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RG-379 (Revised)

Total Organic Carbon (TOC) Guidance Manual

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Prepared by
Water Supply Division

RG-379 (Revised)
September 2002



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1 Introduction

TOC removal is required for certain plants under the Stage 1 Disinfectants and Disinfection By-Products Rule (DBP1R). The Texas regulations relating to TOC removal are contained in Title 30, Texas Administrative Code (30 TAC), Chapter 290, Subchapter F, Section 290.112. The TOC requirements apply only to plants that treat surface water or groundwater under the direct influence of surface water (GUI) using coagulation and sedimentation for treatment.

Disinfection is a crucial way to protect the public from pathogens. Unfortunately, at the same time that disinfectants are inactivating pathogens, they are also reacting with naturally occurring disinfection by-product precursors (DBP-Ps) to form disinfection by-products (DBPs). Some of the DBPs, such as trihalomethanes (THMs), are a health concern. Total organic carbon (TOC) is used as a surrogate measurement for DBP-Ps. The treatment technique for removal of TOC lessens the concentration of DBP-Ps available to form DBPs during disinfection.

If you are a treatment plant operator, you will find clear, easy-to-read guidance on how to comply with the TOC rules in this manual. If you have questions, call the TCEQ Public Drinking Water Section (Drinking Water Quality Team) at 512/239-4691.

The material presented here is adapted from the EPA's *Enhanced Coagulation and Precipitative Softening Guidance Manual*. The EPA publication number for this guidance manual is EPA 815-R-99-012. The EPA guidance document is available from the EPA Safe Drinking Water Hotline: **1-800-426-4791**. The EPA Office of Groundwater and Drinking Water (OGDW) Web site is:

www.epa.gov/OGWDW

The wording in this manual has been changed from the EPA's to make it more readable, but the requirements are intended to be identical with EPA's. This manual is available from TCEQ Publications, **512/239-0028**. TCEQ publications can also be requested on the Web. Go to the TCEQ Web site and click on "Publications" at:

www.tceq.state.tx.us

The TCEQ Web site also has a great deal of other information on public drinking water and links to the 30 TAC Chapter 290 rules for public water systems.

2 Applicability

All surface water treatment plants that use conventional treatment must comply with the TOC requirements. Conventional systems are those that use coagulation, flocculation, sedimentation, and filtration to treat the water. Each treatment plant must meet the TOC requirements. The requirements include monthly monitoring, monthly reporting, and quarterly compliance determinations. You can find the exact rule language and applicability requirements in Title 30 of the Texas Administrative Code (30 TAC), Chapter 290, Subchapter F: Drinking Water Quality and Reporting Requirements for Public Water Supply Systems. The TOC requirements are located in Section 290.112(a).

Two ways to find the TOC rule follow:

- ! See *Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements for Public Water Systems*. Go to **www.tceq.state.tx.us**, click on “Publications,” and enter the publication number (RG-346) to print a copy. This publication covers the requirements for harmful or potentially harmful constituents for water systems that supply potable water to the citizens of Texas.

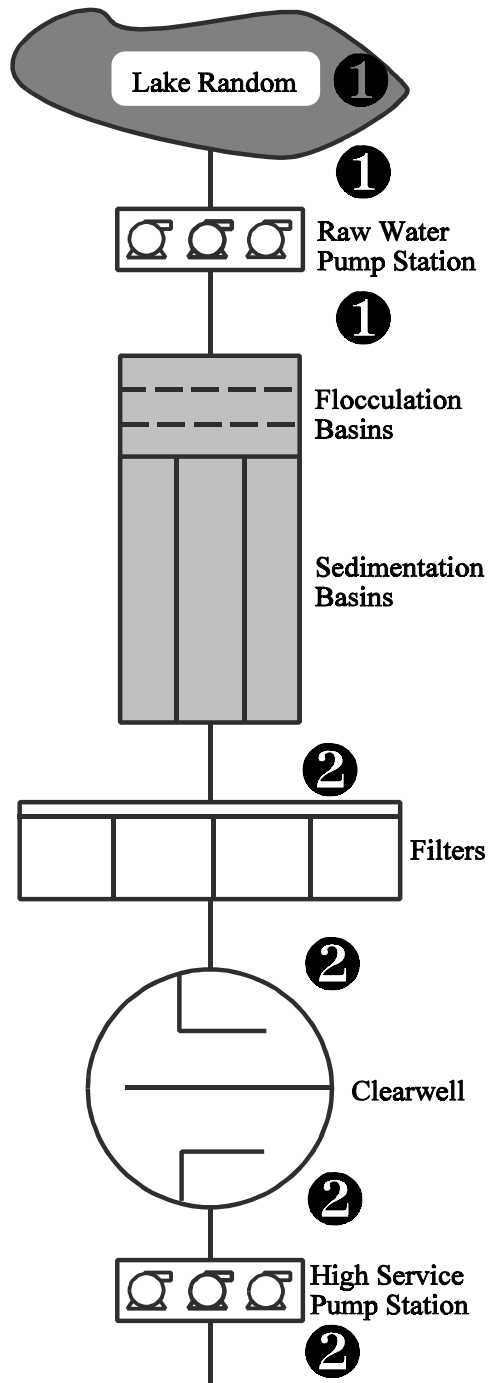
- ! Go to the Secretary of State’s Web site to view the rules online. There is a link from the TCEQ Web site when you click on “Rules” and then use the links to view the rules online.

Each system must do its own sampling and report the results to the TCEQ each month. The Total Organic Carbon Monthly Operating Report (TOC-MOR) reporting forms are shown in Appendix 1 of this document. There, you will also find instructions on when and where to send the reports. After the TCEQ receives the reports, we will determine if the plant has met the monitoring, reporting, and treatment technique requirements.

Systems serving 10,000 people or more must start monitoring in January 2001 and compliance will be calculated starting in January 2002. Data collected during 2001 will not be used for compliance. Systems serving less than 10,000 people must start monitoring in January 2003. Compliance for these smaller systems will be calculated starting in January 2004. Data collected by small systems during 2003 will not be used for compliance.

3 Monitoring Locations

Figure 3-1: TOC Sample Set Locations



Raw water TOC and treated water TOC must be monitored at locations that comply with TOC monitoring requirements established in 30 TAC Section 290.112(c). This page describes acceptable locations.

Raw Water Sampling Location

Raw water must be sampled before any chemicals are added. Raw water TOC and alkalinity samples should be taken at the same location.

The samples may be taken from the lake, from the raw water pump station, from an influent trough or head tank before the rapid mix, or any place that accurately represents raw water quality before chemical addition.

Any of the locations labeled **(1)** in Figure 3-1 are okay for taking raw water samples.

Treated Water Sampling Location

Treated water samples for TOC analysis *must* be taken after sedimentation, but *may* be taken after filtration. Any sampling point after the effluent of the sedimentation basin up to the point of combined effluent filter turbidity sampling is acceptable. (From a regulatory standpoint, it does not matter where the treated water sample point is in relation to any in-plant chemical injection points.)

Any of the locations labeled **(2)** in Figure 3-1 are okay for taking treated water samples.

Note on Monitoring Plan: The raw- and treated-water sampling points must be shown on the plant schematic in the system's monitoring plan.

4 Monitoring Frequency

Every plant must sample the raw water TOC, the raw water alkalinity, and the treated water TOC at least once a month. This group of samples is called a *TOC sample set*. The results of the TOC sample set are used to calculate the percent of the TOC in the raw water that is removed by sedimentation, known as the *actual percent TOC removal*. You can find the exact rule language for the TOC monitoring requirements in 30 TAC Section 290.112(b).

A plant is *required* to do at least one TOC sample set every month. If samples must be sent to a lab, you should consider how long it takes to get samples back from the lab when scheduling sample collection. For instance, if it takes the lab three weeks to return sample results, you should probably sample early in the month, so the results will be back in time to fill out the TOC-MOR.

A plant may *choose* to do more than one TOC sample set in a month. If you choose to, you may take more than one TOC sample set in a month; the results of **all** TOC sample sets that are taken in accordance with the sampling requirements, and at the locations designated in the monitoring plan, must be reported. The average removal ratio for all the TOC sample sets will be used to calculate compliance (see Compliance Determination). Multiple TOC sample sets may be necessary if a plant treats water that is highly variable. For instance, if your plant treats water from two reservoirs in one month, you should probably take a TOC sample set before and after changing between water sources. Or, if heavy rains change the treatability of the source water, you should consider taking a TOC sample set before and after the rain.

Collect the raw water alkalinity sample and the raw water TOC samples at the same time. Collect treated water samples after you collect the raw water samples. The rules say that treated samples must be taken one hour after raw samples. However, you may wish to sample treated water more than an hour after sampling raw water. It takes water more than one hour to flow through most plants. The time it takes for water to get through a plant is called the *detention time*. Some systems would prefer to take samples from treated water one *detention time* after sampling raw water. If you wish to sample treated water more than an hour after raw water, contact the TCEQ for permission (512/239-4691).

Note on Sample Scheduling: The water system operator, not TCEQ's contractor, is required to take TOC samples. The equipment currently used to measure TOC is very expensive (\$20,000 to \$30,000). Many systems will be unable to purchase it until cheaper methods are approved by the EPA. Most systems will send TOC samples to outside laboratories, at a cost of approximately \$40 per sample (or \$80 for a pair of samples). The labs will report the analytical results back to the system; the system must

report the results to the TCEQ. The lab turnaround time for TOC samples averages from two to four weeks. Therefore, you should take the TOC sample set early in the month, so that the analytical results get back in time to report to the TCEQ. Lab approval is discussed in Appendix 8.

4.1 Raw Water Sampling for Systems That Blend

Many utilities use more than one raw water source on a continuous or seasonal basis. These sources—which may be various surface waters or a combination of surface and groundwater—are blended together to create the plant influent. Utilities also may introduce groundwater directly into a treatment train unit process. There are numerous ways for utilities to blend different raw waters and to introduce them to the treatment train. Therefore, only general guidelines are provided here. For more assistance, contact the Chemical Monitoring Team of the TCEQ at 512/239-4691.

TOC samples must be taken from untreated raw water (before any disinfectant, oxidant, or other treatment is applied). Compliance sampling is complicated by this requirement, because utilities frequently apply disinfectant in the source-to-plant transmission lines. This may make it impossible to sample the plant influent immediately after the raw waters are blended, because disinfectant is present. Sampling schemes that address this difficulty are discussed below.

4.1.1 *Blending of Surface and Groundwaters*

Groundwater and surface waters blended before the application of disinfectant can simply be sampled after blending. Groundwater introduced to the treatment train after rapid mix should not be included in the raw water TOC sampling.

Systems that blend groundwater and surface water should consider blending the water after treatment, so that low-turbidity groundwater does not make it harder to treat the surface water.

4.1.2 *One or More Surface Water Sources Oxidized before Blending*

When one or more surface water source is oxidized before blending, sampling of the blended raw water is not allowed, because disinfectant or oxidant is present. Get the raw water parameters by using one of the methods below.

Composite Sample: Get a raw water sample from each source and create a composite sample by mixing the samples in proportion to the percent of the influent each comprises. For example, if a source is 30% of the plant influent, it should be 30% of the composite sample's volume. Once the

composite sample is created, a single TOC or alkalinity analysis can be performed. Composite sampling is less expensive than weighted calculation.

Weighted Calculation: Sample each raw water source and perform a TOC analysis. Calculate the blended water's TOC, based on the flow from each source. The formulae for weighted calculation are:

$$\text{Blended TOC} = \sum (\% \text{ source}) \times (\text{TOC of source}) \quad \text{Equation 4-1a}$$

$$\text{Blended Alkalinity} = \sum (\% \text{ source}) \times (\text{alkalinity of source}) \quad \text{Equation 4-1b}$$

Example 4-1: Determining Raw Water TOC for Blended Sources

A plant uses water from three sources. They contribute 50%, 20% and 30% of the plant influent; and the TOC values are 6.0, 4.0 and 3.0 mg/L respectively. The alkalinities are 70, 90, and 85 mg/L respectively. What is the blended TOC and alkalinity?

Solutions: The operator can either calculate the results mathematically, or make a composite sample and measure it.

(1) Composite Sample:

Collect undisinfected (unoxidized) water from each raw water source. Mix the water together in the proportion it contributes to flow. That is, blend 50 mL from Source 1, plus 20 mL from Source 2, plus 30 mL from Source 3. Measure the alkalinity and TOC.

(2) Calculated Solution: The calculated concentrations will be:

Blended TOC =

$$\{(0.5 \times 6.0) + (0.2 \times 4.0) + (0.3 \times 3.0)\} = 4.7 \text{ mg/L}$$

Blended alkalinity =

$$\{(0.5 \times 70) + (0.2 \times 90) + (0.3 \times 85)\} = 78.5 \text{ mg/L}$$

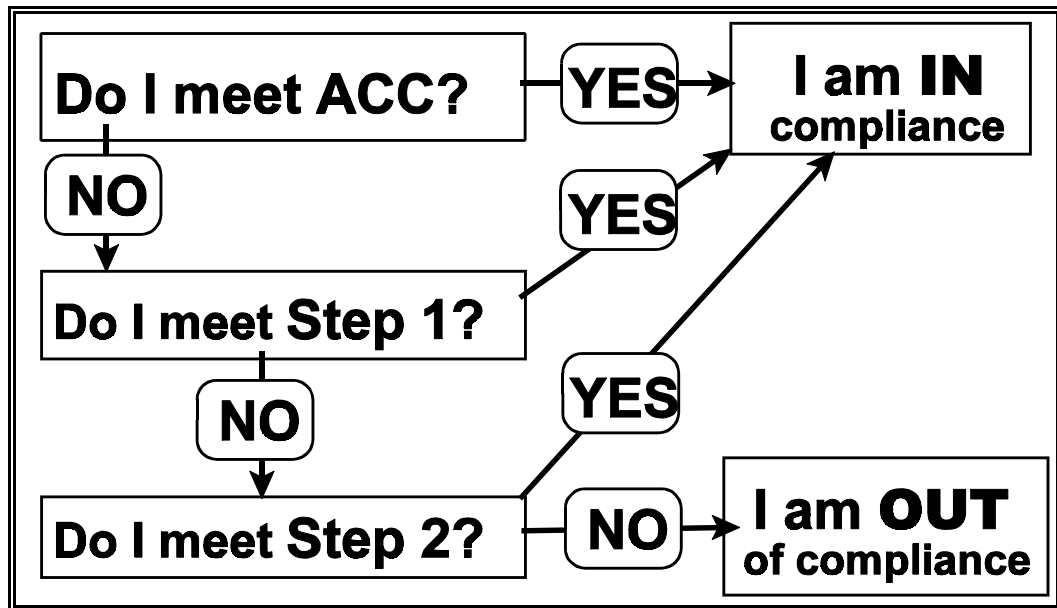
5 Compliance Strategy

There are three ways to be in compliance with the TOC treatment technique requirements:

- ! Meet the Step 1 TOC removal requirement
- ! Meet the Step 2 TOC removal requirement
- ! Meet any of the Alternative Compliance Criteria (ACCs or “outs”).

Most systems will find that they will need to meet the Step 1 TOC removal requirements. The order in which you will consider the plant’s compliance strategy is shown in Figure 5.1 below.

Figure 5-1: Compliance Determination Flowchart



You must first review the ACCs in Chapter 8. If the plant can meet one of these criteria, you must still monitor and report the results of your sample sets each month. However, you do not need to meet a specific TOC removal requirement.

If you have reviewed the list of ACCs and find that the plant *cannot* meet one of the criteria, you need to try to meet Step 1 TOC removal requirements in Chapter 6.

If you determine that the plant **cannot** meet the Step 1 removal requirements, you must run a Step 2 jar test. The Step 2 jar test will give you a Step 2 alternative TOC removal requirement, as described in Chapter 7.

6 Step 1 TOC Removal Requirements

If the plant does **not** meet one of the alternative compliance criteria (ACCs or “outs”) in Chapter 8, **you must determine whether the plant can meet the Step 1 removal requirement for its water**, as shown in Table 6-1. To use the table, measure raw water TOC and alkalinity and find the box on the table that applies to your raw water. The percent shown in the box is your plant’s Step 1 required removal percent. If the plant **cannot** meet the Step 1 TOC removal requirement in Table 6-1, you must use the Step 2 requirements in Chapter 7. The exact language for the TOC removal requirements can be found in 30 TAC Section 290.112(b).

Table 6-1: Step 1 Matrix of Required TOC Removal Percentage

Raw Water TOC (mg/L)	Raw Water Alkalinity (mg/L as CaCO ₃)		
	0 to 60	> 60 to 120	> 120
2.0 ≤ TOC ≤ 4.0	35.0 %	25.0 %	15.0 %
4.0 ≤ TOC ≤ 8.0	45.0 %	35.0 %	25.0 %
TOC ≥ 8.0	50.0 %	40.0 %	30.0 %

Note: Softening plants must meet the TOC removal requirements in the third column, under Raw Water Alkalinity > 120 mg/L (as CaCO₃).

The percent removal requirements specified in Table 6-1 were developed based on the “treatability” of different waters. TOC removal is generally more difficult as alkalinity increases and TOC decreases. When alkalinity is high, more acid must be added to force the pH down, so just adding coagulant may not do the job. The best (optimal) pH range for coagulation with alum is 5.5 to 6.5. In more alkaline waters, TOC removal cannot be achieved easily through the addition of coagulant alone. TOC removal is also generally more difficult as the TOC level decreases because there are fewer opportunities for particles to contact each other and form floc.

Month-to-month changes in raw water TOC and/or alkalinity levels will cause some plants to move from one box of Table 6-1 to another. Therefore, the plant’s required TOC removal percentage may change, based on the TOC and alkalinity levels of the monthly raw water compliance sample.

Example 6-1: Step 1 Removal Requirement

A plant in southeast Texas is treating water that has an alkalinity of 7 mg/L (as CaCO₃) and a TOC of 8.3 mg/L. What is the plant’s Step 1 required removal percentage?

Solution: The operator looks on the chart at the column for alkalinity between 0 to 60 mg/L (as CaCO₃). Looking down the column, to the row for “Raw Water TOC over 8.0 mg/L,” the Step 1 required removal rate for the plant is 50%.

7 Step 2 Alternative TOC Removal Requirement

7.1 Introduction

If a plant fails to meet the Step 1 removal requirement in any month (and does not satisfy one of the ACCs), you must determine the plant's *alternative TOC removal requirement* (Step 2 removal requirement).

Utilities that choose to use jar testing (not pilot testing) to determine their Step 2 removal requirements should follow the procedures described in this guidance manual. A system that chooses to use pilot-scale Step 2 testing should follow the procedures described in the EPA guidance document (EPA 815-R-99-012) discussed on page 1.

