of these parameters may provide important clues for the evaluation. For example, if TOC is higher than normal, you may have had a problem with the coagulation process. If the chlorine concentration is higher than normal, you may have overfed chlorine for primary disinfection. An increase in finished water TTHM and/or HAA5 concentrations could be a result of poor DBP precursor removal, overdose of disinfectant, longer than normal residence times, or other factors.

  If there are no obvious changes in these finished water parameters, the cause of the OEL exceedance may be in the distribution system. Remember, an operational evaluation of source, treatment, and distribution system practices **must** be completed unless the State allows an evaluation with a limited scope. The evaluation may not require a detailed review of all available data in order to identify possible causes of the OEL exceedance. You should determine the level of review necessary based on system-specific circumstances.

Treatment Process Evaluation Checklist

☐ **NO DATA AVAILABLE**

Facility Name:

Checklist Completed by: Date:

A. Review finished water data for the time period prior to the OEL exceedance(s) and compare to historical finished water data using the following questions:

Were DBP precursors (TOC, DOC, SUVA, bromide, etc.) higher than normal?	☐ Yes	☐ No
Was finished water pH higher or lower than normal?	☐ Yes	☐ No
Was the finished water temperature higher than normal?	☐ Yes	☐ No
Was finished water turbidity higher than normal?	☐ Yes	☐ No
Was the disinfectant concentration leaving the plant(s) higher than normal?	☐ Yes	☐ No
Were finished water TTHM/HAA5 levels higher than normal?	☐ Yes	☐ No
Were operational and water quality data available to the system operator for effective decision making?	☐ Yes	☐ No

B. Does the treatment process include predisinfection? ☐ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was disinfected raw water stored for an unusually long time?
☐	☐	Were treatment plant flows lower than normal?
☐	☐	Were treatment plant flows equally distributed among different trains?
☐	☐	Were water temperatures high or warmer than usual?
☐	☐	Were chlorine feed rates outside the normal range?
☐	☐	Was a disinfectant residual present in the treatment train following predisinfection?
☐	☐	Were online instruments utilized for process control?
☐	☐	Did you switch to free chlorine as the oxidant?
☐	☐	Was there a recent change (or addition) of pre-oxidant?
☐	☐	Did you change the location of the predisinfection application?

C. Does your treatment process include presedimentation? ☐ Yes ☐ No

If NO, proceed to item D. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were flows low?
☐	☐	Were flows high?
☐	☐	Were online instruments utilized for process control?
☐	☐	Was sludge removed from the presedimentation basin?
☐	☐	Was sludge allowed to accumulate for an excessively long time?
☐	☐	Do you add a coagulant to your presedimentation basin?
☐	☐	Was there a problem with the coagulant feed?

Treatment Process Evaluation Checklist

D. Does your treatment process include coagulation and/or flocculation? ☐ Yes ☐ No

If NO, proceed to item E. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were there any feed pump failures or were feed pumps operating at improper feed rates?
☐	☐	Were chemical feed systems controlled by flow pacing?
☐	☐	Were there changes in coagulation practices or the feed point?
☐	☐	Did you change the type or manufacturer of the coagulant?
☐	☐	Do you suspect that the coagulant in use at the time of the OEL exceedance did not meet industry standards?
☐	☐	Did the pH or alkalinity change at the point of coagulant addition?
☐	☐	Were there broken or plugged mixers?
☐	☐	Were flow rates above the design rate or was there short-circuiting?

E. Does your treatment process include sedimentation or clarification? ☐ Yes ☐ No

If NO, proceed to item F. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were there changes in plant flow rate that may have resulted in a decrease in settling time or carry-over of process solids?
☐	☐	Were settled water turbidities higher than normal?
☐	☐	Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?
☐	☐	Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
☐	☐	Was sludge allowed to accumulate for an excessively long time or was there a malfunction in the sludge removal equipment?

Treatment Process Evaluation Checklist

F. Does your treatment process include filtration? ☐ Yes ☐ No

If NO, proceed to item G. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was there an increase in individual or combined filter effluent turbidity or particle counts?
☐	☐	Was there an increase in turbidity or particle loading onto the filters?
☐	☐	Was there an increase in flow onto the filters or malfunction of the rate of flow controllers?
☐	☐	Were any filters taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and created the conditions for possible breakthrough?
☐	☐	Were any filters operated beyond their normal filter run time?
☐	☐	Were there any unusual spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
☐	☐	Were all filters run in a filter-to-waste mode during initial filter ripening?
☐	☐	If GAC filters are used, is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred (leave blank if not applicable)?
☐	☐	If biological filtration is used, were there any process upsets that may have resulted in the breakthrough of TOC (leave blank if not applicable)?

G. Does your treatment process include primary disinfection by injecting chlorine prior to a clearwell? ☐ Yes ☐ No

If NO, proceed to item H. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was there a sudden increase in the amount of chlorine fed or an increase in the chlorine residual?
☐	☐	Was there an increase in clearwell holding time?
☐	☐	Was the plant shut down or were plant flows low?
☐	☐	Was there an increase in clearwell water temperature?
☐	☐	Did you switch to free chlorine recently as the primary disinfectant?
☐	☐	Was the inactivation of *Giardia* and/or viruses exceptionally high?
☐	☐	Was there a change in the mixing strategy (i.e., mixers not used, adjustment of tank level)?

H. Does your plant recycle spent filter backwash or other streams? ☐ Yes ☐ No

If NO, proceed to item I. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Did a change in the recycle stream quality contribute to increased DBP precursor loading that was not addressed by treatment plant processes?
☐	☐	Did a recycle event result in flows in excess of typical or design flows?

I. Do you inject a disinfectant after your clearwell to maintain a distribution system residual? ☐ Yes ☐ No

If NO, proceed to item J. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was there a sudden increase in the amount of chlorine fed?
☐	☐	Was there a switch from chloramines to free chlorine for a burnout period?
☐	☐	If using chloramines, was the chlorine to ammonia ratio in the proper range?
☐	☐	Was there a problem with either chlorine or ammonia mixing?

J. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the LT2ESWTR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by other treatment targets/requirements in your ability to control precursors in coagulation/flocculation? ☐ Yes ☐ No

If NO, proceed to item K. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

____

____

K. Conclusion

Did treatment factors and/or variations in the plant performance contribute to the OEL exceedance(s)? ☐ Yes ☐ No ☐ Possibly

If YES or POSSIBLY, explain below.

____

____

____

____

____

____

4.1 Predisinfection

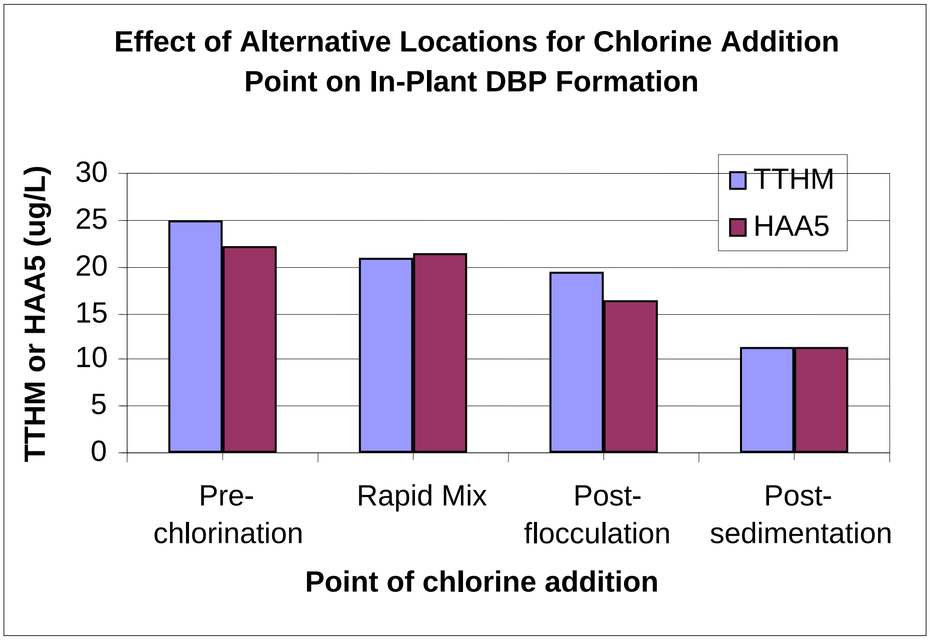
Predisinfection is the addition of a disinfectant to the treatment train prior to filtration. Generally, the purposes of predisinfection are to obtain an additional inactivation credit, to control microbiological growth in subsequent treatment processes, to improve coagulation, to oxidize contaminants such as arsenic or manganese, and to reduce tastes and odors. The most commonly used predisinfectants are chlorine, chlorine dioxide, and ozone. This section focuses on systems using chlorine as their predisinfectant.

Predisinfection with chlorine can result in significant TTHM and HAA5 formation due to the high concentration of DBP precursors available (prior to removal by coagulation, flocculation, sedimentation, and/or filtration) to react with the disinfectant, as well as the increased contact time through the treatment plant. DBPs will continue to form in subsequent treatment processes, not only during predisinfection, as long as there is a disinfectant residual present.
Systems that add chlorine following clarification, or post-filtration, will likely experience lower TTHM and HAA5 concentrations because of the removal of DBP precursors prior to chlorine addition.

Exhibit 4.2 shows one example of the effect of the point of chlorination on treatment plant TTHM and HAA5 concentrations. As shown in the figure, there is little difference in TTHM and HAA5 concentrations between prechlorination and rapid mix. This is primarily due to the fact that DBP precursors have not been removed from the water at this point in the treatment process. However, when the point of chlorine addition is moved to post-sedimentation, in-plant TTHM and HAA5 concentrations are reduced by greater than 70 percent and 50 percent, respectively.

Systems that change the point of chlorine addition seasonally to adjust for changes in raw water quality may experience fluctuations in DBPs. For example, systems that use prechlorination seasonally to control taste and odor may see increases in TTHM and HAA5 concentrations during those periods.

Exhibit 4.2 Effects of Chlorine Addition at Different Treatment Process Locations



Source: A. Franchi and C. Hill (2002).

Data Analysis

You should review predisinfectant feed rates and operational data during the time period that would have most impacted distribution system TTHM and HAA5 levels. You may also want to examine historical predisinfectant feed rates to determine if the chemical feed rates that were in effect at the time of the exceedance were unusual in comparison. Other data, such as flow, may also provide useful information on what factors may have contributed to increased DBP levels.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from problems with predisinfection include:

- **Poorly controlled or excessive pre-chlorine dose.** An increase in the chlorine dosage can increase TTHM and HAA5 concentrations. High chlorine dosages may be intentionally applied during periods of algal bloom for the control of color, taste, and odor. There can also be unintentional results of poor chemical feed regulation amplified by a decrease in water volume processed by the plant or equipment failure. Changes in the plant process that involve the use of pre-oxidation with chlorine (i.e., for arsenic treatment) may also increase DBP formation. **What to check:** Chlorine doses during the time period that would have most impacted distribution system TTHM and HAA5 levels.

- **Change in oxidant.** A change in the preoxidant type may result in a change in DBP concentrations. Systems that switch from potassium permanganate (which does not form TTHM and HAA5) to chlorine may experience increases in TTHM and HAA5. Systems that switch from chlorine to ozone will likely experience a decrease in plant TTHM and HAA5 concentrations. However, ozonation can result in increases in bromate concentrations (also a regulated DBP) in systems with sufficient bromide present in the source water. Some systems use chlorine dioxide because it produces relatively few THMs and HAAs. **What to check:** Plant operating records during the time period that would have most impacted distribution TTHM and HAA5 levels to see if oxidation with chlorine was implemented.

4.2 Presedimentation

Presedimentation is used to allow suspended material (inorganic and organic) to settle out to reduce the loading on the remaining treatment processes. In some plants, a coagulant and/or polymer is added to enhance settling, and mechanical flocculators can be used. Upsets to the presedimentation process can inhibit DBP precursor removal, resulting in higher concentrations of DBP precursors traveling through plant processes to react with disinfectants injected later in the treatment process.

Data Analysis

Review operating practices for the presedimentation basin and weather conditions to determine if there were any activities that might have inhibited settling in the basin (e.g., sludge removal). You should also review plant flow records to see if there was a change in flow through the basin. If you add coagulant and/or polymer to the presedimentation basin, you should review chemical feed records during the time period that would most impact distribution system TTHM and HAA5 levels.

Presedimentation basin with flocculator in foreground.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from problems with presedimentation include:

- **Increased flow rate through the basin.** A sudden increase in flow through the presedimentation basin could upset settled sludge or pass DBP precursors into the treatment plant at levels that are difficult to remove by major plant processes. **What to check:** Review flow rates into and out of the presedimentation basin and determine if flows were unusually high.

- **Decreased flow rate through the basin.** If the residence time in the presedimentation basin is unusually long, the temperature of the water could increase, which could result in increased formation of TTHM and HAA5. **What to check:** Review flow records into and out of the presedimentation basin to determine if longer than usual holding times occurred. You may also want to check temperature data (see Section 5.1 for additional discussion of temperature effects on DBP formation) and turbidity data if available.

- **Maintenance activities in presedimentation basins.** Sludge removal in presedimentation basins can stir up sediment and organic matter that has settled to the bottom of the basin. **What to check:** Review operational records to determine if sludge was removed from the presedimentation basin during the time period that would have most impacted distribution TTHM and HAA5 levels.

- **Poor basin maintenance practices**. Failure to remove sediment or sludge can result in re-suspension of particles, increased turbidity, and increased DBP precursors that could lead to higher TTHM and HAA5 formation in the plant. **What to check:** Review operational records to determine if or when sludge removal was last conducted.

- **Changes in coagulant and/or polymer feed rates.** A failure in the coagulant feed system or failure of the feed system to account for changes in flow could result in poor DBP precursor removal. **What to check:** Examine coagulant/polymer feed records and compare to flow data. Verify that chemical feed pumps are delivering chemicals at set rate (i.e., perform a "pump catch"). Also examine zeta meter or streaming current data, if available.

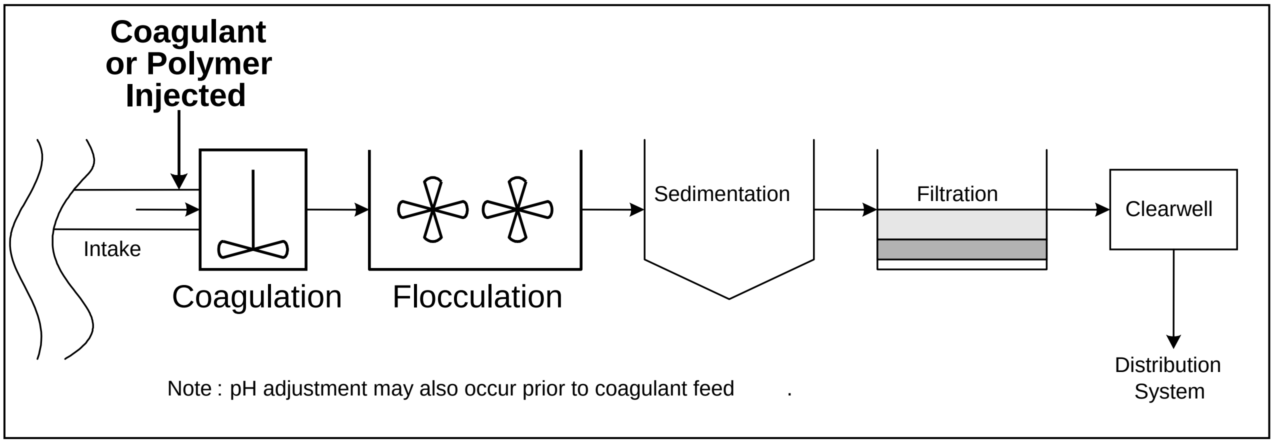
- **Extreme weather changes.** In large presedimentation basins, wind can cause bank erosion, creating deteriorated raw water quality. Ice formation and other weather conditions can also affect performance of the presedimentation basin. **What to check:** Review the weather logs (if available) or operator visual reports.

4.3 Coagulation/Flocculation

Coagulation is a process used for increasing the tendency of small particles in suspension to attach to one another and to attach to surfaces, such as the grains in the filter bed (AWWA, 1999). Coagulation is accomplished by feeding a coagulant, polymer, or combined coagulant/polymer. Flocculation is the "snowballing" of small particles into larger particles (called floc) that can be more easily removed from the water during sedimentation and filtration. Detention time and mixing of the coagulated water is necessary in order for the floc to form. Exhibit 4.3 illustrates where coagulation and flocculation are found in a typical conventional filtration plant.

The coagulant or polymer type and dose are critical for the effective removal of DBP precursors. Alum and ferric chloride (two commonly used coagulants) performance depends on the flow, turbidity, organic content, temperature, alkalinity, and pH of the water. The absence of alkalinity or a pH that is too low or too high will result in poor coagulation and flocculation for DBP precursor removal. Temperature can also affect the performance of certain coagulants, such as alum. Alum is less effective at colder temperatures. Feeding the wrong type or amount of polymer can also result in poor precursor removal. The more DBP precursors that remain in the water and come into contact with a disinfectant, the more potential for TTHM and HAA5 formation, particularly if chlorine is used.

Exhibit 4.3 Typical Conventional Filtration Plant



Data Analysis

Review coagulant, polymer, and other chemical feed records during the time period that would have most impacted distribution TTHM and HAA5 levels in comparison with historical chemical feed rates. Also, it is helpful to compare available raw water to finished water parameters (TOC, turbidity, pH, flow, and other available data). Determine if a change in raw water conditions was not adequately addressed through coagulant/polymer feed rates.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from problems with coagulation and flocculation include:

- **Poor regulation or failure of coagulant/polymer feed rate.** A system's inability to modify the coagulant/polymer feed rate in response to raw water quality changes or flow can result in poor DBP precursor removal. A failure of the feed system can also result in poor DBP removal. **What to check:** Examine coagulant/polymer feed records and compare to available raw water data to determine if a change in raw water conditions was not adequately addressed through coagulant/polymer feed rates. Also examine zeta meter or streaming current data, if available.

- **Poor regulation or failure of chemical feed system used to control pH and alkalinity.** The coagulant's performance depends on (in part) the alkalinity and pH of the water. A system's inability to maintain the proper alkalinity or pH (e.g., though the addition of lime, caustic soda, or acid) can result in poor DBP precursor removal. **What to check:** Check chemical feed records and compare to raw water data to determine if a change in raw water conditions was not adequately addressed through chemical feed rates. Verify that chemical feed pumps are delivering chemicals at set rate.

- **Poor mixing.** Broken or plugged mixers can result in poor mixing between chemicals and the water, resulting in poor floc formation. **What to check:** Check that mixers are properly functioning.

- **Lack of adequate detention time in the flocculation basin due to flows above the design capacity or short circuiting.** Flocculation basins are sized based on a specific design flow and flows in excess of the design flow may result in DBP precursors being passed through to subsequent treatment processes. **What to check:** Check plant flow rates and plant operational records to determine if the increase in flow was due to poor control at the plant inlet or a recycle event. Also examine chemical injection point and mixing mechanism to identify any potential short circuiting.

4.4 Sedimentation/Clarification

Sedimentation basins are designed for specific flows to maintain a certain overflow rate that allows floc and other particles to settle prior to filtration. Flows in excess of these design flows will result in particles, including DBP precursors, loading onto the filters. Short circuiting can also result in poor floc formation and carryover onto the filters. Poor or inadequate removal of sludge from the sedimentation basin, as well as maintenance in the basin that stirs or moves the sludge, can release soluble or particulate organic matter. As a result, organic matter may be carried through to subsequent treatment process and react with the disinfectants used at the plant. Exhibit 4.3 illustrates the sedimentation process in a typical conventional filtration plant.

Sedimentation basin.

Data Analysis

You should review settled water turbidity values during the time period that would have most impacted distribution TTHM and HAA5 levels. You may want to also examine historical settled water turbidity values to determine if these values that resulted in the exceedance were unusual in comparison to historic values. You should also review plant operational records and other data such as flow and temperature.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from problems with sedimentation and clarification include:

- **Short circuiting or flows in excess of design.** When water passes too quickly through a sedimentation or clarification basin, particles will not have sufficient time to settle and will pass through the treatment process. This will result in increased DBP precursors. **What to check:** Review flow rates into and out of the sedimentation basin to determine if flows were above allowed design flow values. Review settled water turbidity values. Also examine settling basin hydraulics to identify any potential short circuiting.

- **Basin cleaning or maintenance.** DBP precursors can be re-suspended during basin cleaning, resulting in increased formation of TTHM and HAA5. **What to check:** Review plant operational records and determine if sludge was removed from the sedimentation basin during the time period that would have most impacted distribution TTHM and HAA5 levels.

- **Poor basin maintenance practices.** Failure to remove sediment or sludge at regular intervals can result in re-suspension of particles and DBP precursors that can subsequently come into contact with chlorine. **What to check:** Review operational records to determine if or when sludge removal was last conducted. Review settled water turbidity data to determine if it has been increasing over time.

- **Weather conditions.** Periods of extended sunlight or uneven sunlight on multiple basins can cause density gradients in the basins and contribute to excessive floc carryover on to the filters. Ice formation and other weather conditions can also affect performance of the sedimentation basin. **What to check:** Review settled water turbidity levels in the sedimentation basin to determine if turbidity values were higher than normal during the OEL exceedance. Review the weather logs (if available) or operator visual reports.

4.5 Filtration

Breakthrough in filters occurs when the level of particles or contaminants in the effluent increase beyond acceptable levels. This may occur as a result of overloading of the filter or excessive filter run times.

Filtration is typically the last treatment process that physically removes particles and contaminants from the water (filtration is highlighted in Exhibit 4.3). Filter performance can be affected by inadequate coagulation, particle loading, hydraulic loading, filter run time, and method for placing a filter back into service. When a filter becomes overloaded or is left in service for too long, particles can begin to pass through the filter, and accumulated particles may be shed from the filter. These particles may contain DBP precursors that are available to react with the disinfectant in the clearwell, resulting in a higher potential for TTHM and HAA5 formation. The more DBP precursors that come into contact with the chlorine, the more likely that TTHM and HAA5 will form.

When biologically active filters and granular activated carbon (GAC) filters are used for organic precursor removal, breakthroughs may be a concern because soluble organic compounds or solids, which may be organic precursors, can be released. Likewise, when GAC columns are used for DBP removal after chlorination, exhaustion of adsorptive capacity may result in sudden TTHM and HAA5 peak concentrations in the finished water.

Membrane filtration technologies including microfiltration and ultrafiltration can remove high levels of bacteria. If systems employing these technologies are allowed to use a lower dosage rate for primary disinfection, lower DBP levels may be achieved. Nanofiltration membranes can remove virtually all particulate matter as well as dissolved organic matter that serve as DBP precursors.

Data Analysis

Review individual and combined filter effluent turbidity data collected during the time period that would have most impacted distribution TTHM and HAA5 levels. These values should be compared to historical individual and combined filter effluent turbidities to determine if the turbidity values are unusual. If particle count data are available on individual or combined filter effluent, these data can also be trended and provide valuable information similar to turbidity. If possible, you should also examine turbidity values from the settled water going onto the filters during the time period that would have most impacted distribution TTHM and HAA5 levels. If settled water turbidity values were higher than usual, you will want to evaluate upstream processes (sedimentation, coagulation, and flocculation) to determine which process may have contributed to the event. Filter operational data may also provide valuable information and is discussed in more detail in the following section.

Causes

The primary causes of filter breakthrough that can result in increased TTHM and HAA5 formation include:

- **Particle loading onto filters.** If upstream processes fail to remove sufficient particles, the increased burden may overload the filters and cause them to shed particles into the water. **What to check:** Examine settled water turbidity data to determine if a sudden increase of particle loading onto the filter occurred. Also review individual and combined filter effluent turbidity

Filter during draining operation.

and particle count data to see if these values increased in conjunction with settled water turbidity data.

- **Hydraulic loading rates onto the filters.** A sudden increase in hydraulic loading rates to the filter can cause particles to be shed. The increased loading rate can be caused by other filters being off-line or an overall increase in plant flows. **What to check:** Check individual and combined filter effluent turbidities and particle count data. Also, check plant operational records to determine if other filters were off-line but plant flow was not adjusted to account for the other filters being off-line. In addition, examine plant flow records and determine if the plant flow suddenly increased due to a recycle event or other event.

- **Filter run time.** If a filter is allowed to stay on-line beyond its design or typical filter run time, breakthrough of particles can occur. **What to check**: Review individual and combined filter effluent turbidity values and see if turbidity values (and particle count data if available) increased steadily toward the end of the filter run. Also review plant operating records and determine if a particular filter or filters were left on-line to the point of breakthrough.

