

*Guidelines
for
Four-Log Virus Treatment of Ground Water*

**Drinking Water Section
Florida Department of Environmental Protection
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Abbreviations and Acronyms

°C	degrees Celsius
µm	micron(s)
AwwaRF	American Water Works Association Research Foundation
BF	baffling factor
C	residual disinfectant concentration, in mg/L, measured before or at the first customer during peak flow
CFE	combined filter effluent
CFR	<i>Code of Federal Regulations</i>
CT	the product obtained by multiplying C times T
D (or d)	wire diameter, in inches, or tank diameter
DPD	<i>N,N</i> -diethyl- <i>p</i> -phenylenediamine
F.A.C.	Florida Administrative Code
FDEP (or DEP)	Florida Department of Environmental Protection (means the FDEP and the approved county health departments – i.e., the county health departments designated by the Florida Department of Health and approved by the FDEP to implement the public water system supervision program)
gpm	gallons per minute
GWR	Ground Water Rule
GWS	ground water system
GWUDI	ground water under the direct influence of surface water
HAV	Hepatitis A virus
mg/L	milligrams/liter
MF	microfiltration
MOR	monthly operation report
MRDL	maximum residual disinfectant level
MWCO	molecular weight cutoff
NF	nanofiltration
nm	nanometer(s)
N ₀	initial (influent) concentration of viable microorganisms
N _T	final (effluent) concentration of viable microorganisms
NTU	nephelometric turbidity unit
O	opening size
psig	pounds per square inch gauge
PWS	public water system
Q	peak flow rate, in gallons per minute
RO	reverse osmosis
SM	<i>Standard Methods for the Examination of Water and Wastewater</i>
SP	salt passage

T	disinfectant contact time, in minutes, during peak flow – i.e., time, in minutes, it takes water to move, during peak flow, between the point of disinfectant application, or the previous point of C measurement, and the point where C is measured
TDT	theoretical detention time, in minutes, during peak flow
UF	ultrafiltration
USEPA (or EPA)	United States Environmental Protection Agency
UV	ultraviolet
UVT	UV transmittance
V (or v)	volume, in gallons
WTP	water treatment plant

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1. Introduction

1.1 Purpose and Background

The purpose of these guidelines is to supplement the federal Ground Water Rule and Rule 62-550.828, Florida Administrative Code, and provide guidance for ground water systems that choose to provide four-log virus treatment of ground water.

Virus treatment means treatment of water to inactivate or remove viruses. The level of inactivation or removal of any microorganisms, including viruses, generally is measured on a logarithmic scale (i.e., in terms of orders of magnitude). Log inactivation or removal is defined as follows:

$$\text{Log Inactivation or Removal} = \text{Log} (N_O/N_T),$$

where N_O = initial (influent) concentration of viable microorganisms;
 N_T = final (effluent) concentration of viable microorganisms; and
Log = logarithm to base ten.

Log inactivation or removal is related to percent inactivation or removal, which is defined as follows:

$$\text{Percent Inactivation or Removal} = \{1 - (N_T/N_O)\} \times 100.$$

The relationship between log inactivation/removal and percent inactivation/removal is as follows:

$$\text{Percent Inactivation or Removal} = \{1 - (1/10^{\text{Log Inactivation/Removal}})\} \times 100, \text{ or}$$
$$\text{Log Inactivation or Removal} = \text{Log} \{100 / (100 - \text{Percent Inactivation/Removal})\}.$$

Table 1-1 presents log inactivations/removals and corresponding percent inactivations/removals.

1.2 Overview of Four-Log Virus Treatment Under the Federal Ground Water Rule (GWR) and Under Rule 62-550.828, Florida Administrative Code (F.A.C.)

The GWR and Rule 62-550.828, F.A.C., apply to ground water systems (GWSs). GWSs include the following public water systems (PWSs):

- PWSs that use only ground water sources;
- PWSs that use both surface water sources and ground water sources, provided the ground water is treated separately from surface water;

Table 1-1: Log Inactivation/Removal Versus Percent Inactivation/Removal

Log Removal or Inactivation	Percent Removal or Inactivation
0.5 log	68.38%
1.0 log	90.00%
1.5 log	96.84%
2.0 log	99.00%
2.5 log	99.68%
3.0 log	99.90%
3.5 log	99.97%
4.0 log	99.99%

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- Consecutive PWSs that receive finished ground water from a wholesale PWS that is in one of the above two groups of PWSs; and
- Consecutive PWSs that use their own ground water sources in addition to water received from a wholesale PWS.

PWSs that combine all their ground water with surface water prior to treatment of the surface water are not GWSs. PWSs that use only ground water sources that have been determined by the Florida Department of Environmental Protection (FDEP) to be ground water under the direct influence of surface water (GWUDI) are not GWSs. FDEP-determined GWUDI sources are subject to the surface water treatment requirements under Rule 62-550.817, F.A.C.

The GWR and Rule 62-550.828, F.A.C., require that GWSs with their own ground water sources shall conduct “triggered” and “assessment” microbial monitoring of their ground water sources if they do not provide four-log virus treatment for their ground water sources. Furthermore, the GWR and Rule 62-550.828 require that GWSs shall take corrective action--which may include providing four-log virus treatment for their ground water sources—if the results of “triggered” or “assessment” source water monitoring indicate that ground water sources are fecally contaminated.

Rule 62-550.828, F.A.C., also requires that GWSs exposing ground water to the open atmosphere (and possible microbial contamination) during treatment shall conduct “assessment” microbial monitoring of their finished water before or at the first customer if they do not provide four-log virus treatment of their ground water after it is last exposed to the open atmosphere. Furthermore, Rule 62-550.828 requires that such GWSs take corrective action—which may include providing four-log virus treatment of their ground water after it is last exposed to the open atmosphere—for significant deficiencies involving a fecal-indicator-positive “assessment” finished water sample. Water treatment facilities that are protected against contamination from birds, insects, wind-borne debris, rainfall, and drainage—i.e., water treatment facilities that are covered by an impervious roof and enclosed within impervious sidewalls or sidewalls of at least 20-mesh* screen—are not considered to be exposing water to the open atmosphere.

As a result of the above rule requirements, GWSs may choose to provide four-log virus treatment for ground water sources, or four-log virus treatment of ground water after it is last exposed to the open atmosphere, for one or more of the following reasons:

* Mesh is the number of openings per linear inch measured from the center of one wire to a point one inch distant. $\text{Mesh} = 1 / (D + O)$, where D = wire diameter in inches and O = opening size, which is the distance between two adjacent parallel wires, in inches.

- To avoid having to conduct “triggered” and “assessment” source water monitoring.
- To avoid having to conduct “assessment” finished water monitoring.
- As corrective action for a fecally contaminated ground water source.
- As corrective action for a significant deficiency involving a fecal-indicator-positive “assessment” finished water sample.

GWSs that are exposing ground water to the open atmosphere may choose to provide four-log virus treatment after their ground water is last exposed to the open atmosphere, in which case the GWSs would avoid having to conduct “triggered” and “assessment” source water monitoring and would avoid having to conduct “assessment” finished water monitoring. Alternatively, such GWSs may choose to just provide four-log virus treatment for their ground water sources, in which case the GWSs would avoid having to conduct “triggered” and “assessment” source water monitoring but would still have to conduct “assessment” finished water monitoring.

GWSs that choose to provide four-log virus treatment in lieu of conducting “assessment” finished water monitoring and/or “triggered” and “assessment” source water monitoring, and GWSs that choose to provide four-log virus treatment as corrective action, shall do the following:

- Notify the FDEP in writing, and obtain written FDEP approval, of the four-log virus treatment in accordance with Section 1.3 below.
- Begin conducting compliance monitoring in accordance with the GWR, Rule 62-550.828, F.A.C., and Section 2 of these guidelines.
- Do both of the above before the GWS will be exempt from “assessment” finished water monitoring, if applicable, and/or “triggered” and “assessment” source water monitoring.

Additionally, GWSs that choose to provide four-log virus treatment as corrective action shall take interim measures as necessary, or as specified by the FDEP, to protect public health until four-log virus treatment is fully operational and GWSs begin compliance monitoring. Such interim measures might include temporarily shutting down a fecally contaminated well, providing temporary four-log virus treatment, or issuing a precautionary boil water notice.

GWSs that are providing FDEP-approved four-log virus treatment and conducting compliance monitoring in accordance with the GWR, Rule 62-550.828, F.A.C., and

Section 2 of these guidelines are in violation of the treatment technique requirements in the GWR and Rule 62-550.828 if...

- They fail to maintain four-log virus treatment by failing to meet the operating requirements identified in the GWR, Rule 62-550.828, these guidelines, and/or the FDEP approval of four-log virus treatment; and
- They do not correct the failure to maintain four-log virus treatment within four hours after determining the failure.

1.3 Written Ground Water System (GWS) Notifications, and Written Florida Department of Environmental Protection (FDEP) Approvals, of Four-Log Virus Treatment

For GWSs that intend to provide four-log virus treatment by using existing treatment facilities without doing anything more than providing necessary uninstalled standby equipment or installing or altering necessary alarm, or continuous monitoring, equipment, the written notification of four-log virus treatment shall consist of the following:

- A four-log virus treatment demonstration prepared under the responsible charge of a professional engineer licensed in Florida; and
- A description of any uninstalled standby equipment being provided and any alarm, or continuous monitoring, equipment installation or alteration work.

The written FDEP approval of four-log virus treatment shall consist of a letter or order.

For GWSs that intend to provide four-log virus treatment by constructing or altering treatment facilities – i.e., by constructing, installing, or altering structures, piping, or equipment other than uninstalled standby equipment or alarm, or continuous monitoring, equipment – the written notification of four-log virus treatment shall consist of a construction permit application and supporting documents, including a four-log virus treatment demonstration prepared under the responsible charge of a professional engineer licensed in Florida. The written FDEP approval of four-log virus treatment shall consist of a construction permit and a letter or order.

Note that, at water treatment plants using chemical disinfection for virus inactivation, GWSs must provide standby equipment, automatic switch-over of gas containers, and alarm systems in accordance with Rule 62-555.320(13), Florida Administrative Code (F.A.C.), and *Recommended Standards for Water Works*.

Demonstrations of Four-Log Virus Treatment. Demonstrations of four-log virus treatment shall be prepared consistent with these guidelines and shall include the following information:

- The cover sheets in Appendix A to these guidelines.
- Whether the WTP exposes ground water to the open atmosphere during treatment and, if so, whether the demonstration is for four-log virus treatment of water after it is last exposed to the open atmosphere or is just for four-log virus treatment for the ground water source(s).
- Identification of the technologies used to provide four-log virus treatment and the virus inactivation or removal credit, in logs, claimed for each technology.
- A schematic diagram of the WTP. The schematic shall show all pumping, treatment, or storage facilities; all chemical disinfectant application points and disinfectant residual monitoring points; application points for any chemicals that will affect pH significantly; any turbidity or conductivity monitoring points; the point of the first customer (often the WTP itself); etc. Also, the schematic shall identify any facilities that expose water to the open atmosphere.
- For chemical disinfection – CT calculations; identification of standby equipment, switch-over devices for gas containers, and alarm systems as required by Rule 62-555.320(13), F.A.C., and *Recommended Standards for Water Works*; identification of the disinfectant residual monitoring frequency and any continuous disinfectant residual monitoring equipment; the proposed disinfectant residual monitoring location(s); and the proposed minimum residual disinfectant concentration(s) for each disinfectant residual monitoring location.
- For ultrafiltration – the absolute pore size of the membranes and, if the absolute pore size is greater than or equal to 0.01 micron, challenge testing information showing at least four-log virus removal capability for the membranes; the direct integrity testing frequency, method, resolution, sensitivity, and control limit for the membrane units if four-log virus removal credit is claimed; identification of the continuous filtrate turbidity monitoring equipment for the membrane units; and identification of the operating requirement (filtrate turbidity no greater than 0.15 nephelometric turbidity unit [NTU]) for each membrane unit.
- For nanofiltration (NF) or reverse osmosis (RO) – the molecular weight cutoff for the membranes; the direct integrity testing frequency, method, resolution, sensitivity, and control limit for the membrane units if four-log virus removal credit is claimed; identification of the continuous monitoring equipment for the membrane units; and the proposed operating requirement – i.e., maximum

percent salt passage (generally no greater than 25% for NF and no greater than 5% for RO) – for each membrane unit.

- For ultraviolet (UV) disinfection – UV reactor validation testing information, including the validated UV dose and validated operating conditions for flow rate, UV intensity, UV lamp status, and if applicable, UV transmittance (UVT); and identification of the equipment for continuously monitoring the flow rate, UV intensity, UV lamp status, and if applicable, UVT for each UV reactor.
- For conventional filtration treatment, including lime softening; direct filtration; or microfiltration preceded by coagulation – identification of the combined filter effluent (CFE) turbidity monitoring frequency and any continuous CFE turbidity monitoring equipment; the CFE turbidity monitoring location; and identification of the operating requirement (CFE turbidity no greater than 1 NTU) for the filtration technology.
- For slow sand filtration or diatomaceous earth filtration – identification of the CFE turbidity monitoring frequency and any continuous CFE turbidity monitoring equipment; the CFE turbidity monitoring location; and identification of the operating requirement (CFE turbidity no greater than 5 NTUs) for the filtration technology.
- For other technologies – information from pilot plant studies, or other performance studies, demonstrating the level of virus treatment that the technology will achieve under the full range of expected operating conditions at the WTP; and the proposed compliance monitoring and operating requirements for the technology.

FDEP Approvals of Four-Log Virus Treatment. FDEP letters or orders approving four-log virus treatment shall...

- For WTPs that are exposing ground water to the open atmosphere during treatment, indicate whether four-log virus treatment is for water after it is last exposed to the open atmosphere or is just for the ground water source(s).
- Identify the technologies being used to provide four-log virus treatment and the virus inactivation or removal credit granted for each technology.
- Identify or establish the compliance monitoring and operating requirements for each virus treatment technology.

- Indicate that failure to meet operating requirements for more than four hours after first determining the failure will constitute a treatment technique violation under the federal Ground Water Rule and Rule 62-550.828, F.A.C.
- Include notice of the right to an administrative hearing.

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2. Accepted Technologies for Four-Log Virus Treatment of Ground Water

The federal Ground Water Rule incorporated into the Florida Administrative Code (F.A.C.) under Rule 62-550.828, F.A.C., lists chemical disinfection and membrane filtration as accepted technologies for virus treatment of ground water. Also, under Rule 62-550.828, F.A.C., the Florida Department of Environmental Protection (FDEP) accepts the following alternative treatment technologies for virus treatment of ground water:

- Ultraviolet (UV) disinfection;
- Conventional filtration treatment (coagulation, flocculation, sedimentation, and filtration), including lime softening;
- Slow sand filtration;
- Direct filtration (coagulation and filtration without sedimentation);
- Microfiltration preceded by coagulation; and
- Diatomaceous earth filtration.

Some of the accepted virus treatment technologies discussed above – such as chemical disinfection, membrane filtration, and UV disinfection – may be used individually to provide four-log virus treatment. Also, various combinations of the accepted virus treatment technologies may be used to provide four-log virus treatment.

Table 2-1 summarizes the virus treatment credit that ground water systems (GWSs) receive for each of the accepted virus treatment technologies. This table also summarizes the compliance monitoring and operating requirements that GWSs must meet in order to receive the listed virus treatment credit for each of the accepted virus treatment technologies. Sections 2.1 through 2.8 below discuss the accepted virus treatment technologies – and their virus treatment credit and compliance monitoring and operating requirements – in detail. Section 2.9 below discusses procedures that GWSs must follow to obtain FDEP acceptance of other virus treatment technologies not discussed in these guidelines.

Table 2-1: Virus Treatment Summary Table – Accepted Treatment Technologies, Virus Treatment Credits, and Compliance Monitoring

Chemical Disinfection for Virus Inactivation			
Disinfection Technology	Virus Inactivation Credit, logs	Compliance Monitoring	
		Monitoring Requirements	Operating Requirements
Chemical Disinfection Using Free Chlorine, Chloramines, Chlorine Dioxide, or Ozone	Based on the calculated CT in relation to the applicable CT table in Appendix B to these guidelines.	Ground water systems (GWSs) serving more than 3,300 people shall conduct continuous residual disinfectant concentration monitoring at one or more Florida-Department-of-Environmental-Protection-specified (FDEP-specified) locations. GWSs serving 3,300 or fewer people shall monitor residual disinfectant concentration at one or more FDEP-specified locations by taking at least one grab sample daily during peak flow.	AT each FDEP-specified monitoring location, GWSs shall maintain a residual disinfectant concentration that is not less than an FDEP-specified minimum.

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Table 2-1: Virus Treatment Summary Table – Accepted Treatment Technologies, Virus Treatment Credits, and Compliance Monitoring (continued)

Membrane Filtration for Virus Removal			
Membrane Filtration Technology	Virus Removal Credit, logs	Compliance Monitoring	
		Monitoring Requirements	Operating Requirements
Ultrafiltration	4	GWSs shall conduct continuous indirect integrity monitoring, consisting of continuous filtrate turbidity monitoring, on each membrane unit. <u>Also</u> , GWSs shall conduct direct integrity testing on each membrane unit at least daily, and whenever the filtrate turbidity exceeds 0.15 nephelometric turbidity unit (NTU) for a period longer than 15 minutes, using a test method having a resolution of 0.01 micron (µm) or less and having a sensitivity of at least four logs.	For each membrane unit, GWSs shall maintain a filtrate turbidity that does not exceed 0.15 NTU. <u>Also</u> , if the result of any direct integrity test is outside the control limit that is established by the GWS, the GWS must remove the membrane unit from service.
	2	GWSs shall conduct continuous indirect integrity monitoring, consisting of continuous filtrate turbidity monitoring, on each membrane unit.	For each membrane unit, GWSs shall maintain a filtrate turbidity that does not exceed 0.15 NTU.

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Table 2-1: Virus Treatment Summary Table – Accepted Treatment Technologies, Virus Treatment Credits, and Compliance Monitoring (continued)

Membrane Filtration for Virus Removal (continued)			
Membrane Filtration Technology	Virus Removal Credit, logs	Compliance Monitoring	
		Monitoring Requirements	Operating Requirements
Nanofiltration; or Reverse Osmosis	4	GWSs shall conduct continuous indirect integrity monitoring, consisting of continuous percent salt passage (SP) monitoring, on each membrane unit. <u>Also</u> , GWSs shall conduct direct integrity testing on each membrane unit at least daily, and whenever the percent SP is greater than an FDEP-specified maximum for a period longer than 15 minutes, using a test method having a resolution of 0.01 µm or less and having a sensitivity of at least four logs.	For each membrane unit, GWSs shall maintain a percent SP that does not exceed an FDEP-specified maximum. <u>Also</u> , if the result of any direct integrity test is outside the control limit that is established by the GWS, the GWS must remove the membrane unit from service.
	2	GWSs shall conduct continuous indirect integrity monitoring, consisting of continuous percent SP monitoring, on each membrane unit.	For each membrane unit, GWSs shall maintain a percent SP that does not exceed an FDEP-specified maximum.

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Table 2-1: Virus Treatment Summary Table – Accepted Treatment Technologies, Virus Treatment Credits, and Compliance Monitoring (continued)

FDEP-Accepted Alternative Treatment for Virus Inactivation or Removal			
Alternative Treatment Technology	Virus Inactivation or Removal Credit, logs	Compliance Monitoring	
		Monitoring Requirements	Operating Requirements
Ultraviolet (UV) Disinfection	Based on the validated UV dose in relation to the UV dose table in Appendix H to these guidelines. GWSs shall use UV reactors that have undergone validation testing to determine the validated UV dose and to determine validated operating conditions for flow rate, UV intensity, UV lamp status, and if applicable, UV transmittance (UVT).	GWSs shall monitor each UV reactor continuously for flow rate, UV intensity, UV lamp status, and if applicable, UVT.	GWSs shall operate each UV reactor within validated operating conditions for flow rate, UV intensity, UV lamp status, and if applicable, UVT.
Conventional Filtration Treatment, Including Lime Softening	2	GWSs serving more than 500 people shall perform combined filter effluent (CFE) turbidity measurements at least every four hours. GWSs serving 500 or fewer people shall perform CFE turbidity measurements at least once per day.	GWSs shall maintain a CFE turbidity that does not exceed 1 NTU. GWSs utilizing lime softening may acidify CFE turbidity samples prior to analysis of the samples.