A Step 2 jar test will establish the plant's required percent removal rate for up to six months (see Chapter 9, "Compliance Determination").

***PURPOSE OF STEP 2 JAR TEST:* The purpose of the jar test is to establish an alternative TOC removal requirement, not to determine full-scale operating conditions.**

In a Step 2 jar test, 10 mg/L increments of alum (or an equivalent amount of iron coagulant) are added to determine the incremental removal of TOC. TOC removal is calculated for each 10 mg/L increment of coagulant added. Coagulant must be added in the required increments until a target pH is achieved. The point where adding another 10 mg/L dose of alum does not remove at least 0.3 mg/L of TOC is defined as the *point of diminishing return* (PODR). Table 7-1 provides an example of how data is used to determine the PODR.

The percentage TOC removal achieved at the PODR in the Step 2 jar test is defined as the plant's *alternative percent TOC removal requirement*, subject to approval by the TCEQ Public Drinking Water Program. For a discussion of how to define the PODR see Section 7.3.11 on page 25.

Table 7-1: Example of PODR Calculation

Alum Dose (mg/L)	TOC Level (mg/L)	Change in TOC (mg/L)	TOC Removal (%)
0	4.9	NA	NA
10	4.2	0.7	14.3
20	3.8	0.4	22.2
30	3.5	0.3	28.6
40	3.3	0.2	32.7
50	3.2	0.1	34.7

PODR

Alternative Percent TOC Removal Requirement

The goal of the Step 2 procedure is to determine the amount of TOC that can be removed with reasonable amounts of coagulant and to define an alternative TOC removal percentage. The procedure is neither designed nor intended to be used to establish a full-scale coagulant dose requirement. Once a plant’s alternative TOC removal percentage is approved by the TCEQ, a plant may achieve this removal at full scale by using any appropriate combination of treatment chemicals.

7.2 Frequency of Step 2 Jar Testing

You **must** perform a Step 2 jar test if the monthly TOC sampling shows that the plant will not meet the Step 1 removal requirements. After the TCEQ approves the alternative TOC removal requirement, the plant may use that alternative TOC removal requirement for each month in both the quarter when the Step 2 test was performed and the following quarter (six months total). For example, if the TCEQ approves the results of a Step 2 jar test you conducted in February, you can use the results for the months of January through June. Once you have an approved Step 2 removal requirement, you may use any combination of coagulant, coagulant aid, filter aid, and pH adjustment to achieve that removal in the full-scale plant.

After you start being required to do Step 2 jar testing, you may do the jar testing once and use those results for six months. However, you may wish to redo the Step 2 jar testing if your raw water changes due to rain or blending. There is no upper limit on frequency of jar testing for a plant required to do Step 2.

7.3 Step 2 Jar Test Method

The Step 2 procedure is based on the incremental addition of a metal-based coagulant to define an alternative TOC removal percentage. Only aluminum- or iron-based coagulants may be used for the Step 2 procedure. **The addition of acid, polymers, or other treatment chemicals to the jars used in the test is not permitted.**

Alum must be used in 10 mg/L increments; the equivalent increments for other coagulants are shown in Table 7-2.

Table 7-2: Coagulant Dosage Equivalents

Jar No.	Regular Grade Alum (Aluminum Sulfate) $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ (mg/L)	Reagent Grade Alum (Aluminum Sulfate) $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ (mg/L)	Ferric Chloride $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ (mg/L)	Ferric Chloride FeCl_3 (mg/L)	Ferric Sulfate $\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ (mg/L)	Ferrous Sulfate $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ (mg/L)
1	10	11.2	9.1	5.5	9.5	9.4
2	20	22.4	18.2	11	19	18.8
3	30	34.6	27.3	16.5	28.5	28.2
4	40	44.8	36.4	22	38	37.6
5	50	56	45.5	27.5	47.5	47
6	60	67.2	54.6	33	57	56.4
7	70	78.4	63.7	38.5	66.5	65.8
8	80	90.6	72.8	44	76	75.2
9	90	100.8	81.9	49.5	85.5	84.6
10	100	112	91	55	95	94

Plants Not Using Metal Coagulant: Some treatment plants use a proprietary polymer blend for coagulation. If your plant does not use a metal coagulant that is mentioned in Table 7-2, you should perform Step 2 jar testing using alum. (*Note:* Step 2 jar test results are not used to set full-scale operating conditions.)

Plants Using Metal Coagulants with Additives: Some treatment plants use coagulants that contain other chemicals, such as polymers or copper sulfate. If your plant uses a *liquid coagulant* with additives, you may **not** use that solution in Step 2 jar tests. You must obtain and use one of the chemicals identified in Table 7-2 to conduct a Step 2 jar test.

The Step 2 procedure requires that coagulant be added in increments until the pH of the tested sample is at or below the *target pH* (Table 7-3). The target pH values are dependent upon the alkalinity of the raw water to account for the fact that higher coagulant dosages are needed to reduce pH in higher alkalinity waters.

Table 7-3: Step 2 Target pH

Alkalinity (mg/L as CaCO₃)	Target pH
0–60	5.5
> 60–120	6.3
> 120–240	7.0
> 240	7.5

For a water with alkalinity of less than 60 mg/L (as CaCO₃)—for which addition of small amounts of coagulant drives the pH below the target pH before significant TOC removal is achieved—add base to maintain the pH between 5.3 and 5.7 until the PODR criterion is met. The chemical used to adjust the pH should be the same chemical used in the full-scale plant unless that chemical does not perform adequately in jar tests. Substitute chemicals should be used in this case.

The following jar test procedure should be used to conduct Step 2 testing. This method relies on the addition of coagulant only; acid and polymers must **not** be used in the jar test, even if they are used in full-scale treatment. Base must be added if the pH of the water drops too much (see Table 7-3). Table 7-4 summarizes the sequence of the Step 2 jar test procedure.

Table 7-4: Step 2 Jar Test Procedure Summary

1.	Gather testing supplies (Section 7.3.1).
2.	Prepare coagulant dosing solution (Section 7.3.2).
3.	Determine the initial coagulant dose that you will use (Section 7.3.3).
4.	Determine the number of jars (and pH adjustment, if applicable) required (Section 7.3.4).
5.	Record starting conditions, coagulant dose, pH, alkalinity (Section 7.3.5).
6.	Collect raw water for testing (Section 7.3.6).
7.	Set up the jars (Section 7.3.7).
8.	Rapid mix the jars and add coagulant (Section 7.3.8).
9.	Slow mix and settle the jars (Section 7.3.9).
10.	Take samples to measure TOC, pH (Section 7.3.10).
11.	Determine PODR (Section 7.3.11).

7.3.1 Step 2 Jar Testing Supplies

- ! **Jar test apparatus** with 1- or 2-L beakers or square mixing jars.
- ! **Dosing solution of alum or other coagulant.** The dosing solution must be freshly prepared the day of the test. See Section 7.3.3 for information on preparing an alum or ferric dosing solution. The dosing solution must be made from straight coagulant that is **not** blended with polymer or other chemicals.
- ! **Base** (if needed to adjust pH).
- ! **Hydrometer.** If using a liquid coagulant, a hydrometer or other equipment to measure the specific gravity of the coagulant.
- ! **pH meter.** Calibrate the pH meter in accordance with *Standard Methods* (American Public Health Association, 1998).
- ! **Sample bottles.** Sample bottles for alkalinity and pH analysis of coagulated water. Sample bottles for TOC analysis.
- ! **25- and 50-mL pipettes, with bulbs.** Pipettes are used to accurately measure volumes during preparation of dosing solutions. Volumetric pipettes may be used for more precise dosages. Plastic disposable syringes (without needles) may be used to measure coagulant doses to be applied during the jar tests, but not to prepare the dosing solution.
- ! **1-L graduated cylinders**
- ! **Large carboys** for collecting raw water (preferably with siphons or taps for dispensing water). A suitable laboratory tap may also be used.
- ! **Magnetic stirrer** with stirring bars
- ! **Miscellaneous beakers and glassware**
- ! **Data sheet** (see Figure 7-6)

7.3.2 Dosing Solutions for a Step 2 Jar Test

You must prepare the Step 2 dosing (stock) solution using a metal-based coagulant. If you use alum in the plant, you will need to make an alum dosing solution; if you use ferric coagulant in the plant, you will need to make a ferric dosing solution. If you use only polymer or polyaluminum chloride (PACl), you will need to obtain some alum to use in Step 2 jar testing.

When you prepare the dosing solution, you should make it strong enough so that when you add 1 mL of it to the jar test jar, you get a 10 mg/L alum dose (or an equivalent amount of iron). For example, if you are using alum and 1-L test jars, you will need to make a 10,000 mg/L (10 g/L, 10 mg/mL) solution. That way, when you add 1 mL of dosing solution to the 1-L test jar, you will get a dose of 10 mg/L. However, if you are using alum and 2-L test jars, you will need to make the

dosing solution twice as strong, so that when you add 1 mL of solution to the larger jar, you still get a 10 mg/L dose.

Note about pH: The pH of the coagulant dosing solution should generally be below 3.0. If the pH of the coagulant dosing solution is allowed to increase significantly above 3.0, some precipitation of metal hydroxide may occur, resulting in the loss of active coagulant. If this happens, you should make a fresh dosing solution.

7.3.2.1 Dry Coagulant Dosing Solution for a Step 2 Jar Test

If you are using a dry chemical to make your dosing solution, Table 7-5 shows how much chemical to use to prepare your dosing solution.

Table 7-5: Step 2 Dosing Solution Recipes for Dry (Solid) Chemicals

Coagulant Chemical	Desired Increment in Step 2 Jars	Dosing Solution Recipe	
		To dose 1-L jars	To dose 2-L jars
Regular Grade Alum (dry) $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$	10 mg/L	10 grams	20 grams
Reagent Grade Alum (dry) $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$	11.2 mg/L	11.2 grams	22.4 grams
Ferric Chloride (dry) FeCl_3	5.5 mg/L	5.5 grams	11 grams
Ferric Chloride (dry) $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	9.1 mg/L	9.1 grams	18.2 grams
Ferric Sulfate (dry) $\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$	9.5 mg/L	9.5 grams	19 grams
Ferrous Sulfate (dry) $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	9.4 mg/L	9.4 grams	18.8 grams

To prepare a dosing solution using one of the dry chemicals listed in Table 7-5, use the following procedure:

1. Add about 400 mL of distilled or deionized water to a 1000-mL volumetric flask.
2. Add the proper amount of dry coagulant to the flask and swirl it until the chemical dissolves.
3. Finish filling the flask to the 1000-mL mark with distilled or deionized water.
4. Stopper the flask and completely mix the dosing solution by inverting the flask several times.

7.3.2.2

Liquid Coagulant Dosing Solution for a Step 2 Jar Test

If you are using a liquid coagulant at your plant, you may be able to prepare your dosing solution using that material. However, you can do this only if you meet all of the following four criteria:

- ! you must be feeding solutions of ferric chloride, liquid alum, liquid ferric sulfate, or liquid ferrous sulfate; **and**
- ! your liquid coagulant does not contain any other chemicals, such as polymer, copper sulfate, etc.; **and**
- ! you know the exact amount (concentration) of active chemical in the liquid coagulant; **and**
- ! you must be able to measure the specific gravity of the liquid coagulant.

If you cannot meet all of the four conditions, you must prepare the dosing solution using the procedure outlined in Section 7.3.3.2 above **and** you must use one of the dry coagulants listed in Table 7-4.

Plants Using Liquid Ferric or Liquid Ferrous Coagulants: Vendors frequently fail to provide the percent ferric (active iron) of the iron solutions they sell. If you do **not** know the amount of iron in your solution, you must obtain dry ferric (or ferrous) coagulant.

The most convenient way to measure liquid coagulants is to use volumetric measurements like milliliters. However, each milliliter of the dosing solution must create an applied dose equal to 10 mg/L of regular grade dry alum. Consequently, you must prepare the dosing solution on a *dry weight* basis, even if you use a liquid coagulant. To do this, you must first determine how much **dry** coagulant is contained in each milliliter of the liquid, and then figure out how much of the liquid coagulant you have to use to make the dosing solution.

Determining how much dry coagulant is contained in each milliliter of the liquid coagulant:

The strength of a liquid iron or alum coagulant is typically reported on a *percent* basis. For example, each pound of a 30 % liquid alum solution contains 0.30 pounds of reactive (**dry**) alum. However, in order to prepare a dosing solution, you must know the amount of reactive (**dry**) chemical, in each milliliter of the liquid solution. Therefore, the first step in preparing a dosing solution is to convert the concentration of the liquid coagulant from **percent** to **milligrams per milliliter (mg/mL)** using Equation 7.1.

Equation 7-1:

$$\begin{aligned} &\text{Concentration [mg/mL]} \\ &= \text{Percent Alum [g of dry alum/100 g of liquid coagulant solution]} \\ &\quad \times \text{Specific Gravity [g solution/mL solution]} \\ &\quad \times 1000 \text{ [mg/g conversion factor]} \end{aligned}$$

Example 7-1 shows the procedure for converting from percent to milligrams per milliliter when using liquid alum.

Example 7-1: Converting from percent to milligrams per milliliter

An operator uses liquid alum with a specific gravity of 1.33. The liquid alum contains about 48% regular grade alum ($\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$) on a **dry weight** basis. What is the concentration of the coagulant in milligrams of dry alum/milliliter of coagulant [mg/mL]?

Solution:

The concentration can be converted to mg/mL using Equation 7-1.

$$\begin{aligned} \text{Alum concentration [mg/mL]} &= \\ &48 \text{ [g alum/100 g solution]} \times 1.33 \text{ [g solution/1 mL solution]} \times 1000 \text{ [mL/L]} \\ &= \mathbf{638} \text{ [mg alum/mL]} \end{aligned}$$

Note about Specific Gravity: As long as the specific gravity of your liquid alum is between 1.32 and 1.35, you can assume that it contains 48% *dry* alum, and you can use the calculations from Example 7-1. If not, use Equation 7.1 and the information contained in Appendix 9 to determine the concentration of your alum solution.

Figuring out how much liquid coagulant to use when making a dosing solution:

After you have determined how much **dry** coagulant each milliliter of liquid coagulant contains, you can figure out how much liquid coagulant is needed to make a liter of dosing solution.

To make a liter of dosing solution, use the following equation.

Equation 7-2:

$$\begin{aligned} \text{Amount of liquid} & \text{ grams of dry coagulant from Equation 7 - 4} \\ \text{coagulant [mL]} &= \frac{\text{[g of } \mathbf{dry} \text{ coagulant]}}{\text{coagulant content of liquid}} \times 1000 \text{ [mg/g]} \\ & \text{[mg/mL; see Example 7.1]} \end{aligned}$$

Example 7-2 shows the calculations for figuring out how much liquid alum to use when making a Step 2 jar test dosing solution.

Example 7-2: Preparing a 20 g/L dosing solution

The operator from Example 7-1 wants to make a dosing solution with the liquid alum he is using at his plant. The liquid alum contains no additional chemicals, and his jar test apparatus has 2-L jars. How much of the liquid alum should he use to make his dosing solution?

Solution:

The liquid alum contains no additional chemicals, so the operator knows it can be used to prepare the dosing solution. He is using 2-L jars and alum, so he uses the far right-hand column of Table 7-4 to find out that he will need 20 g of alum to prepare 1 L of dosing solution. From the calculations he made in Example 7-1, the operator knows that each milliliter of liquid coagulant contains 641 mg of dry alum. Now he can plug all this information into Equation 7-2 to find out how much liquid alum he needs to use to make the dosing solution.

$$\begin{aligned} \text{Amount of liquid coagulant [mL]} &= \\ 20 \text{ [g of alum]} \times 1000 \text{ [mg alum/g alum]} &/ 638 \text{ [mg alum/mL liquid alum]} \\ &= \mathbf{31.3 \text{ [mL liquid alum]}} \end{aligned}$$

Preparing the dosing solution:

To prepare a dosing solution using a liquid coagulant, use the following procedure:

- ! Add about 400 mL of distilled or deionized water to a 1000-mL volumetric flask.
- ! Add the proper amount of liquid coagulant to the flask and swirl it until the chemical dissolves.
- ! Finish filling the flask to the 1000-mL mark with distilled or deionized water.
- ! Stopper the flask and completely mix the dosing solution by inverting the flask several times.

7.3.3 Determine the Initial Coagulant Dose

If you are using alum, ferric, or ferrous coagulants at your plant, you can, if you choose, start dosing jars one increment below the concentration of coagulant that you use full scale. For instance, if you add 55 mg/L of alum at full scale, you can start your jar test at a dose of 50 mg alum/L, so your jars would be: 50, 60, 70, 80, 90, 100 mg/L, and so on.

However, if you are using other coagulants, such as polymer, polyaluminum chloride, or alumina chlorhydrate, you must begin your Step 2 jar test with a dose of 10 mg/L alum dose.

7.3.4 Determine the Number of Jars Required, and pH Adjustment, If Applicable

You will need enough jars to reach both the PODR and the target pH. If the alkalinity level of your raw water is at least 60 mg/L, this is a straightforward process; you just run until the target pH is reached. If the alkalinity level of your raw water is lower than 60 mg/L, the process may be a little more complex, since

you may need to add a base to keep the pH from dropping to the target pH before you reach the PODR.

The first time you do a Step 2 jar test, you should start with one full set of jars. If you meet the PODR after three or four jars, the TCEQ may allow you to run fewer jars in future tests.

7.3.4.1 Determining the Number of Jars When the Raw Water Alkalinity Is 60 mg/L or Higher

If your raw water alkalinity level is at least 60 mg/L, you can use the following procedure to determine the number of jars that you will have to run during this first Step 2 jar test.

- ! Collect a sample of raw water and fill one of the jar test jars to the full mark.
- ! Measure the pH and alkalinity of the raw water.
- ! Place the jar on a magnetic stirrer.
- ! Add alum to this sample in 10-mg/L increments (or equivalent ferric dose). Use Table 7-1 to determine appropriate incremental doses for each type of coagulant.
- ! Measure and record the pH after each incremental coagulant dose.
- ! Determine the alum or ferric dose required to reach the target pH. Use Table 7.2 to determine the target pH).

The number of increments of alum you have to put in to hit the target pH will be the number of jars you need to dose with alum (or iron coagulant) when you do the jar test.

Example 7-3 shows the process of determining the number of jars needed for a Step 2 jar test when the alkalinity is relatively high.

Example 7-3: Determining the number of jars needed for a Step 2 jar test when the raw water alkalinity level is at least 60 mg/L.

An operator at a treatment plant that uses ferric chloride has a raw water with an alkalinity level of 84 mg/L and a pH of 7.6. The plant is currently applying a ferric dose of 19 mg/L.