- **Filter not ripening after being placed back into service.** Filters can experience turbidity spikes after being placed on-line. These spikes can result in particles that contain DBP precursors being passed to the clearwell. Spikes can be attributed to inadequate coagulation, poor backwash practices, improper or inability to filter-to-waste, or placement of a dirty filter back into service without backwashing or proper filter-to-waste period. **What to check:** When reviewing individual and combined filter effluent turbidity (and particle count data if available), determine if the filter routinely experiences spikes after being placed back into service. If so, the system should evaluate coagulation and backwash practices. A floc retention analysis can also be performed (refer to the suggested manuals for this procedure) that may provide more information on how well filters are cleaned during the backwash. The system should also review when and how the filter was placed on-line and if water was sent to the clearwell without an adequate filter-to-waste period.

4.6 Primary Disinfection

The purpose of primary disinfection is to inactivate *Giardia*, *Cryptosporidium,* and viruses. Commonly used primary disinfectants are chlorine, chlorine dioxide, chloramines, ozone, and UV. This section will focus on systems using chlorine since chlorine is the most commonly used primary disinfectant.

Systems are required by the Surface Water Treatment Rule (SWTR) and Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to achieve a certain level of microbial inactivation. For chemical disinfectants, this level of inactivation is determined by multiplying the disinfectant residual concentration (C) measured in a contact basin (vessel, pipeline or plant process) during peak hourly flow and the amount of time (T) the disinfectant is in contact with the water at peak hour flow. The contact time is a function of the contact basin hydraulics, configuration, baffling, and flow rate through the contact basin. Systems, in consultation with the State, will typically identify the minimum CT value needed in order to maintain the required amount of microbial inactivation under all operating conditions for compliance purposes. As the disinfectant dose decreases, the required contact time should be increased to maintain a required level of CT, and vice versa.

Chlorine is commonly used as a primary disinfectant.

Data Analysis

Review primary disinfectant feed rates and operational data during the time period that would have most impacted distribution TTHM and HAA5 levels. You may want to also examine historical primary disinfectant feed rates to determine if the disinfectant feed rates just prior to the exceedance were unusual in comparison to historic primary disinfectant feed rates. You should also check other operational parameters, such as flow, pH, and temperature. This data should be readily available since systems need to measure these parameters to calculate inactivation values.

Causes

The following disinfection related events can increase the formation of TTHM and HAA5:

- **Increased chlorine dose and/or residual (intentional or unintentional).** An increase in the disinfectant dose (particularly chlorine) can increase TTHM and HAA5 concentrations. The change in disinfectant dose may be intentional or unintentional. For example, systems that control the disinfectant dose manually and not based on plant flow may experience increases in TTHM and HAA5 if the plant flow rate suddenly decreases or the dose is not adjusted frequently to account for reductions in plant flow. In such instances, those systems would likely be overdosing chlorine. On the other hand, a system may intentionally increase the dose to account for a decrease in water temperature and maintain the required CT (CT requirements increase as water temperature decreases when using chlorine). **What to check:** Review disinfectant feed rates for the primary disinfectant during the time period that would have most impacted distribution TTHM and HAA5 levels. Systems may want to also examine historical disinfectant feed rates to determine if the chemical feed rates just prior to the exceedance were unusual in comparison to historic disinfectant feed rates.

- **Seasonal changes in water's disinfectant demand.** Systems may use alternate sources of supply to supplement the primary supplies during high demand periods or to temporarily replace a source of supply that has poorer water quality during certain times of the year (e.g., algal blooms in warmer months). When source water quality changes, the water's disinfectant demand may change, requiring a change in the primary disinfection dosage rate in order to maintain similar microbial inactivation levels. **What to check:** Review operational records to determine which sources of supply were in use just prior to the OEL exceedance.

- **Increased free chlorine contact time.** Poor mixing in the clearwell or other chlorine contact facilities (i.e., pipes or other storage tank) can result in dead zones where the hydraulic residence time is significantly higher than the residence time of the bulk of the water passing through the clearwell. As a result of the increased contact (i.e., reaction) time, TTHM and HAA5 concentrations may be significantly higher in the dead zones. A reduction in system demand (particularly in a system with little or no storage beyond the clearwell) may also result in longer hydraulic residence times in the clearwell and increased TTHM and/or HAA5 concentrations. Longer residence time within the clearwell can also result in increased temperatures, further increasing TTHM and HAA5 formation. **What to check:** Review flow records into and out of the clearwell or other chlorine contact facilities during the time period that would have most impacted distribution TTHM and HAA5 levels. This effort may involve the review of flow meter data or pump record data to obtain flows. Also check plant operation records to assess if the plant was shut down or off-line during this time period that resulted in excessive chlorine contact times. You may also want to check temperature values to determine if an increase in finished water temperature occurred.

- **Changes in primary disinfectant type.** Switching from ozone or chlorine dioxide to chlorine for primary disinfection could result in increased TTHM and HAA5 formation. **What to check:** Check plant operation records during the time period that would have most impacted distribution TTHM and HAA5 levels to determine if a switch to chlorine for primary disinfection occurred.

- **Changes in water temperature and pH.** CT requirements increase as water temperature decreases when using chlorine. During times that the water temperature increases, the plant may see a reduction of the CT required. If operating practices are not changed, the chlorine residual may be higher than required, increasing DBP formation. The same is true of pH if the raw water quality changes. **What to check:** Review water temperature, pH and chlorine dosage records. Compare required to actual chlorine dosage rate.

- **Control of ammonia and chlorine feed.** DBP formation can be minimized by using appropriate chlorine to ammonia ratios. In systems where ammonia and chlorine are injected concurrently, rapid and complete initial mixing could reduce the DBP formation rate. **What to check:** Chemical feed equipment for proper maintenance, calibration, and alarm settings. Mixing equipment for proper operation and maintenance. Monitor chlorine to ammonia ratio at point of mixing and downstream.

4.7 Recycle Practices

Some systems recycle residual streams back to the front of the treatment plant, a practice governed by the Filter Backwash Recycling Rule. Commonly recycled streams include filter-to-waste, spent filter backwash, thickener supernatant, and liquids from dewatering processes. These recycle streams may contain elevated concentrations of DBP precursors, in addition to other contaminants. For instance, spent filter backwash has been shown to contain significantly higher levels of TOC and DOC when compared to the raw water concentrations for these same parameters (Cornwell and Lee, 1993; Cornwell et al., 2001). If no additional treatment (e.g., coagulation/settling) of these recycle streams is provided, adjustment of the coagulant dose to account for the resulting change in water quality will likely be necessary. The return of these recycle streams may also cause a sudden increase in plant flow rates that result in treatment processes operating above design flow rates.

The primary causes of increased TTHM and HAA5 formation as a result of recycle practices include:

- **Spikes in the influent DBP precursor concentration and other contaminants.** When backwash water or other recycle streams are returned to the plant influent it increases the load of particles and DBP precursors or other contaminants in subsequent treatment processes. If appropriate treatment adjustments (such as changing the coagulant dose) are not made, the increased particle and contaminant concentrations may overload the subsequent treatment processes and allow the contaminants to pass through the treatment plant. **What to check:** Examine plant operational records to determine if a recycle event occurred during the time period that would have most impacted distribution TTHM and HAA5 levels. Also review coagulant/polymer and chemical feed rates, as suggested in Section 4.3.

- **Increase in the plant flow rate.** When recycle streams are returned to the head of the plant they can increase the overall plant flow rate and can overload subsequent treatment processes. **What to check:** Examine plant operational records to determine if a recycle event occurred during the time period that would have most impacted distribution TTHM and HAA5 levels. Check plant flow rates during that time period to determine if flow rates were above design plant flow.

4.8 Secondary Disinfection

The secondary disinfectant is used to maintain a disinfectant residual in the distribution system. Chlorine and chloramine are the most commonly used. Chlorine dioxide is used by systems that are able to maintain a residual without violating the chlorite MCL or chlorine dioxide MRDL. In some plants, the primary disinfectant is used (instead of adding another disinfectant after the clearwells) to maintain the distribution system residual.

If chlorine is applied as the secondary disinfectant, the concentration in finished water can have a significant impact on TTHM and HAA5 formation within the distribution system. If chloramines are used, chemical feed practices are more important than the concentration with respect to TTHM and HAA5 formation (chloramines do not react as quickly with DBP precursors to form DBPs). Some systems that chloraminate may periodically switch to free chlorine disinfection for a few weeks or month to reduce the population of nitrifying bacteria in the distribution system.

Data Analysis

You should review plant operating records to determine the amount of chlorine fed as the secondary disinfectant, whether temporarily or permanently fed, during the time period that would have most impacted distribution TTHM and HAA5 levels. These values should be compared to historical feed rates to determine if they are unusually high.

Causes

The primary causes of increased TTHM and HAA5 formation resulting from secondary disinfection practices include:

- **Sudden increase in chlorine feed rates.** A sudden increase in the amount of chlorine being fed into the distribution system directly affects the amount of TTHM and HAA5 concentrations. **What to check:** Chlorine doses during the time period that would have most impacted distribution TTHM and HAA5 levels.

- **Switch to chlorine.** A temporary or permanent switch to chlorine may result in increased TTHM and HAA5 formation because chlorine forms THMs and HAAs more readily than other common disinfectants. **What to check:** Review operational records and determine if the system switched to chlorine as the secondary disinfectant during the time period that would have most impacted distribution TTHM and HAA5 levels.

- **Control of ammonia and chlorine feed.** DBP formation can be minimized by using appropriate chlorine to ammonia ratios. In systems where ammonia and chlorine are injected concurrently, rapid and complete initial mixing could reduce the DBP formation rate. **What to check:** Chemical feed equipment for proper maintenance, calibration, and alarm settings. Mixing equipment for proper operation and maintenance. Monitor chlorine to ammonia ratio at point of mixing and downstream.

4.9 References

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4.10 Additional Resources

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USEPA. 1998. *Optimizing Water Treatment Plant Performance Using the Composite Correction Program, 1998 Edition*. August, 1998. EPA 625/6-91/027. Available online at: http://www.epa.gov/ORD/NRMRL/pubs9879.html

Partnership for Safe Water Information Center at http://www.awwa.org/Resources/partnershipforsafewater.cfm?ItemNumber=3787&navItemNumber=33969. The Partnership for Safe Water is a voluntary program designed to help water systems optimize water treatment plant performance without major capital improvements.

For consecutive systems, EPA will be publishing a consecutive systems guidance manual for the Stage 2 DBPR (refer to http://www.epa.gov/safewater/disinfection/stage2/compliance.html for updates. Also refer to the on-going AwwaRF project #3026, *Evaluation of Disinfection Practices for DBP and Precursor Occurrence in Consecutive Systems.*

5. Source Water Evaluation

This chapter covers:

5.1 Water Temperature
5.2 Organic Matter
5.3 Bromide
5.4 Turbidity and Particle Count Data
5.5 pH and Alkalinity
5.6 References
5.7 Additional Resources

This chapter provides guidance on how watershed and source water monitoring data can be evaluated to determine the cause of your operational evaluation level (OEL) exceedance. Different systems will have different types of data available to them – Exhibit 5.1 shows the water quality parameters that ground water systems, filtered surface water systems, and unfiltered surface water systems may be collecting on a regular basis for regulatory purposes and/or for process control. Consecutive systems that purchase all water may want to obtain these data from the wholesaler to help identify the cause of the OEL exceedance.

The checklist on pages 5-3 and 5-4 can be used to collect information and document the source water evaluation. The Stage 2 DBPR does not require the use of the checklist, but you should check with the State regulatory agency to see if any checklists or other forms are required as part of your evaluation report. Items on the checklist are discussed in detail in the applicable sections of this Chapter. There may be additional causes of OEL exceedances that are not identified in the checklist.

Expanded water quality data collection and review can assist systems in meeting OEL requirements (identifying causes and actions that could be considered to minimize future exceedances) and in optimizing treatment processes and distribution system operations.

Before you begin:

- You should have a good understanding of the time of travel from the source water to distribution system monitoring locations to determine the relevant time period for watershed and source water data.

- If you utilize multiple water sources, determine which sources were in use at and just prior to the OEL exceedances, and which source(s) likely influenced the location where the exceedance occurred. This will help narrow the evaluation to only those sources that could have contributed to the OEL exceedance.

Exhibit 5.1 System Source Water Monitoring Data

Source Water Monitoring Parameter	System Type[1]		
	Ground Water	Filtered Surface Water/GWUDI	Unfiltered Surface Water/GWUDI
Total organic carbon (TOC)	Optional	Required[2]	Optional
Dissolved organic carbon (DOC)	Optional	Optional	Optional
Specific ultraviolet absorbance (SUVA)	Optional	Optional	Optional
Color		Optional	Optional
Bromide	Optional	Optional	Optional
Turbidity		Required	Required
Particle counts		Optional	Optional
Temperature		Required	Required
Flow		Required	Required
pH		Required	Required
Alkalinity		Required[2]	

Required = Required data a system should have based on Federal regulatory requirements. Additional monitoring parameters may be required by the State.

Optional = Optional data a system may have for optimization, process control purposes or State requirements.

[1] Consecutive systems may wish to obtain source water information from their wholesaler.

[2] Only conventional filtration systems are required under Stage 1 DBPR to monitor alkalinity and TOC in the source water.

Source Water Evaluation Checklist

☐ **NO DATA AVAILABLE**

System Name:

Checklist Completed by: ______________________ Date: ____________

A. Do you have source water temperature data? ☐ Yes ☐ No

If NO, proceed to item B. If YES, was the source water temperature high? ☐ Yes ☐ No

If NO, proceed to item B. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was the raw water storage time longer than usual?
☐	☐	Did you place another water source on-line?
☐	☐	Were river/reservoir flow rates lower than usual? If yes, indicate the location of lower flow rates and the anticipated impact on the OEL exceedance.
☐	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?

B. Do you have data that characterizes organic matter in your source water (e.g., TOC, DOC, SUVA, color, THM formation potential)? ☐ Yes ☐ No

If NO, proceed to item C. If YES, were these values higher than normal? ☐ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Did lake or reservoir turnover occur?
☐	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?
☐	☐	Did an algal bloom occur in the source water?
☐	☐	If algal blooms were present, were appropriate algae control measures employed (e.g., addition of copper sulfate)?
☐	☐	Did a taste and odor incident occur?

C. Do you have source water bromide data? ☐ Yes ☐ No

If NO, proceed to item D. If YES, were the bromide levels higher or lower than normal? ☐ Yes ☐ No

If NO, proceed to item D. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Has saltwater intrusion occurred?
☐	☐	Are you experiencing a long-term drought?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Are you aware of any industrial spills in the watershed?

Source Water Evaluation Checklist

D. Do you have source water turbidity or particle count data? ☐ Yes ☐ No

If NO, proceed to item E. If YES, were the turbidity values or particle counts higher than normal? ☐ Yes ☐ No

If NO, proceed to item E. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Did lake or reservoir turnover occur?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did logging, fires, or landslides occur in the watershed?
☐	☐	Were river/reservoir flow rates higher than normal?

E. Do you have source water pH or alkalinity data? ☐ Yes ☐ No

If NO, proceed to item F. If YES, was the pH or alkalinity different from normal values? ☐ Yes ☐ No

If NO, proceed to item F. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was there an algal bloom in the source water?
☐	☐	If algal blooms were present, were algae control measures employed?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Has the PWS experienced diurnal pH changes in source water?

F. Conclusion

Did source water quality factors contribute to your OEL exceedance? ☐ Yes ☐ No ☐ Possibly

If YES or POSSIBLY, explain below.

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5.1 Water Temperature

The rate of reaction between chlorine (and chloramines) and DBP precursors increases as the water temperature increases. As a result, TTHM and HAA5 concentrations increase with increasing water temperature. Many water supplies experience seasonal temperature changes with higher temperatures in the summer and early fall and lower temperatures in the winter and early spring. The magnitude of the increase depends on a number of site-specific factors, including source water type (ground or surface water), climate, and hydrology.

Data Analysis

Systems should compare historical water temperature data to water temperature data collected during the period leading up to the OEL exceedance to determine if a significant increase in source water temperature occurred. Systems should also examine recent weather data. Sustained high air temperatures, particularly during droughts when water levels are low, will increase the temperature of surface water bodies, causing increased reaction rates and increased TTHM and HAA5 formation. However, increased demand during warmer weather (e.g., outdoor uses such as watering, car washing, and filling pools) that reduces the residence time may mitigate DBP formation associated with increased temperature. Other operational data may be helpful, as specified below.

Causes

Some potential causes of increased water temperature include:

- **Source water residence time and flows.** Long holding times in raw water storage basins and reservoirs in summer months can increase water temperatures. Low flows in streams and low lake levels can also result in increased water temperatures. **What to check:** Review flow data to determine if a decrease in flow occurred that resulted in longer source water residence times.

- **Air temperatures and sunlight.** An increase in air temperatures and sunlight can lead to an increase in source water temperatures. **What to check:** Review climatological records to determine if air temperatures were warmer than usual.

- **Change in raw water supply.** Ground water sources are typically cooler than surface water sources during the summer months and exhibit less seasonal variability in temperature than surface water sources. Therefore, seasonal use of sources can have a major impact on the temperature of the water entering a plant. For example, a system that supplements a ground water source with a surface water source in the summer may experience a significant increase in temperature. **What to check:** Review operational records to determine if another source was placed on-line that may have impacted temperature.

5.2 Organic Matter

Organic matter in source water generally results from decay of plant and animal materials. Sources of organic matter include water and wastewater treatment plant discharges, some industrial discharges, agricultural and urban area runoff, septic system leachate discharge and natural sources. Surface water tends to have higher levels of organic matter than ground water.

Organic matter is a DBP precursor that reacts with chlorine to form TTHM and HAA5. Organic matter can be classified as hydrophilic (more soluble) or hydrophobic (less soluble). Hydrophilic compounds are more difficult to remove from water than hydrophobic compounds, but also form fewer DBPs (Liang and Singer, 2001). If an increase in source water organic matter is not adequately addressed by adjustments to the treatment process, TTHM and HAA5 levels can increase.

Total organic carbon (TOC) is a direct measurement of the dissolved and particulate organic carbon in water. TOC is often used as a surrogate measurement for DBP precursors, although only a small fraction of the organic carbon will react to form DBPs (Symons et al., 2000). Conventional filtration plants are required to measure source water TOC and alkalinity and compare them to finished water TOC under Stage 1 DBPR.

There are several other measurements of organic carbon that can be useful in characterizing DBP precursors:

- **Dissolved organic carbon (DOC)**. DOC is the soluble portion of TOC that can pass through a membrane with a 0.45 micrometer pore size. Most of the organic carbon in drinking water supplies is typically dissolved.

- **Specific ultraviolet absorbance (SUVA)**. A SUVA analysis can indicate whether the organic matter in water is predominantly hydrophobic or hydrophilic. Hydrophilic compounds have lower SUVA than hydrophobic compounds (Croué et al., 1999). SUVA is determined by dividing the measured UV absorption of the water at 254 nanometer (in m^{-1}) by the measured DOC concentration of the water (in mg/L).

- **Color.** Organic material contributes to the color of a source water. Therefore, monitoring the color of the source water can serve as an indicator of the amount of TOC in the source water. A study by Alvarez et al. (1997) showed good correlation between TOC and color in water from a surficial aquifer. Color is measured using a spectrophotometer and is quantified in color units.

- **Trihalomethane (THM) Formation Potential.** The measurement of THM formation potential for source water indicates the maximum level of THMs that would occur if no treatment is provided. The test is conducted by adding chlorine to identical water samples at various dosage rates and measuring THMs. The water samples are subject to the same conditions (pH adjustment, holding time, temperature, etc.). These tests can also be conducted on finished water to provide information that may be more useful for the operational evaluation.

Data Analysis

If you routinely collect source water TOC, DOC, SUVA, color, or THM formation potential data, you should review these data during the time period that would have most impacted distribution system TTHM and HAA5 levels. You may also want to examine historical concentrations of these parameters to determine if a sudden increase in these concentrations results in an exceedance. If such an increase is identified, you should examine other watershed information (i.e., watershed protection plan, maps, property records, related newspaper articles etc.) to determine the possible cause(s) of the increase in DBP precursors. You should also examine the concentrations of these parameters in the finished water to determine if treatment was adequate in removing DBP precursors prior to disinfectant application (refer to Chapter 4 for more information on treatment plant evaluation).

With respect to SUVA, a change in the balance of hydrophobic and hydrophilic compounds in source waters can affect the formation of DBPs in the finished water. A sudden decrease in SUVA values compared to historical data indicates that the amount of hydrophilic compounds is increasing relative to the amount of hydrophobic compounds. As a result, TOC removal may be more difficult to achieve through coagulation. Alternatively, an increase in SUVA indicates that the organic compounds are more easily removed, but readily form DBPs. This can result in increased TTHM and HAA5 formation if sufficient TOC removal is not achieved prior to disinfection.

Systems that use color data as an indicator of TOC should exercise caution when examining this data because algae, metals, iron, manganese, sulfur bacteria, and industrial wastes can also cause color in water.

Causes

Surface water source with snow in watershed.

There are many possible causes of sudden increases in source water TOC including:

- **Heavy rainfall or snowmelt.** Heavy rainfall and snowmelt cause heavy runoff that washes organic matter from soils into surface water sources. These events do not need to occur locally to result in an increase in TOC. A runoff event miles upstream from a raw water intake can result in increased TOC concentrations. The effects of runoff on TOC levels are most pronounced after a period of drought, when organics are able to accumulate in soils (Aiken and Cotsaris, 1995). **What to check:** Review streamflow records, rainfall data, or other available climatological data during the period that would have most impacted distribution system TTHM and HAA5 levels. Historical and recent streamflow data can be obtained from the National Weather Service, United States Geological Survey (USGS), or other local agencies. Systems can examine recent streamflow and precipitation data to determine when and where runoff events have occurred to wash DBP precursors into surface water supplies.

- **Change in raw water supply.** Ground water sources typically contain less TOC than surface water supplies. Different surface water supplies can also have very different levels of TOC depending on climate and watershed characteristics. Therefore, seasonal use of sources can have a major impact on TOC. In addition, systems that regularly draw water from two sources with different TOC concentrations will have increased TOC if the portion of water withdrawn from the higher TOC source is increased. **What to check:** Review operational records to determine if a different source was placed on-line that may have been high in TOC.

- **Lake or reservoir turnover.** When turnover occurs, sediment and organic matter at the bottom of the lake or reservoir are stirred up and become resuspended. The resuspended organic matter can increase the organic load entering the plant. Reservoir turnover is typically triggered by water temperature differences in the different vertical layers within the water body. Wind can also help to trigger a reservoir turnover. **What to check:** Review operational records to determine if turnover was noted on any particular day. Turnover may also be accompanied by a sudden change in turbidity and water temperature. A review of source water turbidity (see Section 5.4) and temperature (see Section 5.1) data may be useful.

- **Point and non-point source pollution.** Discharge from wastewater treatment plants, upstream water treatment plants, and industrial plants may contain high amounts of organic carbon. Although lakes and rivers dilute the discharge from these plants, these point sources can still cause a significant increase in downstream organic carbon loads. Seasonal or intermittent operation of these facilities can cause fluctuations in organic carbon loads downstream. Other activities within the watershed, such as logging, landslides, or fire, may contribute a significant amount of sediment and organic loading to the source water. **What to check:** Previous watershed surveys, permitted discharges, watershed partnerships, State and Federal natural resource and regulatory agencies may also provide key information on watershed activities and point source dischargers respectively. A watershed survey could also be conducted to try to identify any unusual activities.

- **Algal blooms.** Algae convert inorganic carbon in the water into organic carbon compounds (Knappe et al.; 2004, Nguyen et al., 2000). Although research is not conclusive, studies suggest that in some cases, this process can lead to detectable increases in TOC and DOC in the surface water body during algal blooms (Knappe et al., 2004; Nguyen et al., 2000). Algal blooms also result in the production of organic matter that is generally more hydrophobic than hydrophilic. **What to check:** Review operational records to determine if algal blooms were noted within the raw water and document what control strategies were being used at the time of the OEL exceedance (i.e. copper sulfate addition). If chlorine was added to the source water for algae control, it is a likely contributor to THM formation.

5.3 Bromide

Bromide is an ion that occurs in salts in seas, oceans, mineral springs, and natural salt deposits. It can be found in both surface and ground waters. Bromide is an inorganic DBP precursor that reacts with chlorine and organic DBP precursors to form TTHM and HAA5. Bromide is oxidized by chlorine (hypochlorous acid) to form hypobromous acid. Both hypochlorous acid and hypobromous acid react with organic DBP precursors to form TTHM and HAA5 by substituting chloride or bromide for one or more hydrogen ions on organic molecules. Hypobromous acid is a stronger substituting agent than hypochlorous acid. Therefore, waters with bromide typically form more TTHM and HAA5 than waters without bromide (AWWA 1999; Krasner 1999; Baribeau et al. 2006). Increases in bromide levels in bromide-containing waters can also change the balance of TTHM and HAA5 species formed. For example, a recent AwwaRF research report (Baribeau et al. 2006) shows that waters with increasing influent bromide levels had lower levels of dichloroacetic acid and trichloroacetic acid, and higher levels of monobromoacetic acid and dibromoacetic acid.