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Table 2-1: Virus Treatment Summary Table – Accepted Treatment Technologies, Virus Treatment Credits, and Compliance Monitoring (continued)

FDEP-Accepted Alternative Treatment for Virus Inactivation or Removal (continued)			
Alternative Treatment Technology	Virus Inactivation or Removal Credit, logs	Compliance Monitoring	
		Monitoring Requirements	Operating Requirements
Slow Sand Filtration	2	GWSs shall perform CFE turbidity measurements at least once per day.	Systems shall maintain a CFE turbidity that does not exceed 5 NTUs.
Direct Filtration; or Microfiltration Preceded by Coagulation	1	GWSs serving more than 500 people shall perform CFE turbidity measurements at least every four hours. GWSs serving 500 or fewer people shall perform CFE turbidity measurements at least once per day.	GWSs shall maintain a CFE turbidity that does not exceed 1 NTU.
Diatomaceous Earth Filtration	1	GWSs serving more than 500 people shall perform CFE turbidity measurements at least every four hours. GWSs serving 500 or fewer people shall perform CFE turbidity measurements at least once per day.	GWSs shall maintain a CFE turbidity that does not exceed 5 NTUs.

2.1 Chemical Disinfection Using Free Chlorine, Chloramines, Chlorine Dioxide, or Ozone

Chemical disinfectants applied to water inactivate viruses and other pathogens by rupturing the cell wall of the pathogens and diffusing into the cell and interfering with cellular activity. The most commonly used chemical disinfectants are chlorine, chloramines, chlorine dioxide, and ozone.

2.1.1 Virus Inactivation Credit

Ground water systems (GWSs) using free chlorine, chloramines, chlorine dioxide, or ozone for chemical disinfection of ground water receive the virus inactivation credit listed in the applicable table in Appendix B to these guidelines by meeting the corresponding CT value shown in the table for the applicable water pH and minimum water temperature. CT is the product obtained by multiplying the residual disinfectant concentration (C), in mg/L, measured before or at the first customer times the corresponding disinfectant contact time (T), in minutes. The corresponding T is the time it takes for water to move from the point of disinfectant application, or the previous point of disinfectant residual measurement, to the point where C is measured. CT is calculated during peak flow and under worst-case conditions – i.e., using the minimum water volume expected in tanks during any peak flow period and using the minimum C measured during peak flow.

Calculating CT Provided When Using Chlorine, Chloramines, or Chlorine Dioxide. T in a pipeline during peak flow is calculated based on plug flow by dividing the internal volume of the pipeline by the peak flow rate through the pipeline. T in a tank during peak flow generally is calculated by...

- First dividing the minimum water volume expected in the tank during any peak flow period by the peak flow rate out of the tank to determine the minimum theoretical detention in the tank; and
- Then multiplying the minimum theoretical detention time in the tank times an appropriate baffling factor to calculate T in the tank.

C is measured at the end of each disinfection segment. A disinfection segment is defined as a portion of a water treatment system beginning at a disinfectant application or monitoring point – or beginning at the point where water is last exposed to the open atmosphere when calculating CT for virus inactivation after water is last exposed to the open atmosphere – and ending at the next disinfectant monitoring point. (Every disinfection segment has an associated disinfectant monitoring point. Water treatment plants [WTPs] with multiple treatment trains will have multiple disinfection segments.) The end of the last disinfection segment must be before or at the first customer, which is

often the WTP itself. At WTPs with two or more disinfection segments, CT must be calculated for each segment. A discussion of how to identify disinfection segments and calculate CT, as well as a discussion of how to determine peak flow rate, is included in Appendix C to these guidelines.

Increasing either C or T will increase the CT value and provide additional credit for virus inactivation. Increasing C poses the problem of potentially increasing the formation of disinfection byproducts, especially if chlorine is used. Also, C at the end of the last disinfection segment generally should not be increased above the maximum residual disinfectant level (MRDL) for the disinfectant. (The MRDL for chlorine or chloramines is 4.0 milligrams/liter [mg/L] as Cl₂, and the MRDL for chlorine dioxide is 0.8 mg/L as ClO₂.) T can be increased by increasing the minimum water volume in tanks, by improving tank hydraulics to increase the baffling factor, or by constructing additional water storage after disinfectant application and before the first customer. Increasing T also poses the problem of potentially increasing the formation of disinfection byproducts, especially if chlorine is used.

Calculating CT Provided When Using Ozone. The procedures for calculating CT when using ozone differ from the procedures for calculating CT when using chlorine, chloramines, or chlorine dioxide. Ozone warrants special consideration for estimating virus inactivation efficiency because of the following complications that are specific to ozone disinfection and that distinguish it from other chemical disinfection processes:

- The application of ozone to water is dependent on unique gas-liquid mass transfer characteristics. Also, ozone is extremely reactive and dissipates quickly after application, and thus, an ozone residual persists only a short time after application.
- Ozone contactors exhibit diversified flow configurations ranging from an almost continuously stirred tank reactor to an almost ideal plug flow configuration.
- For many ozone contactors, the ozone residual in the contactor will vary and be nonuniform. Also, ozone contactors are closed vessels because of ozone's toxicity, and thus, the contactors have limited access for measurement of the ozone residual profile within the contactors.

CT for ozone shall be calculated using the procedures in Appendix O to the United States Environmental Protection Agency's (USEPA's) *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991.

Determining CT Required (and Determining C Required). CT tables are used to determine the CT required for a certain level of virus inactivation. The CT tables in Appendix B to

these guidelines give CT values for various levels of virus inactivation as a function of disinfectant type, water pH, and water temperature. The following procedures should be used to obtain the required CT from the tables in Appendix B:

- Find the appropriate table, or the appropriate portion of the appropriate table, based on the disinfectant and, in the case of chlorine or chloramines, based on the water pH value at the point where C is measured.
- Find the appropriate column and row based on the expected **minimum** water temperature at the point where C is measured and based on the desired log inactivation of viruses. The effectiveness of chemical disinfection decreases as water temperature decreases, and virus inactivation must be achieved at all water temperatures; therefore, it is important to use the expected **minimum** water temperature to determine the CT required. In the absence of sufficient system-specific water temperature data, GWSs shall estimate their minimum water temperature to be equal to the applicable minimum water temperature in Table 6 in the Florida Geological Survey's Special Publication Number 34, *Florida's Ground Water Quality Monitoring Program – Background Hydrogeochemistry*, 1992, which presents minimum ground water temperature by aquifer system and water management district. The pertinent portion of this table is reproduced in Table D-1 in Appendix D to these guidelines.
- In cases where the water pH is an intermediate value between the pH values listed in the table, use the CT value for the next higher or lower pH listed in the table, whichever pH value results in a more conservative (i.e., greater) CT value, or determine the CT value using linear interpolation between the CT values associated with the next lower and higher pH values listed in the table.

For inactivation of viruses by free chlorine at pH 9.1 to 9.9 in lime softening environments, GWSs may use the CT values listed in Table B-2 in Appendix B or may determine CT values using linear interpolation between Tables B-1 and B-2 in Appendix B.

The CT values for inactivation of viruses by chloramines in Tables B-3 and B-4 in Appendix B are based on data for inactivation of Hepatitis A virus, which is less resistant to inactivation by chloramines than is rotavirus. Nevertheless, the CT values in Tables B-3 and B-4 may be used for inactivation of all viruses, including rotavirus, if chlorine is added prior to ammonia. This is because rotavirus is very sensitive to inactivation by free chlorine, and thus, the short-term presence of free chlorine prior to the formation of chloramines can be expected to provide at least four-log inactivation of rotavirus. The CT values in Tables B-3 and B-4 may not be used for virus inactivation if ammonia is added prior to chlorine, if ammonia and chlorine are added concurrently, or if preformed chloramines are used because, without the short-term presence of free

chlorine before the formation of chloramines, the CT values will not be adequate for inactivation of rotavirus. If ammonia is added prior to chlorine, if ammonia and chlorine are added concurrently, or if preformed chloramines are used, GWSs must determine CT values by conducting an on-site challenge study in accordance with Appendices F and G to the USEPA's *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991.

For inactivation of viruses by chloramines at pH 8.1 to 9.9 in lime softening environments, GWSs may use the CT values listed in Table B-3 in Appendix B or may determine CT values using linear interpolation between Tables B-3 and B-4 in Appendix B.

Once the required CT is determined, the required C can be determined simply by dividing the required CT by the calculated T provided.

2.1.2 Compliance Monitoring

Monitoring Requirements. GWSs serving greater than 3,300 people shall continuously monitor the residual disinfectant concentration at one or more locations specified by the Florida Department of Environmental Protection (FDEP) each day they serve water to the public. Such systems shall monitor the residual disinfectant concentration using analytical methods specified in 40 CFR 141.74(a)(2) or in Appendix A to Subpart C of 40 CFR 141 or using an on-line chlorine analyzer meeting USEPA Method 334.0. The analytical methods specified in 40 CFR 141.74(a)(2) or Appendix A to Subpart C in 40 CFR 141 are listed in Table E-1 in Appendix E to these guidelines; and draft USEPA Method 334.0, "Determination of Residual Chlorine in Drinking Water Using an On-Line Chlorine Analyzer," is included in Appendix F to these guidelines. The calibration of on-line chlorine analyzers shall be verified in accordance with draft USEPA Method 334.0, while the calibration of all other continuous residual disinfectant monitoring equipment shall be verified in accordance with DEP-SOP-001/01 - FT 1900, "Continuous Monitoring with Installed Meters," a copy of which is included in Appendix G to these guidelines. If continuous residual disinfectant monitoring equipment fails, the GWS must conduct grab sampling every four hours until the continuous monitoring equipment is returned to service. The GWS must resume continuous residual disinfectant monitoring within 14 days.

GWSs serving 3,300 or fewer people shall monitor the residual disinfectant concentration at one or more locations specified by the FDEP by taking at least one grab sample/location during peak flow each day they serve water to the public. Such GWSs shall monitor residual disinfectant concentration using analytical methods specified in 40 CFR 141.74(a)(2) or in Appendix A to Subpart C of 40 CFR 141 or using a DPD colorimetric test kit or the Industrial Test Systems free chlorine test strip. If any daily grab sample measurement is less than the FDEP-specified minimum residual

disinfectant concentration, the GWS must take follow-up samples every four hours until the residual disinfectant concentration is restored to a value equal to, or greater than, the FDEP-specified minimum concentration. Alternatively, GWSs serving 3,300 or fewer people may continuously monitor residual disinfectant concentration and meet the requirements in the preceding paragraph.

The FDEP-specified location(s) for monitoring the residual disinfectant concentration will be the end of each disinfection segment. The end of the last disinfection segment must be before or at the first customer, which is often the WTP itself.

Operating Requirements. GWSs must maintain an FDEP-specified minimum residual disinfectant concentration at each FDEP-specified disinfectant residual monitoring location every day they serve water to the public. The FDEP-specified minimum residual disinfectant concentration for each monitoring location will be determined on a WTP-by-WTP basis, and a disinfection-segment-by-disinfection-segment basis, by dividing the required CT by the minimum T provided during peak flow. The FDEP-specified minimum residual disinfectant concentration at the end of the last disinfection segment generally should not be greater than the MRDL for the disinfectant. Upon request by a GWS, the FDEP will consider specifying a variable minimum residual disinfectant concentration to allow for seasonal changes in water temperature and required CT.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on a revised monthly operation report (MOR) sheet that is similar to Exhibit J-1 in Appendix J to these guidelines:

- The daily lowest residual disinfectant concentration at each FDEP-specified disinfectant residual monitoring location; and
- The date and duration of any failure to maintain any FDEP-specified minimum residual disinfectant concentration, at any FDEP-specified disinfectant residual monitoring location, for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to maintain any FDEP-specified minimum residual disinfectant concentration, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the FDEP as soon as possible but no later than the end of the next business day after the violation.

2.2 Ultrafiltration (UF)

UF is a pressure-driven membrane filtration process that typically employs hollow-fiber membranes with a pore size range of approximately 0.01 to 0.05 micron (μm) and a nominal (i.e., average) pore size of 0.01 μm .

2.2.1 Virus Removal Credit

Ground water systems (GWSs) using UF to treat ground water receive credit for virus treatment only if the UF membranes meet one of the following two criteria:

- The membranes have an absolute (i.e., maximum) pore size less than 0.01 μm ; or
- The membranes are identical in material, and similar in construction, to membranes that have been shown via challenge testing to have at least four-log virus removal capability.

GWSs using UF membranes that meet one of the above two criteria receive credit for four-log virus removal only if GWSs conduct, on each membrane unit, continuous indirect integrity monitoring meeting the requirements in Section 2.2.2 below and daily direct integrity testing having a resolution of 0.01 μm or less and a sensitivity of at least four logs. The Florida Department of Environmental Protection (FDEP) realizes that a resolution requirement this small is very difficult to achieve with currently available direct integrity tests. (The FDEP is not aware of any pressure-based direct integrity test that can achieve a resolution this small, and marker-based direct integrity tests with a resolution this small may be prohibitively expensive.) However, without direct integrity testing having a resolution this small, it is possible that a number of very small integrity breaches could occur as membranes age or degrade, and such breaches could allow the undetected passage of viruses through the membranes. Consequently, unless the GWS conducts direct integrity testing having a resolution of 0.01 μm or less, the FDEP is limiting the virus removal credit for UF to two logs as discussed in the following paragraph.

GWSs using UF membranes that meet one of the two criteria discussed in the first paragraph of this Section 2.2.1 receive credit for two-log virus removal if GWSs conduct, on each membrane unit, continuous indirect integrity monitoring meeting the requirements in Section 2.2.2 below.

2.2.2 Compliance Monitoring

Monitoring Requirements. GWSs receiving four-log virus removal credit for UF shall conduct direct integrity testing on each membrane unit at least once each day that the membrane unit is in operation and whenever the filtrate turbidity exceeds 0.15

nephelometric turbidity unit (NTU) for a period longer than 15 minutes. A “membrane unit” is defined as a group of membrane modules sharing common valving that allows the unit to be isolated from the rest of the membrane treatment process for the purpose of integrity testing or maintenance. The direct integrity test must have a resolution of 0.01 μm or less and a sensitivity of at least four logs.

GWSs receiving two- or four-log virus removal credit for UF shall conduct continuous indirect integrity monitoring on each membrane unit in operation. Continuous indirect integrity monitoring shall consist of continuous filtrate turbidity monitoring.

“Continuous monitoring” is defined as monitoring at a frequency no less than once every 15 minutes. The calibration of all continuous turbidity monitoring equipment shall be verified in accordance with DEP-SOP-001/01 – FT 1900, “Continuous Monitoring with Installed Meters,” a copy of which is included in Appendix G to these guidelines.

Operating Requirements. If the result of any direct integrity test is outside the control limit that is established by the GWS as indicative of an integral membrane unit capable of providing four-log virus removal, the GWS must remove the membrane unit from service. The GWS must conduct a subsequent direct integrity test to verify any repairs and may return the membrane unit to service only if the result of the subsequent direct integrity test is within the established control limit.

For each membrane unit, GWSs must maintain a filtrate turbidity that does not exceed 0.15 NTU.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on an additional monthly operation report (MOR) sheet that is similar to Exhibit J-2 in Appendix J to these guidelines:

- The daily maximum filtrate turbidity for each membrane unit; and
- The date and duration of any failure of a membrane unit to maintain a filtrate turbidity of 0.15 NTU or less for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to maintain a filtrate turbidity of 0.15 NTU or less for any membrane unit, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the FDEP as soon as possible but no later than the end of the next business day after the violation.

2.3 Nanofiltration (NF); or Reverse Osmosis (RO)

NF is a pressure-driven membrane separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water. NF typically is applied for membrane softening (i.e., to selectively remove hardness [calcium, magnesium, and certain other multivalent cations] but allow significant passage of monovalent ions) or the removal of dissolved organic contaminants. The typical range of molecular weight cutoff (MWCO) levels is between 200 and 1,000 Daltons for NF membranes.

RO is a pressure-driven membrane separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water. The typical range of MWCO levels is less than 100 Daltons for RO membranes.

Reverse osmosis is the reverse of the natural osmosis process – i.e., reverse osmosis is the passage of a solvent (e.g., water) through a semi-permeable membrane from a solution of higher concentration to a solution of lower concentration against the concentration gradient, achieved by applying pressure greater than the osmotic pressure to the more concentrated solution.

2.3.1 Virus Removal Credit

Ground water systems (GWSs) using NF or RO to treat ground water receive credit for four-log virus removal only if GWSs conduct, on each membrane unit, continuous indirect integrity monitoring meeting the requirements in Section 2.3.2 below and daily direct integrity testing having a resolution of 0.01 micron (μm) or less and a sensitivity of at least four-logs. The Florida Department of Environmental Protection (FDEP) realizes that a resolution requirement this small is very difficult to achieve with currently available direct integrity tests. (The FDEP is not aware of any pressure-based direct integrity test that can achieve a resolution this small, and marker-based direct integrity tests with a resolution this small may be prohibitively expensive.) However, without direct integrity testing having a resolution this small, it is possible that a number of very small integrity breaches could occur as membranes age or degrade, and such breaches could allow the undetected passage of viruses through the membranes. Consequently, unless the GWS conducts direct integrity testing having a resolution of 0.01 μm or less, the FDEP is limiting the virus removal credit for NF or RO to two logs as discussed in the following paragraph.

GWSs using NF or RO membranes receive credit for two-log virus removal if GWSs conduct, on each membrane unit, continuous indirect integrity monitoring meeting the requirements in Section 2.3.2 below.

2.3.2 Compliance Monitoring

Monitoring Requirements. GWSs receiving four-log virus removal credit for NF or RO shall conduct direct integrity testing on each membrane unit at least once each day that the membrane unit is in operation and whenever the filtrate turbidity exceeds 0.15 nephelometric turbidity unit (NTU) for a period longer than 15 minutes. A “membrane unit” is defined as a group of membrane modules sharing common valving that allows the unit to be isolated from the rest of the membrane treatment process for the purpose of integrity testing or maintenance. The direct integrity test must have a resolution of 0.01 μm or less and a sensitivity of at least four logs.

GWSs receiving two- or four-log virus removal credit for NF or RO shall conduct continuous indirect integrity monitoring on each membrane unit in operation. Continuous indirect integrity monitoring shall consist of continuous percent salt passage (SP) monitoring. “Continuous monitoring” is defined as monitoring at a frequency no less than once every 15 minutes. The calibration of all continuous monitoring equipment shall be verified in accordance with DEP-SOP-001/01 – FT 1900, “Continuous Monitoring with Installed Meters,” a copy of which is included in Appendix G to these guidelines.

Operating Requirements. If the result of any direct integrity test is outside the control limit that is established by the GWS as indicative of an integral membrane unit capable of providing four-log virus removal, the GWS must remove the membrane unit from service. The GWS must conduct a subsequent direct integrity test to verify any repairs and may return the membrane unit to service only if the result of the subsequent direct integrity test is within the established control limit.

For each membrane unit, GWSs must maintain a percent SP that does not exceed an FDEP-specified maximum. The FDEP-specified maximum percent SP will be determined on a water-treatment-plant-by-water-treatment-plant basis using membrane performance information provided by the GWS. The FDEP-specified maximum percent SP generally should be no greater than 25% for NF and no greater than 5% for RO.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on an additional monthly operation report (MOR) sheet that is similar to Exhibit J-3 in Appendix J to these guidelines:

- The daily maximum percent SP for each membrane unit; and
- The date and duration of any failure of a membrane unit to maintain a percent SP less than or equal to the FDEP-specified maximum for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to maintain a percent SP less than or equal to the FDEP-specified maximum for any membrane unit, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the FDEP as soon as possible but no later than the end of the next business day after the violation.

2.4 Ultraviolet (UV) Disinfection

UV radiation is the range of electromagnetic waves 100 to 400 nanometers (nm) long (between the X-ray and visible light spectrums). The optimal UV range for disinfection is between 245 and 285 nm. UV disinfection utilizes either...

- Low-pressure lamps that emit maximum energy output at a wavelength of 253.7 nm;
- Medium-pressure lamps that emit energy at wavelengths from 180 to 1370 nm; or
- Lamps that emit at other wavelengths in a high-intensity “pulsed” manner.

UV radiation inactivates viruses and other microorganisms via UV absorption, which causes a photochemical reaction that alters molecular components essential to cell function. As UV penetrates the cell wall of a microorganism, the energy reacts with nucleic acids and other vital cell components, resulting in injury or death of the exposed cells.