Solution:

Since the plant is using ferric chloride, the operator uses Table 7-1 to determine that a dose of 5.5 mg/L is equivalent to a 10 mg/L alum dose. Since the plant is currently applying 19 mg/L of ferric, the operator can determine the plant's equivalent alum dose using this equation:

$$\begin{aligned} \text{equivalent alum dose} &= \frac{19 \text{ mg/L [ferric dose]}}{5.5 \text{ [mg/L of ferric / 10 mg/L of alum]}} \times 10 \text{ [mg/L of alum]} \\ \text{at the plant} &= 34.5 \text{ mg/L} \end{aligned}$$

Using this result, the operator determines that the Step 2 jar test can begin with an equivalent alum dose of 30 mg/L at Jar 3. Refer to Table 7-1 to determine the appropriate incremental ferric chloride dose. Since the jar test apparatus has 2-L jars and the plant uses a dry coagulant, the operator refers to Table 7-4 and uses 11 grams of FeCl₃ to prepare 1 L of dosing solution. Using one of the 2-L jars and the procedure described in Section 7.3.4.1, she obtains the following results.

Jar No.	Equivalent Alum Dose	Ferric Dose (mL of dosing solution)	Alkalinity	pH
0	0	0 (raw water)	84	7.6
3	30	16.5		7.1
4	40	22		7.0
5	50	27.5		6.8
6	60	33		6.5
7	70	38.5		6.4
8	80	44		6.3
9	90	49.5		6.1

Based on these results and Table 7-3, the operator correctly concludes that she must run the Step 2 jar test out to an equivalent alum dose of at least 80 mg/L.

7.3.4.2 Determining the Number of Jars When the Raw Water Alkalinity Is Less Than 60 mg/L

When the raw water alkalinity level is below 60 mg/L, small increases in coagulant doses can produce rapid decreases in pH. Consequently, an operator may reach the target pH long before reaching the PODR. This problem is particularly severe when the raw water alkalinity level is below 20 to 30 mg/L.

The TCEQ is concerned that the Step 2 jar test may be concluded before the PODR is reached. Consequently, we require that you raise the coagulant dose by at least five increments before concluding the test. Basically, you must run at least

five jars above your current coagulant dose. For example, if you currently apply a 26-mg/L dose of alum, the TCEQ might not approve the results of the jar test unless doses of 20, 30, 40, 50, 60, and 70 mg/L are included in the test. If your raw water alkalinity level is below 60 mg/L, you may find that the pH of your jar falls below the target pH before you reach the maximum dose you need to apply. In this case, you will need to add a base to one or more of the jars to keep the pH within the target pH range. When you have a raw water with relatively low alkalinity, you should use the following procedure to determine the number of jars that you will have to run during your first Step 2 jar test.

- ! Collect a sample of raw water and fill one of the jar test jars to the full mark.
- ! Place the jar test jar on a magnetic stirrer.
- ! Measure the pH and alkalinity of the raw water.
- ! Add alum to this sample in 10 mg/L increments (or equivalent ferric dose). Use Table 7-1 to determine appropriate incremental doses for each type of coagulant.
- ! Measure and record the pH after each incremental coagulant dose.
- ! If the pH of the jar falls below 5.3, add enough base to raise the pH level to between 5.3 and 5.7.
- ! If you have not increased the coagulant dose by at least 5 increments (i.e., 50 mg/L of alum or an equivalent amount of iron), keep going until you have.

The number of increments of alum you have to put in to hit the target pH will be the number of jars you need to dose with alum (or iron coagulant) when you do the jar test.

Example 7-4 shows how an operator goes through the process of determining the number of jars needed for a Step 2 jar test when the alkalinity is below 60 mg/L (as CaCO_3).

Example 7-4: Determining the number of jars needed for a Step 2 Jar Test when the raw water alkalinity level is less than 60 mg/L.

An operator at a treatment plant that uses a pure polymer coagulant has a raw water with an alkalinity level of 21 mg/L and a pH of 7.3. The plant is currently applying a polymer dose of 6.3 mg/L and uses liquid caustic to adjust the pH of its finished water.

Solution:

Because the plant uses polymer as its primary coagulant, the operator realizes that he must prepare his dosing solution using dry alum. Since the jar test apparatus has 2-L jars, the operator refers to Table 7-4 and uses 20 grams of regular grade dry alum to prepare 1 L of dosing solution.

The operator also realizes that Section 7.3.3 requires him to begin the Step 2 jar test at an incremental alum dose of 10 mg/L, because the plant uses polymer as its primary coagulant. In addition, he knows that the TCEQ will probably make him apply an alum dose of at least 50 mg/L (i.e., 5 incremental doses) before they will approve his results.

Each 10 mg/L alum dose will consume about 5 mg/L of alkalinity. Consequently, the operator knows that he will probably need to adjust the pH for the last couple of doses. To address this problem, he prepares a 10% dilution of his liquid caustic to use in the test. Then, using one of the 2-L jars and the procedure described above in Section 7.3.4.2, he obtains the following results.

Jar No.	Alum Dose	Alkalinity	pH	Caustic Applied (mL)	pH
0	0 (raw water)	21	7.3	0	7.3
1	10		7.1	0	7.1
2	20		6.7	0	6.7
3	30		6.4	0	6.4
4	40		5.7	0	5.7
5	50		5.3	2	5.5
6	60		5.1	2	5.4
7	70		5.1	4	5.4

Based on these results, the operator concludes that he must run the Step 2 jar test out to an equivalent alum dose of at least 50 mg/L. However, since the last three increments gave some unclear results, he decides to run the jar test out to a dose of 70 mg/L, just to be safe. Finally, he realizes that he will need to add some of the dilute caustic to the last couple of jars to keep the pH of the settled water between 5.3 and 5.7.

7.3.5 Record Starting Conditions and Desired Chemical Doses

Begin filling out a data sheet similar to the one shown in Table 7-6. Enter the type of coagulant and the concentration of the dosing solution. If a base is going to be used during the test, also record the type and concentration of the base solution. Note the mixing and settling conditions that will be used in the jar test. Record the desired chemical doses for each of the jars and the volume of dosing solution to be added to each. Alum should be dosed at increments of 10 mg/L (or iron coagulant at an equivalent dose from Table 7-1) up to the maximum increment.

7.3.6 Collect Raw Water for Testing

You should conduct the jar test with freshly collected water, if at all possible. Collect as much raw water for the jar test as you will need (10 to 30 L, depending on number and size of jars).

Note on Temperature: It may be difficult to maintain ambient water temperatures during jar testing. Jar testing may take up to two hours (including the mixing and settling times). During this time, the water temperature will gradually change until it reaches the temperature of the room where you are conducting the test. Temperature change during jar testing may interfere with the settling of floc because of convection currents or release of dissolved air from the water. You should make every effort to minimize temperature change during jar testing.

Note on Storage: If you absolutely must store the raw water for subsequent testing, the sample should be refrigerated at approximately 4°C. Before starting any testing with the sample, adjust the temperature of the sample back to the ambient raw water temperature during collection by bringing the temperature up gradually. Samples that have been stored should be inverted to resuspend any solids that have settled to the bottom of the container during storage. It is best to collect fresh raw water for a jar test.

7.3.7 Set up the Jars and Prepare Dosing Syringes

Fill the jar test jars with the proper amount (1 or 2 L) of raw water and place the jars on the jar test apparatus. Lower the stirrer paddles, turn on the mixer, and set the speed just high enough to prevent settling of any suspended materials.

Fill the *coagulant* syringe for each jar with the appropriate amount of coagulant. If pH adjustment is needed for one or more jars, fill the *base* syringe with the appropriate type and amount of base. Lay the syringes next to the respective jars.

7.3.8 Add Chemicals

Increase the mixing speed to achieve rapid mix conditions, and quickly inject the chemicals into each jar. If possible, you should inject both the coagulant and the base at the same time. However, if it is impractical to inject the two chemicals simultaneously, you should add the base first and then add the coagulant. Regardless of whether the chemicals are injected simultaneously, be sure that you get all of the chemicals injected into all of the jars within 5 or 6 seconds. Start timing the rapid mix period as soon as the chemicals are added to the last jar.

7.3.9 Mix and Settle

Rapid mix, flocculate, and settle, using the times listed on the data sheet.

Note on Mixing Conditions: Jar test mixing conditions should reflect full-scale mixing conditions and detention times at the plant's maximum daily flow for the quarter being tested. However, for rapid mixing, a detention time of at least 1 minute should be used. If the plant mixing intensities and durations are not known, use a rapid mix at 100 rpm for 1 minute, flocculate at 30 rpm for 20 minutes, and settle for 30 minutes before sampling.

7.3.10 Take Samples to Measure TOC and pH

After settling, sample the supernatant for TOC analysis. Use 25- or 50-mL wide-bore pipettes, a siphon apparatus, or sampling ports located on the side of the mixing jars. During sampling, the tip of the pipette should be approximately 10 cm (4 in.) below the water surface. In a typical 2 L square jar, the sampling port is also located approximately 10 cm below the 2 L mark on the side of the jar. While sampling, be careful not to disturb the settled floc and to avoid suspended floc.

Note on Sample Preservation: Preserve and/or refrigerate the samples for subsequent TOC analysis. TOC samples must be acidified with sulfuric or phosphoric acid if they are not going to be analyzed within 24 hours. Provide a unique sample ID for each sample, and note the ID numbers on your data sheet. If you are sending out your samples for analysis, follow the lab's instructions.

After settling, measure the pH of the jars. Note the values in the data sheet. Take samples for alkalinity, if desired, and analyze within appropriate holding times.

7.3.11 Determine the PODR

When you get the results of the TOC analysis, fill in those values on a data sheet (like that shown in Table 7-6) and determine the PODR.

7.3.11.1 How to Determine the PODR and Alternative Removal Requirement

The PODR is defined at the point where addition of a 10 mg/L alum dose (or equivalent) results in less than 0.3 mg/L of TOC. This can be easily determined by looking at the data you collect for the Step 2 jar test.

Example 7-5: Determining PODR

A surface water treatment plant runs a Step 2 Jar Test and gets these results:

Example of Step 2 Jar Test Results

Jar No.	Coagulant Dose (mg/L Alum or equivalent dose of iron coagulant)	Settled-water TOC (mg/L)
1	0	8.0
2	10	7.0
3	20	6.6
4	30	6.2
5	40	6.0
6	50	6.0
7	60	6.0

What is the PODR for this jar test? What is the alternative removal requirement for this plant?

Solution:

(1) PODR: The PODR is the point at which 10 mg/L of additional alum removes less than 0.3 mg/L of TOC. Calculate how much TOC each increment of additional alum achieved. Results are shown below:

Example of Step 2 Jar Test Results with Calculation Results

Jar No.	Coagulant Dose (mg/L Alum or equivalent dose of iron coagulant)	Settled-water TOC (mg/L)	Incremental TOC Removed (mg/L)
1	0	8.0	n/a
2	10	7.0	1.0
3	20	6.6	0.4
4	30	6.2	0.4
5	40	6.0	0.2
6	50	6.0	0.0
7	60	6.0	0.0

The PODR is at Jar 5, 40 mg/L of alum added, where addition of a 10 mg/L increment of alum results in removal of 0.2 mg/L of TOC, which is less than 0.3.

(2) Alternative removal requirement: The alternative removal requirement is the percent removal that is achieved in the Step 2 jar test at the PODR. The TOC removal in Jar 5 is the new required removal for this plant. For that jar:

$$\% \text{ TOC removal} = (1 - 6.0/8.0) \times 100 = 25\%$$

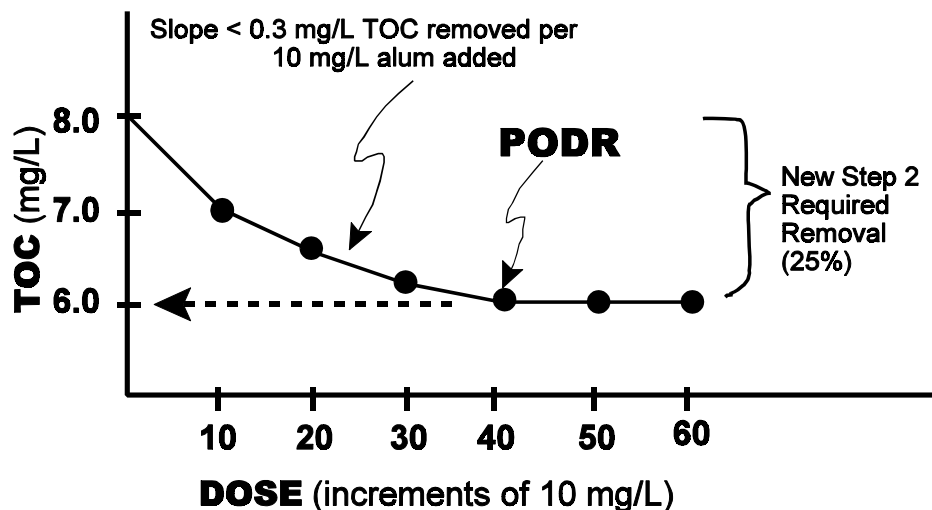
Example of Step 2 Jar Test Results with Calculation Results

Jar No.	Coagulant Dose (mg/L Alum or equivalent dose of iron coagulant)	Raw Water TOC (mg/L)	Settled-water TOC (mg/L)	Incremental TOC Removed (mg/L)	TOC Removal %
5	40	8.0	6.0	0.2	25.0%

The removal at the PODR is 25%. The system must now achieve 25% TOC removal from the raw water, unless the alternative removal requirement is above the Step 1 requirement.

Graphing your results may help you to better understand the Step 2 jar test. Figure 7-1 shows the results of the jar test in Example 7-5.

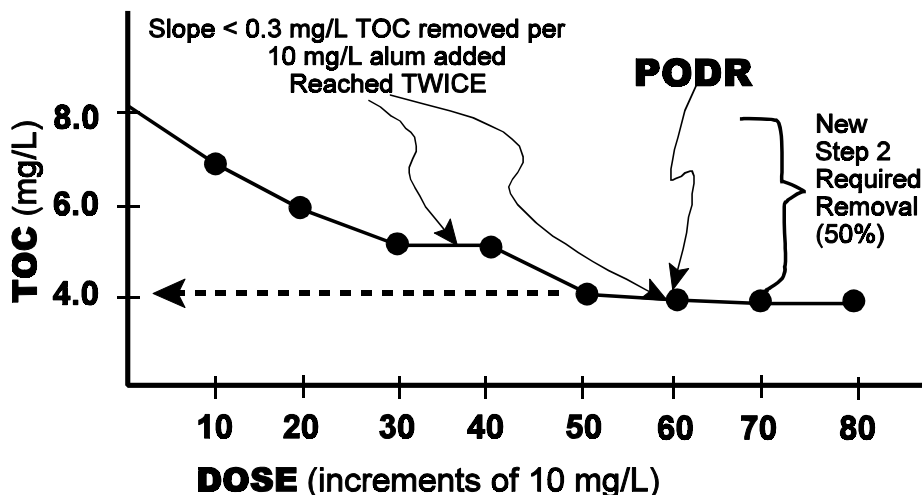
Figure 7-1: Graph of Step 2 Jar Test Results (Data from Example 7-5)



7.3.11.2 Two PODRs

Sometimes, a Step 2 jar test will have two places where the PODR is reached. In this case, the second point at which the TOC removal drops below 0.3 mg/L per 10 mg/L increment of alum (or equivalent added) is considered the *official* PODR. This situation is shown graphically in Figure 7-2.

Figure 7-2: Example of PODR Determination When the PODR Occurs Twice

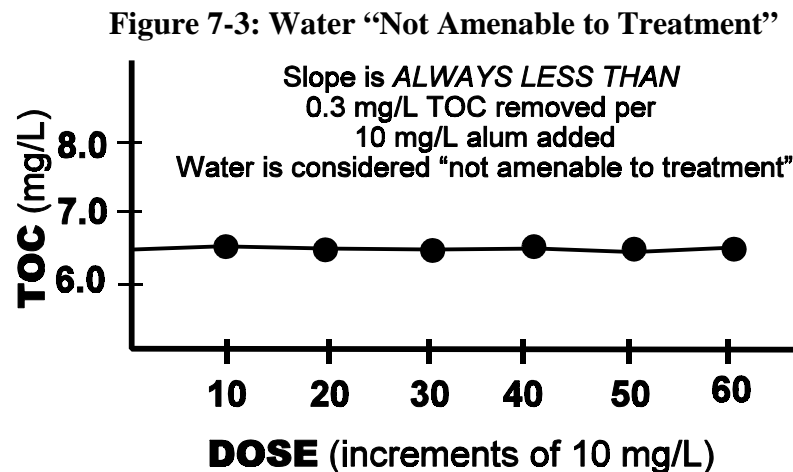


7.3.11.3 Water “Not Amenable to Treatment”

Sometimes, a Step 2 jar test will show that there is no additional TOC removal, no matter how much coagulant is added. Plants may apply to the state for a waiver from the enhanced coagulation requirements if they consistently fail to achieve the PODR.

Note: TOC removal is never greater than 0.3 mg TOC removed/L per 10 mg/L alum or equivalent dose of ferric salt added at all coagulant dosages during the Step 2 jar test procedure.

These plants have a raw water in which enhanced coagulation will not work. An example of the graph of the Step 2 jar test for water not amenable to treatment is shown in Figure 7-3. The plant should send the TCEQ the Step 2 MOR showing the jar test results showing that the PODR cannot be achieved.



8 Alternative Compliance Criteria (ACCs or “Outs”)

The TOC in some waters is not very easy to remove by coagulation or precipitative softening. For this reason, ACCs were developed to allow plants flexibility for establishing compliance with the treatment technique requirements. These criteria recognize the low potential of certain waters to produce disinfection by-products (DBPs), and also account for those waters with TOC that is very difficult to remove.

A plant can establish compliance with the enhanced coagulation or enhanced softening TOC removal requirement by meeting any one of eight ACCs. The ACCs are summarized in Table 8-1 and discussed in detail in Sections 8.1 through 8.8.

Table 8-1: Summary of Alternative Compliance Criteria (ACCs or “Outs”)

ACC	Description	Additional sampling
1	Raw water TOC < 2.0 mg/L	none *
2	Treated water TOC < 2.0 mg/L	none *
3	TTHM < 40 µg/L; and HAA5 < 30 µg/L, and raw water TOC < 4.0 mg/L; and raw water alkalinity > 60 mg/L (as CaCO ₃);	none *
4	TTHM < 40 µg/L; and HAA5 < 30 µg/L, and the system uses only chlorine	none *
5	Raw water SUVA <2.0 L/mg-m	Raw water SUVA
6	Treated water SUVA <2.0 L/mg-m	Treated water SUVA (jar test)
7	Softening; treated water alkalinity less than 60 mg/L (as CaCO ₃)	Treated water alkalinity
8	Softening; magnesium hardness removal greater than or equal to 10 mg/L (as CaCO ₃)	Raw and treated water magnesium

* Raw water TOC and alkalinity and the treated water TOC must be measured and reported in the TOC-MOR every month.