Some water systems have reported that source waters with lower influent bromide resulting in higher finished water HAA5 levels and higher bromide resulting in lower finished water HAA5 levels, which may indicate that higher bromide concentrations shift the formation of HAAs to brominated species that are not part of HAA5 (McGuire, McLain and Obolensky 2003). However, these data trends only represent site-specific conditions and cannot be applied universally.

The operational exceedance provisions do not apply to bromate.

Data Analysis

Compare historical bromide data to bromide levels measured in the period leading up to the OEL exceedance. If it is determined that a significant change in bromide levels occurred, examine other watershed and/or source water monitoring data to determine the cause.

Causes

Some possible causes of increased bromide levels include:

- **Saltwater intrusion.** Because bromide is an ion that occurs in salts, it is naturally present in saltwater. When ground water withdrawals are too high or aquifer levels are depleted during drought, saltwater can displace fresh water. If ground water wells are located within an affected zone, bromide levels in the wells will increase. Some surface water intakes in rivers may draw salt water under low flow conditions if the intakes are located near the mouth of the river and the river discharges into an ocean or bay. In this case, a salt "wedge" extends upriver far enough to influence the bromide concentration in the intake's water. **What to check:** If available, review nearby stream gage and well depth data to determine if there have been tidal influences or other ground water level fluctuations. State and Federal natural resource agencies may also have useful hydrogeologic information. Surface water systems that may be influenced by a salt "wedge" can review tide charts and be informed when high tides may impact their water quality. They should also try to document river flow conditions that allow for the salt wedge to reach their intake. USGS has flow data available for most rivers across the country.

- **Droughts.** Bromide levels can increase when water levels in the aquifer are depleted by withdrawals and recharge is low. As the aquifer's water level decreases, the bromide in the aquifer becomes more concentrated, resulting in higher than normal bromide levels. If rainfall increases and the drought eases, the aquifer is recharged and bromide concentrations are diluted to normal levels. Industrial wastewater discharges that contain bromide or brominated byproducts (e.g., paper mills) may have more of an influence on water quality under low flow conditions during a drought. **What to check:** Review available precipitation data or contact your local National Weather Service to obtain drought status information. State and Federal natural resource agencies may also have useful information on drought conditions.

- **Heavy rainfall or snowmelt.** Runoff events can increase bromide levels in surface water sources if bromide-containing industrial or agricultural chemicals are used in the watershed. **What to check:** Review available streamflow records, rainfall data, or other available climatological data during the time period that would have most impacted distribution TTHM and HAA5 levels. Historical and recent streamflow data can be obtained from the National Weather Service, USGS, or other local agencies. Check with local public works and highway management departments to see whether road salts used under icy or snowy conditions contain bromide.

- **Change in raw water supply.** Systems with multiple sources may find that the sources have significantly different bromide concentrations. If a system uses a seasonal source that has high bromide levels, an increase in DBP formation may occur when the seasonal source is in use. **What to check:** Review operational records to determine if another source was placed on-line that may have been high in bromide.

5.4 Turbidity and Particle Count Data

Turbidity and particle counts are measures of the amount of suspended particles in water. While turbidimeters measure the amount of light reflected by particles in the water, particle counters measure the number of particles in specific size ranges that are present in the water. Many of the factors that contribute to DBP precursors in source waters also affect turbidity and particle counts. Therefore, increased turbidity levels can serve as an indicator of an event that may have resulted in increased DBP precursors in the source water. High turbidity levels and particle counts can also overload treatment processes, resulting in decreased removal and/or breakthrough of DBP precursors (see Chapter 4).

Data Analysis

Historical source water turbidity (or particle count) data should be compared to data collected in the period leading up to the exceedance of OELs to determine if a significant increase in turbidity (or particle counts) occurred. Climatological and operational data should also be examined to identify the event that caused the increase in turbidity or particle counts in the source water. In addition, turbidity and particle count data for finished water should be reviewed to determine if treatment was adequate in removing DBP precursors prior to disinfectant application (refer to Chapter 4 for more information on treatment plant evaluation). Other data, such as streamflow data, may provide useful information on what may have contributed to increased source water turbidity and particle counts.

Causes

Some potential causes of increased source water turbidity include:

- **Lake or reservoir turnover.** When turnover occurs, sediment and organic matter at the bottom of the lake or reservoir are stirred up and become resuspended. Reservoir turnover is typically triggered by water temperature differences in the different vertical layers within the water body. Wind can also help to trigger a reservoir turnover. **What to check:** Review operational records to determine if turnover was noted on any particular day. Turnover is usually accompanied by a sudden change in water temperature and a review of source water temperature data may be useful (see Section 5.1).

- **Heavy rainfall or snowmelt.** Heavy rainfall and snowmelt can create runoff events that wash sediment and soils into surface water sources. These events do not need to occur locally to result in an increase in turbidity. A runoff event miles upstream from a raw water intake can result in increased turbidity at the intake. **What to check:** Review streamflow records, rainfall data, or other available climatological data during the time period that would have most impacted distribution TTHM and HAA5 levels. Historical and recent streamflow data can be obtained from the National Weather Service, USGS, or other local agencies. Systems can examine recent streamflow and precipitation data to determine when and where runoff events occurred to wash DBP precursors into surface water supplies. This effect can be most pronounced after a long dry spell when DBP precursors are able to accumulate in soils.

- **Watershed activities.** Activities such as logging, fires, and landslides loosen soils in the watershed, allowing them to be more easily washed into surface water bodies during runoff events. In addition, landslides or logging near a surface water body can directly introduce large amounts of sediment into the water. **What to check:** Review available watershed information to determine if any unusual activities occurred. A watershed survey could also be conducted to try to identify any unusual activities.

5.5 pH and Alkalinity

Increases in pH can affect DBP formation in several ways. Most coagulation processes using metal salts, such as alum and ferric chloride, are optimized at pH less than 7. Therefore, increases in source water pH may be detrimental to the coagulation process (assuming no pH control is available at the treatment plant). Poor coagulation can result in less DBP precursor removal, leaving them available to react with chlorine or other disinfectants downstream in the treatment process. An increase in pH also decreases the efficacy of chlorine as a disinfectant. At higher pH values, systems may need to add more chlorine to maintain a certain level of inactivation. This in turn will increase DBP formation. A change in pH can affect the balance of HAA5 and TTHM formation. At higher pH, TTHM formation increases and HAA5 formation decreases. At lower pH, the reverse occurs.

Alkalinity is a measure of the capacity of water to neutralize acids. Carbonate, bicarbonate, and hydroxides that are present in the water contribute to alkalinity. Alkalinity is expressed in mg/L as calcium carbonate ($CaCO_3$).

Alkalinity serves as a buffer, making pH changes more difficult to achieve. When metal coagulants are used, the highest removal of DBP precursors occurs at low pH. As alkalinity increases, systems will have more difficulty decreasing the pH of the water for optimum coagulation. This in turn can lead to decreased precursor removal and increased TTHM and HAA5 formation. In addition, some coagulants consume alkalinity in the water. If the alkalinity in the source water decreases significantly, systems may need to add alkalinity to avoid decreased coagulation efficiency and decreased DBP precursor removal.

Data Analysis

You should compare historical pH and alkalinity data to recent data to determine if an increase in source water pH or alkalinity occurred at the time of the OEL exceedance. You should also examine other watershed and source water monitoring data to determine the cause of the pH or alkalinity change.

Causes

Some potential causes of a pH or alkalinity change include:

- **Algae.** During photosynthesis, algae consume carbon dioxide from the water. The series of chemical reactions that convert bicarbonate and carbonate into carbon dioxide result in the production of hydroxide ions, which can significantly increase the pH of the water (Knappe et al., 2004). Algae can result in fluctuations of pH over the course of a day, with pH values generally higher during the day and lower at night. The amount of direct sunlight directly impacts the algae lifecycle and impacts source water pH. **What to check:** Review operational records to determine if an algal bloom was noted in the raw water and document what control strategies were being used at the time of the OEL exceedance (i.e., copper sulfate addition). You may also want to determine if pH fluctuates between daytime and nighttime readings.

- **Change in raw water supply.** Systems with multiple sources may find that the sources have significantly different pH or alkalinity values. If two or more sources with different pH or alkalinity are being utilized at the same time, source water blending in the distribution system may be occurring, and may affect distribution system levels of pH and alkalinity. If a system uses a seasonal source that has a higher pH, an increase in DBP formation may occur when the seasonal source is in use. Intakes at different depths in a thermally stratified reservoir will likely have different pH values, with higher pH values generally being near the surface and lower values being closer to the reservoir or lake bottom. If a system switches its intake depth, it should be aware that the source water may have a different pH. **What to check:** Review operational records to determine if another source was placed on-line or intake depths were changed that may have affected pH or alkalinity.

Seasonal use of surface water sources can significantly affect DBP levels.

- **Heavy rainfall or snowmelt.** Soils have different pH and alkalinity values depending on the types and amounts of ions and organic matter in the soil. When a runoff event occurs, the ions and organic matter can be washed into surface water bodies, changing the pH or alkalinity of the water. **What to check:** Review streamflow records, rainfall data, or other available climatological data during the time period that would have most impacted distribution TTHM and HAA5 levels. Historical and recent streamflow data can be obtained from the National Weather Service, USGS, or other local agencies.

- **Drought.** Like heavy rainfall, a drought changes the ratio of surface water to ground water supplied to a reservoir or river. If the ground water has a higher alkalinity than the surface water, the alkalinity of the supply water will increase if more ground water is supplied during a drought. Surface waters receiving permitted discharges may see a change in pH or alkalinity when flows are low due to drought and the discharges have a greater influence on water quality. **What to check:** Review streamflow records, rainfall data, or other available climatological data during the time period that would have most impacted distribution TTHM and HAA5 levels to determine if a drought occurred. Historical and recent streamflow data can be obtained from the National Weather Service, USGS, or other local agencies.

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6. Minimizing Future Operational Evaluation Level Exceedances

This chapter covers:

6.1 Distribution System Improvements
6.2 Plant Operational Improvement
6.3 Source Water Management
6.4 References

As part of the operational evaluation, steps **must** be identified that could minimize future operational evaluation level (OEL) exceedances. This chapter discusses some common problems that can lead to an OEL exceedance and suggests alternatives for remedying these problems. Steps may include:

- Increasing monitoring,
- Modifying distribution system infrastructure or operations,
- Improving DBP precursor removal through treatment modifications, or
- Improving source water management.

There may be instances when your current system configuration poses limitations in controlling TTHM and HAA5 formation, particularly if you are a consecutive system. Consecutive systems should work with their wholesalers on developing an approach for minimizing DBP formation.

You may find additional information in the *Microbial and Disinfection Byproduct Rules Simultaneous Compliance Guidance Manual,* (USEPA, 2007) which may be useful as you consider options for minimizing TTHM and HAA5 levels in your distribution system.

Exhibit 6.1 provides examples of operational strategies that can be used to reduce DBPs. Note that Exhibit 6.1 does not provide a comprehensive list of strategies - other operational or low-cost capital modifications provided in this chapter may work better for your system.

Exhibit 6.1 Examples of Operational Strategies to Reduce DBPs

- Turn over water in finished water tanks and reservoirs more frequently to reduce water age. (6.1.1.1)
- Use blowoffs or flush dead ends in the distribution system to reduce water age. (6.1.1.2)
- Conduct periodic flushing. (6.1.2.2)
- Increase TOC removal by optimizing coagulation. (6.2.1.1)
- Clean settling basins before your peak DBP period. (6.2.1.3)
- Optimize filtration. (6.2.1.4)
- Review disinfection practices. Note that you MUST contact your State first before making any changes to disinfection practices. (6.2.3)
- Monitor source water and manage intake operations to draw raw water with the lowest possible TOC. (6.3)

6.1 Distribution System Improvements

Higher concentrations of TTHM and HAA5 are often found in the distribution system compared to the concentrations leaving the treatment plant, particularly for systems using free chlorine for secondary disinfection. Factors that can affect TTHM and HAA5 concentrations in the distribution system include water age, type and concentration of DBP precursors, disinfectant type and dose, disinfectant residual concentration in the finished water, and in the case of HAA5, biological activity.

Although there are many good operational practices that will improve overall water quality in distribution systems, this section focuses on the following specific practices that can be used to reduce TTHM and HAA5 levels and minimize future OEL exceedances:

- Managing water age (Section 6.1.1);
- Reducing disinfectant demand (Section 6.1.2); and
- Implementing booster disinfection (Section 6.1.3).

Each water system should prioritize the implementation of these management practices based on their system conditions and needs.

6.1.1 Managing Water Age

As water travels through the distribution system, chlorine continues to react with NOM to form DBPs. The longer the travel time or water age, the more likely it is that water quality will degrade and exhibit higher TTHM and HAA5 concentrations, reduced levels of residual chlorine, reduced effectiveness of chlorine residual through formation of organochlorine compounds, increased microbial activity, nitrification, and/or taste and odor problems. Chapter 3, Section 3.2 discusses how to evaluate system data and operational records to identify areas of the system with high water age.

An overall strategy to manage water age in the distribution system can help systems reduce future OEL exceedances. Establishing a water age goal is system-specific depending on system design and operation, water demands, and water quality (e.g., DBP formation potential). The next two sections provide guidance on controlling water age through management of finished water storage facilities and minimizing hydraulic residence time in distribution system piping.

6.1.1.1 Reducing Water Age and Improving Water Quality in Storage Tanks

Storage tanks with high hydraulic residence time and/or poor mixing can lead to DBP formation.

A storage tank that has a high hydraulic residence time and/or poor mixing characteristics can lead to increased water age, causing high TTHM and possibly high HAA5 formation in the tank. Sometimes, high water age in a tank can also lead to other types of water quality problems such as depletion of the disinfectant residual for chlorinated or chloraminated systems, and nitrification for chloraminated systems. High temperatures during the summer in conjunction with poor water mixing characteristics of a tank may lead to thermal stratification in the tank, causing high DBP formation in a stagnant, stratified layer. Lack of a proper maintenance program in conjunction with poor water mixing characteristics of a tank may lead to sediment accumulation at the bottom of the tank. This accumulation may result in loss of disinfectant residual and increased DBP formation. Chapter 3, Section 3.3 describes how to evaluate storage tank operations to determine if water age is excessive.

A storage tank should be designed and operated so the overall hydraulic residence time is minimized and the water is well-mixed. Generally, water mixing in a distribution system water storage tank is not achieved through mechanical mixers, but through operational procedures such as maintaining adequate volume turnover, inflow rate, and inflow velocity, and through proper design of the inlet/outlet piping. Inspections and maintenance activities such as sediment removal and repairing or replacing coatings are also important to minimize water quality problems.

This section discusses several practices to reduce water age and improve water quality in storage tanks including minimizing the hydraulic residence time, improvements to mixing within the tank and decommissioning storage facilities that are oversized or no longer useful.

Minimizing Hydraulic Residence Time

The average hydraulic residence time in a tank can be estimated by the following equation:

Theoretical average hydraulic residence time = $[V_{max} / (V_{max} - V_{min})] / N$

where, V_{min} = average minimum daily volume
V_{max} = average maximum daily volume
N = number of drain/fill cycles per day

Example 6.1 shows how this formula can be used to calculate the average hydraulic residence time in a tank. It is important to recognize that the above equation provides information about the average amount of time spent by water inside a tank, and it is possible for water in some portions of the tank to spend less time or more time in portions of a tank, especially if the tank is not well-mixed. In a tank with poor mixing characteristics, the residence time of portions of water in the tank can be much higher than the average. The V_{max} and V_{min} values are numbers that are averaged over data from several days or weeks to represent the typical operational characteristics of the tank. If the tank operation is changed from one season to another, then the V_{max} and V_{min} values would be different for different seasons.

Example 6.1 Calculating the Theoretical Average Hydraulic Residence Time

Your City has a 4 million gallon (MG) storage tank located in the distribution system. During the summer, the average maximum volume (V_{max}) in the tank is 3 MG and the average minimum volume (V_{min}) in the tank is 2 MG (obtained by averaging data from several weeks). There are two drain/fill cycles per day (N) during the summer season. Calculate the average hydraulic residence time of the tank.

Theoretical average hydraulic residence time = [3 MG / (3 MG - 2 MG)] / 2 cycles per day

= 1.5 days

The volume turnover can be increased by increasing the volume of water that flows in and out of a tank during a given fill/drain cycle. Kirmeyer et al. (2000) recommend a complete water turnover every three to five days but suggest that water system's establish their own turnover goal based on system-specific needs and goals. Turnover can be accomplished by increasing the water level fluctuation or drawdown between fill and draw cycles. The water level should be lowered in one continuous operation not small incremental drops throughout the day. Converting tanks to hydraulic plug-flow conditions and eliminating common inlet/outlet configurations can also reduce average hydraulic residence time.

Improving Mixing Characteristics of Storage Tanks

Improving the mixing characteristics of a storage tank can help eliminate stagnant zones where DBP formation can be the highest. Old water in stagnant zones can have high TTHM and HAA5 concentrations and no or low disinfectant residual. This water can be released into the system during periods of high demand.

Several tools can be used to predict water mixing characteristics of a tank. A brief description of each is provided below.

- **Desktop calculations of hydraulic residence time, fill time, and inlet momentum.** A method for estimating hydraulic residence time in a tank is presented in Section 6.1.1.1. Fill time and inlet momentum can be estimated from operational records and SCADA data.

- **Computational fluid dynamic (CFD) modeling.** CFD modeling provides a qualitative description of water mixing characteristics by providing visual images of water mixing inside a tank. It can be used to determine the effect of fill time and inlet momentum on the mixing characteristics of a specific tank configuration.

- **Temperature measurements.** Depending on the location of the inlet pipe and tank geometry, the water entering a tank from buried pipes may be cooler than the bulk water in the tank during the summer or warmer than the bulk water in the tank during the winter. In a tank with poor mixing characteristics, colder, denser water remains in the lower portion of the tank, whereas the warmer, less dense water has a tendency to rise to the top of the tank. Water temperature profiles can be used to determine the existence of thermal stratification inside a tank. The temperature profiles can be obtained from continuous water temperature measurements collected at various locations in the tank over the course of several days. Temperature differences as low as 2 degrees Fahrenheit between the top and bottom of a tank may indicate that the tank is thermally stratified and has poor mixing.

- **Disinfectant residual measurements.** Disinfectant residual measurements collected at various locations in a tank can also be used to determine mixing conditions and stratification. Grab samples or continuous online monitoring can be used for this purpose. However, acceptable differences in disinfectant residuals among various locations in a tank are situation specific and depends on a system’s water quality.

After the water mixing characteristics of a storage tank have been evaluated, appropriate operational and/or physical modifications can be selected to improve water mixing in the tank. These modifications, which are discussed in more detail below, include:

- Increasing fill time and inlet momentum,

- Optimizing inlet pipe location and orientation, and

- Prudent use of baffles.

Increasing Fill Time and Inlet Momentum

Mixing a fluid requires a source of energy input. In a distribution system storage tank, this energy is normally introduced during tank filling, and therefore mixing occurs primarily during the fill cycle. As a result, if a tank is relatively well-mixed at the end of each fill cycle, then significant variations in water age and DBP levels within the tank are unlikely. Fill time can be increased by allowing a tank to drain to a lower level before refilling. This strategy also has the desirable effect of decreasing overall hydraulic residence time and increasing volume turnover.

Inlet momentum (defined as velocity x flow rate) is a key factor for mixing water in a storage tank

Inlet momentum (defined as velocity × flow rate) is a key factor for mixing water in a storage tank. The higher the inlet momentum, the better the mixing characteristics of the storage tank. The inlet momentum can be increased by increasing the flow rate (which also has the desirable effect of increasing the velocity). One way to accomplish this is to install pumps near the tank. However, increasing the flow rate may not be practical due to the limitations of system hydraulics. For example, distribution system pressure may not be high enough to get desirable increases in flow rates or a pump may not be available at the tank location to increase the pumping rate into the tanks. In such cases, the inlet momentum can be increased by reducing the inlet diameter to increase the inlet velocity.

Optimizing Inlet Pipe Location and Orientation

The location and orientation of the inlet pipe relative to the tank walls can have a significant impact on mixing characteristics. As water enters a tank through an inlet pipe, a jet is formed and the water present in the tank is drawn into the jet. Circulation patterns are formed that result in mixing. The path of the jet should be long enough to allow the mixing process to develop, and therefore should not be pointed directly towards nearby impediments such as a wall or deflector. For example, for a tall tank with relatively small width or diameter, a horizontal inlet pipe at the bottom of the tank is likely to cause the water jet to hit the vertical wall of the tank resulting in loss of inlet momentum and poor mixing near the top portion of the tank. In general, outlet pipes are located near the bottom of the tank and relocating the inlet pipe near the top of the tank may improve mixing characteristics. However, the system hydraulics need to be evaluated to ensure there would be adequate pressure to allow the tank to fill to the desired level. Inlet pipes located near the bottom of a tank can be angled upwards, or multiple inlet pipes can be used to improve mixing conditions in a tank. The optimum inlet pipe location and orientation for a tank to achieve good mixing depends on a number of factors including:

- Tank geometry,
- Inflow rate, and
- Temperature differences between the inflow and the bulk water in the tank.

CFD modeling can be a useful tool to determine the optimum pipe location and orientation for a tank.

Prudent Use of Baffles

> *The use of baffles should be carefully evaluated.*

In treatment plant tanks, where chlorine contact time is required and there is generally simultaneous inflow and outflow, internal baffles are sometimes placed inside the tanks to encourage plug flow conditions. However, in distribution system tanks and reservoirs, chlorine contact time is not an issue and there is generally a "fill and draw" operation. The use of baffles in distribution system storage tanks encourages plug flow conditions. Plug flow conditions in a storage tank will result in a greater retention time of water in the tank when compared to complete mixing conditions. Because the rate of disinfectant loss is dependent on both concentration and time, plug flow conditions will likely result in a greater disinfectant loss than complete mixing conditions. For distribution system tanks that operate in a fill and draw mode, the use of baffles should be generally avoided to encourage mixed flow condition, and baffles can also produce poor mixing zones (dead zones). These zones can have higher water age and therefore higher DBP formation. There may be special situations such as separate inlet and outlet pipes in close proximity to each other where a baffle wall between the inlet and outlet may be desirable to circulate water throughout the tank. However, because of the wide variations in tank geometry and inlet/outlet piping configurations for distribution system storage tanks, the use of baffles should be carefully evaluated for each specific situation to determine if baffles have any beneficial impact. Tracer testing, CFD modeling, and disinfectant residual monitoring are useful tools to determine the effect of baffles.

Decommissioning of Storage Tanks

Decommissioning storage facilities may also be an appropriate strategy to reduce water age if existing facilities are oversized and not needed for emergency conditions or for maintaining system pressure. Historically, distribution system storage tanks have been built to provide adequate pressures, fire flows, and peak demand capabilities. Often, tanks are also designed to accommodate future growth and long-term water system needs. Therefore, some distribution system storage tanks may be oversized. Storage tanks may also be hydraulically locked out of the distribution system due to high system pressures, low system demands, or inadequate tank height. Oversized tanks and/or tanks that are hydraulically locked out (due to system pressure being comparable to the maximum water level in the tank most of the time) do not have adequate flow through the tanks and turnover, resulting in high water age and high DBP formation. When events such as main breaks, fire flows, or other unexpected peak demand conditions occur in a system, water from these tanks are drawn into the distribution system. Thus, the areas receiving water from the tanks may have higher than normal TTHM and HAA5 levels.

Specific steps you can take to identify tanks that could be decommissioned include:

- Solicit the assistance of a professional engineer to review system needs, system design, and operation to determine if the existing storage capacity is appropriate.

- For a tank that is hydraulically locked out of the system, determine if the operational hydraulic grade in the vicinity of that tank can be lowered so that volume turnover can be achieved. One way to accomplish this is to valve off pipe sections during certain hours so that water demand in the vicinity of the tank is supplied primarily by the tank, rather than directly from the plant through distribution system pipes. If these operational changes cannot be accomplished, permanent decommissioning can be considered.

- For an oversized tank, determine if more water can be forced in and out of the tank on a daily basis by installing pumps, adjusting pumping schedules (if pumps already exist), or adjusting the control settings for altitude valves. If such modifications are not feasible, permanent decommissioning of the tank can be considered.

- Before a tank is decommissioned, the effects of taking the tank out of service should be determined. A distribution system analysis should be performed to make sure that the tank is not needed and there is adequate hydraulic connectivity for equalization storage, fire flow, or emergency conditions such as main breaks or treatment plant shutdowns.

6.1.1.2 Minimizing Hydraulic Residence Time in Pipes

The finished water leaving a treatment plant can spend considerable amount of time (more than a week) in the distribution system pipes before reaching a customer's tap. High hydraulic residence time in the distribution pipe network can lead to high DBP formation.