Unlike chemical disinfection, UV disinfection leaves no residual that can be monitored to determine UV dose and inactivation credit. The UV dose depends on the UV intensity (as measured by a UV sensor), flow rate, and UV transmittance (UVT).

2.4.1 Virus Inactivation Credit

Ground water systems (GWSs) using UV light disinfection of ground water receive the virus inactivation credit listed in Table H-1 in Appendix H to these guidelines by achieving the corresponding UV dose listed in Table H-1.

The virus inactivation credits and doses listed in Table H-1 in Appendix H are for UV light at a wavelength of 254 nm as produced by a low-pressure mercury vapor lamp. To receive virus inactivation credit for other lamp types, GWSs must demonstrate an equivalent germicidal dose through reactor validation testing as described below. Additionally, the UV dose values in Table H-1 are applicable only to post-filter

applications of UV light in water treatment systems with filters and to applications of UV light in water treatment systems without filters.

Reactor validation testing. GWSs must use UV reactors that have undergone validation testing to demonstrate that they are achieving a particular UV dose value and to determine the operating conditions under which the reactor delivers the UV dose (i.e., validated operating conditions). Validated operating conditions must include flow rate, UV intensity (as measured by a UV sensor), UV lamp status, and if applicable, UVT. When determining validated operating conditions, GWSs must account for the following factors: UV absorbance of the water; lamp fouling and aging; measurement uncertainty of on-line sensors; UV dose distributions arising from the velocity profiles through the reactor; failure of UV lamps or other critical system components; and inlet and outlet piping or channel configurations of the UV reactor. Validation testing must include full-scale testing of a reactor that conforms uniformly to the UV reactors used by the GWS and inactivation of a test microorganism whose dose response characteristics have been quantified with a low-pressure mercury vapor lamp. UV reactors generally are validated for one of the following two dose-monitoring strategies:

- The UV Intensity Setpoint Approach. This approach relies on one or more “setpoint(s)” for UV intensity that are established during validation testing to determine UV dose. During reactor operation, the UV intensity (as measured by a UV sensor) must meet or exceed the setpoint(s) to ensure delivery of the required dose. Also, reactors must be operated within validated operating conditions for flow rate and lamp status. The approach can rely on either a single setpoint (one UV intensity setpoint is used for all validated flow rates) or a variable setpoint (the UV intensity setpoint is determined using a lookup table or equation for a range of flow rates).
- The Calculated Dose Approach. This approach uses a dose monitoring equation to estimate the UV dose based on the flow rate, UV intensity, and UVT measured during reactor operation. During reactor operation, the UV reactor control system inputs the measured parameters into the dose monitoring equation to produce a calculated dose. The GWS operator divides the calculated dose by the validation factor and compares the resulting value to the required dose for the target virus inactivation level.

The very high dose requirement for three- or four-log virus inactivation presents challenges for validation testing of UV reactors. At present, the Florida Department of Environmental Protection (FDEP) is unaware of any testing protocols that can validate the performance of UV reactors at the dose of 186 millijoules/centimeter² needed for four-log virus inactivation credit. However, UV reactors validated at lower doses can be used in a series configuration or in combination with other inactivation or removal technologies to provide a total of four-log virus treatment.

2.4.2 Compliance Monitoring

Monitoring Requirements. GWSs shall continuously monitor each UV reactor in operation for UV intensity (as measured by a UV sensor), flow rate, and UV lamp status. Also, GWSs shall continuously monitor UVT for UV reactors operating using the Calculated Dose Approach. "Continuous monitoring" is defined as monitoring at a frequency no less than once every 5 minutes. GWSs shall verify the calibration of UV sensors and UVT transmitters using the protocol discussed in Sections 6.4.1.1 and 6.4.1.2 of the United States Environmental Protection Agency's *Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule, 2006*; and GWSs must recalibrate sensors in accordance with the manufacturer's recommendations.

Operating Requirements. GWSs must operate each UV reactor within validated operating conditions.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on one or more additional monthly operation report (MOR) sheets that are similar to Exhibit J-4 or J-5 in Appendix J to these guidelines:

- The daily maximum flow rate, daily UV intensity requirements, daily minimum UV intensity, and daily total operation time outside validated operating conditions for each UV reactor using the UV Intensity Setpoint Approach;
- The daily dose requirements, daily minimum validated dose, and daily total operation time outside validated operating conditions for each UV reactor using the Calculated Dose Approach; and
- The date and duration of any failure of a UV reactor to operate within validated operating conditions for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to operate any UV reactor within validated operating conditions, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the FDEP as soon as possible but no later than the end of the next business day after the violation.

2.5 Conventional Filtration Treatment, Including Lime Softening

Conventional filtration treatment means a series of processes including coagulation, flocculation, sedimentation, and filtration resulting in substantial particulate removal. Conventional filtration treatment includes lime softening.

2.5.1 Virus Removal Credit

Ground water systems (GWSs) using conventional filtration treatment, including lime softening, to treat ground water receive credit for two-log virus removal if they conduct combined filter effluent (CFE) turbidity monitoring meeting the requirements in Section 2.5.2 below.

2.5.2 Compliance Monitoring

Monitoring Requirements. GWSs serving more than 500 people shall perform CFE turbidity measurements at least every four hours they serve water to the public. GWSs serving 500 or fewer people may perform CFE turbidity measurements just once each day they serve water to the public, but if a daily CFE turbidity measurement exceeds 1 nephelometric turbidity unit (NTU), the GWS must take follow-up samples every four hours until the CFE turbidity is restored to a value less than or equal to 1 NTU. CFE turbidity measurements may be performed at any point after filter effluent is combined and before water treatment plant effluent enters the distribution system. A GWS may substitute continuous turbidity monitoring for grab sample monitoring if it verifies the calibration of the continuous monitoring equipment in accordance with DEP-SOP-001/01 – FT 1900, “Continuous Monitoring with Installed Meters,” a copy of which is included in Appendix G to these guidelines.

Operating Requirements. GWSs shall maintain a CFE turbidity that does not exceed 1 NTU. GWSs utilizing lime softening may acidify CFE turbidity samples prior to analysis of the samples. GWSs that acidify CFE turbidity samples shall do so using the protocol in Appendix I to these guidelines.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on an additional monthly operation report (MOR) sheet that is similar to Exhibit J-6 in Appendix J to these guidelines:

- The daily maximum CFE turbidity; and
- The date and duration of any failure to maintain a CFE turbidity of 1 NTU or less for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to maintain a CFE turbidity of 1 NTU or less, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the Florida Department of Environmental Protection as soon as possible but no later than the end of the next business day after the violation.

2.6 Slow Sand Filtration

Slow sand filtration means a process involving passage of raw water through a bed of sand at low velocity (generally less than 0.4 meter/hour) resulting in substantial particulate removal by physical and biological mechanisms.

2.6.1 Virus Removal Credit

Ground water systems (GWSs) using slow sand filtration to treat ground water receive credit for two-log virus removal if they conduct combined filter effluent (CFE) turbidity monitoring meeting the requirements in Section 2.6.2 below.

2.6.2 Compliance Monitoring

Monitoring Requirements. GWSs shall perform CFE turbidity measurements at least once each day they serve water to the public. If any daily CFE turbidity measurement exceeds 5 nephelometric turbidity units (NTUs), the GWS must take follow-up samples every four hours until the CFE turbidity is restored to a value less than or equal to 5 NTUs. CFE turbidity measurements may be performed at any point after filter effluent is combined and before water treatment plant effluent enters the distribution system. A GWS may substitute continuous turbidity monitoring for grab sample monitoring if it verifies the calibration of the continuous monitoring equipment in accordance with DEP-SOP-001/01 – FT 1900, “Continuous Monitoring with Installed Meters,” a copy of which is included in Appendix G to these guidelines.

Operating Requirements. GWSs shall maintain a CFE turbidity that does not exceed 5 NTUs.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on an additional monthly operation report (MOR) sheet that is similar to Exhibit J-7 in Appendix J to these guidelines:

- The daily maximum CFE turbidity; and
- The date and duration of any failure to maintain a CFE turbidity of 5 NTUs or less for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to maintain a CFE turbidity of 5 NTUs or less, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the

Florida Department of Environmental Protection as soon as possible but no later than the end of the next business day after the violation.

2.7 Direct Filtration; or Microfiltration (MF) Preceded by Coagulation

Direct filtration means a series of processes including coagulation and filtration, but excluding sedimentation, resulting in substantial particulate removal.

MF preceded by in-line coagulation is effective at reducing arsenic levels in ground water. This process also should achieve virus removal comparable to that achieved by direct filtration. MF is a pressure-driven membrane filtration process that typically employs hollow-fiber membranes with a pore size range of approximately 0.1 to 0.2 micron (μm) and a nominal (i.e., average) pore size of 0.1 μm .

2.7.1 Virus Removal Credit

Ground water systems (GWSs) using direct filtration, or MF preceded by in-line coagulation, to treat ground water receive credit for one-log virus removal if they conduct combined filter effluent (CFE) turbidity monitoring meeting the requirements in Section 2.7.2 below.

2.7.2 Compliance Monitoring

Monitoring Requirements. GWSs serving more than 500 people shall perform CFE turbidity measurements at least every four hours they serve water to the public. GWSs serving 500 or fewer people may perform CFE turbidity measurements just once each day they serve water to the public, but if a daily CFE turbidity measurement exceeds 1 nephelometric turbidity unit (NTU), the GWS must take follow-up samples every four hours until the CFE turbidity is restored to a value less than or equal to 1 NTU. CFE turbidity measurements may be performed at any point after filter effluent is combined and before water treatment plant effluent enters the distribution system. A GWS may substitute continuous turbidity monitoring for grab sample monitoring if it verifies the calibration of the continuous monitoring equipment in accordance with DEP-SOP-001/01 – FT 1900, “Continuous Monitoring with Installed Meters,” a copy of which is included in Appendix G to these guidelines.

Operating Requirements. GWSs shall maintain a CFE turbidity that does not exceed 1 NTU.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on an additional monthly operation report (MOR) sheet that is similar to Exhibit J-6 in Appendix J to these guidelines:

- The daily maximum CFE turbidity; and
- The date and duration of any failure to maintain a CFE turbidity of 1 NTU or less for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to maintain a CFE turbidity of 1 NTU or less, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the Florida Department of Environmental Protection as soon as possible but no later than the end of the next business day after the violation.

2.8 Diatomaceous Earth Filtration

Diatomaceous earth filtration means a process resulting in substantial particulate removal in which...

- A precoat cake of diatomaceous earth filter media is deposited on a support membrane (i.e., septum); and
- While the water is filtered by passing through the cake on the septum, additional filter media known as body feed is continuously added to the feed water to maintain the permeability of the filter cake.

2.8.1 Virus Removal Credit

Ground water systems (GWSs) using diatomaceous earth filtration to treat ground water receive credit for one-log virus removal if they conduct combined filter effluent (CFE) turbidity monitoring meeting the requirements in Section 2.8.2 below.

2.8.2 Compliance Monitoring

Monitoring Requirements. GWSs serving more than 500 people shall perform CFE turbidity measurements at least every four hours they serve water to the public. GWSs serving 500 or fewer people may perform CFE turbidity measurements just once each day they serve water to the public, but if a daily CFE turbidity measurement exceeds 5 nephelometric turbidity units (NTUs), the GWS must take follow-up samples every four hours until the CFE turbidity is restored to a value less than or equal to 5 NTUs. CFE turbidity measurements may be performed at any point after filter effluent is combined and before water treatment plant effluent enters the distribution system. A GWS may substitute continuous turbidity monitoring for grab sample monitoring if it verifies the calibration of the continuous monitoring equipment in accordance with DEP-SOP-

001/01 – FT 1900, “Continuous Monitoring with Installed Meters,” a copy of which is included in Appendix G to these guidelines.

Operating Requirements. GWSs shall maintain a CFE turbidity that does not exceed 5 NTUs.

Recordkeeping. Each day they serve water to the public, GWSs shall record the following information on an additional monthly operation report (MOR) sheet that is similar to Exhibit J-7 in Appendix J to these guidelines:

- The daily maximum CFE turbidity; and
- The date and duration of any failure to maintain a CFE turbidity of 5 NTUs or less for a period of more than four hours.

It is a treatment technique violation if a GWS fails to maintain FDEP-approved four-log virus treatment, by failing to maintain a CFE turbidity of 5 NTUs or less, and does not correct the failure within four hours after determining the failure. In addition to being recorded on the MOR, such treatment technique violations must be reported to the Florida Department of Environmental Protection as soon as possible but no later than the end of the next business day after the violation.

2.9 Other Treatment Technologies

The Florida Department of Environmental Protection (FDEP) will consider other treatment technologies for virus treatment. Ground water systems (GWSs) must demonstrate to the FDEP, using pilot plant studies or other performance studies, the level of virus treatment that the treatment technology will achieve under the full range of expected operating conditions for the GWS’s water treatment plant. For virus inactivation technologies, the pilot plant or performance studies should follow a protocol similar to that in Appendix G to the United States Environmental Protection Agency’s (USEPA’s) *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991. For virus removal technologies, pilot plant or performance studies should follow a protocol similar to that in Appendix M to the USEPA’s *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991.

Based on the results of pilot plant or performance studies, the FDEP will establish compliance monitoring and operating requirements that the GWS must meet on an ongoing basis in order for the treatment technology to remain eligible for virus treatment credit.

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Appendix A: Cover Sheets for Demonstration of Four-Log Virus Treatment of Ground Water



Cover Sheets for Demonstration of Four-Log Virus Treatment of Ground Water

General Information

Public Water System (PWS) Information

PWS Name: _____

PWS ID: _____

PWS Type

- Community Water System
 Non-Transient Non-Community Water System
 Transient Non-Community Water System

Population Served by PWS

- > 3,300 people
 501 to 3,300 people
 < 500 people

PWS Owner Information

PWS Owner: _____

Contact Person: _____

Contact Person's Title: _____

Contact Person's Mailing Address: _____

Contact Person's E-mail: _____

Contact Person's Telephone: _____

Water Treatment Plant (WTP) Information

WTP Name: _____

WTP Address: _____

Permitted Maximum-Day Operating Capacity of WTP: _____

Does the WTP expose ground water to the open atmosphere during treatment?*

- Yes
 No

* Water treatment facilities that are protected against contamination from birds, insects, wind-borne debris, rainfall, and drainage—i.e., water treatment facilities that are covered by an impervious roof and enclosed within impervious sidewalls or sidewalls of at least 20-mesh screen—are not considered to be exposing water to the open atmosphere.

Cover Sheets for Demonstration of Four-Log Virus Treatment of Ground Water

Virus Treatment Information

Type of Virus Treatment Demonstration

If the WTP exposes ground water to the open atmosphere during treatment, check one of the following:

- This demonstration is for four-log virus treatment after water is last exposed to the open atmosphere.
- This demonstration is just for four-log virus treatment of the ground water source(s).
- Not applicable (the WTP does not expose ground water to the open atmosphere during treatment).

Summary of Technologies Used for Virus Treatment; and Virus Inactivation or Removal Credit Claimed for Each Technology

Technology	Virus Inactivation or Removal Credit Claimed, logs
<input type="checkbox"/> Chemical disinfection using free chlorine	
<input type="checkbox"/> Chemical disinfection using chloramines	
<input type="checkbox"/> Chemical disinfection using chlorine dioxide	
<input type="checkbox"/> Chemical disinfection using ozone	
<input type="checkbox"/> Ultrafiltration (UF)	
<input type="checkbox"/> Nanofiltration (NF); or reverse osmosis (RO)	
<input type="checkbox"/> Ultraviolet (UV) disinfection	
<input type="checkbox"/> Conventional filtration treatment, including lime softening	
<input type="checkbox"/> Slow sand filtration	
<input type="checkbox"/> Direct filtration; or microfiltration preceded by coagulation	
<input type="checkbox"/> Diatomaceous earth filtration	
<input type="checkbox"/> Other (describe):	
Total	

Checklist of Information Attached and Included in this Demonstration

Required for all demonstrations:

- A schematic diagram of the WTP. (The schematic shall show all pumping, treatment, or storage facilities; all chemical disinfectant application points and disinfectant residual monitoring points; application points for any chemicals that will affect pH significantly; any turbidity or conductivity monitoring points; the point of the first customer [often the WTP itself]; etc. Also, the schematic shall identify any facilities that expose water to the open atmosphere.)

Cover Sheets for Demonstration of Four-Log Virus Treatment of Ground Water

Required for demonstrations involving chemical disinfection:

- CT calculations.
- Identification of standby equipment, switch-over devices for gas containers, and alarm systems as required by Rule 62-555.320(13), Florida Administrative Code, and *Recommended Standards for Water Works*.
- Identification of the disinfectant residual monitoring frequency and any continuous disinfectant residual monitoring equipment.
- The proposed disinfectant residual monitoring location(s).
- The proposed minimum residual disinfectant concentration(s) for each disinfectant residual monitoring location.

Required for demonstrations involving UF:

- The absolute pore size of the membranes and, if the absolute pore size is greater than or equal to 0.01 micron, challenge testing information showing at least four-log removal capability for the membranes.
- The direct integrity testing frequency, method, resolution, sensitivity, and control limit for the membrane units if four-log virus removal credit is claimed.
- Identification of the continuous filtrate turbidity monitoring equipment for the membrane units.
- Identification of the operating requirement (filtrate turbidity ≤ 0.15 NTU) for each membrane unit.

Required for demonstrations involving NF or RO:

- The molecular weight cutoff for the membranes.
- The direct integrity testing frequency, method, resolution, sensitivity, and control limit for the membrane units if four-log virus removal credit is claimed.
- Identification of the continuous monitoring equipment for the membrane units.
- The proposed operating requirement – i.e., maximum percent salt passage (generally $\leq 25\%$ for NF and $\leq 5\%$ for RO) – for each membrane unit.

Required for demonstrations involving UV disinfection:

- UV reactor validation information, including the validated UV dose and validated operating conditions for flow rate, UV intensity, UV lamp status, and if applicable, UV transmittance (UVT).
- Identification of the equipment for continuously monitoring the flow rate, UV intensity, UV lamp status, and if applicable, UVT for each UV reactor.

Required for demonstrations involving conventional filtration treatment, including lime softening; direct filtration; or microfiltration preceded by coagulation:

- Identification of the combined filter effluent (CFE) turbidity monitoring frequency and any continuous CFE turbidity monitoring equipment.
- The CFE turbidity monitoring location.
- Identification of the operating requirement (CFE turbidity ≤ 1 NTU) for the filtration technology.

Cover Sheets for Demonstration of Four-Log Virus Treatment of Ground Water

Required for demonstrations involving slow sand filtration or diatomaceous earth filtration:

- Identification of the CFE turbidity monitoring frequency and any continuous CFE turbidity monitoring equipment.
- The CFE turbidity monitoring location.
- Identification of the operating requirement (CFE turbidity \leq 5 NTUs) for the filtration technology.

Required for demonstrations of other technologies:

- Information from pilot plant studies, or other performance studies, demonstrating the level of virus treatment that the technology will achieve under the full range of expected operating conditions at the WTP.
- The proposed compliance monitoring and operating requirements for the technology.

Certifications

Certification by Professional Engineer in Responsible Charge of Preparing this Demonstration

I, the undersigned professional engineer licensed in Florida, am in responsible charge of this four-log virus treatment demonstration. I certify that, to the best of my knowledge and belief, all the information included in this demonstration is accurate and consistent with the Florida Department of Environmental Protection's draft "Guidelines for Four-Log Virus Treatment of Ground Water," October 2009.

P.E. License Number

Type or Print Name

Signature, Date, and Seal

Cover Sheets for Demonstration of Four-Log Virus Treatment of Ground Water

Certification by PWS

I am duly authorized to sign on behalf of the PWS identified on page 1 of these coversheets. I understand that, if the Florida Department of Environmental Protection approves this four-log virus treatment demonstration, the PWS will have to begin conducting compliance monitoring in accordance with the federal Ground Water Rule and as discussed in this demonstration. I further understand that that the PWS will be in violation of the treatment technique requirements under the federal Ground Water Rule if the PWS (1) fails to maintain four-log virus treatment, by failing to meet the operating requirements discussed in this demonstration, and (2) does not correct the failure to maintain four-log virus treatment within four hours after first determining the failure.