All systems that wish to meet one of these “outs” must send in the ACC-MOR along with their TOC-MOR. The ACC-MOR is included in Appendix 1 of this guidance manual, along with other reporting forms.

8.1 ACC 1: Raw Water TOC < 2.0 mg/L

If the raw water contains less than 2.0 mg/L of TOC, calculated quarterly as a running annual average, a utility is in compliance with the treatment technique for the whole year.

This criterion also can be used on a monthly basis. For example, in every month in which raw water TOC is less than 2.0 mg/L, the plant can establish compliance for that month by meeting this criterion.

Monitoring and Reporting: There are no extra monitoring and reporting requirements for this “out.”

8.2 ACC 2: Treated Water TOC < 2.0 mg/L

If a treated water contains less than 2.0 mg/L TOC calculated quarterly as a running annual average, the utility is in compliance with the treatment technique for the whole year covered by the average.

This criterion also can be used on a monthly basis. For example, for individual months in which treated water TOC is less than 2.0 mg/L, the plant can establish compliance for that month by meeting that criterion.

Monitoring and Reporting: There are no extra monitoring and reporting requirements for this “out.”

8.3 ACC 3: Raw Water TOC < 4.0 mg/L *and* Raw Alkalinity > 60 mg/L (as CaCO₃) *and* TTHM ≤ 40 µg/L *and* HAA5 ≤ 30 µg/L

It is more difficult to remove TOC from waters with higher alkalinity and lower TOC levels. Therefore, utilities that meet the above criteria can establish compliance with the treatment technique requirements. All of the parameters—TOC, alkalinity, total trihalomethanes (TTHM), haloacetic acids (group of five) (HAA5)—are based on running annual averages, computed quarterly. TTHM and HAA5 compliance samples are used to qualify for this alternative performance criterion.

If the running annual average of each measure listed above satisfies the respective values, the plant is in compliance for the whole year.

This ACC cannot be used on a monthly basis because the TTHM and HAA5 averages for a whole year are used to calculate compliance.

Monitoring and Reporting: Systems that meet ACC 3 do not have to do extra monitoring, but they must report their TTHM and HAA5 compliance values on their TOC-MOR.

8.4 ACC 4: TTHM \leq 40 $\mu\text{g/L}$ and HAA5 \leq 30 $\mu\text{g/L}$ and Chlorine Only

Plants that use only free chlorine as their primary disinfectant and for maintenance of a residual in the distribution system and that achieve the stated TTHM and HAA5 levels are in compliance with the treatment technique. The TTHM and HAA5 levels are based on running annual averages, computed quarterly. TTHM and HAA5 compliance samples are used to qualify for this alternative performance criterion.

If the running annual average of TTHM is less than 40 $\mu\text{g/L}$ and the running annual average of HAA5 is less than 30 $\mu\text{g/L}$ and the plant uses only chlorine in the plant and distribution system, the plant is in compliance for the whole year.

This ACC cannot be used on a monthly basis, because the TTHM and HAA5 average for a whole year (running annual average) is used to calculate compliance.

Monitoring and Reporting: Systems that meet ACC 4 are not required to do extra monitoring, but they must report their TTHM and HAA5 compliance values, and certify that only chlorine is used as a disinfectant in the plant and distribution system.

8.5 ACC 5: Raw Water SUVA \leq 2.0 L/mg-m (liters/milligram-meter)

If the raw water *specific ultraviolet absorption* (SUVA) is less than or equal to 2.0 L/mg-m, calculated quarterly as a running annual average, the utility is in compliance with the treatment technique requirements. The EPA guidance document includes a more thorough discussion of SUVA.

If the running annual average SUVA is less than or equal to 2.0 L/mg-m, the utility is in compliance for the whole year.

This criterion also can be used on a monthly basis. For example, in every month in which raw water SUVA is less than 2.0 L/mg-m, the plant can establish compliance for that month by meeting this criterion.

Monitoring and Reporting: Systems that meet ACC 5 must measure and report raw water SUVA. Raw water SUVA samples must be taken before any oxidant has been added to the water. If the plant purchases and treats water that has already been disinfected, the plant must get samples from the lake or reservoir before the disinfection point.

8.6 ACC 6: Treated Water SUVA \leq 2.0 L/mg-m

If the treated water SUVA is less than or equal to 2.0 L/mg-m, calculated quarterly as a running annual average, the utility is in compliance with the treatment technique requirements.

This criterion is also available on a monthly basis; for individual months in which treated water SUVA is less than or equal to 2.0 L/mg-m, the plant can establish compliance for that month by meeting ACC 6.

Monitoring and Reporting: Systems that meet ACC 6 must measure and report treated water SUVA. Treated water SUVA sampling is to be conducted no later than combined filter effluent turbidity. The rule also requires that the sample for treated water SUVA be taken before any oxidant is added to the water. Many plants add an oxidant (disinfectant) to the raw water, so a procedure for measuring treated water SUVA in the lab is included in Section 11.2.6.

8.7 ACC 7: Treated Water Alkalinity < 60 mg/L (as CaCO₃) (Softening Systems)

Softening plants meet ACC 7 if their treated water alkalinity is less than 60 mg/L (as CaCO₃), measured monthly and calculated quarterly as a running annual average. Softening plants that currently practice lime softening are not required to change to lime-soda ash softening.

This criterion can be used on a yearly basis. If treated water alkalinity is less than 60 mg/L, calculated quarterly as a running annual average, the plant is in compliance for the whole year.

This criterion also can be used on a monthly basis. For example, in every month in which a softening plant lowers treated water alkalinity to less than 60 mg/L, the plant can establish compliance for that month by meeting this criterion.

Monitoring and Reporting: Plants that meet this “out” must measure and report **treated** water alkalinity, as well as **raw** water alkalinity.

8.8 ACC 8: Magnesium Removal > 10 mg/L (as CaCO₃) (Softening Systems)

Softening plants meet ACC 8 (in Table 8.1) if they remove at least 10 mg/L of magnesium hardness (as CaCO₃), measured monthly and calculated quarterly as a running annual average. Softening plants that currently practice lime softening are not required to change to lime-soda ash softening.

This criterion can be used on a yearly basis. If magnesium removal is at least 10 mg/L, calculated quarterly as a running annual average, the plant is in compliance for the whole year.

This criterion also can be used on a monthly basis. For example, in every month in which magnesium removal is more than 10 mg/L, the plant can establish compliance for that month by meeting this criterion.

Monitoring and Reporting: Plants that want to meet this “out” must measure and report raw and treated water magnesium hardness. The operator must calculate and report the amount of magnesium hardness that is removed.

9 Compliance Determination

The TCEQ will calculate compliance and notify you if a treatment technique violation occurs. The compliance calculation method is included here to assist you in determining whether you are likely to have a violation. If you take more than one sample set in a month, the results of those sample sets should be averaged. (Process control sample sets do not have to be reported.)

Compliance is based on a running annual average of quarterly averages of monthly averages. Compliance is calculated quarterly. You will find the exact rule language for the TOC compliance determination in 30 TAC Section 290.112(f).

Monthly

Actual Removal: Every month, you must take at least one TOC sample set. For each sample set, calculate the *actual TOC removal*. The actual removal is obtained by first dividing the treated water TOC by the raw TOC, then subtracting that value from 1.

$$\text{Actual Removal} = 1 - \frac{\text{Treated Water TOC}}{\text{Raw Water TOC}}$$

Actual Removal Percent: All of the compliance calculations are based on percent removal. The *actual removal percent* is just the actual removal times 100.

$$\text{Actual Removal \%} = \text{Actual Removal} \times 100$$

Required Removal Percent: The next step is to calculate the removal ratio for the sample set. To do this, you need the *required removal percent*.

$$\text{Required Removal \% from Step 1 matrix or Step 2 jar test}$$

Step 1: If you are using Step 1, the *required removal percent* is in the Step 1 Matrix (Table 6-1).

Step 2: If you are meeting Step 2, the *Step 2 alternative required removal requirement* is determined by doing a Step 2 jar test (Chapter 7). A plant that fails to meet Step 1, and is required to go to Step 2, can use the Step 2 alternative removal requirements for the quarter that the jar test is performed, and for the following quarter. The Step 2 alternative removal requirement can be used for that six-month period, even for months that the plant meets the Step 1 removal percentage.

Removal Ratio: The *removal ratio* for a sample set is the actual removal percent divided by the required removal percent. If the actual removal is greater than the required removal, the ratio is greater than one, and the plant is in compliance for that sample set.

$$\text{Removal Ratio} = \frac{\text{Actual Removal \%}}{\text{Required Removal \%}}$$

Alternative Compliance Criteria: In any month (or for any sample set) that the plant meets one of the eight ACCs (“outs”), the plant can assign a removal ratio of 1.0 for that month (or sample set).

In a month that plant meets an ACC, assign a monthly removal ratio of 1.0

Multiple Sample Sets in a Month: If a plant takes multiple samples in a month, the removal ratio should be calculated for each sample set. The average of all the removal ratios, for all the sample sets taken that month, is reported as the monthly removal ratio for compliance for that month.

Quarterly

Quarterly Average Removal Ratio: The *quarterly average removal ratio* is the average of the monthly average removal ratios for a calendar quarter.

$$\text{Quarterly Average Removal Ratio} = \frac{\text{Month 1 Removal Ratio} + \text{Month 2 Removal Ratio} + \text{Month 3 Removal Ratio}}{3}$$

Annual Average Removal Ratio: The *annual average removal ratio* is the average of the quarterly average removal ratios for last four quarters.

$$\text{Annual Average Removal Ratio} = \frac{\text{Quarter 1 Average Removal Ratio} + \text{Quarter 2 Average Removal Ratio} + \text{Quarter 3 Average Removal Ratio} + \text{Quarter 4 Average Removal Ratio}}{4}$$

Compliance: If the annual average removal ratio is greater than or equal to 1.0, the system is in compliance.

$$\text{Annual Average Removal Ratio} \geq 1.0$$

10 Public Notification

Systems that are required to meet Step 1 *and* have an annual removal ratio of less than 1.00 must notify their customers of the violation. The TCEQ will tell you if you have a violation. The following language is required by federal law in the Code of Federal Regulations [30 CFR 141.32 (79)]. You will find the exact Texas rule language for the TOC public notification in 30 TAC Section 290.112(g).

In the following paragraph, replace [**words in this font**] as needed.

The [**name of the public water system**] failed to meet the minimum treatment technique requirements for total organic carbon for the year running from [**month, year**] to [**month, year**].

The United States Environmental Protection Agency (EPA) sets drinking water standards and requires the disinfection of drinking water. However, when used in the treatment of drinking water, disinfectants react with naturally occurring organic and inorganic matter present in water to form chemicals called disinfection by-products (DBPs). EPA has determined that a number of DBPs are a health concern at certain levels of exposure. Certain DBPs, including some trihalomethanes (THMs) and some haloacetic acids (HAAs), have been shown to cause cancer in laboratory animals. Other DBPs have been shown to affect the liver and the nervous system, and cause reproductive or developmental effects in laboratory animals. Exposure to certain DBPs may produce similar effects in people. EPA has set standards to limit exposure to THMs, HAAs, and other DBPs.

After this language, the system may add more explanation, including language that explains that high TOC alone does not indicate the presence of a known health risk.

The TCEQ will notify you of any noncompliance. We will also tell you if you need to notify your customers. We strongly recommend that you do not issue a public notice for a TOC violation unless you have discussed the potential violation with the TCEQ's Water Quality Team at 512/239-4691.

11 Laboratory Methods

11.1 Introduction

This chapter provides an overview of acceptable analytical methods for compliance with the TOC removal requirements. Required procedures for sample collection, sample handling, and analysis are summarized, along with recommended quality assurance and quality control practices. The purpose of this chapter is to provide a general review of laboratory procedures necessary to implement the TOC requirements, not to replace the analytical methods required by the DBPR.

The water quality parameters that are important for compliance include TOC, alkalinity, pH, total trihalomethane (TTHM), haloacetic acid (group of five) (HAA5), ultraviolet light absorbance at 254 nm (UV_{254}), dissolved organic carbon (DOC), specific ultraviolet absorbance (SUVA), and magnesium hardness. The approved methods are summarized in Table 11.1.

Table 11-1: Analytical Methods for Demonstration of Compliance

Parameter	Method
Total Organic Carbon (TOC)	SM5310 B Combustion-Infrared SM5310 C Persulfate-Ultraviolet Oxidation SM5310 D Wet Oxidant
Dissolved Organic Carbon (DOC)	Same as TOC except for filtration step. (See discussion on SUVA in this chapter.)
Ultraviolet Absorbance at 254 nm (UV_{254})	SM5910 B Ultraviolet Absorption Method
Specific Ultraviolet Absorption (SUVA)	Calculated - requires methods for DOC and UV_{254}
Alkalinity	SM2320 B (Titration), ASTM D-1067-92
pH	SM 4500- H^+B , EPA 150.2, ASTM 1293-84
Haloacetic Acids (HAA5)	EPA 552.1, EPA 552.2, SM 6251 B
Total Trihalomethanes (TTHM)	EPA 502.2, EPA 524.2, EPA 551.1
Magnesium hardness	SM 3500-MgB - Atomic Absorption SM 3500-MgC - Inductively Coupled Plasma SM 3500-MgE - Titrimetric ASTM D 511-93 A - Titrimetric ASTM D 511-93 B - Atomic Absorption EPA 200.7 - Inductively Coupled Plasma

The TOC sample set (required for all compliance strategies) includes both TOC and alkalinity data, which all systems must measure and report on the TOC-MOR. The reporting requirements for Step 2 are summarized in Chapter 7. The reporting requirements for ACCs are summarized in detail in Chapter 8. Table 11-2 shows the methods a system must use, depending on the compliance strategy being used.

Table 11-2: Necessary Analytical Methods for TOC Compliance Strategies

Compliance Strategy	Analyses
Step 1	TOC, alkalinity
Step 2	TOC, alkalinity, pH
ACC 1	TOC, alkalinity
ACC 2	TOC, alkalinity
ACC 3	TOC, alkalinity, TTHM, HAA5
ACC 4	TOC, alkalinity, TTHM, HAA5
ACC 5	TOC, alkalinity, DOC, UV ₂₅₄ (SUVA)
ACC 6	TOC, alkalinity, DOC, UV ₂₅₄ (SUVA)
ACC 7	TOC, alkalinity
ACC 8	TOC, alkalinity, magnesium

11.2 Analytical Methods

This chapter is not comprehensive for all water quality parameters and methods required for compliance with the DBPR. Only those methods necessary for the TOC removal requirement are included.

11.2.1 Total Organic Carbon (TOC)

The methods described here all require analysis using equipment that costs between \$20,000 and \$30,000. Consequently, many systems will send TOC samples to a commercial laboratory. Currently, the turnaround time for commercial labs is about two to four weeks. Therefore, sampling should be scheduled early in the month.

TOC samples must *not* be filtered prior to analysis. TOC samples must be analyzed within 24 hours or must be acidified to achieve pH less than 2.0 by minimal addition of phosphoric or sulfuric acid as soon as practical after sampling (not to exceed 24 hours). Acidified TOC samples must be analyzed within 28 days of the collection date.

In all of the methods, total organic carbon (TOC) is measured after conversion of organic matter to carbon dioxide (inorganic carbon). The methods to accomplish this conversion include heat, ultraviolet irradiation, chemical oxidants, or combinations of oxidants that convert organic carbon to carbon dioxide.

Results are reported in mg/L and are typically rounded to two significant figures. A *minimum reporting level* (MRL) of 0.7 mg/L was established by a panel of experts for the Information Collection Rule (ICR). The *practical quantitation limit* (PQL) reported by laboratories performing TOC analysis should be consistent with this MRL. Values reported by the laboratory at less than the PQL should be reported by the plant as half of the PQL.

Three Standard Methods—5310B, 5310C, and 5310D—are included in the DBPR (Table 11.1). These methods should be followed in accordance with the supplement to the 19th Edition of *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association, 1998. Method 5310B is a combustion-infrared method; Method 5310C is a UV-persulfate oxidant method; and Method 5310D is a wet-oxidant method. A summary of these methods for the determination of TOC is provided below.

Note on High-Turbidity Waters: The high-temperature combustion method is recommended for high-TOC or -turbidity waters. One study (Najm *et al.*, *Journal of the American Water Works Association*, August 2000) notes that the persulfate method under-reports TOC if there is particulate organic carbon present in the sample. Therefore, for waters with TOC over about 2 mg/L, or turbidity over about 2 NTU, more accurate results may be obtained using the combustion method. However, different instruments perform differently. Some UV-persulfate analyzers may be able to handle high TOC.

Note on Low-Turbidity Waters: The UV-persulfate method is generally recommended for very low TOC or turbidity waters. The minimum detection limit for the persulfate method is 0.01–0.02 mg/L; and the minimum detection limit for the combustion method is 0.5 mg/L. Therefore, for waters with a TOC less than 1 mg/L, or turbidity less than about 1 NTU, more accurate results may be obtained with the persulfate method. However, different instruments perform differently. Some combustion analyzers may be able to handle low TOC.

11.2.1.1 Combustion-Infrared Method—Standard Method 5310B (Recommended for High-TOC/Turbidity Waters)

This method measures organic carbon via infrared absorption of the carbon dioxide gas that is produced when the organic carbon in the sample is heated and reacted with an oxidant catalyst. Inorganic carbon is converted to CO₂ by

acidification to $\text{pH} \leq 2$ and is purged from the sample prior to analysis. This process also removes volatile organic carbon from the sample, which contributes to carbon loss. However, this loss is generally insignificant. The CO_2 from oxidation of organic and inorganic carbon is measured using a nondispersive infrared analyzer or titrated colorimetrically. Any combustion instrument used for compliance purposes under the DBP1R should be capable of providing quantitative data at concentrations of at least 0.5 mg/L.

11.2.1.2 Persulfate-Ultraviolet Oxidant Method—Standard Method 5310C (Recommended for Low-TOC/Turbidity Waters)

This method measures organic carbon via infrared absorption of the carbon dioxide gas that is produced when the organic carbon in the sample is simultaneously oxidized by a persulfate solution and irradiated with ultraviolet light. Inorganic carbon is converted to CO_2 by acidification to $\text{pH} \leq 2$, and is purged from the sample prior to analysis. Significant concentrations of chloride ($\geq 0.1\%$) and a low sample pH (<1) can impede the analysis; precautions are specified in the method.