EPANET, a hydraulic model for distribution systems, can be downloaded from http://www.epa.gov/ORD/NRMRL/wswrd/epanet.html#Downloads

Water distribution system models offer an effective way to determine the hydraulic residence time in pipes. To predict water age accurately, the model should include the majority of the pipes in the distribution system and all physical facilities (such as storage tanks, pumps, and valves), provide an accurate simulation of water consumption, and be well-calibrated. Such a model can be used to quickly and accurately simulate complex water systems under various operating conditions. The hydraulic models can be used to determine the need for and the effect of various methods to reduce hydraulic residence time such as looping dead-ends, blow-offs, closing/opening valves, and replacing large diameter pipes with smaller ones. There are some hydraulic models available that have these capabilities. One such model that is available in the public domain is called the EPANET. This hydraulic model is available for free and can be downloaded from http://www.epa.gov/ORD/NRMRL/wswrd/epanet.html#Downloads. It can be used to perform extended period simulation of hydraulic and water quality behavior of distribution system networks. There are also some hydraulic models available that can be integrated with GIS to take advantage of the database capabilities of GIS. One such model that is available for free through EPA is called PipelineNet. In addition to the hydraulic, water quality, and GIS capabilities, the model contains maps and a U.S. Census population database. It can also be connected to the Internet via a model or cellular accessible network.

Minimizing the hydraulic residence time in pipes can help reduce the time available for DBP formation, although it is possible for an increase in HAA5 to occur because of less biological degradation. Reducing hydraulic residence time can also minimize disinfectant residual loss and allow systems to use a lower overall residual concentration, thereby reducing DBPs. Systems can reduce hydraulic residence time and disinfectant loss through physical system improvements such as:

- Looping dead ends,
- Managing valves,
- Installing blow-offs, and
- Replacing oversized pipes.

These system improvements are discussed further below. It is important to note that most of these options require new construction and may be cost-prohibitive for some systems.

Looping Dead-Ends

The highest DBP concentrations in a distribution system are often observed at dead ends. Water at dead ends is stagnant and therefore provides long contact times for DBP formation. Excessive hydraulic residence time at dead ends can be reduced with pipe looping, which generally involves constructing new pipe sections to make appropriate hydraulic connections among existing pipes. However, in some cases, pipe looping can also create zones with very slow moving water elsewhere in the system. For example, looping a dead end may cause water with opposite flow directions and similar flow rates to meet and cause very slow moving water at that location. Therefore, the specific hydraulic response of a system to looping should be assessed to make sure that looping does not negatively impact the residence time of other parts of the system.

Managing Valves

Isolation valves in the distribution system are sometimes in the wrong position (either open or closed), which can change the hydraulic path of water in the distribution system. For example, a closed valve may create a dead end with stagnant water and high TTHM and HAA5 levels. There are many reasons why a valve could be left in the wrong position including human error, lack of training, mechanical failure, poor record keeping and failure to locate valves because the valve boxes are buried or paved-over. A comprehensive valve inventory and maintenance program is necessary to identify the location and status of valves in a system. A valve exercise program is also necessary to determine improperly positioned and broken valves. As these valves are discovered, their positions can be corrected or they can be replaced to minimize stagnant water zones and associated high water age in distribution system pipes.

Using Blow-Offs

Blow-offs can be used to purge old water from dead-end or stagnant zones and pull fresher water into these locations from other areas. Blow-offs may operate in a continuous flow mode or an automatic intermittent flow mode. The velocities for blow-offs are generally insufficient (< 2.5 feet/sec) to remove sediments or biofilms. Continuous or automatic intermittent blow-offs can be used on a seasonal basis when TTHM and HAA5 peaks are more likely to occur (e.g., during high water temperature periods). Blowoffs can be located using hydraulic models, historical water quality data (targeting areas with low disinfectant residuals and high bacteria counts), and customer complaints.

Replacing Oversized Pipes

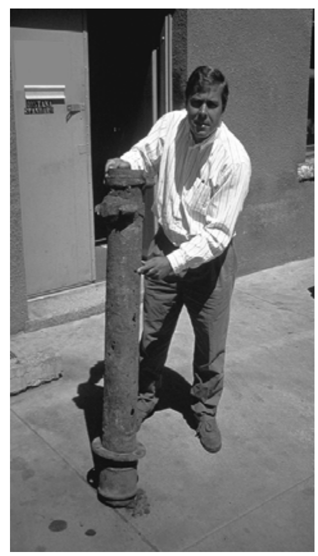
In portions of a distribution system where pipes are oversized, the water velocity is lower and therefore hydraulic residence times are longer than necessary causing high DBP levels. Areas of a distribution system that have been abandoned or have experienced negative demand growth over many years may contain oversized pipes, causing excessive hydraulic residence time. Where appropriate, the pipe sizes in these areas can be reduced or sections of pipes can be valved off if they are no longer needed to reduce the residence time of water. However, the effect of replacing or valving oversized pipes on downstream areas should be evaluated to make sure that such modifications will not cause hydraulic constrictions for the downstream areas.

6.1.2 Reducing Disinfectant Demand

Aging pipes such as unlined cast iron pipes exert high disinfectant demand because of the presence of corrosion byproducts, biofilms, and sediment deposits. To maintain a sufficient disinfectant residual in the distribution system, increased chlorine dose at the treatment plant may be needed, and for systems that use chlorine for secondary disinfection, booster chlorination may also be needed. High chlorine dose at the plant increases TTHM and HAA5 formation, and booster chlorination leads to excess chlorine residual in some areas of the distribution system, resulting in high TTHM and HAA5 formation in these areas. Systems can reduce localized chlorine decay and thus reduce the overall disinfectant demand through:

- Replacing or cleaning and lining pipes, and
- Conducting periodic flushing.

The selection of any specific method depends on water quality data, hydraulic condition, pipe condition, and economic factors.



Aging pipes can exert high disinfectant demand.

6.1.2.1 Replacing or Cleaning and Lining Unlined Cast Iron Pipes

For a water distribution system, disinfectant demand due to pipe corrosion, biofilm, and sediment deposition is most prevalent with unlined cast iron pipes. This problem can be reduced by replacing or cleaning and lining aging unlined cast iron pipes. Pipe replacement may be the preferred option for reducing disinfectant demand if a pipeline has structural problems or if there is a need to increase hydraulic capacity with a larger diameter pipe. If a pipeline is structurally sound, then pipe cleaning is a less expensive option. For unlined cast iron pipes, pipe lining may also be necessary to achieve a permanent improvement and prevent a recurrence of the disinfectant demand problem.

Pipe cleaning methods include high pressure sand blasting, mechanical scrapers, pigging, swabbing, flow-jetting, and chemical cleaning. Among the more common lining materials are cement-mortar, asphalt (bituminous), epoxy resins, rubber, and calcite. Cement is the most commonly used pipe lining material, although several types of degradation of cement material can occur in the presence of acidic waters or waters that are aggressive to calcium carbonate (e.g., soft waters). The AWWA Standard, *Rehabilitation of Water Mains (M28)*, 2nd Ed. (AWWA 2001), provides additional information and guidance on cleaning and lining technologies.

6.1.2.2 Conducting Periodic Flushing

Periodic flushing can be an effective tool to control TTHM and HAA5 peaks by purging stagnant water to reduce water age and by cleaning pipes that exert chlorine demand. There are several approaches to conducting distribution system flushing depending on system configuration and water quality goals. The AwwaRF report, *Guidance Manual for Maintaining Distribution System Water Quality* (Kirmeyer et al. 2000) categorizes flushing as **conventional**, **unidirectional**, or **continuous**.

Conventional flushing typically involves opening hydrants in an area of the distribution system (without closing valves beforehand to direct the water) until certain water quality goals are met. Conventional flushing can be effectively used to restore disinfectant residual concentration and to remove poor quality water from a specific area of the distribution system.

Unidirectional flushing involves flushing of water in one direction through a pipeline through a carefully planned sequence of closing valves and opening hydrants. Unidirectional flushing can achieve higher velocities through the pipe (> 6 feet per second (ft /sec)) as compared to conventional flushing. Higher velocity flushing operations can not only remove poor quality water from an area, but also can scour the inside of the pipeline to remove biofilm, corrosion products, and other debris attached to the pipe wall. Accurate maps of the system, hydraulic models, and a complete database of valves and hydrants facilitate planning and execution of directional flushing programs. Additional guidance on unidirectional flushing is provided by AWWA in DVD format (AWWA 2002).

Unidirectional flushing at high velocities can scour water mains, removing corrosion products, biofilm, and sediment.

Continuous flushing at blowoffs is used by water systems that have numerous dead ends and severe water circulation problems. Typically, velocities at continuous blowoffs are much lower than seen during unidirectional or even conventional flushing (< 1 ft/sec, Kirmeyer et al. 2000).

Minimum elements of a flushing program are outlined in the AWWA G200 Standard and include: (1) a preventive approach including spot flushing to address local problems or customer concerns and routine flushing to avoid water quality problems; (2) use of an appropriate flushing velocity to address water quality concerns; and (3) written procedures for all elements of the flushing program including water quality monitoring, regulatory requirements and specific flushing procedures. Kirmeyer et al. (2000) presents a 4-step approach to assist utilities with developing, implementing, and evaluating the effectiveness of individual flushing programs.

Care should be taken regarding disposal of disinfected water. The AwwaRF report *Guidelines for the Disposal of Chlorinated Water* (Tikkanen et al. 2001) provides strategies for removing chlorine and chloramine from water during flushing.

6.1.3 Implementing Booster Disinfection

Systems can use booster disinfection to improve disinfectant residual maintenance and to minimize formation of DBPs. It allows the system to use a lower chlorine dosage rate at the water treatment plant and feed chlorine at select locations in the distribution system as needed to maintain a residual.

The advantages of using booster disinfection facilities include:

- Increasing disinfectant residual only in the areas that require it without increasing the disinfectant residual in other parts of the system beyond acceptable levels. This prevents potentially high TTHM and HAA5 levels in some parts of the system.
- Reducing residual disinfectant concentration leaving the treatment plant.

The disadvantages of using booster disinfection facilities include:

- Difficulty in controlling the required disinfectant dose due to the dynamic nature of chlorine demand in the system.
- Potential to produce unpredictable disinfectant levels in the system due to over- or under-feeding.
- Regulatory concerns with degradation byproducts if hypochlorite is used or safety issues if chlorine gas is used.
- Concerns with strength and stability of the disinfectants when storage time is long.

The location of booster disinfection facilities in the distribution system is important to obtain desired results. The results from hydraulic models, disinfectant residual data, disinfectant decay data, and other water quality data are needed to determine appropriate booster disinfection locations. For chlorinated systems, the primary controlling factor is the difference between the measured and desired free chlorine residual. For chloraminated systems there are other controlling factors, such as excess free ammonia in the system due to chloramine decay.

6.1.4 Additional Resources

The following references may be useful in evaluating options for minimizing TTHM and HAA5 in the distribution system:

AWWA. *Water Supply Operations: Flushing and Cleaning.* Edition 2006 – DVD

AWWA. *Unidirectional Flushing.* Edition 2002 - DVD

AwwaRF. 2003. *Investigation of Pipe Cleaning Methods.* Denver: AwwaRF.

Brandt, M., J. Clement, J. Powell, R. Casey, D. Holt, N. Harris, C.T. Ta. 2004. *Managing Distribution System Retention Time to Improve Water Quality – Phase I.* Denver: AwwaRF.

Clark, R.M. and Grayman, W.M. 1998. *Modeling Water Quality in Drinking Water Distribution Systems*. Denver: AWWA.

Grayman, W. M., L. A. Rossman, C. Arnold, R. A. Deininger, C. Smith, J. F. Smith, and R. Schnipke. 2000. *Water Quality Modeling of Distribution System Storage Facilities*. Denver: AwwaRF and AWWA.

Grayman, W. M., L. A. Rossman, R. A. Deininger, C. D. Smith, C. N. Arnold, and J. F. Smith. 2004. Mixing and Aging of Water in Distribution System Storage Facilities. *Journal AWWA*, 96:9:70-80.

Kirmeyer, G., M. Friedman, K. Martel, G. Thompson, A. Sandvig, J. Clement, and M. Frey. 2002. *Guidance Manual for Monitoring Distribution System Water Quality*. Denver: AwwaRF and AWWA.

Roberts, P.J.W., X. Tian, F. Sotiropoulos, M. Duer. 2006. *Physical Modeling of Mixing in Water Storage Tanks*. Denver: AwwaRF.

USEPA. 2007. *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules.* Office of Water. EPA 815-R-07-017. http://www.epa.gov/safewater/disinfection/lt2/compliance.html

USEPA. 2006. *Initial Distribution System Evaluation Guidance Manual for the Final Stage 2 DBPR*. Office of Water. EPA 815-B-06-002. http://www.epa.gov/safewater/disinfection/stage2/compliance.html

Walski, T., D.V. Chase, D. Savic, W.M. Grayman, S. Beckwith, and E. Koelle. 2003. *Advanced Water Distribution Modeling and Management*. Bentley Institute Press.

6.2 Plant Operational Improvement

It may be possible to modify water treatment operations to reduce DBP formation. However, any operational changes should be evaluated to assure that they do not compromise treatment effectiveness for inactivating or removing microorganisms.

This section describes the potential impact of operational changes in common treatment units for decreasing TTHM and HAA5 concentrations in the finished water. Operational changes that will be discussed in further detail include:

- General strategies for enhanced precursor removal,
- Seasonal strategies for enhanced precursor removal, and
- Review of disinfection practices.

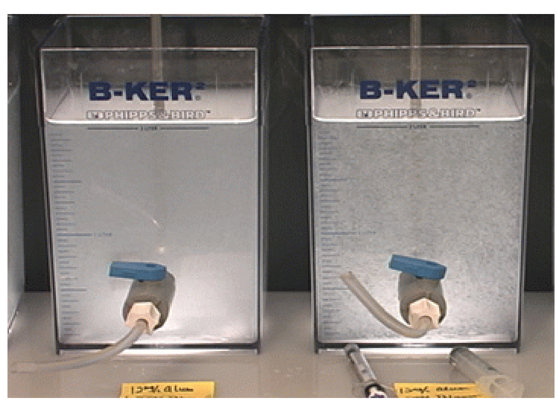
6.2.1 General Strategies for Enhanced Precursor Removal

Strategies that can be implemented to lower DBP levels include:

- Optimize coagulation process to improve removal of organic DBP precursors,
- Optimize settling process,
- Optimize conventional and GAC filtration processes, and
- Adjust pH to balance TTHM vs. HAA5 production.

6.2.1.1 Enhanced Removal of Organic DBP Precursors by Coagulation

Failure to optimize the coagulation process may result in a larger fraction of natural organic matter (NOM) passing through the coagulation/flocculation and settling processes. This increased NOM concentration can lead to increased formation of TTHM and HAA5. Chapter 4 Section 4.3 discusses how to determine if the current coagulation practices are optimized through review of historical water quality data and chemical feed records, and inspection of chemical feed pumps and mixing equipment.



Optimizing coagulation and flocculation can be an effective tool in minimizing DBPs.

If the coagulation process needs further optimization, there are several operational changes that can be implemented independently or in combination to enhance the removal of organic DBP precursors by coagulation (Randtke, 1999). These strategies, which are discussed in greater detail below, include the following:

- Optimize the coagulation pH;
- Optimize the coagulant dosage for particulate removal and/or enhance it for DBP removal;
- Change the type of coagulant;
- Add a polymer; and
- Use a preoxidant.

In general, optimizing the coagulation process should be the goal. The above strategies may be effective alone or in combination with another strategy(s). The first strategy (optimizing the coagulation pH) can be very effective. Switching to an alternative coagulant can also be effective given the wide variety of coagulant products available today.

Optimizing the Coagulation pH

> More information on conducting simulated distribution system tests can be found in EPA's *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules* (http://www.epa.gov/safewater/disinfection/lt2/compliance.html)

The maximum removal of precursors by metal-salt coagulants and cationic polymers typically occurs at a pH between 5.5 and 6 (USEPA 1999). However, the appropriate optimal pH should be selected by balancing the benefits of improving precursor removal with possible negative impacts on turbidity removal and corrosion of concrete and mechanical equipment at lower pH. The pH should be restored to above neutral (greater than 7.0) after treatment. Under most water quality conditions, the addition of alum or ferric salts decreases pH and the optimal pH for precursor removal can be reached by progressively increasing the coagulant dosage. In waters with sufficient alkalinity, the optimum pH can be reached either by increasing the coagulant dosage, by adding an acid, or a combination of both. The major advantage of adding an acid is the reduced production of coagulation residuals. In waters with very low alkalinity or high color, it is often necessary to add a base to maintain the pH in the optimal range. Jar tests are an effective tool to determine the optimal pH of coagulation and to identify precursor removal trends during coagulation. Another tool is the simulated distribution system test, which can give an indication of DBP levels that can be expected at different time intervals in the distribution system.

Increasing the Coagulant Dosage at Constant pH

Increasing the coagulant dosage beyond the amount required for satisfactory turbidity removal can result in improved precursor removal. However, systems should watch for possible problems caused by overfeeding coagulant such as:

- Increased sludge production,
- Poor settling,
- Shortened filter runs,
- Reduced pH and alkalinity, and
- Filter breakthrough.

Jar testing can be used to identify the optimum coagulant dosage that can be use to achieve turbidity and organic DBP precursor removal goals.

Changing the Type of Coagulant

Systems may find that one coagulant can be more effective than another in promoting removal of DBP precursors. Many polymer blends have been developed specifically for removal of TOC/DBP precursors, and cold water applications. However, the differences in performance should be carefully analyzed in terms of equivalent weight and costs. It has been reported that a greater maximum removal of precursors can be achieved with iron salts than with alum (Randtke et al., 1994; Edwards, 1997). However, these differences are only evident when the dosages exceed those used in most practical applications. At lower dosages alum can be more effective than ferric (Edwards, 1997), but these differences are difficult to determine because of the different acidity of alum and iron salts. Before making changes to full-scale treatment processes, systems should conduct jar tests to identify the best coagulant for organic DBP precursor removal with system-specific water quality and operating conditions.

Adding a Polymer

Polymers can improve settleability of floc and thereby result in better removal of DBP precursors through the coagulation/flocculation/sedimentation process. Many types of polymers have been found to be effective, including cationic, anionic, and non-ionic polymers. Because overdosing polymers can adversely affect filter media, water systems should carefully evaluate polymers before adding them to full-scale operations (USEPA 1999).

Using a Preoxidant

In some cases, preoxidation has been found to improve organic DBP precursor removal. For example, in plants that use ozone for disinfection, preoxidation with a small dosage of ozone can promote precursor removal by increasing the number of functional groups on the organic matter available for complexation with metal hydrolysis products and enhancing the biodegradation of organic molecules in biologically active filters. On the other hand, a high dosage of ozone can have negative effects on organic DBP precursor removal (i.e., produce smaller and more soluble organic molecules that are more difficult to remove). Preoxidation with chlorine is not recommended because the addition of chlorine to raw water will increase the contact time between chlorine and high concentrations of DBP precursors. Systems that use prechlorination to control algal growth or to aid coagulation should consider switching to another preoxidant such as potassium permanganate. Potassium permanganate does not cause TTHM or HAA5 formation but presents other operational challenges.

6.2.1.2 Enhanced Removal of Organic DBP Precursors by Softening

Precursor removal by precipitative softening with coagulation follows the same basic mechanisms, but process chemistry and the type of solids formed are very different. In precipitative softening, precursor removal can be enhanced by one or more of the following operational changes (Randtke, 1999):

- Increasing the lime dosage. Precursor removal improves with increasing lime dose as follows:

  - If sufficient carbonate alkalinity is available, more calcium carbonate precipitates, providing an increased opportunity for precursors to co-precipitate.

  - If insufficient carbonate alkalinity is available, excess calcium provided by lime addition promotes precipitation and co-precipitation of precursors and adsorption of precursors on settling solids.

  - The pH increase resulting from the higher lime dose promotes stronger interactions between calcium ions and precursors.

  - If magnesium is present in the raw water and the pH of the water is increased to between 10.5 and 10.8, substantial co-precipitation of magnesium hydroxide and calcium carbonate occurs. Precursor removal is enhanced because precursors have a strong tendency to adsorb onto magnesium hydroxide (Liao and Randtke, 1985).

- Adding a coagulant in combination with lime addition. The addition of a coagulant during lime softening can increase precursor removal. This increase is normally achieved with low coagulant dosages and there is no significant increase when the coagulant dosage is further increased.

- Eliminating or reducing solids recycling. There is limited evidence that eliminating or reducing solids recycling or delaying the application of soda ash to a subsequent stage of treatment can increase precursor removal (Liao and Randtke, 1985). However, these operational changes should be carefully tested to determine their site-specific effectiveness and careful consideration should be given to potential negative impacts on the overall treatment performance.

6.2.1.3 Optimizing Settling

Poor settling can result in floc carryover through the sedimentation basin and to the filters. Because floc contains significant amounts of coagulated precursor material, poor settling may negatively affect DBP levels, especially in those systems that add chlorine upstream of their filters. Chapter 4 Section 4.4 describes how to evaluate existing sedimentation processes using historical water quality and operations data, weather data, and operations records.

Regularly clean out sludge from settling basins.

In many cases, settling can be improved by optimizing the coagulant dosage and/or adding a polymeric aid. Jar tests can be used to determine the optimal amounts of these chemicals. Settling can also be improved by reducing the hydraulic loading rate through the settling basin or balancing the hydraulics amongst multiple settling basins. Systems that operate more than one plant may want to explore the opportunity of shifting some of the hydraulic load from a plant with poor settling to one with better performance during peak DBP season.

Poor or inadequate removal of sludge from the settling basin, as well as maintenance in the basin that stirs or moves the sludge, can release DBP precursors. This "additional" precursor load is available for reaction with free chlorine in the chlorine contact facilities, or may be carried through the settling process to the point of disinfectant addition. To minimize this type of problem a system should improve sludge removal operations. One way to do so is by scheduling basin cleaning before peak DBP periods or on a continuous basis.

6.2.1.4 Optimizing Conventional and GAC Filtration

Increases in organic loading during a filter cycle, or the breakthrough of particles at the end of the filter run cycle, can allow significant concentrations of precursors to come into contact with free chlorine in the clearwell or other chlorine contact facilities. This will lead to an increase in DBP levels in these facilities and ultimately, in the distribution system. Chapter 4 Section 4.5 describes how to evaluate potential causes of filter breakthrough using historical data and operations records.

To minimize the potential of such breakthrough, the following should be evaluated:

- The coagulation process;
- The filter run length;
- Filter loading rates; and

Operational practices to optimize filtration operation include:

- Limiting the amount of backwashing time,
- Distributing hydraulic load across filters,
- Maintaining consistent precursor removal levels, and
- Adjusting the coagulant dose to account for the resulting increase in DBP precursors in recycled water.

- The benefits of applying a filter aid polymer.

This evaluation should include measuring:

- TOC,
- Turbidity,
- Particle counts on individual filters (if available), and
- Alternative filter practices tested at pilot-scale.

Particle breakthrough can also take place during the initial phase of the filtration cycle (ripening). Therefore, systems should check that filters are not backwashed for an excessive length of time. Backwash should be conducted for a duration of time that restores the target headloss but does not completely remove all the filtered solids in the backwash water supernatant. The presence of some solids remaining on the filter media will allow quicker ripening and better filter performance when the unit is placed back into service after backwash. Some systems allow the filter to rest or filter-to-waste after backwash to improve water quality when the filter is brought back into service.

Hydraulic surges can disrupt filter operations and lead to particle breakthrough. Hydraulic surges may occur when filters are taken offline for backwash or maintenance, or if a sudden increase in plant flow occurs. The hydraulic load should be distributed among as many filters as possible, especially in small plants with few filters. When the hydraulic load is distributed across many filters, the relative increase in loading onto each individual filter is lower and is less likely to disrupt the filter.

When biologically active filters and GAC filters are used for organic precursor removal, breakthrough may be a concern because soluble organic compounds can be released. Likewise, when GAC columns are used for DBP removal after chlorination, exhaustion of adsorptive capacity may result in a sudden release of high concentrations of TTHM and HAA5 into the finished water. The performance of these types of filters should be checked to ensure that consistent precursor removal levels are maintained.

Filter backwash may contain elevated concentrations of DBP precursors. If no additional treatment (e.g., coagulation/settling) of recycled backwash water is provided, it is important to adjust the coagulant dose to account for the resulting increase in DBP precursors when recycled water is returned to the head of the plant.

6.2.1.5 Adjust pH to Balance TTHM vs HAA5 Production

The pH of water has been characterized as one of the most important chemical variables affecting the formation and speciation of chlorinated DBPs (Stevens, Moore, and Miltner, 1989). Studies and field observations have shown that TTHM formation typically increases at high pH and decreases at low pH, while HAA5 formation follows an opposite trend. In some cases, this knowledge can be used to adjust the treatment pH after coagulation to improve regulatory compliance. For example, a plant producing water with moderate TTHM levels and high HAA5 could benefit from increasing the pH of filtration, provided that opportunities for pH adjustment during treatment are available. Systems that are considering altering the pH to balance TTHM and HAA5 production should carefully consider the impacts of this strategy on virus and *Giardia* log inactivation because chlorine is less effective at higher pH values. When the pH is increased prior to chlorine contact basins, a higher chlorine dose or longer contact time may be needed to achieve the necessary levels of log inactivation. Systems should also carefully consider the effects of pH changes on corrosion of plant materials and Lead and Copper Rule (LCR) compliance implications.