Type or Print Name

Signature

Title

Date

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Appendix B: CT Values for Inactivation of Viruses by Chemical Disinfection

Tables B-1 through B-6 give CT values for various levels of virus inactivation as a function of disinfectant type, water pH, and water temperature. The following procedures should be used to obtain the required CT from Tables B-1 through B-6:

- Find the appropriate table, or the appropriate portion of the appropriate table, based on the disinfectant and based on the expected water pH value at the point where residual disinfectant concentration (C) is measured.
- Find the appropriate column and row based on the expected **minimum** water temperature at the point where C is measured and based on the desired log inactivation of viruses. The effectiveness of chemical disinfection decreases as water temperature decreases, and virus inactivation must be achieved at all water temperatures; therefore, it is important to use the expected **minimum** water temperature to determine the CT required. In the absence of sufficient system-specific water temperature data, ground water systems shall estimate their minimum water temperature to be equal to the applicable minimum water temperature in Table 6 in the Florida Geological Survey's Special Publication Number 34, *Florida's Ground Water Quality Monitoring Program – Background Hydrogeochemistry*, 1992, which presents minimum ground water temperature by aquifer system and water management district. The pertinent portion of this table is reproduced in Table D-1 in Appendix D to these guidelines.
- In cases where the water pH is an intermediate value between the pH values listed in the table, use the CT value for the next higher or lower pH listed in the table, whichever pH value results in a more conservative (i.e., greater) CT value, or determine the CT value using linear interpolation between the CT values associated with the next lower and higher pH values listed in the table.

Table B-1: CT Values for Inactivation of Viruses by Free Chlorine at Water pH 6.0 - 9.0

Log Inactivation	Water Temperature (degrees Celsius [°C])																
	5	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	5	1	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
2	4	2	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1	1.0	0.9	0.9	0.8	0.8
3	6	3	2.9	2.7	2.6	2.4	2.3	2.1	2	1.8	1.7	1.5	1.4	1.3	1.3	1.2	1.1
4	8	4	3.8	3.6	3.4	3.2	3	2.8	2.6	2.4	2.2	2	1.9	1.8	1.7	1.6	1.5




Source: Table E-7 in Appendix E to the United States Environmental Protection Agency’s *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 (the “Surface Water Guidance Manual”).  = CT value modified or determined by assuming a twofold decrease in CT for every 10-°C increase in temperature above 5 °C (per Appendix F to the “Surface Water Guidance Manual”).  = CT value determined by linear interpolation between 5-°C increments.  = CT value determined by assuming inactivation is a first order reaction (per the “Surface Water Guidance Manual”).



Table B-2: CT Values for Inactivation of Viruses by Free Chlorine at Water pH 10.0 - 11.5 in Lime Softening Environments*




Log Inactivation	Water Temperature (degrees Celsius [°C])																
	5	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	6.2	3.1	2.9	2.8	2.6	2.5	2.3	2.2	2.0	1.8	1.7	1.5	1.5	1.4	1.3	1.2	1.2
2	12.3	6.2	5.8	5.5	5.2	4.9	4.6	4.3	4.0	3.7	3.4	3.1	2.9	2.8	2.6	2.5	2.3
3	18.5	9.2	8.8	8.3	7.8	7.4	6.9	6.5	6.0	5.5	5.1	4.6	4.4	4.2	3.9	3.7	3.5
4	24.6	12.3	11.7	11.1	10.5	9.8	9.2	8.6	8.0	7.4	6.8	6.2	5.8	5.5	5.2	4.9	4.6

Basis: This table is based on predicted CT values from Tables E.1 and 4.10 in the American Water Works Association Research Foundation’s *The Removal and Disinfection Efficiency of Lime Softening Processes for Giardia and Viruses*, 1994. The highest predicted CT value for achieving 2-log inactivation of Hepatitis A virus (HAV) at 5 °C and a pH range of 10.0 - 11.5 was multiplied by a safety factor of 3 to obtain the CT value listed in this table for 2-log inactivation at 5 °C. (The target virus of HAV and the safety factor of 3 were used for this table in order to be consistent with the basis for Table E-7 in Appendix E to the United States Environmental Protection Agency’s *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 [the “Surface Water Guidance Manual”] as discussed in Appendix F to the “Surface Water Guidance Manual.” CT values for 1-, 3-, and 4-log inactivation were determined by assuming inactivation is a first order reaction (per the “Surface Water Guidance Manual”). CT values at temperatures other than 5 °C were determined assuming a twofold decrease in CT for every 10-°C increase (per Appendix F to the “Surface Water Guidance Manual”).

* For inactivation of viruses by free chlorine at pH 9.1 to 9.9 in lime softening environments, use the CT values in Table A-2 or determine CT values using linear interpolation between Tables A-1 and A-2.

Table B-3: CT Values for Inactivation of Viruses by Chloramines (if Chlorine Is Added Prior to Ammonia*) at Water pH 8 +/-

Log Inactivation	Water Temperature (degrees Celsius [°C])																
	5	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	429	214	204	193	182	171	161	150	139	129	118	107	102	96.4	91.1	85.7	80.3
2	857	429	407	386	364	343	321	300	279	257	236	214	204	193	182	171	161
3	1423	712	676	641	605	570	534	498	463	427	392	356	338	320	303	285	267
4	1988	994	944	895	845	795	746	696	646	596	547	497	472	447	423	398	373

Source: Table E-13 in Appendix E to the United States Environmental Protection Agency’s *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 (the “Surface Water Guidance Manual”).  = CT value modified or determined by assuming a twofold decrease in CT for every 10-°C increase in temperature above 5 °C (per Appendix F to the “Surface Water Guidance Manual”).  = CT value determined by linear interpolation between 5-°C increments.  = CT value determined by assuming inactivation is a first order reaction (per the “Surface Water Guidance Manual”).

* If ammonia is added prior to chlorine, if ammonia and chlorine are added concurrently, or if preformed chloramines are used, determine CT values by conducting an on-site challenge study in accordance with Appendix G to the “Surface Water Guidance Manual.”

Table B-4: CT Values for Inactivation of Viruses by Chloramines (if Chlorine Is Added Prior to Ammonia*) at Water pH 10.0 - 11.5 in Lime Softening Environments†

Water Temperature (°C)	pH = 10.0				pH = 10.5				pH = 11.0				pH = 11.5			
	Log Inactivation				Log Inactivation				Log Inactivation				Log Inactivation			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
5	155	309	464	618	121	241	362	482	55	110	165	220	25	50	75	100
15	77.3	155	232	309	60.3	121	181	241	27.5	55	82.5	110	12.5	25	37.5	50
16	73.4	147	220	294	57.2	114	172	229	26.1	52.3	78.4	105	11.9	23.8	35.6	47.5
17	69.5	139	209	278	54.2	108	163	217	24.8	49.5	74.3	99	11.3	22.5	33.8	45
18	65.7	131	197	263	51.2	102	154	205	23.4	46.8	70.1	93.5	10.6	21.3	31.9	42.5
19	61.8	124	185	247	48.2	96.4	145	193	22	44	66	88	10	20	30	40
20	57.9	116	174	232	45.2	90.4	136	181	20.6	41.3	61.9	82.5	9.4	18.8	28.1	37.5
21	54.1	108	162	216	42.2	84.4	127	169	19.3	38.5	57.8	77	8.8	17.5	26.3	35
22	50.2	100	151	201	39.2	78.3	117	157	17.9	35.8	53.6	71.5	8.1	16.3	24.4	32.5
23	46.4	92.7	139	185	36.2	72.3	108	145	16.5	33	49.5	66	7.5	15	22.5	30
24	42.5	85.0	127	170	33.1	66.3	99.4	133	15.1	30.3	45.4	60.5	6.9	13.8	20.6	27.5
25	38.6	77.3	116	155	30.1	60.3	90.4	121	13.8	27.5	41.3	55	6.3	12.5	18.8	25
26	36.7	73.4	110	147	28.6	57.2	85.9	114	13.1	26.1	39.2	52.3	5.9	11.9	17.8	23.8
27	34.8	69.5	104	139	27.1	54.2	81.3	108	12.4	24.8	37.1	49.5	5.6	11.3	16.9	22.5
28	32.8	65.7	98.5	131	25.6	51.2	76.8	102	11.7	23.4	35.1	46.8	5.3	10.6	15.9	21.3
29	30.9	61.8	92.7	124	24.1	48.2	72.3	96.4	11	22	33	44	5	10	15	20
30	29.0	57.9	86.9	116	22.6	45.2	67.8	90.4	10.3	20.6	30.9	41.3	4.7	9.4	14.1	18.8

Basis: This table is based on estimated CT values from Table 4.7 in the AwwaRF's *The Removal and Disinfection Efficiency of Lime Softening Processes for Giardia and Viruses*, 1994. The estimated CT values for achieving 2-log inactivation of Hepatitis A virus (HAV) using preformed monochloramine at 5 °C and pH 10.0, 10.5, 11.0, and 11.5 were used as the CT values listed in this table for 2-log inactivation of viruses at 5 °C and pH 10.0, 10.5, 11.0, and 11.5. No safety factor was applied since chloramination in the field, where some transient presence of free chlorine would occur, is assumed more effective than preformed chloramines. (The target virus of HAV, preformed chloramines, and no safety factor were used for this table in order to be consistent with the basis for Table E-13 in Appendix E to the USEPA's *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 [the "Surface Water Guidance Manual"], as discussed in Appendix F to the "Surface Water Guidance Manual.") CT values for 1-, 3-, and 4-log inactivation were determined by assuming inactivation is a first order reaction (per the "Surface Water Guidance Manual"). CT values at temperatures other than 5 °C were determined assuming a twofold decrease in CT for every 10-°C increase (per Appendix F to the "Surface Water Guidance Manual").

* If ammonia is added prior to chlorine, if ammonia and chlorine are added concurrently, or if preformed chloramines are used, determine CT values by conducting an on-site challenge study in accordance with Appendix G to the "Surface Water Guidance Manual."

† For inactivation of viruses by chloramines at pH 8.1 to 9.9 in lime softening environments, use the CT values in Table A-3 or determine CT values using linear interpolation between Tables A-3 and A-4. In cases where the pH is an intermediate value between the pH values listed in Table A-4, use the CT values for the next lower pH listed in Table A-4 or determine CT values using linear interpolation between the CT values associated with the next lower and higher pH values listed in Table A-4.

Table B-5: CT Values for Inactivation of Viruses by Chlorine Dioxide

Log Inactivation	Water Temperature (degrees Celsius [°C])																
	5	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	2.8	1.4	1.3	1.3	1.2	1.1	1.1	1	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5
2	5.6	2.8	2.7	2.5	2.4	2.2	2.1	2	1.8	1.7	1.5	1.4	1.3	1.3	1.2	1.1	1.1
3	17.1	8.6	8.1	7.7	7.3	6.8	6.4	6	5.6	5.1	4.7	4.3	4.1	3.8	3.6	3.4	3.2
4	33.4	16.7	15.9	15	14.2	13.4	12.5	11.7	10.9	10	9.2	8.4	7.9	7.5	7.1	6.7	6.3







Source: Table E-9 in Appendix E to the United States Environmental Protection Agency’s *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 (the “Surface Water Guidance Manual”).  = CT value determined by linear interpolation between 5-°C increments.  = CT value determined by assuming inactivation is a first order reaction (per the “Surface Water Guidance Manual”).  = CT value determined by assuming a twofold decrease in CT for every 10-°C increase in temperature above 5 °C (per Appendix F to the “Surface Water Guidance Manual”).



Table B-6: CT Values for Inactivation of Viruses by Ozone

Log Inactivation	Water Temperature (degrees Celsius [°C])																
	5	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.3	0.15	0.14	0.14	0.13	0.12	0.11	0.11	0.1	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06
2	0.6	0.3	0.29	0.27	0.26	0.24	0.23	0.21	0.2	0.18	0.17	0.15	0.14	0.14	0.13	0.12	0.11
3	0.9	0.45	0.43	0.41	0.38	0.36	0.34	0.32	0.29	0.27	0.25	0.23	0.21	0.2	0.19	0.18	0.17
4	1.2	0.6	0.57	0.54	0.51	0.48	0.45	0.42	0.39	0.36	0.33	0.3	0.29	0.27	0.26	0.24	0.23

Source: Table E-11 in Appendix E to the United States Environmental Protection Agency’s *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 (the “Surface Water Guidance Manual”).  = CT value modified or determined by assuming a twofold decrease in CT for every 10-°C increase in temperature above 5 °C (per Appendix F to the “Surface Water Guidance Manual”).  = CT value determined by linear interpolation between 5-°C increments.  = CT value determined by assuming inactivation is a first order reaction (per the “Surface Water Guidance Manual”).



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Appendix C: Calculating CT

This appendix contains procedures for calculating CT for ground water systems (GWSs) using chlorine, chloramines, or chlorine dioxide as a disinfectant. Appendix O to the United States Environmental Protection Agency's *Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991 (the "Surface Water Guidance Manual"), contains procedures that shall be used for calculating CT for GWSs using ozone as a disinfectant.

C.1 What Is CT?

CT is a measure of disinfection effectiveness. It is the product obtained by multiplying the residual disinfectant concentration (C), in mg/L measured before or at the first customer times the corresponding disinfectant contact time (T), in minutes. The corresponding T is the time it takes for water to move from the point of disinfectant application, or the previous point of disinfectant residual measurement, to the point where C is measured. Note that C is measured at the end of T.

If there are multiple disinfection segments as discussed in Section C.2 below, CT must be calculated for each disinfection segment.

CT must be calculated during peak flow as discussed in Section C.3 below and under worst-case conditions – i.e., using the minimum water volume expected in tanks during any peak flow period as discussed in Section C.4 below and using the minimum C measured during peak flow as discussed in Section C.5 below.

The following steps may be used to calculate CT for a water treatment plant (WTP):

- Identify the disinfection segments at the WTP.
- Determine the peak flow rate(s) within each disinfection segment.
- Determine or calculate the total T for each disinfection segment during peak flow.
- Measure C at the end of each disinfection segment during peak flow.
- Calculate CT for each disinfection segment during peak flow.

C.2 Identifying Disinfection Segments

A disinfection segment is a portion of a WTP beginning at a disinfectant application or monitoring point – or beginning at the point where water is last exposed to the open

atmosphere when calculating CT for virus inactivation after water is last exposed to the open atmosphere – and ending at the next disinfectant monitoring point. Every disinfection segment has an associated disinfectant monitoring point. WTPs with multiple treatment trains will have multiple disinfection segments. The end of the last disinfection segment must be before or at the first customer, which is often the WTP itself.

When calculating CT for virus inactivation of source water, the first disinfectant application point is the beginning of the first disinfection segment. However, when calculating CT for virus inactivation after water is last exposed to the open atmosphere, the point where water is last exposed to the open atmosphere is the beginning of the first disinfection segment.

For WTPs with multiple points of disinfectant application – such as chlorine application at two different points, chlorine application followed by chloramines application, chlorine dioxide or ozone application followed by chlorine or chloramines application – each disinfectant application point after the beginning of the first disinfection segment is the beginning of a new disinfection segment. Also, for WTPs utilizing lime softening, each point where pH is adjusted after the beginning of the first disinfection segment shall be considered the beginning of a new disinfection segment if chlorine or chloramines are being used for disinfection and the pH adjustment is significant enough to necessitate the use of a different CT table or a different portion of a CT table. Each disinfection segment has an associated disinfectant monitoring point, which must be prior to the next disinfectant application point or before or at the first customer and which establishes the end of the disinfection segment.

For WTPs involving only one point of disinfectant application and no lime softening, ground water systems may determine total inactivation based upon one point of disinfectant monitoring (i.e., based upon one disinfection segment) or may choose to monitor residual disinfectant concentration at two or more points before or at the first customer and, thus, create two or more disinfection segments. Each disinfectant monitoring point establishes the end of a disinfection segment.

If a WTP with multiple treatment trains has identical treatment trains with flow split equally between the treatment trains, the disinfection segment, and the CT, for each treatment train will be the same. However, if the treatment trains are different or if flow is not split equally between the treatment trains, CT must be calculated separately for each treatment train.

Each disinfection segment could include pipelines and/or tanks. The starting point for identifying disinfection segments and the pipelines and/or tanks within each segment is to develop a schematic drawing of the WTP. The schematic drawing shall show all water treatment facilities and disinfectant application and monitoring points and shall

indicate whether treatment facilities are exposing water to the open atmosphere. Treatment facilities are not considered to be exposing water to the open atmosphere if the treatment facilities are covered by an impervious roof and are enclosed within impervious sidewalls or at least 20-mesh screen sidewalls. Also, even in filters that are exposed to the open atmosphere, water is considered to be no longer exposed to the open atmosphere once the water moves below the surface of the filter media, provided the water is not exposed to the open atmosphere after filtration.

C.3 Determining Peak Flow

T is a function of flow rate. When the flow rate increases, T decreases. Using the peak flow rate provides a conservative value for T and, thus, for CT.

Some WTPs might have a single peak flow rate across the WTP. At other WTPs, the peak flow rate might vary across the WTP meaning that, if there are multiple disinfection segments as discussed in Section C.2 above, the peak flow rate might vary between or within the disinfection segments. Smaller GWSs that are designed to serve 300 or fewer connections or 1,000 or fewer people and that are not designed to provide fire protection generally have WTPs that include hydropneumatic tanks, that are designed to meet the GWS's peak instantaneous water demand, and that will have that one peak flow rate (equal to the design peak instantaneous water demand) across the WTP. As the number of service connections approaches 300 or as the service population approaches 1,000 people, peak instantaneous demand approaches peak-hour demand. Thus, larger GWSs that are designed to serve more than 300 service connections or more than 1,000 people or that are designed to provide fire protection generally have WTPs that are designed to meet the GWS's maximum-day water demand and have water storage facilities at the WTP or in the distribution system to meet the GWS's design peak-hour water demands and fire demands. WTPs for such larger GWSs generally will have one peak flow rate, equal to the design maximum-day water demand, upstream of any water storage facilities at the WTP and a different peak flow rate downstream of any water storage facilities at the WTP. The peak flow rate downstream of any water storage facilities at the WTP generally will be sufficient, when combined with any elevated equalization storage capacity in the distribution system, to meet the design peak-hour water demand for four consecutive hours.

The peak flow rate into, through, or out of a pipeline or tank at a WTP is generally the design flow rate as discussed above or the maximum pumping rate into, through, or out of the pipeline or tank. In cases where the design flow rate or maximum pumping rate into a tank is different from the design flow rate or maximum pumping rate out of the tank, the design flow rate or maximum pumping rate out of the tank shall be used to determine T in the tank. In cases where the maximum pumping rate will vary depending on varying pressure in a pipeline or tank, the maximum pumping rate at the

minimum operating pressure in the pipeline or tank shall be used to determine T in the pipeline or tank.

C.4 Determining or Calculating T

If there are multiple disinfection segments as discussed in Section C.2 above, T must be determined or calculated for each disinfection segment.

T must be determined or calculated during peak flow as discussed in Section C.3 above.

In pipelines flowing full, T is calculated assuming plug flow (i.e., assuming all water moves in a uniform manner over time between two points); thus, T in pipelines flowing full is equal to the mean or theoretical detention time (TDT) in the pipeline during peak flow. In mixing basins, flocculation basins, settling basins, filters, clearwells, storage tanks, and any other tanks, water generally does not move in a uniform manner; therefore, T in tanks is defined as the time that 90 percent of the water passing through the tank is retained within the tank (i.e., as the time it takes for ten percent of the water to pass through the tank) and is determined by a tracer study as discussed in Appendix C to the "Surface Water Guidance Manual," or is calculated as discussed below by multiplying the TDT in the tank during peak flow times a baffling factor (BF) that is representative of the baffling conditions in the tank.

The following steps may be used to calculate T for each disinfection segment during peak flow:

- Determine the internal volume of each pipeline, and the water volume in each tank, in the segment.
- Determine the TDT in each of the segment's pipelines and tanks during peak flow.
- Determine the BF for each tank in the segment.
- Calculate the T in each of the segment's pipelines during peak flow based on the TDT in the pipeline during peak flow and determine the T in each of the segment's tanks during peak flow based on the TDT in the tank during peak flow and the BF for the tank.
- Sum the individual Ts in each of the segment's pipelines and tanks during peak flow to obtain the total T for the segment during peak flow.

Determining Water Volume in Tanks. Some tanks, such as clearwells and storage tanks, can have fluctuating water levels that affect the volume of water in the tanks. In such

cases, the volume of water in the tank shall be determined using the lowest water level expected in the tank during any peak flow period or, to be more conservative, using the minimum possible water level that could occur in the tank (i.e., the pump shutoff level).