11.2.1.3 Wet-Oxidation Method — Standard Method 5310D

This method has a detection limit of 0.10 mg/L and is subject to the same interferences as the UV-persulfate method. Persulfate and phosphoric acid are added to the sample, and the sample is purged with pure oxygen to remove inorganic carbon in the form of CO_2 . The purged sample is sealed in an ampule and combusted for four hours at 116-130°C in an oven. This causes the persulfate to oxidize the organic carbon to CO_2 .

11.2.2 Alkalinity

Total alkalinity is measured by titration of the sample to an electrochemically determined endpoint ($\text{pH} 4.5$). Alkalinity is reported in milligrams per liter as calcium carbonate (CaCO_3). The methods are based on the assumption that all of the alkalinity concentration is the sum of carbonate, bicarbonate, and hydroxide concentrations, and assume that other alkalinity-contributing compounds are absent. Borates, phosphates, silicates, or other bases won't be measured if they are present (*Standard Methods*, 1989, pp. 2–35).

Three titration methods are approved for alkalinity measurements at 40 CFR 141.89. These methods are:

- ! Standard Method 2320B—in *Standard Methods for the Examination of Water and Wastewater*, 19th Edition, American Public Health Association, 1998.
- ! Method ASTM D1067-92B—in the *Annual Book of ASTM Methods*, 1998, Vol. 11.01.

! USGS I-1030-85—in *Methods for Determination of Inorganic Substances in Water and Fluvial Sediments*: U.S. Geological Survey Techniques of Water-Resources Investigations.

The sample pH of the raw water where the sample was collected must be recorded. Care must be used in sampling and storage, and in preparation of the primary standards for sodium carbonate, sulfuric acid, hydrochloric acid.

11.2.3 *Specific Ultraviolet Absorption (SUVA)*

SUVA is an indicator of the humic content of water. It is a calculated parameter, and is equal to the UV absorption at 254 nm (measured in m^{-1}) divided by the DOC (measured as mg/L).

Waters with low SUVA values contain primarily non-humic matter that is difficult to remove with enhanced coagulation. On the other hand, the TOC in waters with high SUVA values is generally easier to remove using enhanced coagulation. SUVA is an alternative compliance criterion for demonstrating compliance with TOC removal requirements. Systems are not required to perform enhanced coagulation or enhanced softening if the raw or treated water SUVA is ≤ 2.0 L/mg-m (Chapter 8).

The equation for SUVA is:

$$\text{SUVA [L/mg-m]} = 100 \text{ [cm/m]} (\text{UV}_{254} \text{ [m}^{-1}\text{]} / \text{DOC [mg/L]})$$

Two separate analytical methods are necessary to make this measurement: UV_{254} and DOC. Although these methods are briefly described in sections 11.2.4 and 11.2.5, respectively, they are described in greater detail in the EPA guidance document. DOC and UV_{254} samples used to determine a SUVA value must be taken at the same time and same location. Both samples are filtered according to the procedures outlined in the discussion of DOC. The TCEQ recommends, but does not require, that both DOC and UV samples be filtered as one large aliquot.

11.2.4 *Dissolved Organic Carbon (DOC)*

Dissolved organic carbon (DOC) is that portion of the organic carbon which is fully dissolved in the water. To measure DOC, the particulate portion of the organic carbon must be removed before analysis.

DOC measurements are performed using the same analytical techniques used to measure TOC (methods 5310B, 5310C, and 5310D). However, samples for DOC measurement must be vacuum-filtered or pressure-filtered through a $0.45 \mu m$ pore size filter prior to analysis. Filtering should occur before preservation, storing, or shipping the sample. The lab should ensure that no contamination or dilution of the sample occurs during filtration.

The 0.45 μm pore filters that are used for DOC samples may contain organic plasticizers (binding material), which can leach into the sample during filtration. This leaching can increase the level of organic carbon in the sample after filtration and create experimental error. To prevent contamination from organic binding material in membrane filters, the membrane filter must be washed with reagent-grade water before a sample is passed through it. Typically, washing with several 100-mL volumes of water is required for a 47-mm diameter filter. Vacuum or pressure filtration can be used to help this process. You should experiment to find adequate washing procedures for each batch of filter membranes. Adequate washing is demonstrated when the DOC of the filtered water is within 5% of the TOC of the water prior to filtration.

High turbidity samples may clog the filter, so more than one membrane may be needed. When multiple filter membranes are required for a sample, each sequential filter membrane must be taken through the same washing procedure as described above, and the presample filter blank should be analyzed.

The last aliquot of deionized wash water passed through the filter prior to sample filtration must be saved and used as a filtered blank. This filtered blank must be analyzed using procedures identical to those used for analysis of the samples, and must have a DOC content of less than 0.5 mg/L. The filtration apparatus should be adequately washed to remove organic matter.

DOC samples should be analyzed immediately, if possible. If it is necessary to preserve the samples, filter them first, then acidify them. The filtered DOC samples must be acidified to a pH less than 2.0 by minimal addition of phosphoric or sulfuric acid immediately after filtration. Acidified DOC samples must be analyzed within 28 days. If the DOC of the analyzed sample is less than or equal to the TOC concentration, sample contamination has occurred, and the DOC results are invalid.

11.2.5 *Ultraviolet Light Absorbance at 254 nm (UV_{254})*

UV_{254} is the amount of light with a wavelength of 254 nanometers that a sample will absorb. The principle behind this method is that UV-absorbing constituents, such as humic or fulvic acids, absorb UV light in proportion to their concentration. UV_{254} is measured using Method 5910B (*Standard Methods for the Examination of Water and Wastewater*, 19th Edition, American Public Health Association, 1998).

UV_{254} samples must be measured in waters that do not contain an oxidant or disinfectant. This is necessary because oxidants react with organic compounds and cleave the double bonds that absorb UV_{254} . Samples for UV_{254} must be filtered to remove particles before analysis.

Before measuring UV₂₅₄, the sample should be filtered through a 45 μm pore membrane filter. To prevent contamination from membrane filters, the filters must be washed with reagent-grade water before filtering the sample. Typically, several 100-mL volumes of water are required for a 47-mm diameter filter. Samples must be analyzed as soon as practical after sampling (not more than 48 hours). The pH of a UV₂₅₄ sample must not be adjusted.

UV absorbance is measured at a wavelength of 253.7 nm (rounded to 254 nm), at ambient pH, using a spectrophotometer. The sample volume is chosen based on how big the sample cell is, and how much UV light the sample absorbs. If the water's UV absorbance is over 0.900 cm⁻¹, dilution is required. The sample should be diluted so that its UV absorbance is between 0.005 and 0.900 cm⁻¹.

The spectrophotometer must be zeroed using an organic-free water blank. UV₂₅₄ should be measured on at least two filtered portions of the sample at room temperature. The average value is reported in cm⁻¹ (i.e., the result must be divided by the cell length). UV measurements are typically made within a 1-cm cell.

It is recommended that laboratories performing UV₂₅₄ analysis obtain a *practical quantitation limit* (PQL) of at least 0.009 cm⁻¹ (the minimum reporting limit of the Information Collection Rule). When a laboratory reports results that are less than the PQL, plants are supposed to use half of the PQL for compliance calculations.

Note on Use of UV₂₅₄ as Surrogate for TOC: Some surface plants have found that the level of UV₂₅₄ in their water is closely correlated to the level of TOC in their water. You are free to examine this relationship, and if it exists, to use UV₂₅₄ as an indicator of TOC for process control purposes, but **not** for compliance with the TOC removal requirements. Before using UV₂₅₄ as a process control surrogate, you should measure and record TOC and UV₂₅₄ from identical samples under all of the raw water conditions likely to occur at your plant.

11.2.6 Finished Water SUVA Jar Testing

ACC 6 allows utilities to comply with the TOC treatment technique requirement by producing a finished water with a SUVA value of less than 2.0 L/mg-m. The determination of the SUVA should be made on finished water that has not been exposed to any oxidant during treatment. If there is no oxidant (such as chlorine) added prior to the finished water TOC and UV₂₅₄ monitoring, and the plant uses alum as its only coagulant, full-scale samples can be used to calculate SUVA to allow comparison with this criterion.

In Texas, most plants add an oxidative disinfectant to the raw water. If oxidants are added prior to the finished water TOC and UV₂₅₄ monitoring, the utilities are required to establish treated water SUVA by conducting a jar test in which no

disinfectants are added. The jar test can be performed by adding an equivalent amount of alum that is used at full scale (plus any polymer) in a jar test. Due to interference from iron in the UV₂₅₄ measurement, utilities using ferric salts for coagulation should conduct a finished-water SUVA jar test with an equivalent amount of alum.

Polymer and Acid: Unlike the Step 2 jar test, if polymer or acid is added at full scale, they can also be used in the finished-water SUVA jar test.

Ferric: Ferric plants must replace the ferric with alum in the finished-water SUVA jar test. Ferric interferes with UV₂₅₄ measurements.

Oxidant: No oxidant may be added when performing finished-water SUVA jar testing.

After completion of the jar test, settled-water DOC and UV₂₅₄ should be used to calculate SUVA. Filtration with a pre-washed 0.45 μm pore membrane is required for DOC and UV₂₅₄ determination.

General guidelines for performing process control jar tests are located in Appendix 3 and you may wish to use them as a helpful tool to design appropriate finished-water SUVA jar testing for your plant.

11.2.7 Other Methods

To find methods for pH, magnesium, haloacetic acids, and trihalomethanes see the most current version of *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association.

Appendices

- Appendix 1: TOC Monthly Operating Reports**
- Appendix 2: Side Effects of Enhanced Coagulation**
- Appendix 3: Chemical Feed Rate Calculation Standard Operating Procedure**
- Appendix 4: Example Process Control Jar Test Standard Operating Procedure**
- Appendix 5: Unregulated Disinfection By-Products**
- Appendix 6: Commonly Used Acronyms and Definitions**
- Appendix 7: Conversion Factors**
- Appendix 8: Lab Approval Form and Instructions**
- Appendix 9: Densities and Equivalent Weights of Commercial Alum**

Appendix 1: Total Organic Carbon Monthly Operating Reports

Systems required to remove TOC must fill out the Total Organic Monthly Operating Report (TOC-MOR) each month and submit it to the TCEQ. You may attach it to your Surface Water Monthly Operating Report (SWMOR). Your report is due to the TCEQ no later than the 10th day of the month following the reporting period. The reports must be sent to:

TCEQ
Public Drinking Water Section, MC-155
Water Supply Division
P.O. Box 13087
Austin, Texas 78711-3087

The TOC-MOR actually consists of three parts: the TOC-MOR itself, the Step 2 MOR, and the ACC-MOR. Every system must send in the TOC-MOR every month. However, you only need to send in the Step 2 MOR if you have to do a Step 2 jar test, and you only need to send in the ACC MOR if you meet one of the eight ACCs.

TOC-MOR

You must record the monthly actual TOC removal on the TOC-MOR. The measured values for raw water TOC, raw water alkalinity, and treated water TOC must be recorded on this worksheet, no matter what compliance strategy you are using (Step 1, Step 2, or ACC).

You are required to do only one TOC sample set per month but the worksheet has room for the results of more than one TOC sample set. You may wish to do additional sample sets. Most systems leave all the rows blank except for one. The rows for that data are labeled as “Dates.” You may want to do more than one TOC sample set on one day. If you do that, you can change the labeling to reflect the actual date the data was taken.

The results of all sample sets taken in accordance with the monitoring plan at the designated sampling sites must be reported to TCEQ on the TOC-MOR. If you want to find out how you are doing without reporting your results, you may take process control samples at sites not designated as compliance monitoring points.

The TOC-MOR worksheet is also the worksheet that will calculate the Step 1 monthly compliance. Every system required to comply with the TOC rules must send in a printout of the TOC-MOR worksheet every month.

ACC-MOR

The ACCs are commonly called “outs” because they get you “out” of having to remove TOC. Some of the ACCs reflect the fact that it is very difficult to remove TOC from some raw waters. Other ACCs recognize a treatment process that is working well under special circumstances, like softening. Chapter 8 contains detailed information on the ACCs. You need to submit the ACC-MOR (pages 2 and 3 of the TOC-MOR) if you are achieving compliance with the TOC rule by meeting one of the ACC.

Step 2-MOR

If you are not able to meet either the Step 1 removal requirement (Chapter 6) or one of the ACCs (Chapter 8), you will have to do Step 2 jar testing. Chapter 7 contains detailed information on Step 2. If you can meet the Step 1 removal requirement, or an ACC, you do not need to do Step 2 jar testing.

You only need to submit the Step 2-MOR (page 2 of the TOC-MOR) to the TCEQ if you are required to do Step 2 jar testing. Step 2 jar testing is performed in order to determine your Step 2 alternative removal requirement. You must report the results of Step 2 jar testing on the Step 2-MOR. These results include the mixing conditions, coagulant doses, base addition (if any), and pH and TOC from each jar. The Step 2-MOR includes a graph of your jar test results, which shows the point of diminishing returns (PODR). The removal the plant gets at the PODR is the plant’s alternative minimum removal requirement.

If you are required to do Step 2 jar testing, the Step 2 alternative removal requirement that you determine replaces the value from the Step 1 matrix as the amount of TOC removal that you need to achieve.

MONTHLY TOTAL ORGANIC CARBON REMOVAL REPORT (TOC-MOR)
FOR SURFACE WATER OR GROUND WATER UNDER THE INFLUENCE OF SURFACE WATER SYSTEMS

PUBLIC WATER SYSTEM NAME: _____

PLANT NAME OR NUMBER: _____

PWS ID No.: _____

Month: _____ Year: _____

Type of treatment: Conventional Unconventional, explain: _____

Note: Systems are required to run one TOC Sample Set every month. Additional space is provided for those systems that do additional sampling

Date	Monthly TOC Sample Set			Actual % TOC Removed	Step 1 Required % Removal	Step 1 Removal RATIO	Optional data				COMPLIANCE REMOVAL RATIO	
	Raw Alkalinity	Raw TOC	Treated TOC				Step 2 Required % Removal	Step 2 Removal Ratio	ACC # used	ACC Removal Ratio		
	Required plant data						<i>calculated</i>	<i>from matrix</i>	<i>calculated</i>	<i>attach Step2 form</i>		<i>calculated</i>
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
Avg												
Max												
Min												

TOTAL ORGANIC CARBON (TOC) REMOVAL SUMMARY

	TOC Summary			TOC % Removal Summary		TOC Removal Ratio
	Raw Water Alkalinity	Raw Water TOC	Treated Water TOC	TOC % Removal	Requirement	

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Operator's Signature: _____

Certificate No. and Grade: _____

Date: _____

ALTERNATIVE COMPLIANCE CRITERIA REPORT

FOR SURFACE WATER OR GROUND WATER UNDER THE INFLUENCE OF SURFACE WATER SYSTEMS

PUBLIC WATER SYSTEM NAME: _____

PLANT NAME OR NUMBER: _____

PWS ID No.: _____ Month _____ Year _____

This Alternative Compliance Criteria (ACC) Report is being submitted to request the following ACC: (check one)

(Put an "X" in the box that shows the number of the Alternative Compliance Criteria you are applying for)

#1 #2 #3 #4 #5 #6 #7 #8

ACC #1	Source Water TOC less than or equal to 2.0? (calculated quarterly as a running annual average)												
		1	2	3	4	5	6	7	8	9	10	11	12
	Actual Month/Yr												
	Monthly TOC												
	Quarterly Average	#DIV/0!											
	Yearly Average												

# 2	Treated Water TOC less than or equal to 2.0? (calculated quarterly as a running annual average)												
		1	2	3	4	5	6	7	8	9	10	11	12
	Actual Month/Yr												
	Monthly TOC												
	Quarterly Average	#DIV/0!											
	Yearly Average												

# 3	Source Water TOC less than or equal to 4.0? (calculated quarterly as a running annual average) AND Source water alkalinity over 60 mg/L (as CaCO3)? (calculated quarterly as a running annual average)												
		1	2	3	4	5	6	7	8	9	10	11	12
	Actual Month/Yr												
	Monthly TOC												
	Quarterly Average TOC												
	Yearly Average TOC												
	Monthly Alkalinity												
	Quarterly Ave. Alkalinity	#DIV/0!											
	Yearly Ave. Alkalinity												
	AND TTHM and HAA5 no greater than 0.040 mg/L and 0.030 mg/L, respectively?												
		Yearly Average TTHM: <input type="text"/> mg/L											Yearly Average HAA5: <input type="text"/> mg/L
	ATTACH COPY OF COMPLIANCE REPORT FOR DISINFECTION BY-PRODUCTS (TTHM AND HAA5)												

# 4	TTHM and HAA5 no greater than 0.040 mg/L and 0.030 mg/L, respectively? Yearly Average TTHM: <input type="text"/> mg/L Yearly Average HAA5: <input type="text"/> mg/L ATTACH COPY OF COMPLIANCE REPORT FOR DISINFECTION BY-PRODUCTS (TTHM AND HAA5) AND only chlorine is used in the whole plant and distribution system. I certify that for the last 12 months, only free chlorine was used as a disinfectant for primary disinfection and for maintenance of a residual in the distribution system.
_____ Certified Operators Signature/ Certification Number/Date	

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Operator's Signature: _____ Certificate No. and Grade: _____ Date: _____

ALTERNATIVE COMPLIANCE CRITERIA REPORT

FOR SURFACE WATER OR GROUND WATER UNDER THE INFLUENCE OF SURFACE WATER SYSTEMS

PUBLIC WATER SYSTEM NAME: _____

PLANT NAME OR NUMBER: _____

PWS ID No.: _____

Month _____ Year _____

# 5	Source water SUVA less than or equal to 2.0 L/mg-m? (calculated quarterly as a running annual average)												
	<small>(Source water SUVA is the dissolved organic carbon concentration divided by the ultraviolet light absorption at 254 nanometers in the source water before any treatment of any kind. Measure monthly.)</small>												
		1	2	3	4	5	6	7	8	9	10	11	12
	Actual Month/Year												
	Monthly SUVA												
Quarterly Average SUVA													
Yearly Average SUVA													

# 6	Treated water SUVA less than or equal to 2.0 L/mg-m? (calculated quarterly as a running annual average)												
	<small>(Treated water SUVA is the dissolved organic carbon concentration divided by the ultraviolet light absorption at 254 nanometers in the finished water before any disinfection of any kind, or measured using a finished water SUVA jar test. (See the Instructions worksheet for more info.) Measure monthly.)</small>												
	Finished water measured: <input style="width: 50px;" type="text"/> In Plant <input style="width: 50px;" type="text"/> By Finished Water SUVA Jar Test (attach jar test report)												
		1	2	3	4	5	6	7	8	9	10	11	12
	Actual Month-Year												
Monthly SUVA													
Quarterly Average SUVA													
Yearly Average SUVA													

ACC #7	Treated water alkalinity less than 60 mg/L (as CaCO3)? (calculated quarterly as a running annual average)												
	<small>(softening practiced)</small>												
		1	2	3	4	5	6	7	8	9	10	11	12
	Actual Month-Year												
	Monthly Treated Alkalinity												
Quarterly Ave. Treated Alk.													
Yearly Ave. Treated Alk.													