The pH of water has been characterized as one of the most important chemical variables affecting the formation and speciation of chlorinated DBPs.

6.2.2 Seasonal Strategies for Enhanced Precursor Removal

Variations in temperature, chlorine dosages, and NOM characteristics in water affect DBP formation. Precursor removal targets could be adjusted to follow these water quality changes. This knowledge could be used to adjust treatment objectives and DBP control strategy on a seasonal basis. Chapter 4 Section 4.3 describes how to evaluate existing coagulation practices and seasonal changes in water quality and demand that may reduce treatment effectiveness. Appropriate precursor removal targets can be identified by:

- Conducting a desktop analysis using computer tools, such as EPA's Water Treatment Plant (WTP) simulation program (available through the National Technical Information Service at http://www.ntis.gov), to define the interrelationship between historical finished water TOC, temperature, and DBP levels.

- Monitoring raw and finished water or conducting jar tests and simulated distribution system tests. Suggested monitoring parameters include:

  - TOC,
  - UV_{254} (UV absorption at 254 nanometers (nm)),
  - pH,
  - Temperature,
  - Chemical dosage rate, and
  - Alkalinity.

Some examples of possible seasonal strategies include:

- Improve the performance of the coagulation process by lowering pH, increasing coagulant dosage, adding a polymer, and/or changing coagulation in response to seasonal increases in precursor levels or their increased predisposition to removal.

- Discontinue chlorine addition upstream of gravity filters with a GAC layer and use the filter for biological precursor removal.

- Systems that experience periodic high HAA5 levels while TTHM remain moderate may consider temporarily increasing the pH during settling and filtration to limit HAA5 formation.

- Modify filter operations for different water temperatures.

6.2.3 Review of Disinfection Practices

Systems are required to maintain a certain microbial inactivation level (measured as CT = disinfectant residual (C, in mg/L) x contact time (t, in min)) for disinfection. As the disinfectant dose decreases, the required contact time increases to maintain a required level of CT, and vice versa. TTHM and HAA5 levels increase with the chlorine concentration when precursors are present. The following are examples of intentional or unintentional events that can lead to increased chlorine dosages within a plant:

- Systems that control the disinfectant dose manually and not based on plant flow may experience increases in TTHM and HAA5 if the plant flow rate suddenly decreases or the dose is not adjusted frequently to account for reductions in plant flow. In such instances, those systems would likely be overdosing chlorine.

- Systems may intentionally increase the dose to account for a decrease in water temperature and maintain the required CT (CT requirements increase as water temperature decreases).

- Preoxidation with chlorine is particularly problematic because of the larger concentration of precursors in the untreated water and the long residence time available for the reaction with chlorine.

- Systems may intentionally make changes in the plant process that involve the use of pre-oxidation with chlorine (i.e., for arsenic treatment).

- High chlorine dosages may be intentionally applied during periods of algal bloom for the control of color, taste and odor, and iron and manganese.

- Increasing the holding time of water in the chlorine contact facilities or any unit process results in a longer reaction time between free chlorine and precursors. This can lead to increased TTHM levels. The increased residence time can also lead to increased HAA5 concentrations, but this effect is less pronounced because HAA5 formation occurs more rapidly and may not increase as significantly as TTHM over long periods of time. The issue of residence time within the plant is particularly important for systems that use chloramines for secondary disinfection. In many chloraminated systems, most DBPs are formed within the plant and a much smaller fraction is formed in the distribution system.

In all of the above cases, systems experiencing high TTHM and HAA5 levels should review their disinfection practices to determine if the chlorine dosage can be reduced without compromising disinfection goals. Proper inactivation levels should be maintained at all times.

Chapter 4 describes how to evaluate existing practices for predisinfection (Section 4.1), primary disinfection (Section 4.6) and secondary disinfection (Section 4.8) using historical data and operations records. If a system was required to produce a disinfection profile and benchmark under the Interim Enhanced Surface Water Treatment Rule (IESWTR), the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR), or LT2ESWTR it should use this information to assess the potential impact of changes to the disinfection practices and the State **must** be contacted prior to any changes. The following operational changes to disinfection may be undertaken to limit the production of DBPs within the plant:

- Systems that control the disinfectant dose manually should adjust the chlorine dosage frequently to account for changes in plant flow.

- Systems should frequently check that their chlorine dosage is appropriate to meet the required CT at the current water temperature and pH.

- When possible, preoxidation with chlorine should be discontinued, especially during periods of high DBP formation, and (if available on site) replaced with an alternative preoxidant. For example, potassium permanganate can, in many instances, replace chlorine for the oxidation of iron and manganese (if adequate contact time is available) or taste and odor control.

- Algae control through source management, in many systems, can be implemented instead of prechlorination.

- Excessive retention time within the treatment plant and chlorine contact facilities that occur when the plant is not operating can be mitigated in some cases by adjusting the plant flow rate to more closely match system water demands.

6.2.4 Additional Resources

The following references provide additional information on plant processes that may be useful as you consider options for minimizing TTHM and HAA5 in your distribution system:

AWWA. 2000. *Operational Control of Coagulation and Filtration Processes*. 2nd Edition. AWWA Manual M37. Denver: AWWA.

Logsdon, G.S., A.F. Hess, M.J. Chipps, and A.J. Rachwal. 2002. *Filter Maintenance and Operations Guidance Manual.* Project #2511. Denver: AwwaRF and AWWA.

Parsons, S.A., B. Jefferson, P. Jarvis, E. Sharp, D. Dixon, B. Bolto, and P. Scales. 2007. *Treatment of Water with Elevated Organic Content.* Denver: AwwaRF.

USEPA. 2007. *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules.* Office of Water. EPA 815-R-07-017.
http://www.epa.gov/safewater/disinfection/stage2/compliance.html

USEPA. 2005. *Membrane Filtration Guidance Manual*. Office of Water. EPA 815-R-06-009. November, 2005. http://www.epa.gov/safewater/disinfection/lt2/compliance.html

USEPA. 2003. *LT1ESWTR Disinfection Profiling and Benchmarking: Technical Guidance Manual*. Office of Water. EPA 816-R-03-004. May, 2003. http://www.epa.gov/safewater/mdbp/lt1eswtr.html

USEPA. 2002. *Long Term 1 Enhanced Surface Water Treatment Rule: A Quick Reference Guide*. Office of Water. EPA 816-F-02-001. January, 2002. http://www.epa.gov/safewater/mdbp/lt1eswtr.html

USEPA. 2002. *Filter Backwash Recycling Rule Technical Guidance Manual*. Office of Water. EPA 816-R-02-014. December, 2002. http://www.epa.gov/safewater/filterbackwash.html

USEPA. 1999. *Alternative Disinfectants and Oxidants Guidance Manual*. Office of Water. EPA 815-R-99-014. April, 1999. http://www.epa.gov/safewater/mdbp/implement.html

USEPA. 1999. *Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual*. EPA 815-R-99-012. http://www.epa.gov/safewater/mdbp/implement.html

USEPA. 1998. *Handbook: Optimizing Water Treatment Plant Performance Using the Composite Correction Program*. EPA 625/6-91/027. Available online at: http://www.epa.gov/safewater/mdbp/implement.html

6.3 Source Water Management

Source water precursor concentrations and temperature can have significant effects on DBP formation. For some systems, it may be possible to implement a source water management plan designed to minimize the occurrence of DBPs. The following sections introduce some source water management alternatives and identify source water quality parameters that systems should consider monitoring to aid in process control and in identifying the causes of future OEL exceedances. These alternatives include:

- Watershed management,
- Source water monitoring,
- Seasonal source water management strategies,
- Blending of alternative sources, and
- Optimizing intake operation.

6.3.1 Watershed Management

Watershed management can provide long-term benefits to the water system by helping to reduce the loading of DBP precursors and nutrients into source waters. Systems should be aware, however, that the introduction of watershed management practices frequently does not have an immediate effect on TTHM or HAA5 concentrations.

As a starting point, a water system should identify nonpoint and point sources of organic matter in the watershed. Ideally, the system has delineated the watershed boundary and mapped out land uses, locations of permitted discharges, storm drains, other significant polluters as well as natural sources of organic matter. Locations of potential sources of organic matter and other DBP precursors (or sources of DBPs that have already been formed) should be identified relative to the locations of tributaries to the reservoir. This exercise will help watershed managers prioritize efforts to control inputs that are more likely to contribute to TTHM and HAA5 formation. Controlling organic contamination that is likely to immediately impact the intake should be given the highest priority.

Many successful watershed management programs rely on a committee of stakeholders working together to improve a lake or reservoir's water quality. Water system representatives should consider coordinating with stakeholders such as:

- Local soil and water conservation districts,
- Nonprofit conservation groups,
- Farming organizations,
- Fish and game commissions, and
- Officials from towns located in the watersheds,

as well as other groups that may have an interest in land and water management in the watershed. By forming a watershed committee that meets regularly, committee members can identify the various issues and interests that need to be addressed in order to more effectively control nutrient and organic loading that contributes to TTHM and HAA5 formation.

EPA provides technical tools for watershed management at http://www.epa.gov/owow/watershed/tools/.

6.3.2 Source Water Monitoring

Source water monitoring is a key first step for systems considering using source water management for TTHM and HAA5 control. Water system personnel that collect and otherwise handle water quality samples should have adequate training in sample handling techniques.

Systems Using either Surface or Ground Water

To determine changes in water quality conditions that may impact DBP levels and precursor removal, systems using either surface or ground water sources should consider monitoring the following parameters:

Source water monitoring enables systems to appropriately manage their water supplies.

- TOC,
- SUVA,
- Temperature,
- Bromide,
- Alkalinity, and
- pH.

Systems should also consider monitoring hardness to ensure consistent corrosion control practices. Chapter 5 provides details on how each monitoring parameter can help evaluate potential OEL exceedances.

Systems Using Surface Water

Systems using surface water sources may also find it useful to measure additional parameters such as:

- Turbidity,
- Secchi disk depth, and
- Color

to help identify conditions that adversely affect water treatment, such as storm events, stratification, and turnover. To detect the early stages of algal blooms, surface water systems should also consider measuring:

- Algae counts,
- Chlorophyll *a*, and
- Nutrients (particularly phosphorus).

Data will be valuable in proactive efforts to avoid OEL exceedances. Systems may want to develop a database of historical data that can be analyzed for trends, unusual events, etc. Historical data can be compared to current data to help identify any potential problems with DBP precursors or DBP levels.

6.3.3 Seasonal Source Water Management Strategies

Using an alternate ground water source to supplement surface water supply during the summer can be an effective strategy to reduce DBP levels.

Systems can consider using an alternative water source to reduce high DBP levels that may occur seasonally. For example, for systems that use surface water, high temperatures during the summer may lead to high DBP formation at the treatment plant. The system may be able to draw water from an intake located at a lower depth during summer in order to utilize colder water. Water systems with significant concentrations of bromide in their raw water supply should consider using an alternative supply (if available) or blending during high DBP formation periods. Using an available ground water source or high quality surface water source to supplement a poorer quality surface water supply during high DBP periods can be a valuable strategy to reduce DBP levels. Ground water tends to have lower TOC levels and lower temperatures during the summer than surface water and therefore has a lower DBP formation potential than many surface water sources.

Algal blooms can result in a variety of water quality problems including tastes and odors, shortened filter runs, increased chlorine demand, increased turbidity, pH fluctuations, and, in some cases, increased organic DBP precursors. There are several techniques including aeration, destratification, dredging, and aquatic weed harvesting that have been used with some success for managing eutrophication. Systems may also have the option of utilizing other sources of supply that do not have algal blooms. However, it is uncertain whether any of these techniques significantly reduce organic DBP precursors. Many water systems that use lakes or reservoirs for their surface water supply have been practicing algae control through the use of chemicals, such as copper sulfate. It is generally possible for water systems to detect the early stages of an algal bloom through an aggressive source water quality monitoring program and at that time, use copper sulfate to control algal growth. Systems that are considering using copper sulfate should first consult with the State to determine if it will be allowed. In many States, copper sulfate application requires a pesticide permit application or certified pesticide applicator. Directly applying chlorine to a supply from a reservoir undergoing an algal bloom will very likely result in an increase in TTHM or HAA5 concentrations.

The effects of algal blooms can be minimized with an aggressive source water quality monitoring program.

6.3.4 Blending of Alternative Sources

Blending water sources is another possible strategy for controlling DBP levels. When two or more sources are mixed, the characteristics of the blended water depend on the characteristics of the individual sources and the blending ratio. For DBP control, the primary water quality characteristics of concern for determining blending ratios are:

- The types and concentrations of DBP precursors; and
- Temperature in each water source.

Other water quality characteristics of the resulting blended water should also be considered:

- Corrosion potential,
- pH,
- Taste,
- Loss of disinfectant residual, and
- Hardness.

In general, it is more advantageous to blend alternative sources prior to entering the distribution system. For example, two surface waters should be blended before entering the plant. When an alternative source of ground water is blended with a surface water source that requires treatment or with a ground water source that only requires disinfection, the blending location should be carefully selected. Ideal blending locations include the plant clearwell or a well-mixed finished water tank where the two waters can mix before entering the system. Blending may incur infrastructure and operating costs as well as operational changes.

6.3.5 Optimizing Intake Operations

Poor water quality in a reservoir can result from a number of factors including flooding, thermal stratification, and eutrophication. In some cases, systems can avoid withdrawing poor quality water with high DBP formation potential by optimizing the management of raw water intake operations.

One method for avoiding withdrawing water with poor quality is to have raw water intakes located at several levels. Systems that are able to draw water from multiple depths should consider regularly measuring TOC, color, temperature, turbidity, bromide, or other parameters (see Chapter 5) to determine which depth is providing the highest water quality. During flood events, systems may hold water longer in reservoirs to allow turbidity associated with agricultural or urban runoff to settle to lower levels. These systems can then draw water from an alternate intake level where the water quality is better. If thermal stratification occurs, systems can opt for their intake level with the lowest potential for DBP formation. Some systems aerate their raw water reservoirs to minimize or prevent thermal stratification, but this option can lead to other water quality problems such as algal blooms and increased dissolved oxygen concentrations. Increased dissolved oxygen concentrations can result in microbially-influenced corrosion in the treatment plant, or more likely, the distribution system. Dissolved oxygen can be consumed by aerobic bacteria causing localized pH gradients or the production of corrosive metabolites, such as hydrogen sulfide or iron phosphide, which may result in increased corrosion (Lee et al., 1980; Tuovinen et al. 1980). Dissolved oxygen itself is also corrosive, and if not removed through treatment, it can directly cause lead and copper corrosion in the distribution system.

Poor water quality in a reservoir can result from a number of factors including flooding, thermal stratification, and eutrophication.

Summer and early fall algal blooms tend to occur in the warmest layer of water, or epilimnion, nearer the surface of a thermally stratified reservoir. Systems that routinely monitor their water temperature profile and perform algae counts or measure chlorophyll *a* can withdraw water from the intake level with the lowest algae counts or chlorophyll *a* concentration to avoid algae-related problems such as tastes and odors, shortened filter runs, and DBP precursors. Systems should be careful, however, to avoid anoxic waters with elevated concentrations of iron, manganese, and sulfide that may be found in the bottom layer, or hypolimnion, of their reservoirs.

Another intake management method involves the adjustment of the spill structure of a reservoir so that water from the poor water quality zones or layers can be spilled.

If there are more than one interconnected reservoirs, partitioning the reservoirs and withdrawing water from the reservoir that has the lowest potential for DBP formation should be considered. Finally, bypassing basins that contain algae blooms (such as presedimentation basins) may be appropriate if other efforts are unsuccessful.

6.3.6 Additional Resources

The following references provide additional information on source water management practices that may help minimize formation of TTHM and HAA5:

AWWA Standard G300-07 Source Water Protection. 2007. Denver: AWWA.

Cooke, G. D. and R. E. Carlson. 1989. *Reservoir Management for Water Quality and THM Precursor Control*. Denver: AwwaRF.

Cooke, G.D. and R.H. Kennedy. 2001. Managing drinking water supplies. *Lake and Reservoir Management*. 17(3): 157-174.

Kornegay, B.H. 2000. *Natural Organic Matter in Drinking Water: Recommendations to Water Utilities*. Denver: AwwaRF.

MacLaughlin, K. and P. Chernin. 2002. *Source Water Protection Reference Manual*. Denver: AwwaRF.

USEPA. 2007. *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules.* Office of Water. EPA 815-R-07-017. http://www.epa.gov/safewater/disinfection/stage2/compliance.html

6.4 References

AWWA. 2001. *Rehabilitation of Water Mains.* 2nd Edition. AWWA Manual M28. Denver: AWWA.

Edwards, M. 1997. Predicting DOC Removal During Enhanced Coagulation. *Journal AWWA.* 89(5):78.

Kirmeyer, G.J., M. Friedman, J. Clement, A. Sandvig, P.F. Noran, K.D. Martel, D. Smith, M. LeChevallier, C. Volk, E. Antoun, D. Hiltebrand, J. Dykesen, and R. Cushing. 2000. *Guidance Manual for Maintaining Distribution System Water Quality.* AwwaRF Report 90798. Project #357. Denver: AwwaRF.

Lee, S.H., O'Conner, J.T. and Banerji, S.K. (1980). Biologically mediated corrosion and its effects on water quality in the distribution system. *J. AWWA*, 72:11:636.

Liao, M.Y. and S.J. Randtke. 1985. Removing Fulvic Acid by Lime Softening. *Journal AWWA.* 77(8):78.

Randtke S.J., et al. 1994. A Comprehensive Assessment of DBP Precursors Removal by Enhanced Coagulation and Softening. In *Proc. Of the 1994 AWWA Annual Conference*. Denver: AWWA.

Randtke S.J. 1999. In *Formation and Control of Disinfection By-Products in Drinking Water*. Singer P.C. editor. Denver: AWWA.

Stevens, A.A., L.A. Moore, and R.J. Miltner. 1989. Formation and Control of Non-Trihalomethane Disinfection By-products. *Journal AWWA.* 81(8):54-60.

Tikkanen, M., J.H. Schroeter, L.Y.C. Leong, and R. Ganesh. 2001. *Guidance Manual for Disposal of Chlorinated Water.* AwwaRF Report 90863. Project #2513. Denver: AwwaRF.

Tuovinen, O.H. et al. (1980). Bacterial, chemical, and mineralogical characteristics of tubercles in distribution pipelines. *J. AWWA*, 72:11:626.

USEPA. 2007. *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules.* Office of Water. EPA 815-R-07-017. http://www.epa.gov/safewater/disinfection/lt2/compliance.html

USEPA. 1999. *Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual*. EPA 815-R-99-012. http://www.epa.gov/safewater/mdbp/implement.html

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Appendix A

Fundamentals of TTHM and HAA5 Formation

A.1 Introduction

The formation of total trihalomethanes (TTHM) and haloacetic acids (five) (HAA5) is a function of many factors, including:

- Precursor concentration,
- Chlorine dose,
- Chlorination pH,
- Temperature,
- Contact time, and
- Bromide ion concentration.

The purpose of this appendix is to provide a brief summary of the factors that affect the formation of these disinfection byproducts (DBPs) in water treatment processes and distribution systems. More detailed information on this subject can be found in the existing literature, including the additional resources in section A.4:

A.2 Formation of TTHM and HAA5

All organic DBPs (and oxidation byproducts) are formed by the reaction between organic substances, inorganic compounds such as bromide, and oxidizing agents that are added to water during treatment (e.g., chlorine). The following are the major factors affecting the type and amount of TTHM and HAA5 formed.

- Type of disinfectant, dose, and residual concentration;
- Contact time and mixing conditions between disinfectant (oxidant) and precursors;
- Concentration and characteristics of precursors;
- Water temperature; and
- Water chemistry (including pH and bromide ion concentration).

Sections A.2.1 through A.2.5 provide a discussion of each major factor.

A.2.1 Type of Disinfectant

All other factors being equal, TTHM and HAA5 formation are highest for waters that are chlorinated either for primary disinfection, residual disinfection, or both. All chemical disinfectants, however, are known to form various types of DBPs. The following is a discussion of DBP formation by alternative disinfectants including chloramines, chlorine dioxide, ultraviolet (UV), and ozone.

Chloramines

Many water systems have experienced significant decreases in TTHM and HAA5 levels when switching from free chlorine to chloramines in the distribution system. The AwwaRF manual, *Optimizing Chloramine Treatment* (Kirmeyer et al. 2004), reports typical reductions in TTHM concentrations of 40 to 80 percent after chloramine conversion, although reductions as high as 95 percent were observed at some water systems. TTHM formation is known to still occur under chloraminated conditions, but at a very slow rate. Formation of TTHM is possibly attributable to hydrolysis of monochloramine to hypochlorous acid, which reacts with DBP precursors to form TTHM; the presence of free chlorine that has not reacted with ammonia to form chloramines; or the transfer of a chlorine atom from dichloramine to an organic compound (Kirmeyer et al. 2004 and references therein). Several studies have reported minimal production of haloacetic acids (HAAs) such as dichloracetic acid and trichloracetic acid by chloramines. Other studies, however, show formation of brominated HAAs by chloramines.

The design and location of chlorine and ammonia feed systems to form chloramines can have significant implications on TTHM and HAA5 formation. Any contact time with free chlorine prior to the addition of ammonia will increase TTHM and HAA5 concentrations. Additionally, insufficient mixing of chlorine and ammonia could lead to additional TTHM and HAA5 production.

Chlorine Dioxide

Under typical water treatment conditions, chlorine dioxide oxidizes rather than chlorinates organic matter and thus, does not form chlorination byproducts such as TTHM and HAA5. Chlorine produced as an impurity in the chlorine dioxide generation process, however, can lead to formation of TTHM and HAA5. Chlorine dioxide can react with organic matter to form chlorite, which is a regulated DBP, and chlorate.

Ultraviolet Light

Multiple research studies have found that UV light at doses commonly used at water treatment plants does not effect the formation of THMs or HAAs in subsequent chlorination (USEPA 2006 and references therein).

Ozone

Ozone does not directly produce chlorinated DBPs. However, if chlorine is added before or after ozonation, mixed bromo-chloro DBPs as well as chlorinated DBPs can form. Ozone can alter the characteristics of precursors and affect the concentration and speciation of halogenated DBPs when chlorine is subsequently added downstream. In waters with sufficiently high bromide concentrations, ozonation can lead to the formation of bromate and other brominated DBPs. Bromate, like TTHM and HAA5, is a regulated DBP. Ozonation of natural waters also produces aldehydes, haloketones, ketoacids, carboxylic acids, and other types of biodegradable organic material.

A.2.2 Chlorine Dose

Free chlorine can be introduced to water directly as a primary or secondary disinfectant, or as a byproduct of the manufacturing of chlorine dioxide and chloramines. As the concentration of chlorine increases, the production of DBPs increases. The formation reactions may take place in the treatment plant and the distribution system. Formation reactions continue as long as precursors and disinfectant are present (Krasner, 1999 and references therein).

In general, the impact of chlorine concentration is greater during primary disinfection than during secondary disinfection. The amount of chlorine added during primary disinfection is usually less than the long-term demand; therefore, the concentration of chlorine is often the limiting factor while un-reacted precursors are available. Conversely, reactions in the distribution system are often precursor limited since an excess of chlorine is added to the water to maintain a residual concentration (Singer and Reckhow, 1999). DBP formation reactions can become disinfectant-limited, however, when the free chlorine residual drops to low levels. As a rule of thumb, Singer and Reckhow (1999) suggested this event takes place when the chlorine concentration drops below approximately 0.3 mg/L.

Booster disinfection is applied in some systems to raise disinfectant residual concentration, especially in remote areas of the distribution system or near storage tanks where water age may be high and disinfectant residuals can be low. The additional chlorine dose applied to the water at these booster facilities may increase THM and HAA levels. Further, booster chlorination can maintain high HAA concentrations because the increased disinfection residuals can prevent the biodegradation of HAAs. However booster chlorination can also be useful in decreasing TTHM and HAA5 levels by reducing the concentration of secondary disinfectant needed in the finished water leaving the plant.

A.2.3 Contact Time

The longer the contact time between disinfectant/oxidant and precursors, the greater the amount of DBPs that can form. Generally, DBPs continue to form in drinking water as long as chlorine residual and precursors are present. In chlorinated systems, the highest TTHM levels usually occur where water is the oldest. Conversely, HAAs cannot be consistently related to water age because HAAs are known to biodegrade over time when the disinfectant residual is low. This might result in relatively low HAA concentrations in areas of the distribution system where disinfectant residuals are depleted.

A.2.4 Concentration and Characteristics of Precursors

The formation of TTHM and HAA5 is related to the concentration of precursors at the point of chlorination. In general, greater DBP levels are formed in waters with higher concentrations of precursors.