The volume of water in horizontal hydropneumatic tanks with a separate inlet and outlet shall be determined using the water level in the tank at minimum operating pressure. Exhibit C-1 can be used to determine this water volume in cases where the tank diameter and gross tank volume, as well as the water level in the tank at minimum operating pressure, are known. For minimally sized hydropneumatic tanks that are pre-pressurized to five or ten pounds per square inch gauge (psig) below a minimum operating pressure of 35 psig, the volume at minimum operating pressure will be about ten or 20 percent, respectively, of the gross tank volume. Hydropneumatic tanks with a single inlet/outlet do not necessarily provide any T, and thus, the volume of such tanks shall be ignored when determining T.

The volume of water in clearwells and storage tanks may be determined assuming the water level in the tank during peak flow is above the low water level (i.e., the pump shutoff level) in the tank by an amount representing 15 percent of the water volume between the low water level and high water level in the tank.

Filters generally can be considered to have a porosity of about 0.4. Therefore, the volume of water in filter media pores (i.e., the volume of water in filters below the surface of the filter media) shall be determined by multiplying the internal volume of the filter box below the surface of the filter media times 0.4.

Determining TDT in Pipelines or Tanks. TDT is the time that water is in a pipeline or tank assuming plug flow (i.e. assuming all water moves in a uniform manner over time between two points). TDT in pipelines flowing full during peak flow is determined by dividing the internal volume of the pipeline by the peak flow rate through the pipeline, and TDT in tanks during peak flow is determined by dividing the minimum water volume expected in the tank during any peak flow period by the peak flow rate out of the tank.

Equation C-1:

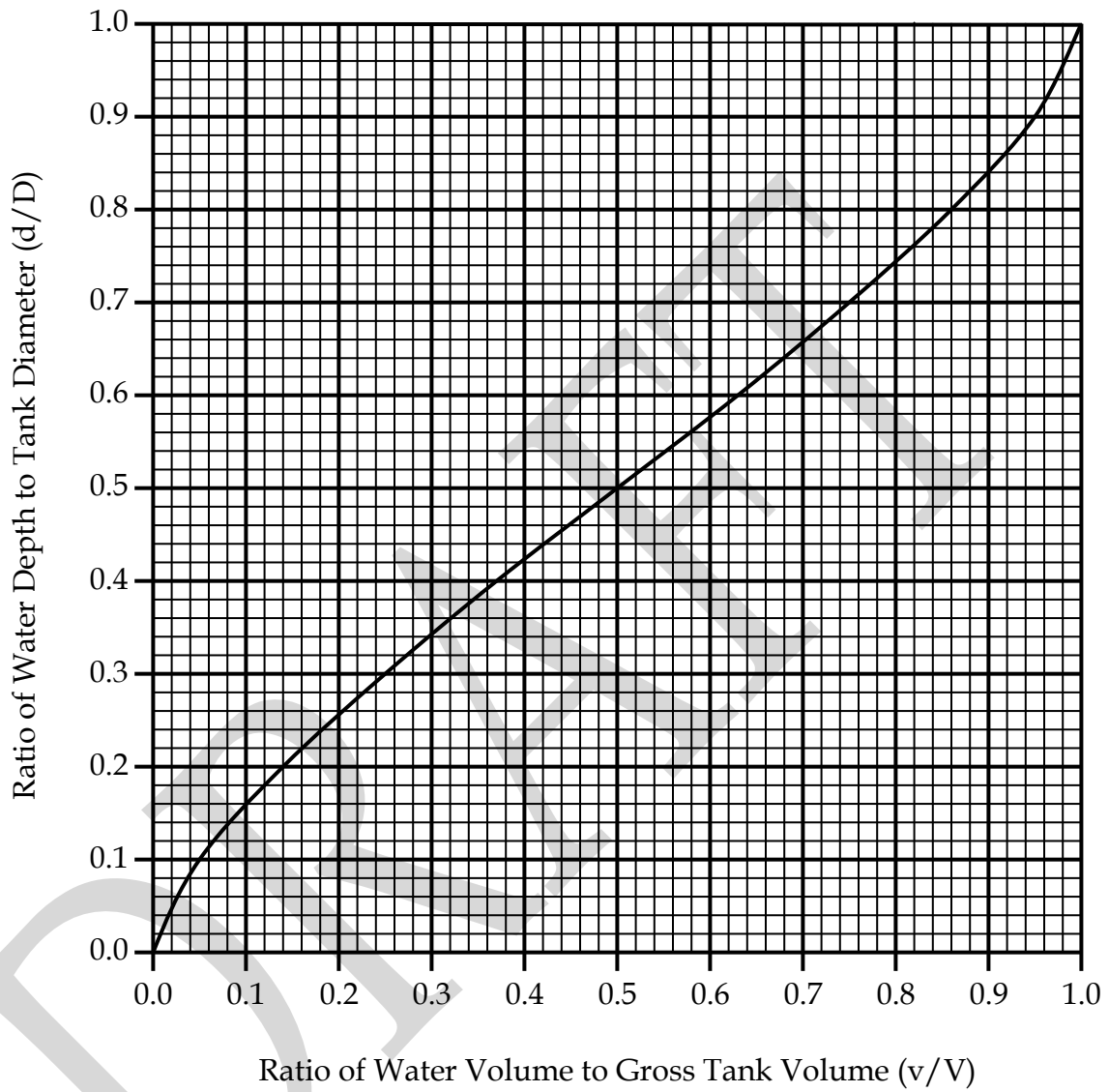
$$TDT = V/Q,$$

where TDT = theoretical detention time, in minutes, in pipeline during peak flow; or theoretical detention time, in minutes, in tank during peak flow;

V = volume, in gallons, in pipeline; or minimum water volume, in gallons, expected in tank during any peak flow period; and

Q = peak flow rate, in gallons per minute (gpm), through pipeline; or peak flow rate, in gpm, out of tank.

Exhibit C-1: Hydraulic Elements of Horizontal Hydropneumatic Tanks



Determining BFs. BFs are “rule-of-thumb” fractions representing the ratio of T to TDT for tanks and will vary depending on tank baffling conditions. Based on tracer studies, BFs have been developed for five general classifications of baffling conditions – unbaffled (mixed flow), poor, average, superior, and perfect (plug flow) – as shown in Table C-1. The BF for plug flow is included in Table C-1 for comparative purposes; however, in practice, the BF of 1.0 for plug flow is seldom achieved because of the effect of dead space in tanks.

The Florida Rural Water Association currently is conducting a special Florida Department of Environmental Protection study consisting of tracer studies for typical horizontal hydropneumatic tanks with a separate inlet and outlet. Pending completion of this study, GWSs shall use a BF of 0.1 for horizontal hydropneumatic tanks with a separate inlet and outlet and for clearwells or storage tanks with a separate inlet and outlet and no intra-tank baffling.

Calculating T. T in pipelines flowing full during peak flow is equal to the TDT in the pipeline during peak flow. T in tanks during peak flow is calculated by multiplying the TDT in the tank during peak flow times the BF for the tank.

Equation C-2:

$$T \text{ (in tanks)} = TDT \times BF,$$

where T = disinfectant contact time, in minutes, in tank during peak flow;

TDT = theoretical detention time, in minutes; in tank during peak flow;

and

BF = baffling factor.

The total T for the segment during peak flow is calculated by summing the individual Ts in each of the segment’s pipelines and tanks during peak flow.

C.5 Measuring C

C must be measured before or at the first customer. The first customer is the point at which water is first consumed. In many cases, the WTP itself is the first customer.

If there are multiple disinfection segments as discussed under Section C.3 above, C must be measured for each segment. The C measurement point establishes the end of each disinfection segment.

C must be measured during peak flow. If there are multiple disinfection segments and if peak flow occurs at different times in the different segments, C for each segment shall be measured during the time of peak flow through the last segment. In cases where daily grab sample measurements are taken, the samples shall be taken when pumps are

Table C-1: Baffling Factors (BFs)

Baffling Condition	BF	Baffling Description	Examples
Unbaffled (mixed flow)	0.1	No baffling, agitated basin, very low length-to-width ratio, high inlet and outlet flow velocities	<ul style="list-style-type: none"> • Circular, turbine ozone contactor • Clearwell or storage tank, including a hydropneumatic tank, with a separate inlet and outlet and no intra-tank baffling*
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles	<ul style="list-style-type: none"> • Rectangular basin with multiple unbaffled inlet and outlet pipes and with no intra-basin baffles • Circular basin with an unbaffled center-feed inlet and with a weir at the outlet • Unbaffled, single-compartment flocculation basin • Single-stage ozone contactor • Settling basin that has an integrated flocculator without effective baffling at the flocculator/settling basin interface and without intra-basin baffling • Clearwell or storage tank with one or two intra-tank baffles or with a length-to-width ratio greater than 10
Average	0.5	Baffled inlet or outlet with some intra-basin baffles	<ul style="list-style-type: none"> • Rectangular basin with an inlet diffuser wall and with intra-basin baffling • Circular basin with an annular-ring baffle at the center-feed inlet and with a weir at the outlet • Baffled flocculation basin with two or more compartments • Multiple-stage ozone contactor • Settling basin that has an integrated flocculator without effective baffling at the flocculator/settling basin interface but with intra-basin and outlet baffling • Clearwell or storage tank with three or four intra-tank baffles or with a length-to-width ratio greater than 20

continued on next page

Table C-1: Baffling Factors (BFs) (continued)

Baffling Condition	BF	Baffling Description	Examples
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders	<ul style="list-style-type: none"> • Rectangular basin with submerged target-baffled ports at the inlet and with a sharp-crested full-width weir at the outlet • Circular basin with a perforated baffle at the center-feed inlet and with submerged orifice ports at the outlet • Filters, including the water volume above the filter media, within the filter media and support gravel, and in the underdrains • Clearwell or storage tank with five or more intra-tank baffles or with a length-to-width ratio greater than 50
Perfect (plug flow)	1.0	Very high length-to-width ratio (pipeline flow), perforated inlet and outlet, and intra-basin baffles	

Source: Appendix C to the United States Environmental Protection Agency’s *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, 1991, and the American Water Works Association Research Foundation’s *Improving Clearwell Design for CT Compliance*, 1999.

* Pending completion of the Florida Department of Environmental Protection special study being conducted by the Florida Rural Water Association and consisting of tracer studies of typical horizontal hydropneumatic tanks with a separate inlet and outlet.

pumping at maximum capacity. For community water systems with multiple or variable speed pumps, the pumps generally will be pumping at maximum capacity between 7:00 A.M. and 1:00 P.M. or between 5:00 and 9:00 P.M.

The minimum C measured during peak flow must be used.

C.6 Calculating CT

CT is calculated for each disinfection segment during peak flow by multiplying the C measured at the end of the segment during peak flow times the total T for the segment during peak flow.

If there are multiple disinfection segments using the same disinfectant under the same water pH and temperature conditions, the individual CT values for each segment can be summed to obtain the total CT value for the disinfectant.

Equation C-3:

CT (in minutes-milligrams per liter) = $C \times T$,
where C = residual disinfectant concentration, in milligrams per liter (mg/L),
determined before or at the first customer during peak flow; and
 T = disinfectant contact time, in minutes, during peak flow.

Appendix D: Minimum Ground Water Temperature by Aquifer System and Water Management District

In the absence of sufficient system-specific water temperature data, ground water systems shall estimate their minimum water temperature to be equal to the applicable minimum water temperature in Table D-1.

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Table D-1: Minimum Ground Water Temperature by Aquifer System and Water Management District

Surficial Aquifer System	
Water Management District or Aquifer	Minimum Water Temperature, degrees Celsius (°C)
Northwest Florida Water Management District	18.0
Suwanee River Water Management District	21.0
St. Johns River Water Management District	19.0
Southwest Florida Water Management District	21.0
South Florida Water Management District	18.5
Sand and Gravel Aquifer	18.0
Biscayne Aquifer	18.5
Intermediate Aquifer System	
Water Management District	Minimum Water Temperature, °C
Northwest Florida Water Management District	21.0
Suwanee River Water Management District	18.0
St. Johns River Water Management District	18.0
Southwest Florida Water Management District	23.0
South Florida Water Management District	22.3
Floridan Aquifer System	
Water Management District	Minimum Water Temperature, °C
Northwest Florida Water Management District	19.0
Suwanee River Water Management District	15.0
St. Johns River Water Management District	18.0
Southwest Florida Water Management District	21.5
South Florida Water Management District	22.2

Source: Table 6 in the Florida Geological Survey's Special Publication Number 34, *Florida's Ground Water Quality Monitoring Program - Background Hydrogeochemistry*, 1992.

Appendix E: Analytical Methods Specified in 40 CFR 141.74(a)(2) or in Appendix A to Subpart C of 40 CFR 141

Table E-1 lists analytical methods specified in 40 CFR 141.74(a)(2) or in Appendix A to Subpart C of 40 CFR 141 under the heading "Alternative Testing Methods for Disinfectant Residuals Listed at 40 CFR 141.74(a)(2)." Also, note that the Florida Department of Environmental Protection approves the use of DPD colorimetric test kits for the measurement of residual disinfectant concentrations for free chlorine or chloramines and approves the use of the Industrial Test Systems free chlorine test strip for the determination of free chlorine.

Table E-1: Analytical Methods Specified in 40 CFR 141.74(a)(2) or in Appendix A to Subpart C of 40 CFR 141

Residual	Methodology	SM ¹	SM ²	SM Online ³	Other
Free Chlorine	Amperometric Titration.....	4500-Cl D	4500-Cl D	4500-Cl D-00	D1253-03 ⁴
	DPD Ferrous Titrimetric	4500-Cl F	4500-Cl F	4500-Cl F-00.	
	DPD Colorimetric	4500-Cl G	4500-Cl G	4500-Cl G-00.	
	Syringaldazine (FACTS)	4500-Cl H.....	4500-Cl H	4500-Cl H-00.	
Total Chlorine.....	Amperometric Titration.....	4500-Cl D	4500-Cl D	4500-Cl D-00	D1253-03 ⁴
	Amperometric Titration (low level measurement).....	4500-Cl E.....	4500-Cl E	4500-Cl E-00.	
	DPD Ferrous Titrimetric	4500-Cl F	4500-Cl F	4500-Cl F-00.	
	DPD Colorimetric	4500-Cl G	4500-Cl G	4500-Cl G-00.	
	Iodometric Electrode	4500-Cl I.....	4500-Cl I	4500-Cl I-00.	
Chlorine Dioxide....	Amperometric Titration.....	4500-ClO ₂ C.....	4500-ClO ₂ C	4500-ClO ₂ C-00.	327.0, Revision 1.1 ⁵
	DPD Method.....	4500-ClO ₂ D.			
	Amperometric Titration.....	4500-ClO ₂ E	4500-ClO ₂ E.....	4500-ClO ₂ E-00.	
	Spectrophotometric				
Ozone.....	Indigo Method	4500-O ₃ B	4500-O ₃ B.....	4500-O ₃ B-97.	

¹ All the listed methods are contained in the 18th, 19th, and 20th editions of *Standard Methods for the Examination of Water and Wastewater*, 1992, 1995, and 1998; the cited methods published in any of these four editions may be used.

² *Standard Methods for the Examination of Water and Wastewater*, 21st edition (2005). Available from American Public Health Association, 800 I Street, Northwest, Washington DC 20001-3710.

³ Standard Methods Online are available at <http://www.standardmethods.org>. The year in which each method was approved by the Standard Methods Committee is designated by the last two digits in the method number. The methods listed are the only online versions that may be used.

⁴ *Annual Book of ASTM Standards*, Vol. 11.01, 2004; ASTM International; any year containing the cited version of the method may be used. Copies of this method may be obtained from ASTM International, 100 Barr Harbor Drive, Post Office Box C700, West Conshohocken, PA 19428-2959.

⁵ United States Environmental Protection Agency (USEPA) Method 327.0, Revision 1.1, "Determination of Chlorine Dioxide and Chlorite Ion in Drinking Water Using Lissamine Green B and Horseradish Peroxidase with Detection by Visible Spectrophotometry," USEPA, May 2005, EPA 815-R-05-008. Available online at <http://www.epa.gov/safewater/methods/sourcalt.html>.

Appendix F: Draft United States Environmental Protection Agency Method 334.0, "Determination of Residual Chlorine in Drinking Water Using an On-Line Chlorine Analyzer"



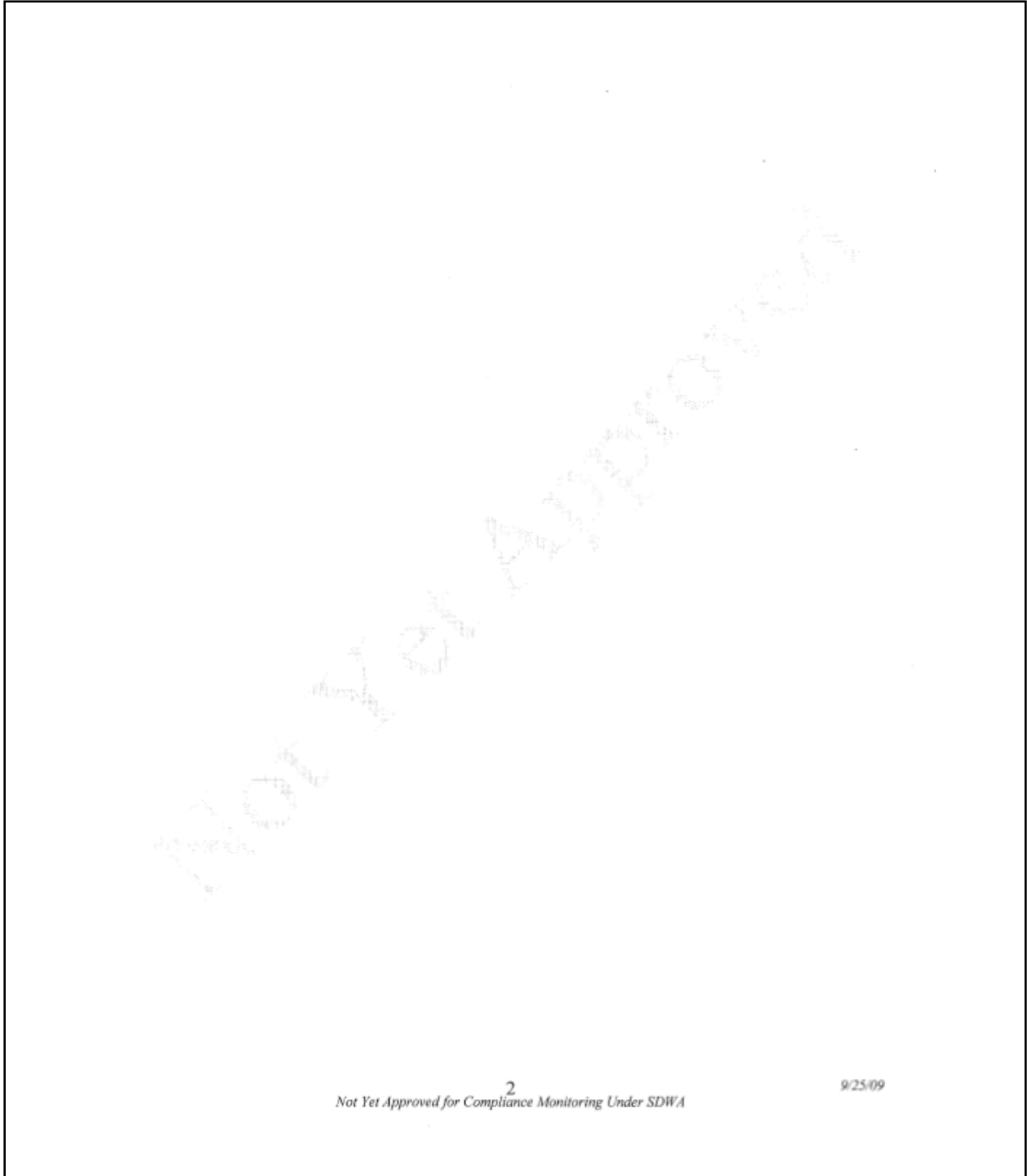
EPA 815-B-09-XXX

**METHOD 334.0 DETERMINATION OF RESIDUAL CHLORINE
IN DRINKING WATER USING AN ON-LINE
CHLORINE ANALYZER**

September 2009

Not Yet Approved for Compliance Monitoring Under SDWA

9/25/09



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Not Yet Approved for Compliance Monitoring Under SDWA

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EPA 815-B-09-XXX

**METHOD 334.0: DETERMINATION OF RESIDUAL CHLORINE
IN DRINKING WATER USING AN ON-LINE
CHLORINE ANALYZER**

Version 1.0

September 2009

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9/23/09

METHOD 334.0**DETERMINATION OF RESIDUAL CHLORINE IN DRINKING WATER
USING AN ON-LINE CHLORINE ANALYZER****1. SCOPE AND APPLICATION**

- 1.1 This method is for the analysis of residual chlorine (free or total) in drinking water. It is primarily intended to be used by drinking water utilities for compliance with daily monitoring requirements. This method allows the use of any type of on-line chlorine analyzer (e.g., amperometric, DPD, etc.) for compliance monitoring when used in conjunction with a grab sample reference method that is approved for drinking water compliance monitoring. This method is intended to be used when chlorine residuals (free or total) are in the range of 0.2 mg/L to 4 mg/L.
- 1.2 The grab sample reference method must be listed in the methods table of the regulation under which the monitoring is being conducted. (A method in Appendix A may be used if it is listed as approved for the regulation.) Color wheels or optical comparison scales are not allowed for methods which specify the use of a spectrophotometer.