AND cannot achieve the Step 1 TOC removal

Step 1 Compliance Summary:

TOC % Removal Summary		TOC Removal Ratio
TOC % Removal	Requirement	

# 8	Magnesium hardness removal greater than or equal to 10 mg/L (as CaCO3)? (calculated quarterly as a running annual)												
	<small>(softening practiced)</small>												
		1	2	3	4	5	6	7	8	9	10	11	12
	Actual Month-Year												
	Monthly Raw Mg. Hardness												
Monthly Treated Mg. Hardness													
Monthly Mg Removal													
Quarterly Ave. Mg Removal													
Yearly Ave. Mg Removal													

AND cannot achieve the Step 1 TOC removal

Step 1 Compliance Summary:

TOC % Removal Summary		TOC Removal Ratio
TOC % Removal	Requirement	

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Operator's Signature: _____

Certificate No. and Grade: _____ Date: _____

STEP 2 JAR TEST REPORT

FOR SURFACE WATER OR GROUND WATER UNDER THE INFLUENCE OF SURFACE WATER SYSTEMS

PUBLIC WATER SYSTEM
NAME: _____
PWS ID No.: _____

PLANT NAME
OR NUMBER: _____
Month _____ Year _____

CURRENT OPERATING CONDITIONS

COAGULANT BEING USED			
COAGULANT CONC.		%	
COAGULANT FEED RATE		LBS/DAY	Maximum Allowable
RAW WATER FLOW RATE		GPM	Alum Dose in Jar 1: <input style="width: 50px;" type="text"/> mg/L

DOSING SOLUTION CALCULATIONS

COAGULANT USED TO MAKE THE DOSING SOLUTION:	(Aluminum Sulfate, Ferric chloride,...) <input style="width: 90%;" type="text"/>	SIZE OF THE JAR TEST JARS:	<input style="width: 50px;" type="text"/> L
Other Dry Coagulants		Other Liquid Coagulants	
Coagulant	<input style="width: 90%;" type="text"/>	Coagulant	<input style="width: 90%;" type="text"/>
Chemical Formula	<input style="width: 90%;" type="text"/>	Chemical Formula	<input style="width: 90%;" type="text"/>
Molecular Formula	<input style="width: 90%;" type="text"/>	Molecular Formula	<input style="width: 90%;" type="text"/>
Molecular Weight	<input style="width: 90%;" type="text"/>	Molecular Weight	<input style="width: 90%;" type="text"/>
Cationic Charge	<input style="width: 90%;" type="text"/>	Cationic Charge	<input style="width: 90%;" type="text"/>
AMOUNT OF COAGULANT NEEDED TO MAKE 1 L OF DOSING SOLUTION: <input style="width: 100px;" type="text"/> mls or grams			

STEP 2 JAR TEST PARAMETERS

COAGULANT		BASE		MIXING CONDITIONS				
Type	Dosing Solution Concentration (g/L)	Concentration		Rapid Mix		Flocculation		Settling
		Type	(g/L)	Speed (rpm)	Duration (minutes)	Speed (rpm)	Duration (minutes)	Duration (minutes)

PERFORMANCE DATA

Jar No.	COAGULANT		BASE		Alkalinity (mg/L as CaCO ₃)	pH	TOC (mg/L)	Incremental TOC Removal (mg/L)	TOC Removal (%)
	Dose (mg/L)	Volume (mL)	Dose (mg/L)	Volume (mL)					
RAW									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Operator's
Signature: _____

Certificate
No. and Grade: _____ Date: _____

Appendix 2: Side Effects of Enhanced Coagulation

This appendix merely summarizes some of the possible side effects for systems that do not soften water. In pursuing the goal of additional TOC removal, systems should be aware of potential side effects that may impact their plant. The EPA guidance manual called *Enhanced Coagulation and Precipitative Softening Guidance Manual* (EPA 815-R-99-012) is available from the Safe Drinking Water Hotline at 1-800-426-4791. It provides additional information on the secondary effects of enhanced coagulation and enhanced softening.

Coagulant Dose

Generally, it is necessary to add more coagulant to remove TOC than is needed to remove turbidity. Therefore, the problems that arise are those you would expect from increasing coagulant dose and decreasing pH.

pH of Coagulation

Besides adding additional coagulant, it may be necessary to lower the pH in some waters, to ensure that coagulation occurs at the best pH. For alum, the best pH range is from 6.8 to 7.5, depending on the water constituents and whether the plant is operating in the charge neutralization or sweep floc mode. Therefore, the problems that arise are those you would expect from increasing coagulant dose and decreasing pH.

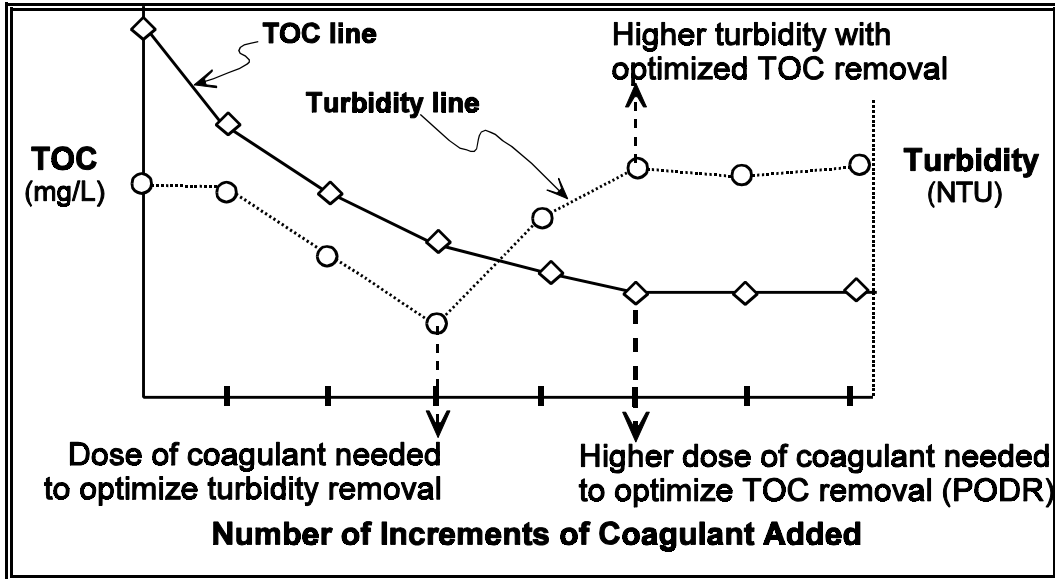
Floc Quality

Adding coagulant beyond that needed to optimize turbidity removal and lowering the pH of coagulation may adversely impact floc formation. Floc may tend to be larger, fluffier, and more difficult to settle. This is true especially if the plant is operating in the range of charge neutralization.

Turbidity

Adding additional coagulant, beyond the dose needed to optimize turbidity removal may increase settled-water turbidity. This is especially true if the plant is operating in the charge neutralization range. This phenomenon is illustrated in Figure A2-1. Increased settled-water turbidity may make it more difficult for filters to remove the turbidity and may shorten filter runs.

Figure A2-1: Example of Increased Turbidity with Enhanced Coagulation



Sludge Quantity

Adding additional coagulant beyond the dose needed to optimize turbidity removal may adversely impact the quality and quantity of sludge. Sludge production will likely increase. In order to estimate how much this will cost, you should do jar, pilot, or full-scale testing. Full-scale testing will provide the most and best information. Predictive equations are given in Table A2.1 for sludge production from alum or ferric coagulation, but the equations are only an estimate.

Table A2-1: Sludge Production Equations

Coagulant	Additional Sludge Prediction	Variables
Alum	$S = Q \times 8.34 \times ((AD \times 0.36) + X + TOC_{rem})$	S = sludge generated in pounds per day Q = flow in MGD AD = Alum dose in mg/L or
Ferric	$S = Q \times 8.34 \times ((FD \times 0.5 + X + TOC_{rem})$	FD = Ferric dose in mg/L X = other chemical doses, such as polymer or PACl, in mg/L TOC _{rem} = TOC removed in mg/L

From the USEPA *Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual*, publication number EPA 815-R-99-012, pages 6-24 and 6-25.

Sludge Quality

Sludge will likely be more difficult to dewater. Enhanced coagulation usually results in an increased coagulant dose, so clarifier sludge may contain more metals.

Aluminum

If you are using alum or lime that has aluminum in it, the concentration of dissolved aluminum may increase if the pH is decreased. Aluminum is very soluble from pH 6.2 to 6.5 and over pH 8.0.

Manganese

For systems that need to remove manganese, if the manganese is not entirely oxidized before the settling tank, manganese may break through. Chlorine or potassium permanganate need to be in contact with the water for a period of 15 minutes to 4 hours to get complete oxidation of manganese. Chlorine dioxide will oxidize manganese in 5 minutes. If greensand filters are used to remove manganese, letting the pH get below 6.2 will make the filters work poorly. Also, manganese may be found in some ferric coagulant products. If one of these products is used, it may actually add dissolved manganese to the water.

Corrosion

Lowering the pH and increasing the dissolved metal salts in the water may make the water more corrosive. Corrosion in a distribution system is not an equilibrium state—it is always in a state of change. You should check the Langelier index and Baylis curve for the water entering the distribution system after changing your process to meet the TOC removal requirements.

Disinfectant

The disinfectant demand may decrease, because TOC is part of the disinfectant demand. Therefore, reducing the TOC level will reduce chlorine (or other disinfectant) demand.

Appendix 3: Chemical Feed Rates

Example Standard Operating Procedure (SOP) for Measuring and Adjusting Chemical Feed Rates

Summary:

In order to treat water effectively, chemicals must be dosed accurately. This SOP contains the procedures for measuring and adjusting the alum and polymer feed rates. Adjusting the coagulant feed involves:

1. measuring the current alum and polymer feed rates,
2. calculating the current dosages using the results of the first step,
3. comparing the results of the second step with the target values set using jar tests or the plant superintendent's recommendation,
4. making necessary adjustments to the alum and polymer feed rates, and
5. verifying that the new feed rate produces the desired doses.

Equipment Needed (Example):

The equipment needed for your plant to go through this process may be different. For the example here, the operator would need:

- ! 500-mL and 250-mL graduated cylinder (a plant could have calibration cylinders on feed pumps)
- ! bowl to collect lime sample
- ! stopwatch or wristwatch with a second hand
- ! calculator
- ! waste bucket (old milk jug)
- ! triple-beam balance

Procedure (Example):

A. Measuring Feed Rates

I. Alum

- A. Take the stopwatch and the appropriately sized graduated cylinder to the rapid mix (if there are no calibration cylinders on the feed stream that you can use).
- B. Measure and record the volume of alum pumped into the rapid mix for 60 seconds.
 1. If you are not going to conduct a jar test, empty the cylinder into the rapid mix.
 2. If you are going to conduct a jar test, pour most of the alum into the rapid mix, but keep enough to prepare the dosing solution.

II. Polymer

- A. Take the stopwatch and the appropriately sized graduated cylinder to the chemical room (if there are no calibration cylinders on the feed stream that you can use).

- B. Get the waste bucket (old milk jug).
- C. Valve off the polymer injection line.
- D. Open the valve on the polymer pump sampling tap and flush the injection line into the waste bucket for 60 seconds.
- E. Using the graduated cylinder, measure and record the volume of polymer pumped for 60 seconds.
 - 1. If you are not going to conduct a process control jar test, empty the cylinder back into the polymer drum.
 - 2. If you are going to conduct a process control jar test, pour most of the polymer back into the polymer barrel, but keep a little to prepare the dosing solution.
- F. Close the sampling tap valve and open the valve to the feed (water) line.

III. Lime

- A. Take the bowl and the stopwatch to the lime feeder.
- B. Place the bowl under the point where the lime drops into the dilution water, and measure and record the amount of lime that is fed in 60 seconds.
- C. Take the bowl containing the lime to the lab.
- D. Set up the balance, transfer the lime to the weighing paper, and weigh the sample.

B. Calculating the Current Chemical Dosage

I. Alum

Because the alum dosing solution for the jar tests is based on a *dry weight*, the actual chemical dosages should be calculated on a similar basis, so that the results can be compared. To calculate the current alum dosage, use Equation A3-1.

Equation A3-1: Calculating the current alum dose

$$\text{alum dose (ppm)} = \frac{\text{alum feed rate}^* \times (1 \text{ gal. alum}/3,785 \text{ mL}) \times (5.34 \text{ lbs. dry alum}/\text{gal. alum})}{\text{raw water flow rate}^{**} \times (8.34 \text{ lbs. water}/1 \text{ gal. water}) \times (1 \text{ lb. dry alum}/1,000,000 \text{ lbs. water})}$$

$$= \frac{\text{alum feed rate}^* \times 5.34 \times 1,000,000}{\text{raw water flow rate}^{**} \times 8.34 \times 3,785} = \frac{\text{alum feed rate}^*}{\text{raw water flow rate}^{**}} \times 169$$

* expressed in mL / min.

** expressed in gal./min. (gpm)

In Equation A3-1, it is assumed that the *equivalent dry weight* of the liquid alum solution is 5.34 lbs of dry alum per gallon of alum. If the specific gravity of your alum solution is not close to 1.33, this assumption may lead to slightly inaccurate results. For better accuracy, measure the specific gravity of each batch of alum delivered by the vendor and then read the corresponding *equivalent dry weight* from the dry weight equivalency chart supplied by that vendor. **Note: When comparing the current alum dose with a target dose obtained from the jar test (see Appendix 4), you must use the same value for the equivalent dry weight in both procedures.**

II. Polymer

Because the polymer dosing solution for the jar tests is based on a purely volumetric basis, the actual chemical dosages should be calculated on a similar basis, so that the results can be compared. To calculate the current polymer dose, use Equation A3-2.

Equation A3-2: Calculating the current polymer dose

$$\begin{aligned} \text{polymer dose (ppm)} &= \frac{\text{polymer feed rate}^* \times (1 \text{ gal. polymer} / 3,785 \text{ mL polymer})}{\text{raw water flow rate}^{**} \times (1 \text{ gal. polymer} / 1,000,000 \text{ gal. water})} \\ &= \frac{\text{polymer feed rate}^* \times 1,000,000}{\text{raw water flow rate}^{**} \times 3,785} = \frac{\text{polymer feed rate}^*}{\text{raw water flow rate}^{**}} \times 264 \end{aligned}$$

*expressed in mL / min

**expressed in gal./min (gpm)

III. Lime

Because the lime dosing solution for the jar tests is based on *dry weight*, the actual chemical dosages should be calculated on a similar basis, so that the results can be compared. To calculate the current lime dose, use Equation A3-3.

Equation A3-3: Calculating the current lime dose

$$\begin{aligned} \text{lime dose (ppm)} &= \frac{\text{lime feed rate}^* \times (1 \text{ lb. lime} / 454 \text{ g lime})}{\text{raw water flow rate}^{**} \times (8.34 \text{ lbs. water} / 1 \text{ gal. water}) \times (1 \text{ lb. lime} / 1,000,000 \text{ lbs. water})} \\ &= \frac{\text{lime feed rate}^* \times 1,000,000}{\text{raw water flow rate}^{**} \times 8.34 \times 454} = \frac{\text{lime feed rate}^*}{\text{raw water flow rate}^{**}} \times 264 \end{aligned}$$

*expressed in grams of lime / minute

**expressed in gal./min. (gpm)

C. Adjusting the Chemical Feed Rates

I. Alum

Adjustments to the alum feed rate should be based on the results of jar tests or recommendations of the plant superintendent. Because the alum dosing (stock) solution for the jar tests is prepared on a dry weight basis, Equation A3-4 applies:

Equation A3-4: Calculating the required alum feed rate

$$\begin{aligned} \text{required alum feed rate}^* &= \text{dosage}^* \times \left(\frac{1 \text{ gal. alum}}{5.34 \text{ lbs. alum}} \right) \times \left(\frac{3,785 \text{ mL alum}}{1 \text{ gal. alum}} \right) \times \text{raw water flow rate}^* \times \left(\frac{8.34 \text{ lbs. water}}{1 \text{ gal. water}} \right) \\ &= \frac{\text{dosage}^* (\text{ppm}) \times \text{raw water flow rate}^* \times 8.34 \times 3785}{1,000,000 \times 5.34} \\ &= \frac{\text{dosage}^* \times \text{raw water flow rate}^*}{169} = \text{dosage}^* \times \text{raw water flow rate}^* \times 0.0059 \end{aligned}$$

*See "Explanation of Units in Equation A3 - 4" on next page.

Explanation of Units in Equation A3-4 (on preceding page):

Measure this quantity ...	in these units ...
required alum feed rate	milliliters per minute (mL/min)
dosage	pounds of alum per 1,000,000 lbs. water (ppm)
raw water flow rate	gallons per minute (gpm)

Note: When adjusting the alum dose, you **must** use the same *dry weight equivalent* value in this calculation as was used to prepare the dosing solution for the jar test. In this equation, it is assumed that the *equivalent dry weight* of the concentrated alum solution is 5.34 lbs of dry alum per gallon of alum. If the specific gravity of the alum solution differs substantially from 1.33, this assumption may be slightly inaccurate. For better accuracy, measure the specific gravity of each batch of alum delivered by the vendor and then read the corresponding *equivalent dry weight* from the dry weight equivalency chart supplied by that vendor.

II. Polymer

Adjustments to the polymer feed rate should be based on the results of jar tests or recommendations of the plant superintendent. Because the polymer dosing solution for the jar tests is based on a purely volumetric basis, Equation A3-5 applies:

Equation A3-5: Calculating the required polymer feed rate

$$\begin{aligned} \text{required polymer} \\ \text{feed rate}^* &= \text{dosage (ppm)}^{**} \times \left(\frac{3,785 \text{ mL polymer}}{1 \text{ gal. polymer}} \right) \times \text{raw water flow rate}^{***} \\ &= \frac{\text{dosage (ppm)} \times \text{raw water flow rate (gpm)} \times 3785}{1,000,000} \\ &= \frac{\text{dosage (ppm)} \times \text{raw water flow rate (gpm)}}{264} \\ &= \text{dosage (ppm)} \times \text{raw water flow rate (gpm)} \times 0.0038 \end{aligned}$$

* expressed in mL / min.