In most water sources, natural organic matter (NOM) is the major constituent of organic substances and DBP precursors. Total organic carbon (TOC) is typically used as a surrogate measure for precursor levels and is used in Stage 1 DBPR to determine precursor removal compliance. Dissolved organic carbon (DOC) and UV absorption at 254 nm [UV_{254}] are also often used as surrogate parameters for monitoring precursor levels.

Studies conducted with different fractions of NOM have indicated the reaction between chlorine and NOM with high aromatic content tends to form higher DBP levels than NOM with low aromatic content. For this reason, UV_{254}, which is generally linked to the aromatic and unsaturated components of NOM, is considered a good predictor of the tendency of a source water to form TTHM and HAA5 (Owen 1998; Singer and Reckhow, 1999).

Specific ultraviolet light absorbance (SUVA) is also often used to characterize aromaticity and molecular weight distribution of NOM. This parameter is defined as the ratio between UV_{254} and the dissolved organic carbon (DOC) concentration of water (Letterman et al., 1999). It should be noted, that the more highly aromatic precursors, characterized by high UV_{254}, in source waters are more easily removed by coagulation. Thus, it is the UV_{254} measurement immediately upstream of the point(s) of chlorination within a treatment plant that is more directly related to THM and HAA formation potential.

A.2.5 Water Temperature

The rate of formation of TTHM and HAA5 increases with increasing temperature. Consequently, the highest THM and HAA levels may occur in the warm summer months. However, water demands are often higher during these months, resulting in lower water age within the distribution system. Furthermore, high temperature conditions in the distribution system promote the accelerated depletion of residual chlorine, which can reduce DBP formation and allow biodegradation of HAAs unless chlorine dosages are increased to maintain high residuals (Singer and Reckhow, 1999). For these reasons, depending on the specific system, the highest THM and HAA levels may be observed during months that are warm, but not necessarily the warmest.

A.2.6 Water Chemistry

In the presence of precursors and chlorine, TTHM formation generally increases with increasing pH, whereas the formation of some HAA5 species decreases with increasing pH. The increased THMs production at high pH is likely promoted by base hydrolysis (favored at high pH). HAAs are not sensitive to base hydrolysis but their precursors are. Consequently, pH can alter their formation pathways leading to decreased production with increasing pH (Singer and Reckhow, 1999).

Studies have shown that the rate of TTHM formation is higher in waters with increased bromide concentrations (Krasner, 1999 and references therein). If the ratio of bromide to precursors (measured as TOC) increases, the percentage of brominated DBPs also increases.

A.3 References

Kirmeyer, G.J., M. LeChevallier, H. Barbeau, K. Martel, G. Thompson, L. Radder, W. Klement, and A. Flores. 2004. *Optimizing Chloramine Treatment*, 2nd edition. AwwaRF Report 90993. Project #2760. Denver: AwwaRF and AWWA.

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A.4 Additional Resources

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Appendix B

Example Operational Evaluation Report

for

OEL Exceedances Due to Changes in Source Water Quality with Limited Operational Evaluation Scope Approved by the State

Operational Evaluation Reporting Form

Page 1 of 2

I. GENERAL INFORMATION

A. Facility Information

Facility Name: Elm City Water Department PWSID: US4598765

Facility Address: 3456 East Street

City: Elm City State: US Zip: 12345

B. Report Prepared by:

(Print): Ronald Doe Date prepared: July 31, 2018

(Signature): *Ronald Doe*

Contact Telephone Number: 123-465-7890

II. MONITORING RESULTS

A. Provide the Compliance Monitoring Site(s) where the OEL was Exceeded.

Stage 2 DBPR compliance site #7; Located in Cedarville neighborhood

Note: The site name or number should correspond to a site in your Stage 2 DBPR compliance monitoring plan.

B. Monitoring Results for the Site(s) Identified in II.A (include duplicate pages if there was more than one exceedance)

1. Check TTHM or HAA5 to indicate which result caused the OEL exceedance. ☑ TTHM ☐ HAA5

2. Enter your results for TTHM or HAA5 (whichever you checked above).

	Quarter			**Operational Evaluation Value**
	Results from Two Quarters Ago	Prior Quarter's Results	Current Quarter	
	A	B	C	D = (A+B+(2*C))/4
Date sample was collected	12/02/2017	03/05/2018	06/03/2018	
TTHM (mg/L)	0.063	0.067	0.098	0.082
HAA5 (mg/L)				

Note: *The operational evaluation value is calculated by summing the two previous quarters of TTHM or HAA5 values plus twice the current quarter value, divided by four. If the value exceeds 0.080 mg/L for TTHM or 0.060 mg/L for HAA5, an OEL exceedance has occurred.*

C. Has an OEL exceedance occurred at this location in the past?	☑ Yes	☐ No
If NO, proceed to item D. If YES, when did exceedance occur?	2nd quarter 2014. See attachment II.C for additional details.	
Was the cause determined for the previous exceedance(s)?	☐ Yes	☑ No
Are the previous evaluations/determinations applicable to the current OEL exceedance?	☐ Yes	☑ No

Operational Evaluation Reporting Form

III. OPERATIONAL EVALUATION FINDINGS

A. Did the State allow you to limit the scope of the operational evaluation? ☑ Yes ☐ No

If NO, proceed to item B. If YES, attach written correspondence from the State.

B. Did **the distribution system** cause or contribute to your OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If NO, proceed to item C. If YES or POSSIBLY, explain (attach additional pages if necessary):

C. Did the **treatment** system cause or contribute to your OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If NO, proceed to item D. If YES or POSSIBLY, explain (attach additional pages if necessary):

D. Did **source water quality** cause or contribute to your OEL exceedance(s)? ☑ Yes ☐ No ☐ Possibly

If NO, proceed to item E. If YES or POSSIBLY, explain (attach additional pages if necessary):
See attachment III.B

E. Attach all supporting operational or other data that support the determination of the cause(s) of your OEL exceedance(s).

F. If you are unable to determine the cause(s) of the OEL exceedance(s), list the steps that you can use to better identify the cause(s) in the future (attach additional pages if necessary):

G. List steps that could be considered to minimize future OEL exceedances (attach additional pages if necessary)
See attachment III.G

H. Total **Number of Pages** Submitted, Including Attachments and Checklists: 12

July 1, 2018

Mr. Ronald Doe
Elm City Water Department
3456 East Street
Elm City, US 12345

RE: Request for limiting scope of operational evaluation level exceedence occurring for the 2^{rd} quarter 2018

Dear Mr. Doe:

Thank you for sending the raw and finished water TOC data from the Elm City Water Treatment Plant for May 25 through June 5. Based on our review of this data and based on our telephone conversation on June 15, 2018, we have approved your request to limit the scope of your operational evaluation to your source water and treatment only. Please keep this letter for your records and submit it along with your operational evaluation report.

Sincerely,

Bill Smith

William H. Smith
State Regulator, Drinking Water Program

Attachments

II.C. Past Exceedances

Historic DBP data are presented below for Stage 2 DBPR monitoring site # 7. During 2nd quarter of 2014, the TTHM level for Stage 2 DBPR monitoring site # 7 was 95 ug/L. Using the current definition of OEL, the computed THM value for the 2nd quarter of 2014 is 82 ug/L, and therefore an OEL exceedance occurred.

TTHM Data (ug/L)

Quarter	1	2	3	4
2012	53	58	82	58
2013	51	65	79	75
2014	62	95	72	69
2015	58	61	81	66
2016	52	53	75	79

HAA5 Data (ug/L)

Quarter	1	2	3	4
2012	43	58	45	49
2013	51	49	56	41
2014	46	64	41	52
2015	48	61	52	56
2016	34	44	53	51

III.B. Changes in Source Water

The most probable cause of the DBP excursion noted during the June 2018 sampling event was a rapid increase of the organic matter concentration in the Softwood River. A heavy rainfall event in May 31 – June 1, 2018 was identified as the primary cause of TOC and turbidity increase. A significant portion of the land upstream of the treatment plant is agricultural land, and excessive runoff from these areas causes high concentration of organic matter (TOC) and soil particles (turbidity). Following two days of heavy rainfall on May 31 - June 1, 2018, the TOC measured in the plant raw water increased from 2.7 mg/L on June 1, 2018, to 8.4 mg/L on June 3, 2018. At the same time, turbidity of the source water also increased from 5 NTU on June 1, 2018, to a maximum of 98 NTU on June 3, 2018.

The coagulant (ferric chloride) dose was steadily increased from 20 mg/L to 75 mg/L during June 1-3, 2018, to match water quality changes. For the duration of this high turbidity/ high TOC event, the pH of coagulation was maintained between 6.1 and 6.3. The concentration of TOC in the plant effluent increased from 1.8 mg/L on June1, 2018, to 3.8 mg/L on June 2, 2018. Jar testing conducted at the time of the event indicated that a further increase of the coagulant dose (dosages up to 120 mg/L were tested) would have not significantly improved TOC removal under the pH conditions presently used to conduct the coagulation process. The chlorine residual for the finished water leaving the treatment plant is maintained at 2 mg/L.

Monitoring sites # 7 and 8 are both supplied by Softwood River water. The hydraulic residence time between the Softwood plant and these monitoring sites is approximately three days. Laboratory tests indicated that for an initial chlorine residual of 2 mg/L, the THM levels will exceed 80 mg/L within three days when the TOC of the finished water increases above 3 mg/L.

The following data are attached to support the conclusion stated above:

1. TOC and turbidity data for raw and finished water from May 25 2018, to June 4, 2018 (*not included as part of this example*).
2. Jar test results conducted with Softwood river water for TOC ranging from 1.0 to 3.0 mg/L (*not included as part of this example*).

III.G. Minimizing Future Exceedances

Because some of the runoff comes from agricultural areas, the turbidity causing suspended soil particles are also a source of TOC because of the adsorbed organic matter to the soil particles. The raw water intake needs to be skillfully managed during rainfall events. The raw water intake has two levels. During a storm event, the suspended particles from agricultural runoff are likely to remain in suspension as a result of turbulence, and therefore the top level intake can be closed. Water can be withdrawn from the lower intake during the storm. As the storm subsides and turbulence decreases, particles will tend to settle down, and the lower level intake can be closed allowing water to be withdrawn from the upper level intake only. After the turbidity returns to normal, the bottom intake level can be opened also. We will conduct additional testing to determine the optimum operation of the intake system during storm events.

In addition to evaluating intake operations, we will investigate the use of a coagulant aid to address short term turbidity and TOC spikes. We will identify various options and perform jar testing. We will also investigate whether or not lower sedimentation flow rates would have helped reduce TOC concentrations in the plant effluent.

Treatment Process Evaluation Checklist

☐ **NO DATA AVAILABLE**

Facility Name: Elm City Water

Checklist Completed by: Ronald Doe   Date: July 31, 2018

A. Review finished water data for the time period prior to the OEL exceedance(s) and compare to historical finished water data using the following questions:

	Yes	No
Were DBP precursors (TOC, DOC, SUVA, bromide, etc.) higher than normal?	☑	☐
Was finished water pH higher or lower than normal?	☐	☑
Was the finished water temperature higher than normal?	☐	☑
Was finished water turbidity higher than normal?	☐	☑
Was the disinfectant concentration leaving the plant(s) higher than normal?	☐	☑
Were finished water TTHM/HAA5 levels higher than normal?	☑	☐
Were operational and water quality data available to the system operator for effective decision making?	☑	☐

B. Does the treatment process include predisinfection? ☑ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was disinfected raw water stored for an unusually long time?
☐	☑	Were treatment plant flows lower than normal?
☑	☐	Were treatment plant flows equally distributed among different trains?
☐	☑	Were water temperatures high or warmer than usual?
☐	☑	Were chlorine feed rates outside the normal range?
☑	☐	Was a disinfectant residual present in the treatment train following predisinfection?
☐	☑	Were online instruments utilized for process control?
☐	☑	Did you switch to free chlorine as the oxidant?
☐	☑	Was there a recent change (or addition) of pre-oxidant?
☐	☑	Did you change the location of the predisinfection application?

C. Does your treatment process include presedimentation? ☐ Yes ☑ No

If NO, proceed to item D. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were flows low?
☐	☐	Were flows high?
☐	☐	Were online instruments utilized for process control?
☐	☐	Was sludge removed from the presedimentation basin?
☐	☐	Was sludge allowed to accumulate for an excessively long time?
☐	☐	Do you add a coagulant to your presedimentation basin?
☐	☐	Was there a problem with the coagulant feed?

Treatment Process Evaluation Checklist

D. Does your treatment process include coagulation and/or flocculation? ☑ Yes ☐ No

If NO, proceed to item E. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Were there any feed pump failures or were feed pumps operating at improper feed rates?
☑	☐	Were chemical feed systems controlled by flow pacing?
☑	☐	Were there changes in coagulation practices or the feed point?
☐	☑	Did you change the type or manufacturer of the coagulant?
☐	☑	Do you suspect that the coagulant in use at the time of the OEL exceedance did not meet industry standards?
☐	☑	Did the pH or alkalinity change at the point of coagulant addition?
☐	☑	Were there broken or plugged mixers?
☐	☑	Were flow rates above the design rate or was there short-circuiting?

E. Does your treatment process include sedimentation or clarification? ☑ Yes ☐ No

If NO, proceed to item F. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Were there changes in plant flow rate that may have resulted in a decrease in settling time or carry-over of process solids?
☑	☐	Were settled water turbidities higher than normal?
☐	☑	Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?
☐	☑	Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
☐	☑	Was sludge allowed to accumulate for an excessively long time or was there a malfunction in the sludge removal equipment?

F. Does your treatment process include filtration? ☑ Yes ☐ No

If NO, proceed to item G. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☑	☐	Was there an increase in individual or combined filter effluent turbidity or particle counts?
☑	☐	Was there an increase in turbidity or particle loading onto the filters?
☐	☑	Was there an increase in flow onto the filters or malfunction of the rate of flow controllers?
☐	☑	Were any filters taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and created the conditions for possible breakthrough?
☐	☑	Were any filters operated beyond their normal filter run time?
☐	☑	Were there any unusual spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
☑	☐	Were all filters run in a filter-to-waste mode during initial filter ripening?
☐	☐	If GAC filters are used, is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred (leave blank if not applicable)?
☐	☐	If biological filtration is used, were there any process upsets that may have resulted in the breakthrough of TOC (leave blank if not applicable)?

G. Does your treatment process include primary disinfection by injecting chlorine prior to a clearwell? ☑ Yes ☐ No

If NO, proceed to item H. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there a sudden increase in the amount of chlorine fed or an increase in the chlorine residual?
☐	☑	Was there an increase in clearwell holding time?
☐	☑	Was the plant shut down or were plant flows low?
☐	☑	Was there an increase in clearwell water temperature?
☐	☑	Did you switch to free chlorine recently as the primary disinfectant?
☐	☑	Was the inactivation of *Giardia* and/or viruses exceptionally high?
☐	☑	Was there a change in the mixing strategy (i.e., mixers not used, adjustment of tank level)?

H. Does your plant recycle spent filter backwash or other streams? ☐ Yes ☑ No

If NO, proceed to item I. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Did a change in the recycle stream quality contribute to increased DBP precursor loading that was not addressed by treatment plant processes?
☐	☐	Did a recycle event result in flows in excess of typical or design flows?

I. Do you inject a disinfectant after your clearwell to maintain a distribution system residual? ☐ Yes ☑ No

If NO, proceed to item J. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was there a sudden increase in the amount of chlorine fed?
☐	☐	Was there a switch from chloramines to free chlorine for a burnout period?
☐	☐	If using chloramines, was the chlorine to ammonia ratio in the proper range?
☐	☐	Was there a problem with either chlorine or ammonia mixing?

J. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the LT2ESWTR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by other treatment targets/requirements in your ability to control precursors in coagulation/flocculation? ☐ Yes ☑ No

If NO, proceed to item K. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

____

____

____

____

K. Conclusion

Did treatment factors and/or variations in the plant performance contribute to the OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If YES or POSSIBLY, explain below.

____

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Source Water Evaluation Checklist

☐ **NO DATA AVAILABLE**

System Name: Elm City Water Department

Checklist Completed by: Ronald Doe Date: July 31, 2018

A. Do you have source water temperature data? ☑ Yes ☐ No

If NO, proceed to item B. If YES, was the source water temperature high? ☐ Yes ☑ No

If NO, proceed to item B. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was the raw water storage time longer than usual?
☐	☐	Did you place another water source on-line?
☐	☐	Were river/reservoir flow rates lower than usual? If yes, indicate the location of lower flow rates and the anticipated impact on the OEL exceedance.
☐	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?

B. Do you have data that characterizes organic matter in your source water (e.g., TOC, DOC, SUVA, color, THM formation potential)? ☑ Yes ☐ No

If NO, proceed to item C. If YES, were these values higher than normal? ☑ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☑	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☑	Did you place another water source on-line?
☐	☑	Did lake or reservoir turnover occur?
☑	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?
☐	☑	Did an algal bloom occur in the source water?
☐	☐	If algal blooms were present, were appropriate algae control measures employed (e.g., addition of copper sulfate)?
☐	☑	Did a taste and odor incident occur?

C. Do you have source water bromide data? ☐ Yes ☑ No

If NO, proceed to item D. If YES, were the bromide levels higher or lower than normal? ☐ Yes ☐ No

If NO, proceed to item D. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Has saltwater intrusion occurred?
☐	☐	Are you experiencing a long-term drought?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Are you aware of any industrial spills in the watershed?

Source Water Evaluation Checklist

D. Do you have source water turbidity or particle count data? ☑ Yes ☐ No

If NO, proceed to item E. If YES, were the turbidity values or particle counts higher than normal? ☑ Yes ☐ No

If NO, proceed to item E. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☑	Did lake or reservoir turnover occur?
☑	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☑	Did logging, fires, or landslides occur in the watershed?
☐	☑	Were river/reservoir flow rates higher than normal?

E. Do you have source water pH or alkalinity data? ☑ Yes ☐ No

If NO, proceed to item F. If YES, was the pH or alkalinity different from normal values? ☐ Yes ☑ No

If NO, proceed to item F. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was there an algal bloom in the source water?
☐	☐	If algal blooms were present, were algae control measures employed?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Has the PWS experienced diurnal pH changes in source water?

F. Conclusion

Did source water quality factors contribute to your OEL exceedance? ☑ Yes ☐ No ☐ Possibly

If YES or POSSIBLY, explain below.

We had heavy rainfall on May 31 – June 1, 2018, with runoff from agricultural land that brought increased turbidity and organic DBP precursors in our source water.

Appendix C

Example Operational Evaluation Report

for

OEL Exceedance Due to Changes in Distribution System Operation

Operational Evaluation Reporting Form

I. GENERAL INFORMATION

A. Facility Information

Facility Name: Elm City Water Dept. PWSID: US4598762

Facility Address: 34561 East Street

City: Elm City State: US Zip: 12345

B. Report Prepared by:

(Print): Ronald Doe Date prepared: June 22,2012

(Signature): Ronald Doe

Contact Telephone Number: 123-555-9876

II. MONITORING RESULTS

A. Provide the Compliance Monitoring Site(s) where the OEL was Exceeded.

Stage 2 DBPR compliance monitoring location #2; Located in Pineville neighborhood

Note: The site name or number should correspond to a site in your Stage 2 DBPR compliance monitoring plan.

B. Monitoring Results for the Site(s) Identified in II.A (include duplicate pages if there was more than one exceedance)

1. Check TTHM or HAA5 to indicate which result caused the OEL exceedance. ☑ TTHM ☐ HAA5

2. Enter your results for TTHM or HAA5 (whichever you checked above).

	Quarter			**Operational Evaluation Value**
	Results from Two Quarters Ago	Prior Quarter's Results	Current Quarter	
	A	B	C	D = (A+B+(2*C))/4
Date sample was collected	12/03/2011	03/03/2012	06/03/2012	
TTHM (mg/L)	0.065	0.072	0.098	0.083
HAA5 (mg/L)				

Note: *The operational evaluation value is calculated by summing the two previous quarters of TTHM or HAA5 values plus twice the current quarter value, divided by four. If the value exceeds 0.080 mg/L for TTHM or 0.060 mg/L for HAA5, an OEL exceedance has occurred.*

C. Has an OEL exceedance occurred at this location in the past?	☐ Yes	☑ No
If NO, proceed to item D. If YES, when did exceedance occur?		
Was the cause determined for the previous exceedance(s)?	☐ Yes	☐ No
Are the previous evaluations/determinations applicable to the current OEL exceedance?	☐ Yes	☐ No

Operational Evaluation Reporting Form	Page 2 of 2

III. OPERATIONAL EVALUATION FINDINGS

A. Did the State allow you to limit the scope of the operational evaluation? ☐ Yes ☑ No

If NO, proceed to item B. If YES, attach written correspondence from the State.

B. Did **the distribution system** cause or contribute to your OEL exceedance(s)? ☑ Yes ☐ No ☐ Possibly

If NO, proceed to item C. If YES or POSSIBLY, explain (attach additional pages if necessary):

See attachment III.D

C. Did the **treatment** system cause or contribute to your OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If NO, proceed to item D. If YES or POSSIBLY, explain (attach additional pages if necessary):

D. Did **source water quality** cause or contribute to your OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If NO, proceed to item E. If YES or POSSIBLY, explain (attach additional pages if necessary):

E. Attach all supporting operational or other data that support the determination of the cause(s) of your OEL exceedance(s).

F. If you are unable to determine the cause(s) of the OEL exceedance(s), list the steps that you can use to better identify the cause(s) in the future (attach additional pages if necessary):

G. List steps that could be considered to minimize future OEL exceedances (attach additional pages if necessary)

See attachment III.G

H. Total **Number of Pages** Submitted, Including Attachments and Checklists: 12

Attachments

III.D. Changes in the Distribution System

A main break in the Pineville neighborhood occurred on June 2, 2012, early in the morning. The system pressure in the vicinity of the main break dropped to 30 psi, which is significantly below the normal pressure range for that area (50-60 psi). SCADA data indicated that rapid drawdown from the Pineville tank began on June 3, 2012, at 5 am. The water level in the tank dropped to a hydraulic grade of 80 feet at 7 am. The normal minimum hydraulic grade for the tank is 115 feet as determined from historic SCADA data for the tank. It is anticipated that the rapid and excessive drawdown was due to the main break and subsequent pressure drop in the region. The tank did not refill prior to the morning peak demand period (7 am to 9 am), and the water level dropped to 70 feet during this period, as evident from the SCADA data.

The DBP sampling at monitoring site # 2 was conducted on June 3 at 10 am. The city's hydraulic model was used to predict whether a significant portion of the water at that site originated from the Pineville tank. A main break was simulated and the pressures in the surrounding areas were within 5 psi of what was observed on June 3, 2012, in the early morning. The results from the model indicated that a significant portion of the water at monitoring site # 2 originated from the Pineville tank during the morning hours of June 3.

The Pineville elevated tank has a large diameter inlet (36-inch) at the base of the tank. When the tank supplies water during normal conditions, water comes from the bottom portion of the tank where the turnover is expected to be good and water age is expected to be relatively low. However, during the main break that resulted in pressure loss in the vicinity of monitoring site # 2, water was introduced into the area from the top portion of that tank. It is anticipated that the top portion of the tank remains relatively unmixed and therefore has high water age and DBP levels.

The following data are attached to support the conclusion stated above:

1. Schematic of distribution system map
2. SCADA data for Pineville tank level from May 3, 2012, to June 4, 2012 (*not included as part of this example*)
3. Results from hydraulic model indicating contribution of Pineville tank water to monitoring site # 2 (*not included as part of this example*)

III.G. Minimizing Future Exceedances

The water turnover in the top portion of Pineville tank needs to be improved to minimize water age and DBP formation in that part of the tank so that high DBP levels are not introduced into the distribution system. We plan to reduce the inlet diameter to increase the inlet velocity. The water jet will then reach the top portion of the tank and mix the stored water in that portion of the tank. Computational fluid dynamic modeling for the tank indicated that under current inflow rate conditions, the inlet pipe diameter needs to be 12-inches to produce a water jet sufficient enough to reach the top portion of the tank.

Distribution System Evaluation Checklist

System Name: Elm City Water Dept.

Checklist Completed by: Ronald Doe   Date: June 22, 2012

A. Do you have disinfectant residual or temperature data for the monitoring location where you experienced the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item B. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was the water temperature higher than normal for that time of the year at that location?
☐	☑	Was the disinfectant residual lower than normal for that time of the year at that location?
☐	☑	Was the disinfectant residual higher than normal for that time of the year at that location?

B. Do you have maintenance records available for the time period just prior to the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions:

Yes	No	
☑	☐	Did any line breaks or replacements occur in the vicinity of the exceedance?
☐	☑	Were any storage tanks or reservoirs taken off-line and cleaned?
☐	☑	Did flushing or other hydraulic disturbances (e.g., fires) occur in the vicinity of the exceedance?
☐	☑	Were any valves operated in the vicinity of the OEL exceedances?