2. SUMMARY OF METHOD

- 2.1 An on-line chlorine analyzer is used to continuously monitor the chlorine concentration at a drinking water sample point. The instrument is calibrated using aqueous standards or the results from paired grab samples that are collected at the same sample point and time. The grab samples are analyzed for chlorine (free or total) using a method that is approved for drinking water compliance monitoring. The on-line analyzer accuracy is periodically verified/adjusted based on results from grab sample analyses.

3. INTERFERENCES

- 3.1 A general discussion of potential interferences to the grab sample measurements is included in Standard Method 4500-Cl A.¹ More specific information is included with each reference method and should guide the user when selecting a method. Amperometric titration methods are less subject to interferences from common oxidizing agents, turbidity and color. Organic contaminants and high concentrations of monochloramine may produce false free chlorine readings in colorimetric methods. Colorimetric methods specify procedures to reduce interferences from copper, chromate, and reduced manganese. Strong oxidizing agents (e.g., permanganate, ozone) interfere with free chlorine measurements in all methods.

- 3.2 Consult the manufacturer's literature regarding potential interferences to the measurements by on-line chlorine analyzers. Amperometric analyzers are sensitive to pH, flow and temperature changes, but compensation for these variables is usually incorporated into the design of the analyzer. DPD analyzers are subject to the same interferences as the DPD grab sample methods.

4. SAFETY

- 4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely identified; each chemical compound should be treated as a potential health hazard, and exposure to these chemicals should be minimized. The laboratory/water system is responsible for maintaining documentation of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of Material Safety Data Sheets (MSDS) should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available.²⁻⁵

5. EQUIPMENT AND SUPPLIES

- 5.1 **ON-LINE CHLORINE ANALYZER** – The selection of an analyzer must consider the water quality characteristics of the drinking water, the treatment process, and the physical location of the analyzer installation. Some of the water quality parameters to consider include variability in the water pH, temperature, ionic strength and the presence of potential interferences such as iron, manganese, and copper. The treatment process dictates whether the on-line analyzer must measure free or total chlorine residuals. The concentration of residual chlorine being measured establishes the required instrument range. The range should be as small as possible, while still bracketing expected concentrations (e.g., Residual concentrations in the range of 0.5 to 1.5 mg/L should be monitored using an analyzer with a linear dynamic range of 0 to 2 mg/L rather than 0 to 10 mg/L.) The analyzer must be installed according to the manufacturer's instructions so that changes in pressure or flow will not influence the analyzer measurements. Install the analyzer as close to the sampling point as feasible and in a location that is easily accessible for maintenance. Install a sample tap as close as feasible to the location where the sample enters the analyzer to allow for collection of discrete grab samples for calibration and accuracy verification.
- 5.1.1. The analyzer must have a readout at its installation location and the readings must be continually recorded (hard copy chart or electronic data). For remote installations, the analyzer should also have the capability for transmission of the output to a centralized location.
- 5.1.2. The on-line monitoring system should have the capability to activate an alarm when the chlorine concentration is outside the normal operating range.

- 5.1.3. The analyzer must allow manual adjustment for calibration.
- 5.2. GRAB SAMPLE REFERENCE METHOD – Amperometric titration or N,N-Diethyl-p-phenylenediamine (DPD) colorimetric methods are the most commonly used approved grab sample methods. Additional choices are included in the methods table of the regulation under which monitoring is being conducted. Consult the method for a listing of equipment and supplies.
- 5.3. GLASSWARE – Free of chlorine demand. See ASTM D 1253-03⁶ or Standard Method 4500-Cl D¹, if glassware needs to be treated to remove chlorine demand.
- 5.3.1. BEAKERS – Varying sizes.
- 5.3.2. VOLUMETRIC FLASKS – Class A, of varying sizes.
- 5.3.3. PIPETTES – Class A, varying sizes or a variable volume single channel pipette with disposable plastic tips. (e.g., Eppendorf Series 2000 pipetter, No. 022470302; or Hach Tensette® pipette, No 1970001)

6. REAGENTS AND STANDARDS

- 6.1. REFER TO THE ON-LINE CHLORINE ANALYZER OPERATING MANUAL FOR A LIST OF REAGENTS SPECIFIC TO THE INSTRUMENT – Reagent grade or better chemicals should be used. Unless otherwise indicated, all reagents should conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first determined that the reagent is of sufficiently high purity to permit its use without lessening the quality of the determination. Reagents must be stored according to the manufacturer's recommendations and only used within the manufacturer's designated lifespan (prior to expiration date).
- 6.2. REFER TO THE SELECTED GRAB SAMPLE METHOD FOR A LIST OF REAGENTS SPECIFIC TO THE METHOD – Reagent grade or better chemicals should be used. Unless otherwise indicated, all reagents should conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first determined that the reagent is of sufficiently high purity to permit its use without lessening the quality of the determination. Titrants that are purchased in their diluted form, ready to use in the grab sample method, should be NIST traceable or certified in an equivalent manner. Reagents must be stored according to the manufacturer's recommendations and only used within the manufacturer's designated lifespan (prior to expiration date).
- 6.3. REAGENT WATER – Purified water (typically either deionized or distilled) is usually acceptable. Reagent water can be purchased from a scientific supply company, if it is not available on site. If a chlorine demand is present, suggested

procedures for preparing chlorine demand-free water are included in ASTM D 1253-03⁶ and Standard Method 4500-Cl C¹.

- 6.4 **CALIBRATION STANDARD SOLUTIONS** – Use the type of aqueous standard (e.g., chlorine or potassium permanganate) specified in the selected grab sample method. A concentrated stock standard solution can be purchased from a commercial source (e.g., Environmental Resource Associates, Catalog # 696; Hach, Product # 1426820, or equivalent). A purchased stock standard must be NIST traceable or certified in an equivalent manner. The stock standard must be stored according to the manufacturer's recommendations and only used within the manufacturer's designated lifespan (prior to expiration date). The stock solution is diluted using reagent water to obtain calibration standard solutions in the range of 0.2 mg/L to 4.0 mg/L. Calibration standards should be prepared fresh for each use unless manufacturer's instructions specify otherwise.
- 6.5 **ROUTINE GRAB SAMPLE CALIBRATION CHECK STANDARD** – Calibration standards prepared above may also be used as calibration check standards. Calibration check standards must be freshly prepared.
- 6.6 **SECONDARY STANDARD** – Colorimetric standards may be purchased for use with DPD spectrophotometers/colorimeters. The accuracy of secondary standards must be verified on each recently-calibrated spectrophotometer/colorimeter for which they will be used. Secondary standards may not be used to calibrate the spectrophotometer.
- 6.7 **INDEPENDENT REFERENCE SAMPLE** – Purchase a chlorine standard solution that is NIST traceable or certified in an equivalent manner from a different source than the source of the calibration standards. Calibration standards and the independent reference samples that are purchased from the same supplier must be from different lots. The independent reference sample must be stored according to the manufacturer's recommendations and only used within the manufacturer's designated lifespan (prior to expiration date).

7. **SAMPLE COLLECTION, PRESERVATION, AND STORAGE**

- 7.1 **SAMPLE COLLECTION** – The grab sample collection point should be as close as possible to the location where the sample enters the on-line chlorine analyzer, so that the grab sample reflects the same water as the on-line analyzer is measuring. A sample line may be equipped with a valve (e.g., T or Y configuration) that allows for intermittent grab sampling with minimal disruption of flow to the analyzer. Follow the sample collection instructions specified in the grab sample method. Collect the grab sample with minimal agitation. Exposure to sunlight or strong light will cause loss of chlorine. Begin analysis immediately after sample collection. Do not store samples.

8. QUALITY CONTROL

- 8.1 Quality control (QC) procedures are incorporated into analytical methods in order to demonstrate that the results are valid and within the accuracy and precision ranges needed for protection of public health. Grab sample methods for measuring chlorine residuals are designed to be independent of other chlorine measurement methods. As a result, some of the normal QC requirements may not be necessary when the grab sample method is used in conjunction with an on-line chlorine analyzer. For example, Part 4020 in Standard Methods¹ indicates daily analysis of method blanks, calibration check standards, fortified blanks, and duplicates (with each batch of samples). Although these QC samples are useful and may be included as part of the standard operating procedure (SOP), they are not necessary when the grab sample measurement is being compared to an analyzer measurement because the comparison of the two measurements serves as a QC check. If grab sample analyses are only being performed in conjunction with on-line chlorine analyzers, the analyst is only required to follow the minimum requirements set forth in this method. However, this method is not intended to supersede the QC requirements that are requisite when the data are used for other purposes.
- 8.2 The requirements of the QC program for the grab sample method that is used as the reference for the on-line chlorine analyzer consist of an Initial Demonstration of Capability (IDC) and periodic analyses of calibration check standards and independent reference samples. The QC program for the on-line chlorine analyzer consists of an IDC and periodic comparisons of the instrument reading to results of a sample analyzed using the grab sample reference method. These QC procedures and the acceptance criteria are described in Sections 10 and 11 of this method. It is desirable to maintain consistency with regard to personnel responsible for instrument QA/QC checks and related field sampling.
- 8.3 **OPTIONAL QC** – Laboratories/water systems are encouraged to institute additional QC practices to meet their specific needs. The remainder of this section describes various optional QC procedures that may be incorporated into a QC program for grab sample verification of on-line chlorine analyzer performance.
- 8.3.1. **GRAB SAMPLE DUPLICATE** – Analysis of duplicate grab samples (two samples collected at the same time) provides an estimate of the precision of the grab sample analyses that are used to verify/adjust the accuracy of the on-line chlorine analyzer. Poor grab sample precision can cause problems in the analyzer adjustment. Analysis of grab sample duplicates is suggested when there are difficulties in adjusting the analyzer calibration to agree with the grab sample measurement. Calculate the relative percent difference (RPD) between the Sample (FD1) and the Sample Duplicate (FD2) as shown below. The RPD for samples with concentrations greater than the lowest calibration standard should not exceed 15%. The RPD at concentrations at or near the lowest calibration standard should not exceed 50%.

$$RPD = \frac{|FD1 - FD2|}{(FD1 + FD2)/2} \times 100\%$$

If the *RPD* for the Sample and the Sample Duplicate falls outside the designated range, perform duplicate analyses of a calibration check standard to verify that the grab sample method is in control.

- 8.3.2. **INDEPENDENT REFERENCE SAMPLE** – Analysis of a sample from an external source (different from the calibration standards) provides an independent check of the calibration of the grab sample method. It is recommended semiannually or any time a new calibration curve is generated.
- 8.3.3. **PROFICIENCY TESTING (PT) or PERFORMANCE EVALUATION (PE) SAMPLE** – Successful participation in a PT or PE Study is a good QC tool for demonstrating proficiency with the grab sample method. A certified solution of chlorine whose concentration is unknown to the analyst can be purchased by the laboratory/water system. An aliquot of the certified solution is added to a known volume of reagent water and analyzed as a grab sample. The analytical results are reported to the PT/PE Study Provider where they are compared to data from all analyses of the sample. Acceptance criteria are established for each study. Generally, a different analyst should participate in each study, so that over time each analyst has an opportunity to demonstrate proficiency. If the analyst is a field sampler, the sample can be prepared by laboratory personnel for the analyst.

9. CALIBRATION

- 9.1 An acceptable initial calibration for the grab sample method must be established before the results from the grab sample method can be used to verify the accuracy of an on-line chlorine analyzer. After initial calibration is successful, a calibration check standard or independent reference sample is periodically analyzed to verify that the grab sample method calibration is still valid.
- 9.2 The calibration of the on-line chlorine analyzer is verified against a grab sample measurement. (On-line chlorine analyzers that use the same chemistry as an approved grab sample method may use aqueous standards for initial calibration verification instead of comparison to grab sample measurements. Routine calibration checks are made by comparison with grab sample measurements.)
- 9.3 The calibration procedures and acceptance criteria are described in Sections 10 and 11 of this method.

10. START-UP PROCEDURES

10.1 GRAB SAMPLE METHOD – Refer to the selected grab sample method for a complete description of the procedure. (Each drinking water regulation includes a tabular listing of methods that are approved for analyses of compliance samples. The regulation also identifies how to obtain a copy of each method.) Section 15 – Table 1 and Flowchart 1 summarize the start up QC for the grab sample method.

10.1.1. **Prepare or verify the initial calibration curve.** This must be done for each meter or titrator according to the procedure described below. The accuracy of secondary standards must also be verified. These steps can be performed by laboratory personnel or field samplers. A record of the calibration results must be maintained for each meter/titrator.

10.1.1.1. Prepare a method blank (reagent water) and a set of at least three aqueous calibration standards. The lowest concentration calibration standard must be at or below 0.2 mg/L or the minimum chlorine residual required by the state. The standards must span the concentration range that is expected to be observed in the grab samples. (Note: If the range extends above the maximum concentration specified for the DPD reagents and colorimeter, prepare three standards within the range specified by the manufacturer and a fourth standard at the highest concentration expected for the grab samples.)

10.1.1.2. Analyze the calibration standards and method blank according to the grab sample procedure. (Note: If the highest concentration standard is above the maximum concentration specified for the DPD reagents and colorimeter, dilute and analyze it according to manufacturer's instructions. Use the data from this analysis to check the accuracy of the dilution process, not the calibration curve.)

10.1.1.2.1. For methods that do not require the preparation of a curve or that use an internal, factory set calibration curve, compare the measured concentration of each standard to the expected value. Each calibration point must be within $\pm 15\%$ of its expected value. If the internal curve does not meet these criteria, the internal curve must be updated by following the manufacturers' instructions for generating/inputting a curve. Otherwise, send the meter to the vendor for repair/updating.

10.1.1.2.2. For methods that require the preparation of a curve, use the concentration of each standard versus the instrument response to calculate the best fit curve according to the procedure described in the grab

sample method. Validate the curve by calculating the concentration of each standard using the curve. Each calibration point must be within $\pm 15\%$ of its expected value.

10.1.1.3. If secondary standards are available for the grab sample method, they must be verified prior to use by analyzing them immediately after initial calibration is verified. The secondary standards must be within $\pm 10\%$ of their expected concentrations when compared to the initial calibration curve. New secondary standards must be purchased if this criterion cannot be met. The secondary standards must meet the criterion on every meter for which they will be used. Secondary standards must be verified each time the initial calibration procedure is repeated. Secondary standards must not be used beyond the manufacturer's expiration date.

10.1.2. Each field sampler must perform an **initial demonstration of capability (IDC)** prior to using the grab sample method to verify the accuracy of on-line chlorine analyzers. If the accuracy and precision criteria described below are not met, determine the source of the problem, take corrective action and repeat the IDC. The IDC consists of a demonstration of accuracy and a demonstration of precision using the procedure described below.

10.1.2.1. INITIAL DEMONSTRATION OF ACCURACY – Prepare and analyze a method blank (reagent water) and five independent reference samples at the same concentration. The concentration of the samples should be in the mid range of the calibration curve or near the expected concentration of the water samples. Calculate the average chlorine concentration for the five analyses. The average concentration for the five replicates must be within $\pm 15\%$ of the expected value. The method blank concentration must be $\leq \frac{1}{4}$ the concentration of the lowest standard used to prepare/verify the calibration curve (Section 10.1.1.1).

10.1.2.2. INITIAL DEMONSTRATION OF PRECISION – Using the same set of replicate data generated for Section 10.1.2.1, calculate the standard deviation and relative standard deviation (*RSD*) of the replicate values. The *RSD* is calculated using the equation

$$RSD = \frac{S}{\bar{X}} \times 100\%$$

where

S is the standard deviation for the replicate values,

and \bar{X} is the average value for the replicates.

The RSD of the results of the replicate analyses must be $\leq 15\%$.

10.1.3. Each field sampler must successfully complete the IDC procedure described above (Section 10.1.2) prior to using the grab sample method in conjunction with an on-line chlorine analyzer. Laboratory personnel may prepare the independent reference samples for analyses by field samplers. A record of the IDC results must be maintained for each field sampler.

10.2 ON-LINE CHLORINE ANALYZER – Install the analyzer according to the manufacturer's specifications. Follow all start-up procedures outlined in the operator's manual including specific instructions regarding calibration of the analyzer. The following procedure must be followed for each analyzer. (Section 15 – Table 2 and Flowchart 2 summarize the start-up QC for on-line chlorine analyzers.)

10.2.1. After the analyzer is providing stable readings, proceed with verifying/adjusting the **initial calibration**. If the analyzer uses the same chemistry as an approved grab sample method, the calibration curve can be established/verified using aqueous chlorine standards in a manner similar to the grab sample procedure described above in Section 10.1.1. Alternately, calibration of the analyzer may be verified/adjusted based on the results of grab sample measurements as described below. All other types of analyzers must use the following procedure:

10.2.1.1. Collect and analyze a grab sample collected as close as feasible to the location where the sample enters the on-line chlorine analyzer. Compare the results from the grab sample analysis to the measurement made by the on-line chlorine analyzer.

10.2.1.2. Follow the manufacturer's instructions to adjust the calibration of the analyzer so it gives the same value as the grab sample analysis.

10.2.1.3. Repeat steps 10.2.1.1 and 10.2.1.2 until the on-line chlorine analyzer measurement agrees with the grab sample measurement. (Ideally, the two measurements will be the same, but realistically this won't always be possible. Note that during routine operation of the analyzer, the readings must be within ± 0.1 mg/L or $\pm 15\%$ of the grab sample measurement. Use that criterion as a guide for deciding when the analyzer calibration is properly adjusted during this start-up procedure.)

10.2.2. Conduct the **initial demonstration of capability (IDC)** after the calibration of the on-line chlorine analyzer has been verified. Requirements for the IDC are described in 10.2.2.3. The full IDC must be conducted prior to using the analyzer for compliance monitoring

measurements. This will take a minimum of 14 days. The data collected during the IDC must be recorded and maintained.

10.2.2.1. The IDC for the on-line chlorine analyzer is not required if historical operating data for the on-line chlorine analyzer demonstrate the criterion are being met on an on-going basis. Historical data must show that the analyzer remains in agreement with the grab sample method over a period of two consecutive weeks without analyzer maintenance or calibration adjustment. Agreement is defined as being within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement. The following procedures must be completed prior to using the analyzer for compliance monitoring.

10.2.2.1.1. Verify the calibration of the grab sample measurement according to 10.1.1.

10.2.2.1.2. Each field sampler must complete the IDC requirements for the grab sample measurement according to 10.1.2.

10.2.2.1.3. Calibration of the on-line chlorine analyzer must be verified according to 10.2.1 after the grab sample IDC is completed.

10.2.2.1.4. Proceed to 10.2.3.

10.2.2.2. When multiple on-line chlorine analyzers are being installed, the primacy agency may allow the IDC to be shortened under the following conditions.

10.2.2.2.1. The same model analyzer is installed at each location.

10.2.2.2.2. The water quality characteristics and treatment processes are equivalent at each location.

10.2.2.2.3. A successful IDC (Section 10.2.2.3) is completed for the first analyzer that is placed in service.

10.2.2.2.4. The IDC for subsequent analyzers can be shortened to 7 consecutive days (or 7 consecutive business days) of daily grab sample comparisons. The analyzer reading must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement for each data pair. When you obtain 7 consecutive days (or business days) of data pairs

that meet the acceptance criterion, proceed to 10.2.3.