** expressed in gal. polymer / 1,000,000 gal. water

***expressed in gallons of **water** per minute (gpm)

III. Lime

Adjustments to the lime feed rate should be based on either the results of jar tests or the recommendations of the plant superintendent. Because the lime dosing solution for the jar test is on a dry weight basis, Equation A3-6 applies:

Equation A3-6: Calculating the required lime feed rate

$$\begin{aligned} \text{required lime} \\ \text{feed rate}^* &= \text{dosage}^{**} \times \left(\frac{454 \text{ g lime}}{1 \text{ lbs. lime}} \right) \times \text{raw water flow rate}^{***} \times \left(\frac{8.34 \text{ lbs. water}}{1 \text{ gal. water}} \right) \\ &= \frac{\text{dosage (ppm)} \times \text{raw water flow rate (gpm)} \times 454 \times 8.34}{1,000,000} \\ &= \frac{\text{dosage (ppm)} \times \text{raw water flow rate (gpm)}}{264} \\ &= \text{dosage (ppm)} \times \text{raw water flow rate (gpm)} \times 0.0038 \end{aligned}$$

* expressed in mL / min.

** expressed in lbs. alum / 1,000,000 lbs. water (parts per million; ppm)

***expressed in gal./min. (gpm)

IV. Adjusting Feed Rates

Any time that the alum or polymer feed rates are adjusted, you must verify the impact of the adjustments by repeating the feed rate measurement and dosage calculations from Steps 1 and 2.

Appendix 4: Process Control Jar Testing

Example Standard Operating Procedure (SOP) for Process Control Jar Test

Summary

Jar testing can be a very useful way to determine the desired coagulant feed rate and the effect of different coagulants or coagulant aids, such as polymers. Process control jar testing is very different from the Step 2 jar testing described in Chapter 4. For process control jar testing, you can choose what chemicals to feed and what doses to feed. When the process control jar test is finished, you will have useful information to run the plant better. A Step 2 jar test is much more limited, and it's only product is a regulatory compliance number. However, after running a Step 2 jar test and determining the plant's new required TOC removal, doing a process control jar test may help you set full scale operating conditions to meet that new required removal.

This example SOP provides instructions on the preparation of dosing solutions and procedures for a process control jar test. It should be used in conjunction with Appendix 3, which discusses chemical feed-rate measurement and adjustment. This example is for a plant that uses alum, polymer, and lime (or caustic) and has 2-L jars.

Note about Personalizing the SOP: You will need to modify this example to work for other chemicals or operating conditions. In other words, if your plant uses other chemicals or uses different solutions from those in this example, you must write an SOP that works for those chemicals.

Note about Mixing Times: Generally, jar tests result in better coagulation and settling than occurs full scale. One main reason for this is that mixing in jar tests is almost perfect, but mixing full scale is not. Obviously, the hydraulics in a 2-L jar are more controlled than in a large flow-through plant, where short circuiting and dead zones are present. It may be necessary for the operator to modify the mixing times for jar testing to better match full-scale results. One way to start down this road is to determine the hydraulic detention time and baffling factor in each process unit and compare the resulting mixing times with the mixing times recommended in this SOP and the Step 2 process. Then, the operator can change the mixing times, compare the results to full scale and repeat the process until the results correlate better.

Equipment Needed (Example)

The equipment needed for your plant to go through this process may be different. For this example, the operator would need:

- ! the log book for jar test results
- ! two 2-gallon raw water containers
- ! jar test apparatus with six 2-L jars (this example uses 2-L jars)
- ! three 1000-mL volumetric flasks
- ! 10-mL TenSette (automatic pipettor)
- ! several 5-mL, 10-mL, and 25-mL syringes
- ! equipment to conduct pH, turbidity, and alkalinity tests
- ! triple-beam balance

Procedure (Example):

I. Preparation of Dosing (Stock) Solutions:

Dosing solutions must be prepared in concentrations that allow accurate dosing of the amount of raw water being tested in a jar test. Dosing solutions tend to lose their strength over time and should be used within 24 hours of preparation.

A. Polymer dosing solution (0.2% solution on a volumetric basis).

A dosage of 1.0 mL of this solution to 2 L raw water is a dosage rate of 1.0 ppm on a volumetric basis.

1. Using a TenSette pipette, measure 2 mL of polymer solution.
2. Place the 2 mL of polymer into a 1000-mL volumetric flask.
3. Add enough demineralized water to bring the volume in the flask to the 1000-mL mark.
4. Stopper the flask and mix the solution.
5. Use the dosing solution within 24 hours of preparation.

B. Alum Dosing Solution (2.0% solution on a dry weight basis).

A dosage of 1 mL of this solution to 2 L of raw water is a dosage rate of 10 ppm on a dry weight basis.

1. Using the TenSette pipette, measure 31 mL of liquid alum solution (see Equation A4.1).
2. Place the 31 mL of liquid alum into a 1000-mL volumetric flask.
3. Add enough demineralized water to bring the volume in the flask to the 1000-mL mark.
4. Stopper the flask and mix the solution.
5. Use the dosing solution. Discard it when it is 24 hours old.

Equation A4-1: Preparing the alum dosing solution (“stock solution”)

$$\begin{aligned} \text{mL (liquid) alum per liter of stock solution} &= \frac{\% \text{ dry weight of stock solution} \times 1000 \text{ mL stock solution}}{\text{concentration of alum}^{**} \times \text{specific gravity of alum}^{***}} \\ &= \frac{\% \text{ dry weight} \times 1000}{0.48 \times 1.33} = \% \text{ dry weight} \times 15.66 \end{aligned}$$

*expressed as g dry alum/100 g water

** 0.48 g **dry** alum/g alum

*** 1.33 g alum/g water

C. Lime Dosing Solution (2.0% solution on a *dry weight* basis).

A dosage of 1 mL of this solution to 2 L of raw water is a dosage rate of 10 ppm on a dry weight basis.

1. Add about 20 mL of distilled water to a 1000-mL volumetric flask.
2. Using the balance and weighing paper, measure 2 grams of lime.
3. Carefully add the lime to the volumetric flask.
4. Add enough demineralized water to bring the volume in the flask to the 1000-mL mark.
5. Stopper the flask and mix the solution.
6. The dosing solution should be used within 24 hours of preparation.

D. Caustic Dosing Solution (alternative pH adjustment) (0.2% solution on a volumetric basis).

A dosage of 1 mL of this solution to 2 L of raw water is a dosage rate of 1 ppm on a purely volumetric basis.

1. Using the TenSette pipette, measure 2 mL of caustic solution.
2. Place the 2 mL of liquid alum into a 1000-mL volumetric flask.
3. Add enough demineralized water to bring the volume in the flask to the 1000-mL mark.
4. Stopper the flask and mix the solution.
5. The dosing solution should be used within 24 hours of preparation.

II. CONDUCTING THE JAR TEST

A. Record the test conditions.

In the jar test log book, record the combinations of polymer and alum dosages you wish to test. These will be the dosages. Generally, you will hold one of the dosages constant and vary the other to make your combinations.

B. Collect raw water.

Fill the two 2-gallon raw water jugs with raw water from the raw water sample point. When you reach the lab, invert the raw water jugs three times to ensure that settling has not occurred.

C. Fill the jar test jars.

Fill each of the five jar test jars halfway full with the raw water from one of the jugs. Finish filling the five jars to the 2-L mark with water from the **other** jug.

D. Measure raw water turbidity, pH, and alkalinity.

Fill the 250-mL raw water beaker with some of the raw water. Use this water to run raw water turbidity, pH, and alkalinity.

E. Set up the jars.

Place the five jars on the jar test apparatus, lower the stirring paddles into the beakers, lock the paddle shafts, and start stirring the raw water samples at a rate of 100 rpm.

F. Prepare the dosing syringes.

Fill the polymer, alum, and lime syringes with the appropriate volume of dosing solution to reach the dosage you are testing. Mix the flask of lime dosing solution **thoroughly** before filling each syringe. Place each of the syringes next to the jar it will be injected into.

! Use 1 cc of alum dosing solution for each 10 ppm of alum dosage required.

! Use 1 cc of lime dosing solution for each 10 ppm of lime dosage required.

! Use 1cc of polymer dosing solution for every ppm of polymer dosage required.

G. Dose the jars.

As quickly as possible, inject each sample of raw water with the required alum and polymer dose.

H. Flash mix.

Let the samples stir at 100 rpm for 30 seconds to simulate the flash mix (use the time and speed that best represents your plant, if known).

I. Flocculate.

Reduce the stirring rate of the jar test apparatus to 30 rpm, inject each sample of coagulated water with the required lime dose, and let the samples mix for 15 minutes to simulate the flocculator (use the time and speed that best represents your plant, if known).

J. Settle.

Turn the stirrers off and let the samples sit for 30 minutes to simulate the sedimentation process (use the time and speed that best represents your plant, if known).

K. Evaluate the flocculation and settling process.

During the jar test, the following evaluations should be made:

1. Which combination of dosages formed a floc first?
2. What is the appearance of the floc in each sample?
3. After flash mix and flocculation, which sample had the best settling floc?
4. What is the appearance of the settled-water in each sample?

L. Collect supernatant samples.

At the end of the settling time, flush the jar test sample spigots and collect a sample of settled-water from each jar.

M. Measure the turbidity and pH.

Measure the turbidity and pH of each sample to determine the effect of coagulation on the raw water samples.

N. Record the data.

Record the dosages for each sample of raw water, and the observations and results of the jar test on the jar test work sheet.

O. Choose the best chemical combination.

Based on the observations made during the jar test, record your conclusions of which combination of coagulant and coagulant aid dosages gave the best results for the raw water tested.

P. Make changes, as appropriate.

If appropriate, contact the supervisor, make necessary adjustments to the coagulant feed rate, and then verify and document the new feed rate on the jar test result log and the daily operational log.

Note on Dynamic Jar Testing: In this SOP, and in most jar testing, disinfectants are not added. Because disinfectants may act as a coagulant aid, leaving them out may prevent the jar test from matching full-scale results. One way that you may be able to make the jar test match full-scale results is to pull samples for jar testing from the plant *after* disinfectant is added. If coagulant is added concurrently with disinfectant, this can be tricky. You will need to consider where in the plant samples can be taken to best represent the water entering the settling basins. Or, possibly, you could add disinfectant to the jars, but this is less likely to represent full-scale conditions.

Appendix 5: Unregulated Disinfection By-Products

Table A5-1: Impact of Changing Disinfection Strategy on DBPs

Changing from... (plant ⁽¹⁾ /distribution system ⁽²⁾)	to.....	Will make these DBPs....		
		Decrease, or	increase	or not change
Cl ₂ /Cl ₂	Cl ₂ / chloramine ⁽³⁾	TTHM, HAA5, HAN, HAK, CP, CNX		
	chloramine/ chloramine ⁽³⁾	TTHM, HAA5, HAN, HAK, aldehydes	CNX	CP
	O ₃ /Cl ₂ ⁽³⁾	TTHM ⁽⁴⁾ , HAA5 ⁽⁴⁾ , HAN ⁽⁴⁾	HAK ⁽⁴⁾ , CP, aldehydes ⁽⁴⁾	
	O ₃ /chloramine	TTHM ⁽⁵⁾		
	ClO ₂ /chloramine	TTHM ⁽⁵⁾		
Cl ₂ /chloramine	Chloramine/ chloramine	TTHM ⁽⁵⁾		
	O ₃ /chloramine ⁽³⁾	TTHM, HAA5, HAN, CP	HAK, aldehydes ⁽⁶⁾	CNX
	ClO ₂ /chloramine	TTHM ⁽⁵⁾		
O ₃ /Cl ₂	O ₃ /chloramine ⁽³⁾	TTHM, HAA5, HAN, HAK, aldehydes	CP, CNX	
Chloramine/ chloramine	O ₃ /chloramine ⁽³⁾	TTHM ⁽⁴⁾ , HAA5 ⁽⁴⁾	HAK ⁽⁴⁾ , aldehydes, CP, CNX	HAN

DISINFECTANTS:

Cl₂ = Free chlorine

Chloramine = Monochloramine-dominant mixture of the chloramines (mono-, di- and tri-) formed as reaction products of free chlorine and nitrogen (from ammonia) at a mass ratio of between 3:1 to 5:1 Cl₂:NH₄-N. (If chloramines are used in the plant, free chlorine is not used in the distribution system.)

ClO₂ = Chlorine dioxide (ClO₂ is only suitable as a primary disinfectant)

O₃ = Ozone (O₃ is only suitable as a primary disinfectant)

DISINFECTION BY-PRODUCTS:

TTHM = Total of the four trihalomethanes that contain bromine or chlorine.

HAA5 = Total of the five haloacetic acids (that contain bromine or chlorine) that are regulated

Aldehydes: includes halogenated and non-halogenated aldehyde species.

HAK = Haloketones

HAN = Haloacetonitriles

CNX = Cyanogen halides

CP = Chloropicrin

NOTES:

(1) Plant disinfectant is the primary disinfectant.

(2) Distribution system disinfectant is the secondary disinfectant.

(3) Adapted from Table 3-2. Impacts of Disinfection Practice on DBP Formation, EPA Guidance Manual: *Microbial and Disinfection By-product Rules Simultaneous Compliance Guidance Manual* (EPA 815-R-99-011) August 1999, U.S. EPA, Washington D.C. Available from the Safe Drinking Water Hotline, 1-800-426-4791).

(4) One of the two utilities reported no change.

(5) From experience with Texas utility data.

(6) One of the two utilities did not analyze for this DBP.

Table A5-2: Health-Based Values for Unregulated Ozonation Disinfection By-Products*

Disinfection By-Product ⁽¹⁾	MCL or Health-Based Limit Determined by TCEQ (mg/L)
Aldehydes: Formaldehyde Benzaldehyde	1 0.7
Acetone	0.7
Acetonitrile	0.04
Haloacetonitriles (HANs) Dichloroacetonitrile Bromochloroacetonitrile Dibromoacetonitrile	0.02 0.03 0.05
Haloketones (HAKs) 1,1-Dichloropropanone 1,1,1-Trichloropropanone	0.007 0.02
Cyanogen halides (CNX) Cyanogen bromide Cyanogen chloride	0.6 NHL
Trichloroacetaldehyde Chloral hydrate (CH)	0.01
Chloropicrin (CP)	0.02
Total Organic Halides (TOX)	0.08

* Developed by the Toxicology and Risk Assessment Section of the Texas Natural Resource Conservation Commission.

Appendix 6: Acronyms and Definitions

A5.1 Acronyms

AA	atomic absorption
ACC	alternative compliance criteria. The eight alternative compliance criteria are part of the TOC removal requirements of the DBP1R. A plant that meets one of the ACC is not required to remove TOC for the period of time that the ACC covers.
AOC	assimilable organic carbon. A parallel measurement to biodegradable organic carbon (BDOC).
AOP	advanced oxidation process
ASTM	American Society for Testing Materials
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BAT	best available technology
BCAA	bromochloroacetic acid (see HAA)
BDL	below detection limit. If a contaminant is measured in a concentration lower than the method can be accurately used, it is considered BDL. Often, values reported as BDL are reported as zero. See MDL.
BDOC	biodegradable organic carbon. This is a concern in distribution systems, because a high concentration of BDOC may result in regrowth of microorganisms in the distribution system. A parallel measurement to AOC.
BF	baffling factor. The BF is used to account for potential short circuiting when calculating the effective contact time for calculating CT.
BOD	biological oxygen demand. Usually used in wastewater applications. This is a measure of how much oxygen will be used up by the biological components present in water.
CCP	Composite Correction Program. This is the EPA evaluation and adjustment program, which includes the CPE and CTA processes.
CCR	Consumer Confidence Report. The report of drinking water quality that every community public water system is required to send to their customers every year.
CCN	Certificate of Convenience and Necessity.
CCPP	calcium carbonate precipitation potential. This describes the extent to which a water may tend to form calcium carbonate scale on surfaces such as pipes.
CDBAA	chlorodibromoacetic acid (see HAA)
CFR	Code of Federal Regulations
COD	chemical oxygen demand. Usually used in wastewater applications. This is a measure of how much oxygen will be used up by the chemical components present in water.
CPE	Comprehensive Performance Evaluation. This is the extensive evaluation process designed to determine what specific factors are limiting a plant's ability to achieve optimized performance. The CPE is part of the EPA's Composite Correction Program (CCP).
CT	concentration-time (the product of disinfectant concentration and effective contact time (T_{10})). This value describes the effectiveness of a given level of disinfectant in a given unit process.