C. If your system is metered, do you have access to historical records showing water use at individual service connections? ☑ Yes ☐ No

If NO, proceed to item D. If YES, was overall water use in your system unusually low, indicating higher than normal water age? ☐ Yes ☑ No

D. Do you have high-volume customers in your system (e.g., an industrial processing plant)? ☑ Yes ☐ No

If NO, proceed to item E. If YES, was there a change in water use by a high-volume customer? ☐ Yes ☑ No

E. Is there a finished water storage facility hydraulically upstream from the monitoring location where you experienced the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item F. If YES, review storage facility operations and water quality data to answer the following questions for the period in which the OEL exceedance occurred:

Yes	No	
☐	☑	Was a disinfectant residual detected in the stored water or at the tank outlet?
☑	☐	Do you know of any mixing problems with the tank or reservoir?
☑	☐	Does the facility operate in "last in-first out" mode?
☑	☐	Was the tank or reservoir drawn down more than usual prior to OEL exceedance, indicating a possible discharge of stagnant water?
☐	☑	Was there a change in water level fluctuations that would have resulted in increased water age within the tank or reservoir?

Distribution System Evaluation Checklist

F. Does your system practice booster chlorination? ☐ Yes ☑ No

If NO, proceed to item G. If YES, was there an increase in booster chlorination feed rates? ☐ Yes ☐ No

G. Did you have customer complaints in the vicinity of the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item H. If YES, explain.

There were complaints of low water pressure in the vicinity.

H. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the TCR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by the need to maintain a detectable disinfectant residual in your ability to control DBP levels in the distribution system? ☐ Yes ☑ No

If NO, proceed to item I. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

I. Conclusion

Did the distribution system cause or contribute to the OEL exceedance(s)? ☑ Yes ☐ No ☐ Possibly

If NO, proceed to evaluations of treatment systems and source water. If YES or POSSIBLY, explain below.

A main break caused a sudden decrease in Pineville tank water levels. Model results indicate the main break and associates pressure loss caused high age water from the tank to flow into the distribution system.

Treatment Process Evaluation Checklist

☐ **NO DATA AVAILABLE**

Facility Name: Elm City Water Treatment Plant

Checklist Completed by: Ronald Doe, PE   Date: June 22, 2012

A. Review finished water data for the time period prior to the OEL exceedance(s) and compare to historical finished water data using the following questions:

	Yes	No
Were DBP precursors (TOC, DOC, SUVA, bromide, etc.) higher than normal?	☐	☑
Was finished water pH higher or lower than normal?	☐	☑
Was the finished water temperature higher than normal?	☐	☑
Was finished water turbidity higher than normal?	☐	☑
Was the disinfectant concentration leaving the plant(s) higher than normal?	☐	☑
Were finished water TTHM/HAA5 levels higher than normal?	☐	☑
Were operational and water quality data available to the system operator for effective decision making?	☑	☐

B. Does the treatment process include predisinfection? ☐ Yes ☑ No

If NO, proceed to item C. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was disinfected raw water stored for an unusually long time?
☐	☐	Were treatment plant flows lower than normal?
☐	☐	Were treatment plant flows equally distributed among different trains?
☐	☐	Were water temperatures high or warmer than usual?
☐	☐	Were chlorine feed rates outside the normal range?
☐	☐	Was a disinfectant residual present in the treatment train following predisinfection?
☐	☐	Were online instruments utilized for process control?
☐	☐	Did you switch to free chlorine as the oxidant?
☐	☐	Was there a recent change (or addition) of pre-oxidant?
☐	☐	Did you change the location of the predisinfection application?

C. Does your treatment process include presedimentation? ☐ Yes ☑ No

If NO, proceed to item D. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were flows low?
☐	☐	Were flows high?
☐	☐	Were online instruments utilized for process control?
☐	☐	Was sludge removed from the presedimentation basin?
☐	☐	Was sludge allowed to accumulate for an excessively long time?
☐	☐	Do you add a coagulant to your presedimentation basin?
☐	☐	Was there a problem with the coagulant feed?

Treatment Process Evaluation Checklist

D. Does your treatment process include coagulation and/or flocculation? ☑ Yes ☐ No

If NO, proceed to item E. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Were there any feed pump failures or were feed pumps operating at improper feed rates?
☑	☐	Were chemical feed systems controlled by flow pacing?
☐	☑	Were there changes in coagulation practices or the feed point?
☐	☑	Did you change the type or manufacturer of the coagulant?
☐	☑	Do you suspect that the coagulant in use at the time of the OEL exceedance did not meet industry standards?
☐	☑	Did the pH or alkalinity change at the point of coagulant addition?
☐	☑	Were there broken or plugged mixers?
☐	☑	Were flow rates above the design rate or was there short-circuiting?

E. Does your treatment process include sedimentation or clarification? ☑ Yes ☐ No

If NO, proceed to item F. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Were there changes in plant flow rate that may have resulted in a decrease in settling time or carry-over of process solids?
☐	☑	Were settled water turbidities higher than normal?
☐	☑	Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?
☐	☑	Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
☐	☑	Was sludge allowed to accumulate for an excessively long time or was there a malfunction in the sludge removal equipment?

F. Does your treatment process include filtration? ☑ Yes ☐ No

If NO, proceed to item G. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there an increase in individual or combined filter effluent turbidity or particle counts?
☐	☑	Was there an increase in turbidity or particle loading onto the filters?
☐	☑	Was there an increase in flow onto the filters or malfunction of the rate of flow controllers?
☐	☑	Were any filters taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and created the conditions for possible breakthrough?
☐	☑	Were any filters operated beyond their normal filter run time?
☐	☑	Were there any unusual spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
☑	☐	Were all filters run in a filter-to-waste mode during initial filter ripening?
☐	☐	If GAC filters are used, is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred (leave blank if not applicable)?
☐	☐	If biological filtration is used, were there any process upsets that may have resulted in the breakthrough of TOC (leave blank if not applicable)?

G. Does your treatment process include primary disinfection by injecting chlorine prior to a clearwell? ☑ Yes ☐ No

If NO, proceed to item H. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there a sudden increase in the amount of chlorine fed or an increase in the chlorine residual?
☐	☑	Was there an increase in clearwell holding time?
☐	☑	Was the plant shut down or were plant flows low?
☐	☑	Was there an increase in clearwell water temperature?
☐	☑	Did you switch to free chlorine recently as the primary disinfectant?
☐	☑	Was the inactivation of *Giardia* and/or viruses exceptionally high?
☐	☑	Was there a change in the mixing strategy (i.e., mixers not used, adjustment of tank level)?

H. Does your plant recycle spent filter backwash or other streams? ☐ Yes ☑ No

If NO, proceed to item I. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Did a change in the recycle stream quality contribute to increased DBP precursor loading that was not addressed by treatment plant processes?
☐	☐	Did a recycle event result in flows in excess of typical or design flows?

I. Do you inject a disinfectant after your clearwell to maintain a distribution system residual? ☑ Yes ☐ No

If NO, proceed to item J. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there a sudden increase in the amount of chlorine fed?
☐	☑	Was there a switch from chloramines to free chlorine for a burnout period?
☐	☐	If using chloramines, was the chlorine to ammonia ratio in the proper range?
☐	☑	Was there a problem with either chlorine or ammonia mixing?

J. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the LT2ESWTR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by other treatment targets/requirements in your ability to control precursors in coagulation/flocculation? ☐ Yes ☑ No

If NO, proceed to item K. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

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____
____
____

K. Conclusion

Did treatment factors and/or variations in the plant performance contribute to the OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If YES or POSSIBLY, explain below.

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Source Water Evaluation Checklist

☐ **NO DATA AVAILABLE**

System Name: Elm City Water Dept.

Checklist Completed by: Ronald Doe, PE Date: June 22, 2012

A. Do you have source water temperature data? ☑ Yes ☐ No

If NO, proceed to item B. If YES, was the source water temperature high? ☐ Yes ☑ No

If NO, proceed to item B. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was the raw water storage time longer than usual?
☐	☐	Did you place another water source on-line?
☐	☐	Were river/reservoir flow rates lower than usual? If yes, indicate the location of lower flow rates and the anticipated impact on the OEL exceedance.
☐	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?

B. Do you have data that characterizes organic matter in your source water (e.g., TOC, DOC, SUVA, color, THM formation potential)? ☑ Yes ☐ No

If NO, proceed to item C. If YES, were these values higher than normal? ☐ Yes ☑ No

If NO, proceed to item C. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Did lake or reservoir turnover occur?
☐	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?
☐	☐	Did an algal bloom occur in the source water?
☐	☐	If algal blooms were present, were appropriate algae control measures employed (e.g., addition of copper sulfate)?
☐	☐	Did a taste and odor incident occur?

C. Do you have source water bromide data? ☐ Yes ☑ No

If NO, proceed to item D. If YES, were the bromide levels higher or lower than normal? ☐ Yes ☐ No

If NO, proceed to item D. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Has saltwater intrusion occurred?
☐	☐	Are you experiencing a long-term drought?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Are you aware of any industrial spills in the watershed?

Source Water Evaluation Checklist

D. Do you have source water turbidity or particle count data? ☑ Yes ☐ No

If NO, proceed to item E. If YES, were the turbidity values or particle counts higher than normal? ☐ Yes ☑ No

If NO, proceed to item E. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Did lake or reservoir turnover occur?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did logging, fires, or landslides occur in the watershed?
☐	☐	Were river/reservoir flow rates higher than normal?

E. Do you have source water pH or alkalinity data? ☑ Yes ☐ No

If NO, proceed to item F. If YES, was the pH or alkalinity different from normal values? ☐ Yes ☑ No

If NO, proceed to item F. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was there an algal bloom in the source water?
☐	☐	If algal blooms were present, were algae control measures employed?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Has the PWS experienced diurnal pH changes in source water?

F. Conclusion

Did source water quality factors contribute to your OEL exceedance? ☐ Yes ☑ No ☐ Possibly

If YES or POSSIBLY, explain below.

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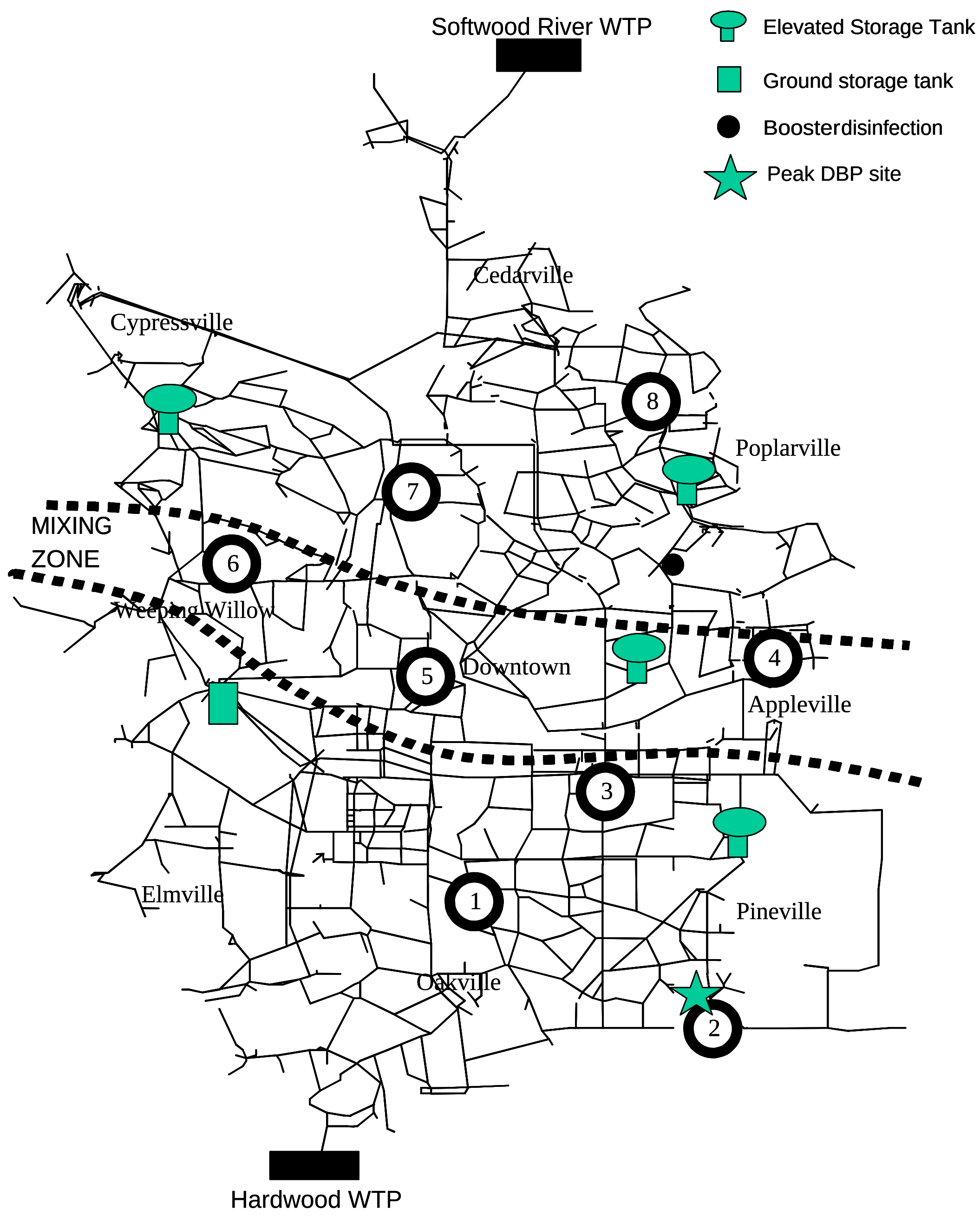
System Schematic



Appendix D

Example Operational Evaluation Report

for

OEL Exceedance Due to Changes in Source Water Quality and Booster Disinfection

Operational Evaluation Reporting Form

I. GENERAL INFORMATION

A. Facility Information

Facility Name: Oak City PWSID: US1234570

Facility Address: 101 Main St.

City: Oak City State: US Zip: 98768

B. Report Prepared by:

(Print): Jim Green Date prepared: September 3, 2010

(Signature): *Jim Green*

Contact Telephone Number: 124-666-9876

II. MONITORING RESULTS

A. Provide the Compliance Monitoring Site(s) where the OEL was Exceeded.

Stage 2 DBPR compliance monitoring location #1; See enclosed system schematics

Note: The site name or number should correspond to a site in your Stage 2 DBPR compliance monitoring plan.

B. Monitoring Results for the Site(s) Identified in II.A (include duplicate pages if there was more than one exceedance)

1. Check TTHM or HAA5 to indicate which result caused the OEL exceedance. ☑ TTHM ☐ HAA5

2. Enter your results for TTHM or HAA5 (whichever you checked above).

	Quarter			**Operational Evaluation Value**
	Results from Two Quarters Ago	Prior Quarter's Results	Current Quarter	
	A	B	C	D = (A+B+(2*C))/4
Date sample was collected	02/03/2018	05/03/2018	08/03/2018	
TTHM (mg/L)	0.065	0.062	0.108	0.086
HAA5 (mg/L)				

Note: *The operational evaluation value is calculated by summing the two previous quarters of TTHM or HAA5 values plus twice the current quarter value, divided by four. If the value exceeds 0.080 mg/L for TTHM or 0.060 mg/L for HAA5, an OEL exceedance has occurred.*

C. Has an OEL exceedance occurred at this location in the past?	☑ Yes	☐ No
If NO, proceed to item D. If YES, when did exceedance occur?	Third quarter of 2013, 2015, 2016	
Was the cause determined for the previous exceedance(s)?	☑ Yes	☐ No
Are the previous evaluations/determinations applicable to the current OEL exceedance?	☑ Yes	☐ No

Operational Evaluation Reporting Form

III. OPERATIONAL EVALUATION FINDINGS

A. Did the State allow you to limit the scope of the operational evaluation? ☐ Yes ☑ No

If NO, proceed to item B. If YES, attach written correspondence from the State.

B. Did **the distribution system** cause or contribute to your OEL exceedance(s)? ☐ Yes ☐ No ☑ Possibly

If NO, proceed to item C. If YES or POSSIBLY, explain (attach additional pages if necessary):

Increased chlorine dosage at booster station and increased temperature in the distribution system.

See attachment III.D.

C. Did the **treatment** system cause or contribute to your OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If NO, proceed to item D. If YES or POSSIBLY, explain (attach additional pages if necessary):

D. Did **source water quality** cause or contribute to your OEL exceedance(s)? ☐ Yes ☐ No ☑ Possibly

If NO, proceed to item E. If YES or POSSIBLY, explain (attach additional pages if necessary):

Algae bloom, increased wastewater baseflow, and high temperature in river water.

See attachment III.B.

E. Attach all supporting operational or other data that support the determination of the cause(s) of your OEL exceedance(s).

F. If you are unable to determine the cause(s) of the OEL exceedance(s), list the steps that you can use to better identify the cause(s) in the future (attach additional pages if necessary):

G. List steps that could be considered to minimize future OEL exceedances (attach additional pages if necessary)

See attachment III.G

H. Total **Number of Pages** Submitted, Including Attachments and Checklists: 12

Attachments

II.C. Past Exceedances

Oak City is a consecutive system purchasing all of its finished water from Maple City. Historically, TTHM levels in the water supplied during the summer months are higher than during the rest of the year. The OEL exceedance observed in this quarter is consistent with those observed in previous years. We have discussed this problem with the wholesaler (Maple City) and it is apparent that the high TTHM levels are a result of increased DBP precursor levels and water temperature in the Maple City's source water and distribution system. Increased chlorine dosage delivered at our booster chlorine station located at the entry point to our system also contributed to the exceedance.

III.B. Changes in the Source Water Quality

According to Maple City's treatment plant staff, the increased precursor concentration in the source water was a result of two factors:

- Algal blooms that normally take place in the Long River from which the water is withdrawn.
- Increased contribution (up to 15 percent) of wastewater effluent to the river flow during the month of August when the river is normally at its lowest level.

During the summer months, Maple City has taken measures to lower DBP precursors at the water treatment plant by increasing the coagulant dosage (ferric sulfate) and lowering the pH of coagulation from the usual 7.1 to 7.3 range to the 5.5 to 6.2 range. However, precursor levels in the finished water are still higher than during the rest of the year. Algae management in the river has been attempted in past years with modest results.

Data in support of the above assessment is available upon request from Maple City.

III.D. Changes in the Distribution System

Two factors related to the distribution system may have contributed to increased TTHM levels:

- Due to a lower than normal chlorine residual at the Oak City system entry point, the chlorine dosage rate at the booster chlorine station was increased. This increase is needed to ensure a minimum residual of at least 0.3 mg/L throughout the distribution system.
- Temperature across the distribution system is at the highest level of the year during the month of August.

Data on chlorine dosage rates fed at the booster station feed point, chlorine residuals before and after booster chlorination, and distribution system water temperature are available upon request. Water delivered by Maple City is typically less than two days old.

III.G. Minimizing Future Exceedances

Since the latest OEL exceedance occurred after the booster chlorination rate was increased, we will research whether this rate can be reduced slightly and still maintain chlorine residuals throughout the distribution system. It is possible that we can improve residual maintenance at dead ends and low usage areas by implementing periodic flushing with blow off valves. We will also use our hydraulic model to become more familiar with flow paths from the entry point to the extremes of the system. This exercise will help us to identify areas of the system that may have higher water age. Next we will review summer operating procedures to see if water age can be further reduced in these areas by changing pumping schedules, tank operating levels or otherwise increase tank water turnover rates.

Distribution System Evaluation Checklist

System Name: Oak City

Checklist Completed by: Jim Green   Date: September 3, 2018

A. Do you have disinfectant residual or temperature data for the monitoring location where you experienced the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item B. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was the water temperature higher than normal for that time of the year at that location?
☐	☑	Was the disinfectant residual lower than normal for that time of the year at that location?
☐	☑	Was the disinfectant residual higher than normal for that time of the year at that location?

B. Do you have maintenance records available for the time period just prior to the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions:

Yes	No	
☐	☑	Did any line breaks or replacements occur in the vicinity of the exceedance?
☐	☑	Were any storage tanks or reservoirs taken off-line and cleaned?
☐	☑	Did flushing or other hydraulic disturbances (e.g., fires) occur in the vicinity of the exceedance?
☐	☑	Were any valves operated in the vicinity of the OEL exceedances?

C. If your system is metered, do you have access to historical records showing water use at individual service connections? ☑ Yes ☐ No

If NO, proceed to item D. If YES, was overall water use in your system unusually low, indicating higher than normal water age? ☐ Yes ☑ No

D. Do you have high-volume customers in your system (e.g., an industrial processing plant)? ☑ Yes ☐ No

If NO, proceed to item E. If YES, was there a change in water use by a high-volume customer? ☐ Yes ☑ No

E. Is there a finished water storage facility hydraulically upstream from the monitoring location where you experienced the OEL exceedance? ☐ Yes ☑ No

If NO, proceed to item F. If YES, review storage facility operations and water quality data to answer the following questions for the period in which the OEL exceedance occurred:

Yes	No	
☐	☐	Was a disinfectant residual detected in the stored water or at the tank outlet?
☐	☐	Do you know of any mixing problems with the tank or reservoir?
☐	☐	Does the facility operate in “last in-first out” mode?
☐	☐	Was the tank or reservoir drawn down more than usual prior to OEL exceedance, indicating a possible discharge of stagnant water?
☐	☐	Was there a change in water level fluctuations that would have resulted in increased water age within the tank or reservoir?

F. Does your system practice booster chlorination? ☑ Yes ☐ No

If NO, proceed to item G. If YES, was there an increase in booster chlorination feed rates? ☑ Yes ☐ No

G. Did you have customer complaints in the vicinity of the OEL exceedance? ☐ Yes ☑ No

If NO, proceed to item H. If YES, explain.

H. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the TCR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by the need to maintain a detectable disinfectant residual in your ability to control DBP levels in the distribution system? ☐ Yes ☑ No

If NO, proceed to item I. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

I. Conclusion

Did the distribution system cause or contribute to the OEL exceedance(s)? ☐ Yes ☐ No ☑ Possibly

If NO, proceed to evaluations of treatment systems and source water. If YES or POSSIBLY, explain below.

Booster chlorination levels were increased to maintain sufficient residuals at the system ends.

The distribution system temperature was also high, but this is normal for August.

Treatment Process Evaluation Checklist

☐ **NO DATA AVAILABLE**

Facility Name: Oak City

Checklist Completed by: Jim Green, assisted by Maple City TP personnel Date: 09/03/2018

A. Review finished water data for the time period prior to the OEL exceedance(s) and compare to historical finished water data using the following questions:

	Yes	No
Were DBP precursors (TOC, DOC, SUVA, bromide, etc.) higher than normal?	☑	☐
Was finished water pH higher or lower than normal?	☐	☑
Was the finished water temperature higher than normal?	☐	☑
Was finished water turbidity higher than normal?	☐	☑
Was the disinfectant concentration leaving the plant(s) higher than normal?	☐	☑
Were finished water TTHM/HAA5 levels higher than normal?	☐	☑
Were operational and water quality data available to the system operator for effective decision making?	☐	☑

B. Does the treatment process include predisinfection? ☐ Yes ☑ No

If NO, proceed to item C. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was disinfected raw water stored for an unusually long time?
☐	☐	Were treatment plant flows lower than normal?
☐	☐	Were treatment plant flows equally distributed among different trains?
☐	☐	Were water temperatures high or warmer than usual?
☐	☐	Were chlorine feed rates outside the normal range?
☐	☐	Was a disinfectant residual present in the treatment train following predisinfection?
☐	☐	Were online instruments utilized for process control?
☐	☐	Did you switch to free chlorine as the oxidant?
☐	☐	Was there a recent change (or addition) of pre-oxidant?
☐	☐	Did you change the location of the predisinfection application?

C. Does your treatment process include presedimentation? ☐ Yes ☑ No

If NO, proceed to item D. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were flows low?
☐	☐	Were flows high?
☐	☐	Were online instruments utilized for process control?
☐	☐	Was sludge removed from the presedimentation basin?
☐	☐	Was sludge allowed to accumulate for an excessively long time?
☐	☐	Do you add a coagulant to your presedimentation basin?
☐	☐	Was there a problem with the coagulant feed?

Treatment Process Evaluation Checklist

D. Does your treatment process include coagulation and/or flocculation? ☑ Yes ☐ No

If NO, proceed to item E. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Were there any feed pump failures or were feed pumps operating at improper feed rates?
☑	☐	Were chemical feed systems controlled by flow pacing?
☑	☐	Were there changes in coagulation practices or the feed point?
☐	☑	Did you change the type or manufacturer of the coagulant?
☐	☑	Do you suspect that the coagulant in use at the time of the OEL exceedance did not meet industry standards?
☑	☐	Did the pH or alkalinity change at the point of coagulant addition?
☐	☑	Were there broken or plugged mixers?
☐	☑	Were flow rates above the design rate or was there short-circuiting?

E. Does your treatment process include sedimentation or clarification? ☑ Yes ☐ No

If NO, proceed to item F. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Were there changes in plant flow rate that may have resulted in a decrease in settling time or carry-over of process solids?
☐	☑	Were settled water turbidities higher than normal?
☐	☑	Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?
☐	☑	Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
☐	☑	Was sludge allowed to accumulate for an excessively long time or was there a malfunction in the sludge removal equipment?