CTA	Comprehensive Technical Assistance. An intensive period of technical assistance to a plant, in which technical skills are transferred to the plant operators. CTA is part of the EPA's Composite Correction Program (CCP).
CWS	community water system
DAF	dissolved air flotation
DBP	disinfection by-product
DBP1R	Stage 1 Disinfection By-Product Rule
DBP2R	Stage 2 Disinfection By-Product Rule
DBPFP	disinfection by-product formation potential
DBPP	disinfection by-product precursor. Molecules present in natural water that will tend to form disinfection by-products when the water is disinfected. The EPA is using total organic carbon (TOC) and specific ultraviolet absorbance (SUVA) as surrogates for DBPP.
DBPR	Disinfection By-Product Rule
DCAA	dichloroacetic acid
DI	deionized
DOC	dissolved organic carbon. This group parameter measures the total amount of carbon present in organic molecules dissolved in the water. Basically, it is done on the same machine as total organic carbon (TOC), but the sample is filtered before analysis.
DOX	dissolved organic halogen. This group parameter measures the total amount of dissolved organic carbon that has halogen atoms attached to it. The halogens of interest are bromine and chlorine. Iodine and fluorine are generally not of interest in this context.
EBCT	empty-bed contact time
EC	enhanced coagulation
EPA	Environmental Protection Agency
ES	enhanced softening
ESWTR	Enhanced Surface Water Treatment Rule
FACA	Federal Advisory Committee Act
FP	formation potential (as in DBPFP)
G	velocity gradient. It is used to calculate the energy transferred to water in a mixing process.
GAC	granular activated carbon. GAC is a form of carbon that has been activated using heat so that each grain contains many pores. The surface area of a gram of GAC is the size of a football field. Because of this high surface area, GAC has many more sites upon which contaminants can adsorb than other filter media, such as sand.
GC	gas chromatograph
HAA	haloacetic acid (a DBP). There are nine different HAAs.
HAA5	haloacetic acid (group of 5). The Stage 1 Disinfection By-Product Rule includes a maximum contaminant level (MCL) for the sum of five HAAs. These are monochloroacetic acid (MCAA), dichloroacetic acid (DCAA), trichloroacetic acid (TCAA), monobromoacetic acid (MBAA), and dibromoacetic acid (DBAA).
HAAFP	haloacetic acid formation potential. The theoretical maximum amount of HAA a water can form.
HDT	hydraulic detention time

HLR	hydraulic loading rate for filters (see SLR)
ICR	Information Collection Rule
IESWTR	Interim Enhanced Surface Water Treatment Rule
LCA	Limited Compliance Assistance
LSI	Langelier saturation index
LT1ESWTR	Stage 1 Long-Term Enhanced Surface Water Treatment Rule
LT2ESWTR	Stage 2 Long-Term Enhanced Surface Water Treatment Rule
LTA	Limited Technical Assistance
LTESWTR	Long-Term Enhanced Surface Water Treatment Rule
MCL	maximum contaminant level. The concentration level of a contaminant that is regulated. If a system has a contaminant concentration greater than the MCL, they may be in violation of the regulations (see RAA).
MCLG	maximum contaminant level goal. The health-effects based ideal level for a contaminant. This is not the regulated concentration.
MDL	method detection limit. The concentration below which a given method cannot accurately measure concentration (see BDL).
MF	microfiltration
MIB	methylisoborneol. An odor-causing compound produced by some algae.
MOR	monthly operating report
MRDL	maximum disinfectant residual limit. Regulations promulgated by EPA in November 1998 put in place these limits on the allowable concentration of disinfectant leaving a plant.
MRDLG	maximum disinfectant residual limit goal
MTBE	methyl tert-butyl ether
MW	molecular weight
MWCO	molecular weight cutoff
NF	nanofiltration
NOAEL	no observed adverse effect level
NOM	natural organic matter
NPDWR	National Primary Drinking Water Regulation
NTNCWS	nontransient, noncommunity water system: A water system that serves the same people all year, but is not a community. A school or factory may be a NTNCWS.
NTU	Nephelometric turbidity unit. A measurement of the cloudiness of water.
PAC	powdered activated carbon (often used to remove taste and odor compounds)
PACl	polyaluminum chloride (sometimes abbreviated as PAC, but <i>not</i> to be confused with powdered activated carbon)
PE	professional engineer <i>or</i> performance evaluation
PODR	point of diminishing returns. This has specific meaning for the DBP1R TOC removal requirements. In a Step 2 jar test, the PODR is the point at which an additional 10 mg/L of alum results in the removal of no more than 0.3 mg/L of TOC.
psi	pounds per square inch (pressure)
RAA	running annual average
RO	reverse osmosis

rpm	revolutions per minute
SDS	simulated distribution system
SDWA	Safe Drinking Water Act
SHMP	sodium hexametaphosphate
SLR	surface loading rate for filters (also referred to as HLR)
SMCL	secondary maximum contaminant level
SOC	synthetic organic chemical
SOR	surface overflow rate <i>or</i> supplemental operating report
SUVA	specific ultraviolet absorbance
SWTR	Surface Water Treatment Rule
T	detention time (see HDT) <i>or</i> temperature
T 10	effective contact time. The time within which 10% of a tracer material will have passed through a unit process. Theoretical T10 can be calculated by multiplying the baffling factor (BF) by the theoretical hydraulic detention time (HDT).
TBAA	tribromoacetic acid (see HAA)
TCAA	trichloroacetic acid (see HAA)
TEEX	Texas Engineering Extension Service.
THM	trihalomethane (a DBP). These are halogenated organic molecules with one carbon, three halogens, and one hydrogen. The four THMs of interest are: chloroform (three chlorines, also called trichloromethane), dichlorobromomethane, dibromochloromethane, and bromoform (three bromines, also called tribromomethane).
THMFP	trihalomethane formation potential. A group parameter describing what concentration of THMs a water may form under set conditions (see FP and UFC).
TCEQ	Texas Commission on Environmental Quality
TOC	total organic carbon. A group parameter measuring the total amount of carbon in a water present as organic molecules. EPA is using TOC as a surrogate for DBPPs in the DBP1R (see DOC).
TON	threshold odor number
TOX	total organic halogen
TTHM	total trihalomethanes. The sum of the four THMs (see THM).
TWDB	Texas Water Development Board
TWUA	Texas Water Utilities Association
UF	ultrafiltration
UFC	uniform formation conditions. Specific disinfection conditions for measuring how much of a given disinfection by-product a water may form.
UV	ultraviolet
UV ₂₅₄	absorbance of ultraviolet light at a wavelength of 254 nanometers (nm)

A5.2 Definitions

Note: More definitions are contained in the regulations. See page to learn how to obtain copies of regulations.

approved laboratory—a laboratory that is *approved* by TCEQ. To be approved, the laboratory must submit, and have approved, the Laboratory Approval Form included in Appendix 6 of this guide. For questions about laboratory approval contact TCEQ’s Drinking Water Quality Team at 512/239-4691.

certified laboratory—a laboratory that is *certified* by the TCEQ or EPA. For questions about lab certification, contact TCEQ’s Quality Section at 512/239-5420.

community water system—a public water system that has a potential to serve at least 15 residential service connections on a year-round basis, or that serves at least 25 residents on a year-round basis.

compliance sample—a sample that a PWS is required to collect and report to TCEQ in order to determine compliance with the Drinking Water Standards (30 TAC Subchapter F: Drinking Water Standards Governing Drinking Water Quality and Reporting Requirement for Public Water Systems).

demand water source—a well, surface source, or purchased water source that is used on a regular basis, usually annually, to meet peak demand.

drinking water—all water distributed by any agency or individual, public or private, for the purpose of human consumption, or which may be used in the preparation of foods or beverages or for the cleaning of any utensil or article used in the course of preparation or consumption of food or beverages for human beings. The term “drinking water” also includes all water supplied for human consumption or used by any institution catering to the public.

emergency source—a well or purchased water source that is not used on an annual basis, but is maintained for use only under emergency conditions, such as fire.

enhanced coagulation—the addition of sufficient coagulant for improved removal of disinfection by-product precursors by conventional filtration treatment (EPA definition).

enhanced precipitative softening—the improved removal of disinfection by-product precursors by precipitative softening (EPA definition).

entry point—any point where treated water enters the distribution system. Entry points to the distribution system may include points where chlorinated well water, treated surface water, or water purchased from another supplier enters the distribution system.

groundwater under the direct influence of surface water (GUI)—any water beneath the surface of the ground with either significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as *Giardia lamblia* or *Cryptosporidium*, or significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions.

maximum contaminant level (MCL)—a primary MCL is a health-based level below which the EPA considers water safe to drink. Compliance with MCLs is often **not** based on the result of a single sample, but instead is calculated. For instance, compliance could be based on whether the average of all samples collected in a year is over the MDL (See RAA).

nontransient noncommunity system—a public water system that is not a community water system and regularly serves at least 25 of the same persons at least six months out of the year.

process control sample—a sample that a water system collects in order to make operational decisions, but that does not have to be reported to TCEQ.

public water system—a system that provides to the public water for human consumption through pipes or other constructed conveyances, which includes all uses described under the definition for drinking water. Such a system must have at least 15 service connections, or serve at least 25 individuals at least 60 days out of the year. This term includes any collection, treatment, storage, and distribution facilities under the control of the operator of such system and used primarily in connection with such system; and any collection or pretreatment storage facilities not under such control that are used primarily in connection with such system. When two or more systems owned by the same entity are combined to serve more than 25 people at least 60 days out of the year will be considered a public water system. An individual is considered served by a water system if they live in, use as place of employment, or work in a place where drinking water is supplied by the system.

purchased water system—a public water system that purchases at least some portion of its potable water from a different public water system.

running annual average—the average of all sample results collected in the most recent twelve months, four quarters, or one year.

sampling site—the site at which a sample is collected.

transient noncommunity system—a public water system that is not a community water system and serves at least 25 persons at least 60 days out of the year, yet by its characteristics, does not meet the definition of a nontransient noncommunity water system.

wholesaler—a public water system that sells water to another public water system.

Appendix 7: Formulas and Conversions

Percent Solution Values

1% = 0.084 lb/gal or 1.3 oz/gal (or 10,000 mg/L)
2% = 0.170 lb/gal or 2.7 oz/gal
3% = 0.258 lb/gal or 4.1 oz/gal
4% = 0.348 lb/gal or 5.6 oz/gal
5% = 0.440 lb/gal or 7.0 oz/gal
6% = 0.533 lb/gal or 8.5 oz/gal
7% = 0.629 lb/gal or 10.1 oz/gal
8% = 0.726 lb/gal or 11.6 oz/gal
9% = 0.825 lb/gal or 14.9 oz/gal (or 90,000 mg/L)

Conversions

ounces (fluid) x 29.57	= mL
ounces (dry) x 28.35	= grams
cubic feet x 7.48	= gallons
gal x 8.34	= lbs
gal x 3785	= mL
gal/hr x 63	= mL/min
grains/gal x 17.1	= PPM
grams x 15.43	= grains
MGD x 694	= gpm
10,000 ppm (mg/L)	= 1%
pounds x 453	= grams
ppm x 8.33	= lb/million gallons
quarts x 946	= mL
cubic feet x 62.4	= pounds
pounds x 7000	= grains
gal x 3.785	= liters
1 mile	= 5280 ft
2.31 ft of water	= 1 psi
0.433 psi	= 1 ft of water

Feed Rate Formulas

$\frac{\text{ppm (mg/L)} \times \text{gpm}}{2000}$	= lb/hr
$\frac{\text{ppm (mg/L)} \times \text{GPM} \times 0.06}{\% \text{ solution}}$	= gal/hr
$\frac{(\text{lb/6 minutes}) \times 20,000}{\text{gpm}}$	= ppm (mg/L)
$\frac{(\text{gram/6 minutes}) \times 44}{\text{gpm}}$	= ppm (mg/L)

- * gpm = gallons per minute of plant
- * 6 minute collection for dry feeder

Equations

In the following calculations:
 $\pi = 3.14$, L = length, W = width,
 d = diameter, r = radius, H = height

Area = A (sq ft):

Rectangle: $A = L \times W$

Circle: $A = \pi r \times r$

Volume = V (cu ft):

Rectangular tanks: $V = L \times W \times H$

Circular tanks: $V = \pi r \times r \times H$

In pipes: $V = \frac{\pi d \times d \times L}{4}$

(Divide pipe diameter by 12 to convert from inches to feet.)

Appendix 8: Laboratory Approval Form and Instructions

Description of Columns

Analyte

Analyte means the chemical or value that you are analyzing for. The heading of this column is not “chemicals” because temperature, UV₂₅₄ and turbidity are not chemicals.

Method (& Analyzer Type)

Under “Method (& Analyzer Type), you should write the method that you use to measure for each analyte (for example: Standard Method Cl-4500D). If you use some kind of analyzer, write that in this blank also (for example: Hach 1720D).

Accuracy

Report the number of decimal places to which you can accurately report the value for each analyte. For those analytes that have required accuracy levels, you can just report whether you can or cannot measure to the required accuracy.

Calibration

You should report the frequency and method with which you calibrate your equipment. For some methods, the TCEQ has rules about calibration. These rules are in the Texas Administrative Code, specifically in 30 TAC 290.46(s)(2).

Frequency

Under “Calibration Frequency,” you should state the frequency with which you calibrate equipment used for an analyte.

Method

Under “Calibration Method,” you should list the calibration method you use.

Record Retention

Under “Record Retention,” you should state how long you keep records of your data. For some analytes, the TCEQ has rules about record retention. These rules are in the Texas Administrative Code, specifically in 30 TAC 290.46(f).

Definitions

Approved-Lab Analytes

Public water systems must run a number of samples at a laboratory *approved* by TCEQ. Most utilities will get their lab approved and analyze these samples at their own lab. The *approved-lab analytes* are:

- ! alkalinity
- ! turbidity
- ! pH
- ! temperature
- ! disinfectant residual
- ! daily point-of-entry chlorite
- ! chlorine dioxide
- ! total organic carbon
- ! ultraviolet light absorbance at 254 nm
- ! calcium
- ! phosphate

Lab Approval Procedure

In order for a utility's lab to be approved, the utility must submit (and have approved) the Laboratory Approval Form, indicating the methods and quality control procedures used at the utility. The form must be signed by the certified operator with responsibility for laboratory operations. The TCEQ will review these forms upon receipt and contact the system if the form is incomplete or if the methods noted are not acceptable.

If the system sends any of the samples listed on the Laboratory Approval Form to an outside lab that is **not** run by a public water system (a commercial lab), that lab must be **certified** by the Texas Department of Health (TDH) to perform those analyses. For information on laboratory certification, contact the TDH at 512/458-7587.

Analytes Run by Other Labs

Utilities may have approved lab analytes run by commercial labs or other water system labs, if that outside lab is approved by the TCEQ. When you fill out the lab approval form, write the name of the outside lab in the line for the analyte they measure. The outside lab should give the water utility a copy of their Lab Approval form so the utility can attach it to the Monitoring Plan.

“Not Required” Analytes

The analytes that are listed on the form include all of those that must be analyzed at an approved lab. Your system may not be required to analyze for all of the analytes on the list. For example, if your system treats groundwater, you are not required to measure turbidity, and you should write “Not Required” on the form in the line for turbidity.

As another example, only systems that use chlorine dioxide must measure chlorite and chlorine dioxide. If you do not use chlorine dioxide, write the words “Not Required” in the spaces for chlorite and chlorine dioxide.

Calcium and phosphates are also examples of chemicals a system may not be required to measure. If you are not required to optimize corrosion control as a result of the Lead/Copper Rule, write “Not Required” on the lines for calcium and phosphate.

Certified-Lab Analytes

Public water systems must have the following analyses performed by a lab **certified** by the TDH:

- ! bacteriological
- ! trihalomethane (TTHM)
- ! haloacetic acid (HAA5)
- ! bromate
- ! synthetic organic chemical (SOC)
- ! volatile organic chemical (VOC)
- ! inorganic chemical (IC)
- ! monthly distribution system chlorite

Except for the bacteriological samples and monthly chlorite samples, all the certified-lab analyte samples are collected by TCEQ’s sampling contractor. The contractor delivers the samples to TDH for analysis.

Lab Versus Operator Sampling

At many utilities, the laboratory does some sampling and the water plant operators do other sampling. If that is the case for your utility, you can use two separate forms. One form should list the analytes run by the laboratory and be signed by the lab analyst and the other form should list the analytes run by the plant operator and be signed by the plant operator.

Monitoring Plan

A copy of the Laboratory Approval Form must be attached to the system’s monitoring plan. For information on monitoring plans, contact the TCEQ’s Public Drinking Water Chemical Monitoring Team at 512/239-4691. On the monitoring

plan, the system must attach documentation showing that any outside labs it uses are approved or certified, as appropriate.

If you send approved-lab analytes to a commercial lab, that commercial lab must be TDH-certified in the appropriate analysis. Evidence of the commercial lab's certification must be attached to the monitoring plan.

If you send approved-lab analytes to a different public water system's lab, that public water system's lab must be TCEQ approved in the appropriate analysis. You must attach a copy of that public water system lab's Laboratory Approval Form to your monitoring plan.

LAB APPROVAL FORM

PUBLIC WATER SYSTEM NAME: _____

PLANT NAME OR NUMBER: _____

PWS ID NO.: _____

DATE: _____

I certify that I am familiar with the information contained in this report and that, to the best of my knowledge, the information is true, complete, and accurate.

Operator's Signature: _____
Certificate No. & Grade: _____

Analyte ¹	Method (& Analyzer Type)	Accuracy	Calibration		Record Retention
			Frequency	Method	
Turbidity					
pH					
Temperature					
TOC					
UV ₂₅₄					
Alkalinity					
Disinfectant ²					
Free Chlorine					
Total Chlorine					
Chlorine Dioxide					
Chlorite ³ at point of entry					
Calcium ³					
Phosphate ³					

- 1 Write "Not Required" next to analytes you are not required to measure. If samples are sent to an outside lab, write the name of the lab next to the analytes you send there.
- 2 For systems using chlorine dioxide.
- 3 For systems reporting water quality parameters for the Lead/Copper Rule.

Appendix 9:Densities and Equivalent Weights of Commercial Alum Solutions

Specific Gravity	Lb/Gal	% Al ₂ O ₃	Equivalent % Dry Alum*	Pound Dry Alum per Gal Solution	Gram Dry Alum per Liter Solution
1.0069	8.40	0.19	1.12	0.09	11.277
1.0140	8.46	0.39	2.29	0.19	23.221
1.0211	8.52	0.59	3.47	0.30	35.432
1.0284	8.58	0.80	4.71	0.40	48.438
1.0357	8.64	1.01	5.94	0.51	61.521
1.0432	8.70	1.22	7.18	0.62	74.902
1.0507	8.76	1.43	8.41	0.74	88.364
1.0584	8.83	1.64	9.65	0.85	102.136
1.0662	8.89	1.85	10.88	0.97	116.003
1.0741	8.96	2.07	12.18	1.09	130.825
1.0821	9.02	2.28	13.41	1.21	145.110
1.0902	9.09	2.50	14.71	1.34	160.368
1.0985	9.16	2.72	16.00	1.47	175.760
1.1069	9.23	2.93	17.24	1.59	190.830
1.1154	9.30	3.15	18.53	1.72	206.684
1.1240	9.37	3.38	19.88	1.86	223.451
1.1328	9.45	3.60	21.18	2.00	239.927
1.1417	9.52	3.82	22.47	2.14	256.540
1.1508	9.60	4.04	23.76	2.28	273.430
1.1600	9.67	4.27	25.12	2.43	291.392
1.1694	9.75	4.50	26.47	2.58	309.540
1.1789	9.83	4.73	27.82	2.74	327.970
1.1885	9.91	4.96	29.18	2.89	346.804
1.1983	9.99	5.19	30.53	3.05	365.841
1.2083	10.08	5.43	31.94	3.22	385.931
1.2185	10.16	5.67	33.35	3.39	406.370
1.2288	10.25	5.91	34.76	3.56	427.131
1.2393	10.34	6.16	36.24	3.74	449.122
1.2500	10.43	6.42	37.76	3.93	472.000
1.2609	10.52	6.67	39.24	4.12	494.777
1.2719	10.61	6.91	40.65	4.31	517.027
1.2832	10.70	7.16	42.12	4.51	540.484
1.2946	10.80	7.40	43.53	4.71	563.539
1.3063	10.89	7.66	45.06	4.91	588.619
1.3182	10.99	7.92	46.59	5.12	614.149
1.3303	11.09	8.19	48.18	5.34	640.938
1.3426	11.20	8.46	49.76	5.57	668.078
1.3551	11.30	8.74	51.41	5.81	696.657
1.3679	11.41	9.01	53.00	6.05	724.987

* 17% Al₂O₃ in Dry Alum + 0.03% Free Al₂O₃ (from *Allied Chemical Company Alum Handbook* and *EPA CPE Handbook*, page K-2)