F. Does your treatment process include filtration? ☑ Yes ☐ No

If NO, proceed to item G. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there an increase in individual or combined filter effluent turbidity or particle counts?
☐	☑	Was there an increase in turbidity or particle loading onto the filters?
☐	☑	Was there an increase in flow onto the filters or malfunction of the rate of flow controllers?
☐	☑	Were any filters taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and created the conditions for possible breakthrough?
☐	☑	Were any filters operated beyond their normal filter run time?
☐	☑	Were there any unusual spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
☑	☐	Were all filters run in a filter-to-waste mode during initial filter ripening?
☐	☐	If GAC filters are used, is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred (leave blank if not applicable)?
☐	☐	If biological filtration is used, were there any process upsets that may have resulted in the breakthrough of TOC (leave blank if not applicable)?

G. Does your treatment process include primary disinfection by injecting chlorine prior to a clearwell? ☑ Yes ☐ No

If NO, proceed to item H. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there a sudden increase in the amount of chlorine fed or an increase in the chlorine residual?
☐	☑	Was there an increase in clearwell holding time?
☐	☑	Was the plant shut down or were plant flows low?
☐	☑	Was there an increase in clearwell water temperature?
☐	☑	Did you switch to free chlorine recently as the primary disinfectant?
☐	☑	Was the inactivation of *Giardia* and/or viruses exceptionally high?
☐	☑	Was there a change in the mixing strategy (i.e., mixers not used, adjustment of tank level)?

H. Does your plant recycle spent filter backwash or other streams? ☑ Yes ☐ No

If NO, proceed to item I. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Did a change in the recycle stream quality contribute to increased DBP precursor loading that was not addressed by treatment plant processes?
☐	☑	Did a recycle event result in flows in excess of typical or design flows?

Treatment Process Evaluation Checklist

I. Do you inject a disinfectant after your clearwell to maintain a distribution system residual? ☐ Yes ☑ No

If NO, proceed to item J. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was there a sudden increase in the amount of chlorine fed?
☐	☐	Was there a switch from chloramines to free chlorine for a burnout period?
☐	☐	If using chloramines, was the chlorine to ammonia ratio in the proper range?
☐	☐	Was there a problem with either chlorine or ammonia mixing?

J. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the LT2ESWTR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by other treatment targets/requirements in your ability to control precursors in coagulation/flocculation? ☐ Yes ☑ No

If NO, proceed to item K. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

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K. Conclusion

Did treatment factors and/or variations in the plant performance contribute to the OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If YES or POSSIBLY, explain below.

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Source Water Evaluation Checklist

☐ **NO DATA AVAILABLE**

System Name: Oak City

Checklist Completed by: Jim Green, assisted by Maple City TP personnel Date: 09/03/2018

A. Do you have source water temperature data? ☑ Yes ☐ No

If NO, proceed to item B. If YES, was the source water temperature high? ☑ Yes ☐ No

If NO, proceed to item B. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☑	Was the raw water storage time longer than usual?
☐	☑	Did you place another water source on-line?
☐	☑	Were river/reservoir flow rates lower than usual? If yes, indicate the location of lower flow rates and the anticipated impact on the OEL exceedance.
☑	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?

B. Do you have data that characterizes organic matter in your source water (e.g., TOC, DOC, SUVA, color, THM formation potential)? ☑ Yes ☐ No

If NO, proceed to item C. If YES, were these values higher than normal? ☑ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☑	Did heavy rainfall or snowmelt occur in the watershed?
☐	☑	Did you place another water source on-line?
☐	☑	Did lake or reservoir turnover occur?
☑	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?
☑	☐	Did an algal bloom occur in the source water?
☑	☐	If algal blooms were present, were appropriate algae control measures employed (e.g., addition of copper sulfate)?
☐	☑	Did a taste and odor incident occur?

C. Do you have source water bromide data? ☑ Yes ☐ No

If NO, proceed to item D. If YES, were the bromide levels higher or lower than normal? ☐ Yes ☑ No

If NO, proceed to item D. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Has saltwater intrusion occurred?
☐	☐	Are you experiencing a long-term drought?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Are you aware of any industrial spills in the watershed?

D. Do you have source water turbidity or particle count data? ☑ Yes ☐ No

If NO, proceed to item E. If YES, were the turbidity values or particle counts higher than normal? ☐ Yes ☑ No

If NO, proceed to item E. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Did lake or reservoir turnover occur?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did logging, fires, or landslides occur in the watershed?
☐	☐	Were river/reservoir flow rates higher than normal?

E. Do you have source water pH or alkalinity data? ☑ Yes ☐ No

If NO, proceed to item F. If YES, was the pH or alkalinity different from normal values? ☑ Yes ☐ No

If NO, proceed to item F. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☑	☐	Was there an algal bloom in the source water?
☐	☑	If algal blooms were present, were algae control measures employed?
☐	☑	Did heavy rainfall or snowmelt occur in the watershed?
☐	☑	Has the PWS experienced diurnal pH changes in source water?

F. Conclusion

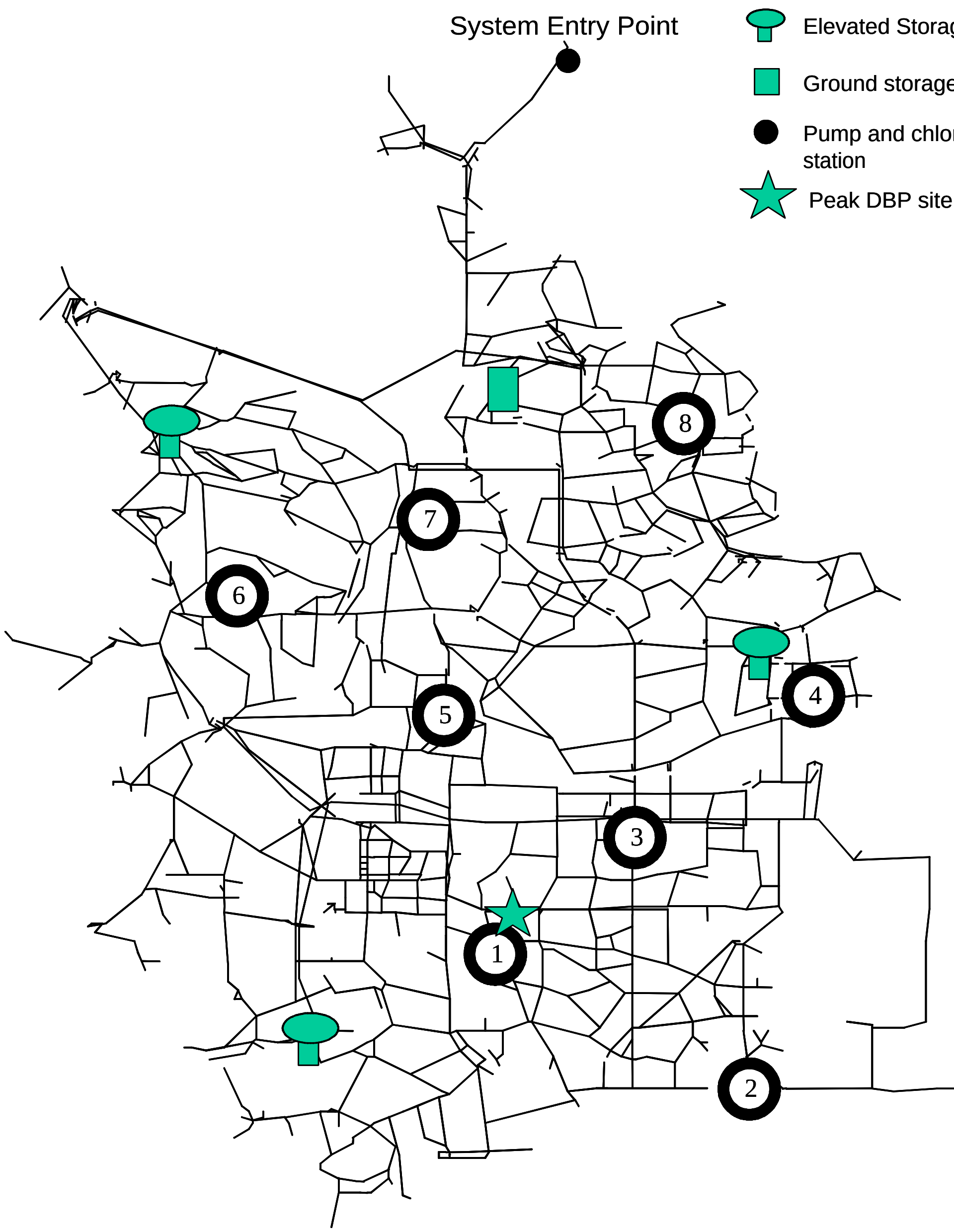
Did source water quality factors contribute to your OEL exceedance? ☐ Yes ☐ No ☑ Possibly

If YES or POSSIBLY, explain below.

Algae bloom is typical for the Maple City source water during the month of August.

See report form for explanation.

Oak City Distribution System Schematic



Appendix E

Example Operational Evaluation Report

for

OEL Exceedances Due to Maintenance Activities in the Wholesale System

Operational Evaluation Reporting Form

I. GENERAL INFORMATION

A. Facility Information

Facility Name: Pine City PWSID: US1234575

Facility Address: 101 Broadway St.

City: Pine City State: US Zip: 88768

B. Report Prepared by:

(Print): John Brown Date prepared: June 15, 2014

(Signature): *John Brown*

Contact Telephone Number: 456-666-7777

II. MONITORING RESULTS

A. Provide the Compliance Monitoring Site(s) where the OEL was Exceeded.

Stage 2 DBPR compliance monitoring location #2; Located in downtown area – fed by water from Poplar City

Note: The site name or number should correspond to a site in your Stage 2 DBPR compliance monitoring plan.

B. Monitoring Results for the Site(s) Identified in II.A (include duplicate pages if there was more than one exceedance)

1. Check TTHM or HAA5 to indicate which result caused the OEL exceedance. ☐ TTHM ☑ HAA5

2. Enter your results for TTHM or HAA5 (whichever you checked above).

	Quarter			**Operational Evaluation Value**
	Results from Two Quarters Ago	Prior Quarter's Results	Current Quarter	
	A	B	C	D = (A+B+(2*C))/4
Date sample was collected	11/30/2013	02/26/2014	05/31/2014	
TTHM (mg/L)				
HAA5 (mg/L)	0.054	0.050	0.081	0.062

Note: *The operational evaluation value is calculated by summing the two previous quarters of TTHM or HAA5 values plus twice the current quarter value, divided by four. If the value exceeds 0.080 mg/L for TTHM or 0.060 mg/L for HAA5, an OEL exceedance has occurred.*

C. Has an OEL exceedance occurred at this location in the past?	☐ Yes	☑ No
If NO, proceed to item D. If YES, when did exceedance occur?		
Was the cause determined for the previous exceedance(s)?	☐ Yes	☐ No
Are the previous evaluations/determinations applicable to the current OEL exceedance?	☐ Yes	☐ No

Operational Evaluation Reporting Form

III. OPERATIONAL EVALUATION FINDINGS

A. Did the State allow you to limit the scope of the operational evaluation? ☐ Yes ☑ No

If NO, proceed to item B. If YES, attach written correspondence from the State.

B. Did **the distribution system** cause or contribute to your OEL exceedance(s)? ☑ Yes ☐ No ☐ Possibly

If NO, proceed to item C. If YES or POSSIBLY, explain (attach additional pages if necessary):

See attachment III.D

C. Did the **treatment** system cause or contribute to your OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If NO, proceed to item D. If YES or POSSIBLY, explain (attach additional pages if necessary):

D. Did **source water quality** cause or contribute to your OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If NO, proceed to item E. If YES or POSSIBLY, explain (attach additional pages if necessary):

E. Attach all supporting operational or other data that support the determination of the cause(s) of your OEL exceedance(s).

F. If you are unable to determine the cause(s) of the OEL exceedance(s), list the steps that you can use to better identify the cause(s) in the future (attach additional pages if necessary):

G. List steps that could be considered to minimize future OEL exceedances (attach additional pages if necessary)

See attachment III.G

H. Total **Number of Pages** Submitted, Including Attachments and Checklists: 11

Attachments

III.D. Changes in the Distribution System

The OEL exceedance occurred in an area served by water we purchase from Poplar City. We contacted Poplar City's Department of Public Works for an explanation. We were told that as a consequence of maintenance work on a main near Pine City's entry point, water in an elevated tank remained practically unused for two weeks. High HAA5 levels in the Pine City downtown area are most likely the result of "old" water being released by the tank.

SCADA data for Poplar City's tank levels from May 10, 2014, to May 31, 2014, and Poplar City's maintenance records are available upon request.

III.G. Minimizing Future Exceedances

We have asked Poplar City to review their maintenance and tank management practices to minimize future exceedances. We have also asked Poplar City to contact us by telephone (John Brown at 456-666-7777) 24 hours in advance of maintenance work in the area of the distribution system that feeds our system so that we can be aware of potential problems.

Distribution System Evaluation Checklist

System Name: Pine City

Checklist Completed by: John Brown   Date: June 15, 2014

A. Do you have disinfectant residual or temperature data for the monitoring location where you experienced the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item B. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was the water temperature higher than normal for that time of the year at that location?
☐	☑	Was the disinfectant residual lower than normal for that time of the year at that location?
☐	☑	Was the disinfectant residual higher than normal for that time of the year at that location?

B. Do you have maintenance records available for the time period just prior to the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item C. If YES, answer the following questions:

Yes	No	
☐	☑	Did any line breaks or replacements occur in the vicinity of the exceedance?
☐	☑	Were any storage tanks or reservoirs taken off-line and cleaned?
☐	☑	Did flushing or other hydraulic disturbances (e.g., fires) occur in the vicinity of the exceedance?
☐	☑	Were any valves operated in the vicinity of the OEL exceedances?

C. If your system is metered, do you have access to historical records showing water use at individual service connections? ☑ Yes ☐ No

If NO, proceed to item D. If YES, was overall water use in your system unusually low, indicating higher than normal water age? ☐ Yes ☑ No

D. Do you have high-volume customers in your system (e.g., an industrial processing plant)? ☑ Yes ☐ No

If NO, proceed to item E. If YES, was there a change in water use by a high-volume customer? ☐ Yes ☑ No

E. Is there a finished water storage facility hydraulically upstream from the monitoring location where you experienced the OEL exceedance? ☑ Yes ☐ No

If NO, proceed to item F. If YES, review storage facility operations and water quality data to answer the following questions for the period in which the OEL exceedance occurred:

Yes	No	
☑	☐	Was a disinfectant residual detected in the stored water or at the tank outlet?
☐	☑	Do you know of any mixing problems with the tank or reservoir?
☐	☑	Does the facility operate in "last in-first out" mode?
☐	☑	Was the tank or reservoir drawn down more than usual prior to OEL exceedance, indicating a possible discharge of stagnant water?
☑	☐	Was there a change in water level fluctuations that would have resulted in increased water age within the tank or reservoir?

Distribution System Evaluation Checklist

F. Does your system practice booster chlorination? ☐ Yes ☑ No

If NO, proceed to item G. If YES, was there an increase in booster chlorination feed rates? ☐ Yes ☐ No

G. Did you have customer complaints in the vicinity of the OEL exceedance? ☐ Yes ☑ No

If NO, proceed to item H. If YES, explain.

H. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the TCR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by the need to maintain a detectable disinfectant residual in your ability to control DBP levels in the distribution system? ☐ Yes ☑ No

If NO, proceed to item I. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

I. Conclusion

Did the distribution system cause or contribute to the OEL exceedance(s)? ☑ Yes ☐ No ☐ Possibly

If NO, proceed to evaluations of treatment systems and source water. If YES or POSSIBLY, explain below.

Due to maintenance in the vicinity of a Poplar City tank, the tank was hardly used during a two week period in May. This allowed water age to significantly increase, which contributed to our exceedance when the water was released into our system.

Treatment Process Evaluation Checklist

☐ **NO DATA AVAILABLE**

Facility Name: Pine City

Checklist Completed by: John Brown, assisted by Poplar City DPW   Date: June 15, 2014

A. Review finished water data for the time period prior to the OEL exceedance(s) and compare to historical finished water data using the following questions:

	Yes	No
Were DBP precursors (TOC, DOC, SUVA, bromide, etc.) higher than normal?	☐	☑
Was finished water pH higher or lower than normal?	☐	☑
Was the finished water temperature higher than normal?	☐	☑
Was finished water turbidity higher than normal?	☐	☑
Was the disinfectant concentration leaving the plant(s) higher than normal?	☐	☑
Were finished water TTHM/HAA5 levels higher than normal?	☐	☑
Were operational and water quality data available to the system operator for effective decision making?	☑	☐

B. Does the treatment process include predisinfection? ☐ Yes ☑ No

If NO, proceed to item C. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Was disinfected raw water stored for an unusually long time?
☐	☐	Were treatment plant flows lower than normal?
☐	☐	Were treatment plant flows equally distributed among different trains?
☐	☐	Were water temperatures high or warmer than usual?
☐	☐	Were chlorine feed rates outside the normal range?
☐	☐	Was a disinfectant residual present in the treatment train following predisinfection?
☐	☐	Were online instruments utilized for process control?
☐	☐	Did you switch to free chlorine as the oxidant?
☐	☐	Was there a recent change (or addition) of pre-oxidant?
☐	☐	Did you change the location of the predisinfection application?

C. Does your treatment process include presedimentation? ☐ Yes ☑ No

If NO, proceed to item D. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were flows low?
☐	☐	Were flows high?
☐	☐	Were online instruments utilized for process control?
☐	☐	Was sludge removed from the presedimentation basin?
☐	☐	Was sludge allowed to accumulate for an excessively long time?
☐	☐	Do you add a coagulant to your presedimentation basin?
☐	☐	Was there a problem with the coagulant feed?

Treatment Process Evaluation Checklist

D. Does your treatment process include coagulation and/or flocculation? ☑ Yes ☐ No

If NO, proceed to item E. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Were there any feed pump failures or were feed pumps operating at improper feed rates?
☑	☐	Were chemical feed systems controlled by flow pacing?
☐	☑	Were there changes in coagulation practices or the feed point?
☐	☑	Did you change the type or manufacturer of the coagulant?
☐	☑	Do you suspect that the coagulant in use at the time of the OEL exceedance did not meet industry standards?
☐	☑	Did the pH or alkalinity change at the point of coagulant addition?
☐	☑	Were there broken or plugged mixers?
☐	☑	Were flow rates above the design rate or was there short-circuiting?

E. Does your treatment process include sedimentation or clarification? ☐ Yes ☑ No

If NO, proceed to item F. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Were there changes in plant flow rate that may have resulted in a decrease in settling time or carry-over of process solids?
☐	☐	Were settled water turbidities higher than normal?
☐	☐	Was there any disruption in the sludge blanket that may have resulted in carryover to the point of disinfection?
☐	☐	Was there any maintenance in the basin that may have stirred sludge from the bottom of the basin and caused it to carry over to the point of disinfectant addition?
☐	☐	Was sludge allowed to accumulate for an excessively long time or was there a malfunction in the sludge removal equipment?

F. Does your treatment process include filtration? ☑ Yes ☐ No

If NO, proceed to item G. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there an increase in individual or combined filter effluent turbidity or particle counts?
☐	☑	Was there an increase in turbidity or particle loading onto the filters?
☐	☑	Was there an increase in flow onto the filters or malfunction of the rate of flow controllers?
☐	☑	Were any filters taken off-line for an extended period of time that caused the other filters to operate near maximum design capacity and created the conditions for possible breakthrough?
☐	☑	Were any filters operated beyond their normal filter run time?
☐	☑	Were there any unusual spikes in individual filter effluent turbidity (which may indicate particulate or colloidal TOC breakthrough) in the days leading to the excursion?
☑	☐	Were all filters run in a filter-to-waste mode during initial filter ripening?
☐	☐	If GAC filters are used, is it possible the adsorptive capacity of the GAC bed was reached before reactivation occurred (leave blank if not applicable)?
☐	☐	If biological filtration is used, were there any process upsets that may have resulted in the breakthrough of TOC (leave blank if not applicable)?

G. Does your treatment process include primary disinfection by injecting chlorine prior to a clearwell? ☑ Yes ☐ No

If NO, proceed to item H. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there a sudden increase in the amount of chlorine fed or an increase in the chlorine residual?
☐	☑	Was there an increase in clearwell holding time?
☐	☑	Was the plant shut down or were plant flows low?
☐	☑	Was there an increase in clearwell water temperature?
☐	☑	Did you switch to free chlorine recently as the primary disinfectant?
☐	☑	Was the inactivation of *Giardia* and/or viruses exceptionally high?
☐	☑	Was there a change in the mixing strategy (i.e., mixers not used, adjustment of tank level)?

H. Does your plant recycle spent filter backwash or other streams? ☐ Yes ☑ No

If NO, proceed to item I. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☐	Did a change in the recycle stream quality contribute to increased DBP precursor loading that was not addressed by treatment plant processes?
☐	☐	Did a recycle event result in flows in excess of typical or design flows?

Treatment Process Evaluation Checklist

I. Do you inject a disinfectant after your clearwell to maintain a distribution system residual? ☑ Yes ☐ No

If NO, proceed to item J. If YES, answer the following questions for the period in which an OEL exceedance occurred:

Yes	No	
☐	☑	Was there a sudden increase in the amount of chlorine fed?
☐	☑	Was there a switch from chloramines to free chlorine for a burnout period?
☐	☑	If using chloramines, was the chlorine to ammonia ratio in the proper range?
☐	☑	Was there a problem with either chlorine or ammonia mixing?

J. Did concern about complying with a rule other than Stage 2 DBPR, such as the Lead and Copper rule, the LT2ESWTR, or any other rule constrain your options to reduce the DBP levels at this site? For example, are you limited by other treatment targets/requirements in your ability to control precursors in coagulation/flocculation? ☐ Yes ☑ No

If NO, proceed to item K. If YES, explain below and consult EPA's *Simultaneous Compliance Guidance Manual* for alternative compliance approaches.

K. Conclusion

Did treatment factors and/or variations in the plant performance contribute to the OEL exceedance(s)? ☐ Yes ☑ No ☐ Possibly

If YES or POSSIBLY, explain below.

Source Water Evaluation Checklist

☐ **NO DATA AVAILABLE**

System Name: Pine City

Checklist Completed by: John Brown, assisted by Poplar City DPW Date: June 15, 2014

A. Do you have source water temperature data? ☑ Yes ☐ No

If NO, proceed to item B. If YES, was the source water temperature high? ☐ Yes ☑ No

If NO, proceed to item B. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was the raw water storage time longer than usual?
☐	☐	Did you place another water source on-line?
☐	☐	Were river/reservoir flow rates lower than usual? If yes, indicate the location of lower flow rates and the anticipated impact on the OEL exceedance.
☐	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?

B. Do you have data that characterizes organic matter in your source water (e.g., TOC, DOC, SUVA, color, THM formation potential)? ☑ Yes ☐ No

If NO, proceed to item C. If YES, were these values higher than normal? ☐ Yes ☑ No

If NO, proceed to item C. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Did lake or reservoir turnover occur?
☐	☐	Did point or non-point sources in the watershed contribute to the OEL exceedance?
☐	☐	Did an algal bloom occur in the source water?
☐	☐	If algal blooms were present, were appropriate algae control measures employed (e.g., addition of copper sulfate)?
☐	☐	Did a taste and odor incident occur?

C. Do you have source water bromide data? ☐ Yes ☑ No

If NO, proceed to item D. If YES, were the bromide levels higher or lower than normal? ☐ Yes ☐ No

If NO, proceed to item D. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Has saltwater intrusion occurred?
☐	☐	Are you experiencing a long-term drought?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did you place another water source on-line?
☐	☐	Are you aware of any industrial spills in the watershed?

D. Do you have source water turbidity or particle count data? ☑ Yes ☐ No

If NO, proceed to item E. If YES, were the turbidity values or particle counts higher than normal? ☐ Yes ☑ No

If NO, proceed to item E. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Did lake or reservoir turnover occur?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Did logging, fires, or landslides occur in the watershed?
☐	☐	Were river/reservoir flow rates higher than normal?

E. Do you have source water pH or alkalinity data? ☑ Yes ☐ No

If NO, proceed to item F. If YES, was the pH or alkalinity different from normal values? ☐ Yes ☑ No

If NO, proceed to item F. If YES, answer the following questions for the time period prior to the OEL exceedance.

Yes	No	
☐	☐	Was there an algal bloom in the source water?
☐	☐	If algal blooms were present, were algae control measures employed?
☐	☐	Did heavy rainfall or snowmelt occur in the watershed?
☐	☐	Has the PWS experienced diurnal pH changes in source water?

F. Conclusion

Did source water quality factors contribute to your OEL exceedance? ☐ Yes ☑ No ☐ Possibly

If YES or POSSIBLY, explain below.