- 10.2.2.3. Compare the concentration determined by the on-line chlorine analyzer with grab sample analyses collected at least daily for 14 days. (If samples cannot be collected during the weekend, 14 consecutive business days is acceptable.) During the 14 days, grab samples should be collected at concentrations that represent highs and lows, as indicated by the analyzer. (e.g., if the analyzer indicates the chlorine concentration varies between 0.5 mg/L and 1.0 mg/L, grab samples should be collected to verify accuracy at both of these concentrations.) The analyzer reading must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement for each data pair. If this criterion is not met, determine the source of the problem, take corrective action and continue collecting daily grab samples. When you obtain 14 consecutive days (or business days) of data pairs that meet the acceptance criterion, proceed to 10.2.3.
- 10.2.2.4. If you are unable to meet the criterion in 10.2.2.3, verify you have chosen an appropriate analyzer for your water quality and operating conditions. An on-line chlorine analyzer that cannot meet the criterion in 10.2.2.3 may be used for compliance monitoring only if grab sample comparisons are conducted daily or at a frequency approved by the primacy agency.
- 10.2.3. Upon successful completion of the IDC, the analyzer can be put into service for compliance monitoring. Control or warning limits should be established for the analyzer readings, so that operators are immediately alerted to unexpected changes in the chlorine measurements. For remote installations, interfacing the analyzer with a SCADA system, automated phone dialer, or a similar notification system is a critical consideration.
- 10.2.4. A routine schedule for grab sample comparisons can be established based on the results from intense monitoring over the course of the first few months of operation. **The maximum time between grab samples must not exceed once every seven days.** (Appendix A provides an optional systematic approach for establishing a routine schedule for grab sample comparisons. Alternative approaches may be used to determine the optimum frequency of grab sample comparisons.)
- 10.2.5. All manufacturers' recommendations for routine maintenance should be followed. When maintenance is performed, the accuracy of the analyzer must be verified with a grab sample comparison after the analyzer is placed back in service. The accuracy must be verified again after one day of operation (Section 11.2). If the accuracy criteria are not met and

the analyzer is operating properly, adjust the analyzer calibration according to the procedure in Sections 11.2.3 – 11.2.7.

11. ROUTINE PROCEDURES

11.1 **ROUTINE CALIBRATION CHECK FOR THE GRAB SAMPLE METHOD** – Prepare an aqueous calibration check standard at a concentration near the expected concentration of the water samples. (Over time, vary the grab sample calibration check standard concentration when multiple analyzers are being verified and the drinking water chlorine concentration at each analyzer is different.) The grab sample measured concentration of the calibration check standard must be within $\pm 15\%$ of the expected value. If this criterion is not met, the analyst must identify and resolve the problem with the grab sample method prior to proceeding with analyses of grab samples to verify the on-line chlorine analyzer accuracy. The results from analyses of calibration check standards must be recorded and maintained according to the requirements of the primacy agency.

11.1.1. A check standard must be analyzed:

11.1.1.1. when the grab sample measurement is used to adjust the calibration of the on-line chlorine analyzer

11.1.1.2. a minimum of once quarterly.

11.1.2. Analysis of secondary standards is an easy way to verify the spectrophotometer is operating properly for colorimetric methods. Analysis of secondary standards does not replace the analysis of aqueous check standards. Each secondary standard must be within $\pm 10\%$ of its expected concentration.

11.2 **ROUTINE CALIBRATION CHECK FOR ON-LINE CHLORINE ANALYZER** – The accuracy of the on-line chlorine analyzer is monitored during routine use by periodic comparisons of the analyzer readings to grab sample measurements. The maximum time between grab samples must not exceed once every 7 days (i.e., a weekly grab sample). The analyzer concentration must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement. (Section 15 – Table 4 and Flowchart 3 summarize the routine QC for on-line chlorine analyzers.) All data from these comparisons must be recorded and maintained according to the requirements of the primacy agency.

11.2.1. Disagreement between the grab sample and analyzer measurements may indicate a need for maintenance on the analyzer (e.g., flow adjustment, pH adjustment, cleaning, new membrane, fresh reagents, etc.) The operator must conduct trouble-shooting activities and rule out problems with the analyzer prior to making calibration adjustments.

- 11.2.1.1. The operator may perform a second comparison between the analyzer and a grab sample to rule out variability in the grab sample as the cause for disagreement.
- 11.2.1.2. Follow the manufacturer's instructions for troubleshooting problems with the analyzer.
- 11.2.2. If the analyzer is operating properly, verify that the grab sample measurement is accurate by analyzing a grab sample calibration check standard (Section 11.1).
- 11.2.2.1. For remote sites, the accuracy of the grab sample measurement can initially be verified using secondary standards that have been tested for accuracy according to Section 10.1.1.3. The secondary standards must be within $\pm 10\%$ of their expected concentration.
- 11.2.2.2. If secondary standards are used in the field, a grab sample calibration check standard should be analyzed using the same lot of reagents within 24 hours unless an alternative time frame is approved by the primacy agency.
- 11.2.3. After the accuracy of the grab sample measurement is verified, follow the manufacturer's instructions to adjust the calibration of the analyzer so it gives the same value as the grab sample analysis.
- 11.2.4. Confirm that the calibration adjustment is accurate by analyzing another grab sample and comparing the result to the reading from the analyzer.
- 11.2.5. Repeat steps 11.2.3 and 11.2.4 until the on-line chlorine analyzer measurement agrees with the grab sample measurement. (The two measurements should be as close as possible. Note that during routine operation of the analyzer, the readings must be within ± 0.1 mg/L or $\pm 15\%$ of the grab sample measurement. Use that criterion as a guide for deciding when the analyzer calibration is properly adjusted.)
- 11.2.6. An additional grab sample must be collected and analyzed after one day of operation in order to verify that the calibration adjustment was performed accurately. If the criterion is not met, follow 11.2.3 -11.2.6 to adjust the calibration of the analyzer or take other corrective steps consistent with manufacturer instructions.
- 11.2.7. Return to the routine schedule for grab sample comparisons. **A grab sample must be analyzed at least once each week.**
- 11.3 NON-ROUTINE CALIBRATION CHECK FOR ON-LINE CHLORINE ANALYZER – Certain conditions may trigger the need to compare the analyzer reading to a grab sample measurement outside the routine schedule. When a non-

routine comparison is made, the analyzer concentration must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement. If this criterion is not met, the operator must take corrective action to bring the analyzer back into agreement with the grab sample measurement. The steps in Section 11.2 must be followed. Problems with the analyzer must be ruled out or fixed prior to any calibration adjustment to the on-line chlorine analyzer.

11.3.1. The on-line chlorine analyzer measurement must be compared to a grab sample measurement when routine maintenance (such as cleaning, replenishment of reagents, membrane replacement, adjustment of flow rate, pH calibration, etc.) is performed on the analyzer.

11.3.2. If the analyzer measurements indicate a gradual drift upward or downward when no changes in chlorine concentration are expected, a grab sample measurement should be performed.

11.4 **EMERGENCY CALIBRATION CHECK FOR ON-LINE CHLORINE ANALYZER** – If the on-line chlorine analyzer indicates a large ($\geq 50\%$) unexpected change in chlorine residual concentration (based on process control and water quality conditions), a grab sample should be collected and analyzed as soon as possible. When an emergency comparison is made, the analyzer concentration must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement. If this criterion is not met, the operator must take corrective action to bring the analyzer back into agreement with the grab sample measurement. The steps in Section 11.2 must be followed. Problems with the analyzer must be ruled out or fixed prior to any calibration adjustment to the on-line chlorine analyzer.

11.5 **RETURNING AN ON-LINE CHLORINE ANALYZER TO SERVICE** – After a major repair or after replacement of the on-line chlorine analyzer with an equivalent model, follow all start-up procedures outlined in the operator's manual. Calibrate according to the procedure in Section 10.2.1. Return to the routine schedule for grab sample comparisons (Section 11.2) after verifying the accuracy of the analyzer on a daily basis for 7 consecutive days (or business days) or for a period specified by the primacy agency.

12. **POLLUTION PREVENTION**

12.1 Pollution prevention encompasses any technique that reduces or eliminates the quantity or toxicity of waste at the point of generation. Numerous opportunities for pollution prevention exist in laboratory operation. EPA has established a preferred hierarchy of environmental management techniques that places pollution prevention as the management option of first choice. Whenever feasible, laboratory personnel should use pollution prevention techniques to address their waste generation. When wastes cannot be feasibly reduced at the source, the Agency recommends recycling as the next best option.

- 12.2 Quantity of a chemical purchased should be based on expected usage during its shelf-life and disposal cost of unused material. Actual reagent preparation volumes should reflect anticipated usage and reagent stability.
- 12.3 For information about pollution prevention that may be applicable to laboratory operations, consult "Less is Better: Guide to Minimizing Waste in Laboratories."⁷

13. WASTE MANAGEMENT

- 13.1 The analytical procedures described in this method generate relatively small amounts of waste since only small amounts of reagents are used. The matrices of concern are drinking water. However, the Agency requires that waste management practices be conducted consistent with all applicable rules and regulations, and that the air, water, and land is protected by minimizing and controlling all releases from bench operations. Also, compliance is required with any sewage discharge permits and regulations, particularly the hazardous waste identification rules and land disposal restrictions.

14. REFERENCES

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5. Occupational Safety and Health Administration (OSHA), Occupational Exposure to Hazardous Chemicals in Laboratories. 29 CFR 1910.1450.
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7. *Less is Better: Guide to Minimizing Waste in Laboratories*. American Chemical Society, Task Force on Laboratory Environment, Health, & Safety, Washington DC, 2002. (available for download at http://membership.acs.org/C/CCS/pub_9.htm).

15. TABLES AND FLOWCHARTS

Table 1. Summary of Start-up QC for Grab Sample Methodology

Method Reference	Requirement	Specification	Acceptance Criteria
10.1.1.2	Generate or validate calibration curve	Analyze method blank & 3 calibration standards that span concentration range (Lowest standard ≤ 0.2 mg/L or the minimum required by primacy agency.)	Each standard is within $\pm 15\%$ of its expected concentration when compared to curve
10.1.1.3	Verify accuracy of secondary standards	Analyze secondary standards on each meter for which they will be used.	Each secondary standard is within $\pm 10\%$ of its expected concentration
10.1.2.1	Initial Demonstration of Capability (IDC) - Accuracy	Analyze method blank & 5 replicate independent reference samples fortified at a concentration near the drinking water concentration	Method blank $\leq \frac{1}{2}$ concentration of lowest calibration standard; Average of 5 replicates is within $\pm 15\%$ of expected concentration
10.1.2.2	Initial Demonstration of Capability (IDC) - Precision	Calculate relative standard deviation (RSD) for 5 independent reference sample replicate analyses	RSD $\leq 15\%$
10.1.3	Field Sampler IDC	Each sampler must successfully complete 10.1.2.1 and 10.1.2.2 (IDC samples may be prepared by laboratory personnel for analyses by field samplers.)	

Table 2. Summary of Start-up QC for On-line Chlorine Analyzer

Method Reference	Requirement	Specification and Frequency	Acceptance Criteria
10.2.1	Verify or adjust analyzer calibration	Analyze grab sample & compare to analyzer reading; Adjust analyzer to agree with grab sample measurement; Iterative process until agreement is reached	Analyzer reading is within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of grab sample measurement
10.2.2	Initial Demonstration of Capability (IDC)	Compare analyzer measurement to a grab sample analysis on a daily basis for 14 consecutive days (or business days)	Analyzer reading must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement for each data pair

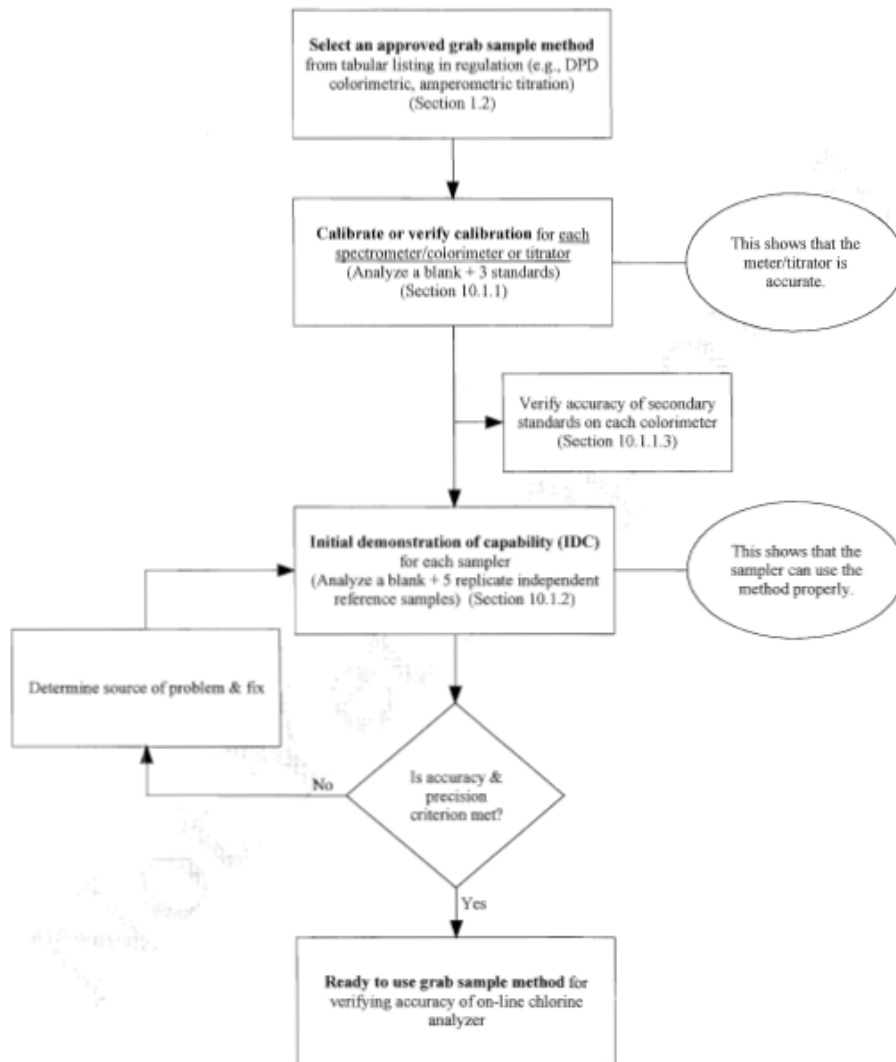
Table 3. Routine QC for Grab Sample Methodology

Method Reference	Requirement	Specification and Frequency	Acceptance Criteria
11.1.1	Routine calibration check	Analyze a check standard: <ul style="list-style-type: none"> • When calibration of the on-line chlorine analyzer is adjusted • At least quarterly 	Standard is within $\pm 15\%$ of its expected concentration
11.1.2	Secondary standards	Recommended: analyze each day grab sample method is used (This is only applicable to methods that use a spectrophotometer/colorimeter.)	Each secondary standard is within $\pm 10\%$ of its expected concentration

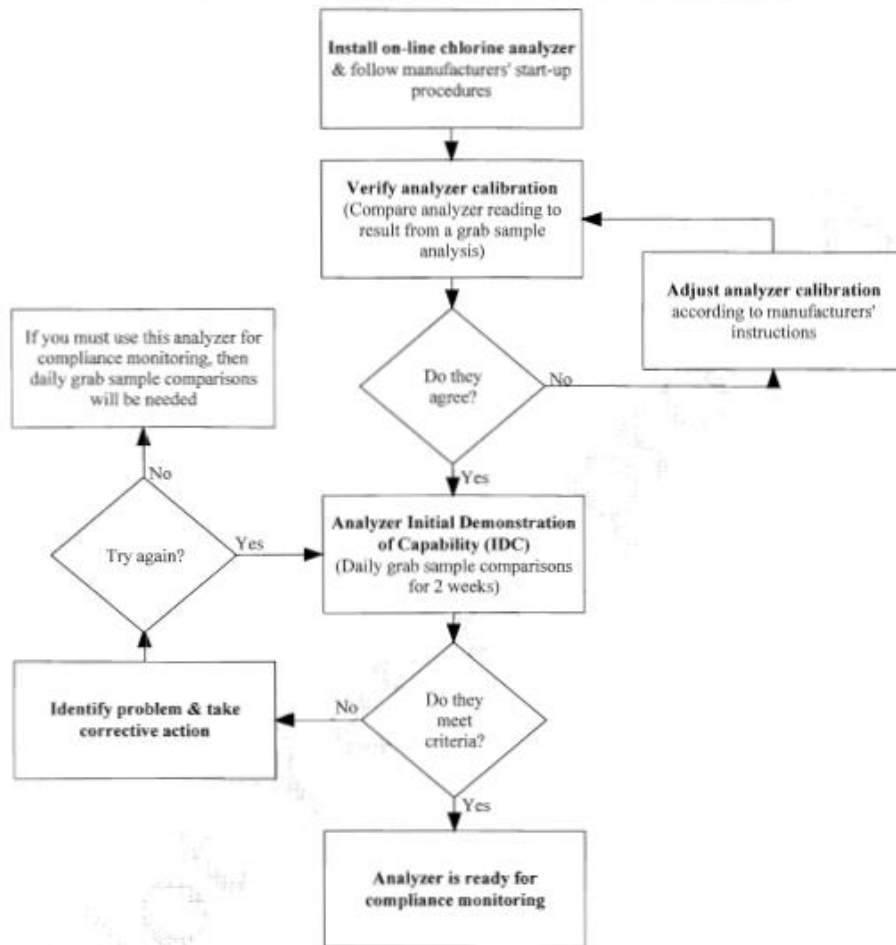
Table 4. QC for On-line Chlorine Analyzer

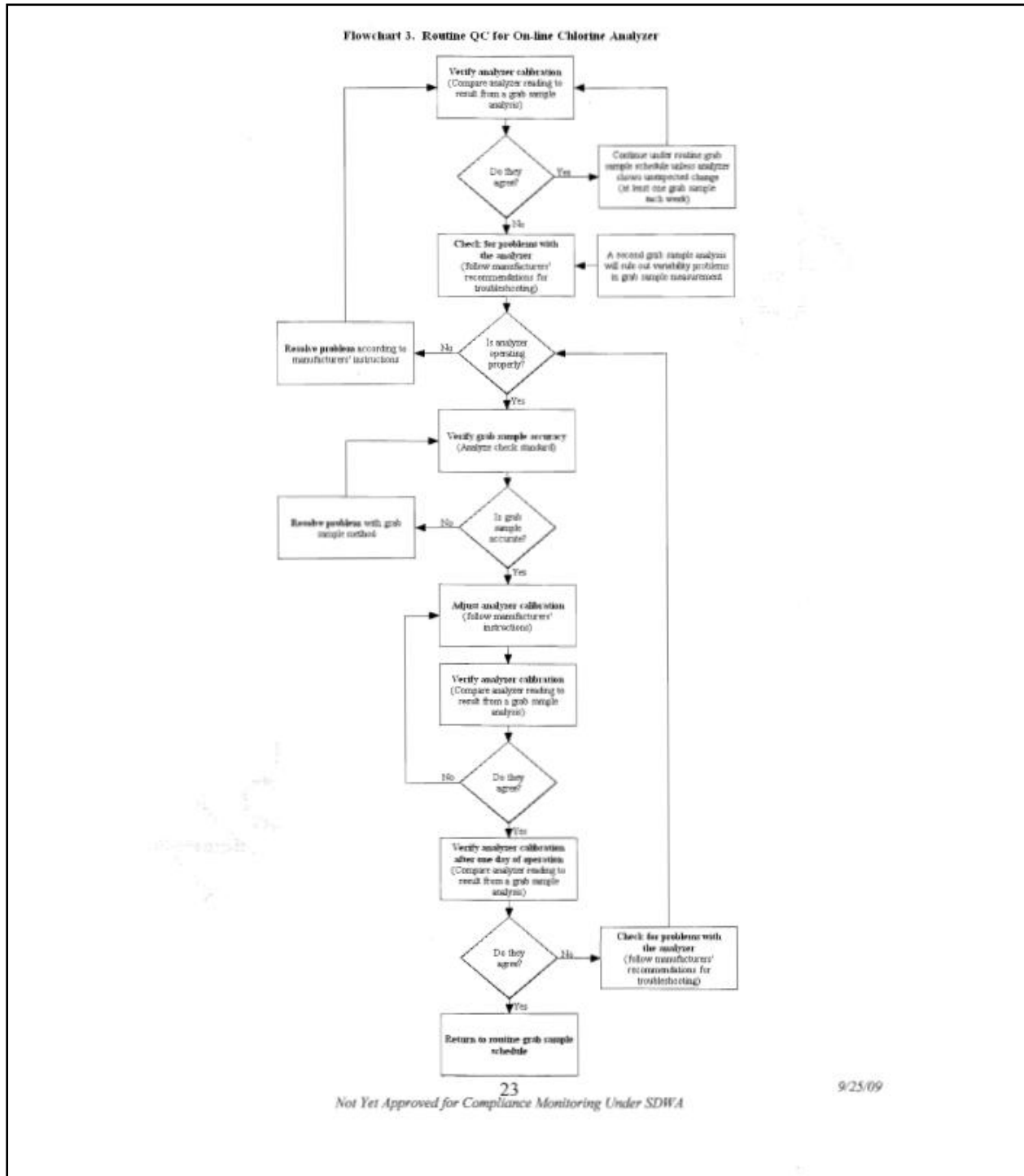
Method Reference	Requirement	Specification and Frequency	Acceptance Criteria
11.2	Routine calibration check	Compare analyzer measurement to a grab sample analysis: <ul style="list-style-type: none"> • on a routine basis (at least once each week) • immediately after analyzer calibration is adjusted • one day after analyzer calibration is adjusted 	Analyzer reading must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement
11.3	Non-routine calibration check	Compare analyzer measurement to a grab sample analysis: <ul style="list-style-type: none"> • after routine maintenance • when analyzer drifts upward or downward without explanation (recommended) 	Analyzer reading must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement
11.4	Emergency calibration check	If the analyzer indicates a large ($\geq 50\%$) unexpected change in chlorine residual, compare analyzer measurement to a grab sample analysis as soon as possible	Analyzer reading must be within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement

Flowchart 1. Start-up Procedure for Grab Sample Method



Flowchart 2. Start-up QC for On-line Chlorine Analyzer



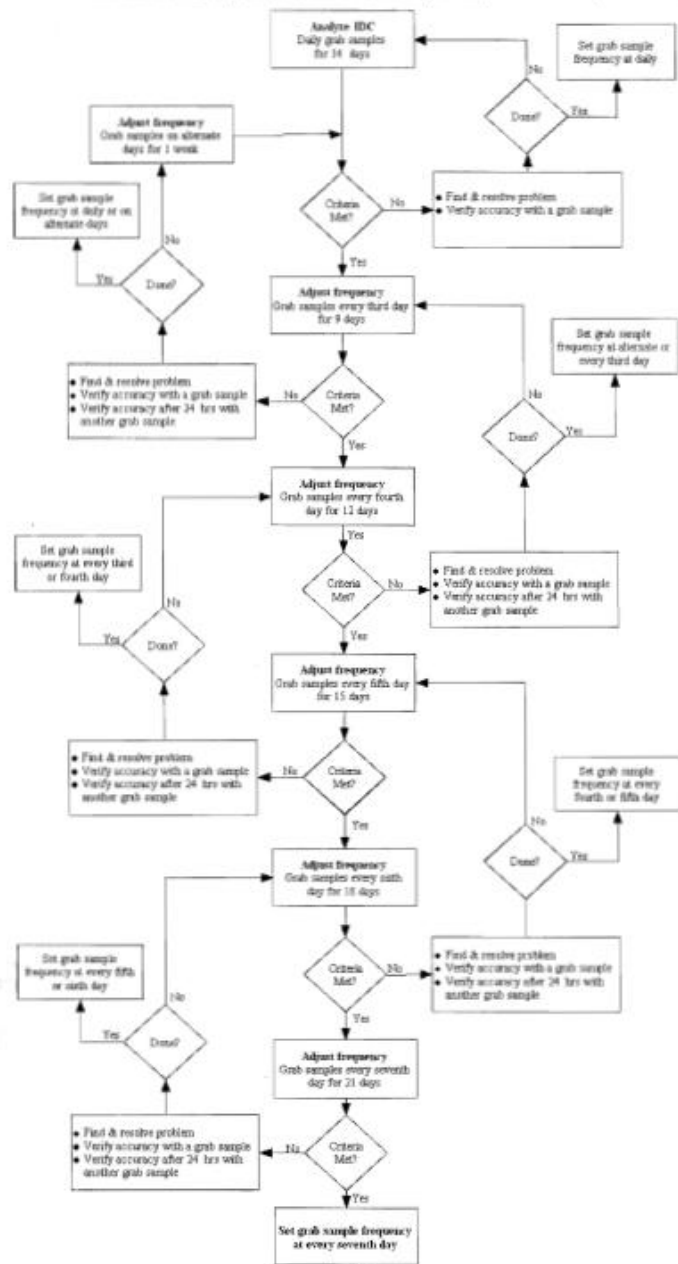


METHOD 334.0 APPENDIX A

OPTIONAL PROCESS FOR ESTABLISHING A SCHEDULE FOR ROUTINE GRAB
SAMPLE COMPARISONS TO ON-LINE CHLORINE ANALYZER READINGS

- A. Historical data can be used to establish a routine schedule for comparing grab sample measurements to the results from the on-line chlorine analyzer. The data must demonstrate that the grab sample measurements are frequent enough to detect problems with the analyzer within a reasonable period of time after the problems occur. The following protocol is presented as a conservative approach to developing a routine schedule when historical data are not available. The acceptance criterion that must be met in each step is that the on-line chlorine analyzer reading is within ± 0.1 mg/L or $\pm 15\%$ (whichever is larger) of the grab sample measurement. (Section B provides a flowchart of this process.)
- A.1 The data from the on-line analyzer IDC (See Section 10.2.2) can be used as the initial data set. If the on-line chlorine analyzer and grab sample results meet the acceptance criteria over the 14 day period of the IDC, compare the concentration determined by the on-line chlorine analyzer with grab sample analyses collected every three days for 9 days.
- A.2 If the on-line chlorine analyzer continues to meet acceptance criteria over the above 9 day period, the grab sample interval can be extended to once every four days for 12 days.
- A.3 As long as the acceptance criterion is met, continue extending the interval between grab samples using the same pattern as established in A.2 (i.e., once every 5 days for 15 days, once every 6 days for 18 days, etc). Collect a minimum of three grab samples each time the interval is extended by one day. **The maximum time between grab samples must not exceed once every 7 days (i.e., a weekly grab sample).**
- A.4 When the on-line analyzer fails to meet the acceptance criteria, resolve the problem following the protocol in Section 11.2. After the analyzer/grab sample agreement has been reestablished, examine the data collected in steps A.2 to A.3 to decide whether to continue extending the time between grab samples or to establish a schedule based on the existing data. Continue extending the time intervals between grab samples beginning with the interval that was being used prior to when the on-line analyzer failed to meet the acceptance criteria.
- A.5 Establish the routine grab sample frequency at an interval which is no greater than one seventh of the average length of time between observed failures. **The maximum time between grab samples must not exceed once every seven days.**

B. Process for Establishing Frequency of Routine Grab Sample Comparisons to Analyzer Readings



DRAFT

Appendix G: DEP-SOP-001/01 – FT 1900, “Continuous Monitoring with Installed Meters”

DEP-SOP-001/01
FT 1900 Continuous Monitoring With Installed Meters

FT 1900. Continuous Monitoring with Installed Meters

Use in conjunction with:

- FT 1000 General Field Testing and Measurement
- FT-series Field Testing SOPs for applicable parameters
- FS 1000 General Sampling Procedures
- FD 1000 Documentation Procedures

1. INTRODUCTION: Many facilities rely on in-line continuous measurement devices to monitor parameters such as dissolved oxygen, conductivity, pH, temperature, residual chlorine and turbidity. In order to ensure the stability and reliability of such measurements, the calibration of these instruments must be checked regularly. In cases where it is impractical to take these instruments off-line on a daily basis, use the calibration procedures described below.

2. CALIBRATION AND VERIFICATION

2.1. Calibrate the continuous monitoring instrument **before installation** according to the manufacturer's specifications for initial calibration. Ensure that the instrument has been calibrated and the calibration verified according to the requirements in the applicable DEP SOPs.

2.2. **On a daily basis**, measure a grab sample taken at or as near as possible to the same location as the in-line meter. The grab-sample test measurements must be taken with an instrument that has been properly calibrated and verified per the applicable DEP SOPs for individual parameter tests.

2.3. Compare the results of the daily verification with the continuous meter reading taken at the same time as the grab sample was collected. The continuous meter calibration is acceptable for the applicable parameters if the differences with the grab-sample results meet the following criteria:

2.3.1. Dissolved Oxygen: no greater than 0.2 mg/L difference (or historically established criteria not to exceed 0.5 mg/L difference);

2.3.2. Specific Conductance: no greater than 10% of the calibrated instrument reading;

2.3.3. pH: no greater than 0.2 pH units difference (or historically established criteria not to exceed 0.5 pH units difference);

2.3.4. Temperature: no greater than 0.5°C difference;

2.3.5. Residual Chlorine: no greater than 20% of the calibrated instrument reading; and

2.3.6. Turbidity: no greater than 20% of the calibrated instrument reading.

2.4. When the comparisons performed in section 2.3 above indicate a changing trend in the difference between the grab sample measurement and the continuous meter measurement for any parameter, determine the cause of the problem and perform appropriate corrective actions, such as maintenance, repair, calibration or other activities needed for the proper operation of the continuous meter under calibrated conditions.

2.5. Perform the initial calibration (per section 2.1 above) each time the instrument is taken off-line, after every preventative maintenance activity, and **immediately** after determining that any of the criteria verifications in 2.3.1 through 2.3.6 above are not met.

DEP-SOP-001/01
FT 1900 Continuous Monitoring With Installed Meters

- 2.6. All acceptable field data must be bracketed by acceptable calibration verifications (see section 2.3 above). Qualify data that are not bracketed by acceptable calibration verifications.
3. EXTENDED VERIFICATION INTERVALS
- 3.1. If historically generated data demonstrate that a specific instrument remains stable for longer periods of time, the time interval between initial calibration and calibration verifications may be increased.
- 3.2. The maximum time interval is one month or at the conclusion of a sampling event, whichever is less.
- 3.3. Base the selected time interval on the shortest interval that the instrument maintains stability.
- 3.4. If an extended time interval is used, and the instrument consistently fails to meet the final calibration verification:
- 3.4.1. The instrument may need maintenance to correct the problem; or
- 3.4.2. The time period is too long and must be decreased.
- 3.5. Retain all data associated with studies that support a decreased frequency of calibration verifications for at least five years after the procedure was last used.
4. PREVENTIVE MAINTENANCE: Refer to FT 1000, section 3.
5. DOCUMENTATION
- 5.1. Record all information specified in the individual field-testing SOPs.
- 5.2. Document the daily verifications of the continuous meter by recording:
- Project name (if applicable)
 - Date and time (including time zone, if applicable)
 - Source and location of the measurement or test sample (e.g., monitoring well identification number, outfall number, station number or other description)
 - Analyte or parameter measured
 - Reading from the continuous meter, including reporting units
 - Reading from the second instrument used for the grab-sample measurement, including reporting units
 - The name of the person conducting the verification
 - Unique identification of the specific instrument unit(s) used for the test(s)
- 5.3. Where applicable, record the differences for the results of meter comparisons as specified in section 2.3 above.
- 5.3.1. Calculate the differences in the results between the meter measurements of the grab sample with the corresponding measurements from the continuous meter for the applicable parameters
- 5.4. Indicate the acceptability of the verifications per the criteria in section 2.3

Appendix H: Ultraviolet Dose Values for Inactivation of Viruses

The virus inactivation credits listed in Table H-1 are for ultraviolet (UV) light at a wavelength of 254 nanometers as produced by a low-pressure mercury vapor lamp. To receive virus inactivation credit for other lamp types, public water systems must demonstrate an equivalent germicidal dose through reactor validation testing as described in Section 2.4 of these guidelines. Also, the UV dose values in Table H-1 are applicable only to post-filter applications of UV disinfection in water treatment systems with filters and to applications of UV disinfection in water treatment systems without filters.

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Table H-1: UV Dose Values for Inactivation of Viruses

Inactivation (log)	UV Dose (milliJoules/centimeter²)
0.5	39
1.0	58
1.5	79
2.0	100
2.5	121
3.0	143
3.5	163
4.0	186

Source: 40 CFR 141.720(d)(1).

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Appendix I: Protocol for Acidifying Combined Filter Effluent Turbidity Samples from Lime Softening Plants Prior to Analysis

Protocol:

1. Lower the pH of turbidity samples to less than 8.3 by adding either hydrochloric acid or sulfuric acid of Standard Lab Grade to the samples. Care should be taken when handling acid and adding acid to samples.
2. Invert samples several times to mix thoroughly and dissolve calcium carbonate.
3. Measure turbidity as usual.
4. Maintain documentation regarding the turbidity with and without acidification, pH values before and after acidification, and the quantity of acid added to a given sample volume.

Source: Section 2.2.2 in the United States Environmental Protection Agency's (USEPA's) *Guidance Manual for Compliance with the Interim Enhanced Surface Water Treatment Rule: Turbidity Provisions*, 1999, and Section 2.4 in the USEPA's *Long Term 1 Enhanced Surface Water Treatment Rule Turbidity Provisions Technical Guidance Manual*, 2004.

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Appendix J: Monthly Operation Report (MOR) Pages/Sheets for Ground Water Systems (GWSs) Providing Florida-Department-of-Environmental-Protection-Approved (FDEP-Approved) Four-Log Virus Treatment

Exhibit J-1 is a modified page 2 of DEP Form 62-555.900(3), "Monthly Operation Report for PWSs Treating Raw Ground Water or Purchased Finished Water," that should be used by GWSs using chemical disinfection for FDEP-approved four-log virus treatment.

Exhibits J-2 through J-7 are additional MOR sheets for GWSs using ultrafiltration; nanofiltration; reverse osmosis; ultraviolet disinfection; conventional filtration treatment, including lime softening; direct filtration; microfiltration preceded by coagulation; slow sand filtration; or diatomaceous earth filtration for FDEP-approved four-log virus treatment. The appropriate additional sheet(s) based on the technology(ies) used for virus treatment, should be attached to DEP Form 62-555.900(3), "Monthly Operation Report for PWSs Treating Raw Ground Water or Purchased Finished Water."

Exhibit J-1: Modified Page 2 of DEP Form 62-555.900(3) for GWSs Using Chemical Disinfection for FDEP-Approved Four-Log Virus Treatment

MONTHLY OPERATION REPORT FOR PWSs TREATING RAW GROUND WATER OR PURCHASED FINISHED WATER

PWS Identification Number: _____ Plant Name: _____

III. Daily Data for the Month/Year

Means of Achieving Four-Log Virus Inactivation/Removal: * Free Chlorine Combined Chlorine (Chloramines) Chlorine Dioxide Ozone Ultrafiltration
 Nanofiltration Reverse Osmosis UV Light Disinfection Conventional Filtration, Including Lime Softening Other (Describe): _____

Type of Disinfectant Residual Maintained in Distribution System: Free Chlorine Combined Chlorine (Chloramines) Chlorine Dioxide

Compliance Monitoring for Systems Using Chemical Disinfection for Virus Inactivation*							
Day of the Month	Days Plant Staffed or Visited by Operator (Place "X")	Hours Plant in Operation	Net Quantity of Finished Water Produced, gal	Lowest Residual Disinfectant Concentration at End of Disinfection Segment 1, mg/L	Lowest Residual Disinfectant Concentration at End of Disinfection Segment 2, mg/L	Disinfection Segment 1	Disinfection Segment 2
1						Disinfection Segment 1 • DEP-specified minimum residual disinfectant concentration at end of segment: _____ • Was the disinfectant residual concentration at the end of the segment ever < the DEP-specified minimum during the reporting month? _____ If yes, ... - Was it monitored at least every 4 hours until it returned to a value ≥ the DEP-specified minimum? _____ - Was it ever < the DEP-specified minimum for more than 4 consecutive hours? _____ If yes, ... - What was the date and duration of this <u>treatment technique violation</u> ? _____	• DEP-specified minimum residual disinfectant concentration at end of segment: _____ • Was the disinfectant residual concentration at the end of the segment ever < the DEP-specified minimum during the reporting month? _____ If yes, ... - Was it monitored at least every 4 hours until it returned to a value ≥ the DEP-specified minimum? _____ - Was it ever < the DEP-specified minimum for more than 4 consecutive hours? _____ If yes, ... - What was the date and duration of this <u>treatment technique violation</u> ? _____
2							
3							
4							
5							
6							
7							
8							
9							
10						Disinfection Segment 2 • DEP-specified minimum residual disinfectant concentration at end of segment: _____ • Was the disinfectant residual concentration at the end of the segment ever < the DEP-specified minimum during the reporting month? _____ If yes, ... - Was it monitored at least every 4 hours until it returned to a value ≥ the DEP-specified minimum? _____ - Was it ever < the DEP-specified minimum for more than 4 consecutive hours? _____ If yes, ... - What was the date and duration of this <u>treatment technique violation</u> ? _____	• DEP-specified minimum residual disinfectant concentration at end of segment: _____ • Was the disinfectant residual concentration at the end of the segment ever < the DEP-specified minimum during the reporting month? _____ If yes, ... - Was it monitored at least every 4 hours until it returned to a value ≥ the DEP-specified minimum? _____ - Was it ever < the DEP-specified minimum for more than 4 consecutive hours? _____ If yes, ... - What was the date and duration of this <u>treatment technique violation</u> ? _____
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23						On-Line Disinfectant Analyzers • Was continuous residual disinfectant monitoring equipment used during the reporting month? _____ If yes, ... - Was the calibration of the equipment verified during the month? _____ - Did the equipment fail during the month? _____ If yes, ... - Were grab samples collected every 4 hours until the equipment was returned to service? _____ - Date the equipment failed: _____ - Date the equipment was returned to service: _____	• Was continuous residual disinfectant monitoring equipment used during the reporting month? _____ If yes, ... - Was the calibration of the equipment verified during the month? _____ - Did the equipment fail during the month? _____ If yes, ... - Were grab samples collected every 4 hours until the equipment was returned to service? _____ - Date the equipment failed: _____ - Date the equipment was returned to service: _____
24							
25							
26							
27							
28							
29							
30							
31							
Total							
Average							
Maximum							

* Only plants providing DEP-approved 4-log virus treatment must provide this information.

Exhibit J-2: Additional MOR Sheet for GWSs Using Ultrafiltration for FDEP-Approved Four-Log Virus Treatment

DAILY DATA SHEET FOR FILTERED SYSTEMS (For system use only)					
Month _____	System/Treatment Plant _____				
Year _____	Filtration Technology _____				
	PWSID _____				
Date	Maximum Filtrate Turbidity				No. of Turbidity Measurements > 0.15 NTU
	Membrane Unit 1	Membrane Unit 2	Membrane Unit 3	Membrane Unit 4	
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					

• Did filtrate turbidity for any membrane unit ever exceed 0.15 NTU during the reporting month? _____ If yes, ...
 – Did filtrate turbidity for any membrane unit ever exceed 0.15 NTU for more than 4 consecutive hours? _____
 If yes, ...
 – What was the date and duration of this **treatment technique violation**? _____

• Was the calibration of the continuous turbidity monitoring equipment verified during the month? _____

• Was direct integrity testing, with a resolution $\leq 0.01 \mu\text{m}$ and a sensitivity ≥ 4 logs, conducted on each membrane unit daily and whenever the filtrate turbidity exceeded 0.015 NTU for > 15 minutes? _____ If yes, ...
 – Was any test result outside the control limit? _____ If yes, ...
 – How many test results were outside the control limit and what corrective action was taken? _____

Exhibit J-3: Additional MOR Sheet for GWSs Using Nanofiltration or Reverse Osmosis for FDEP-Approved Four-Log Virus Treatment

DAILY DATA SHEET FOR FILTERED SYSTEMS (For system use only)					
Month _____		System/Treatment Plant _____			
Year _____		Filtration Technology _____			
		PWSID _____			
Date	Maximum % Salt Passage (SP)				Number of % SP Measurements > DEP-Specified Maximum
	Membrane Unit 1	Membrane Unit 2	Membrane Unit 3	Membrane Unit 4	
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					

- DEP-specified maximum % SP: _____
- Did % SP for any membrane unit ever exceed the DEP-specified maximum during the reporting month? _____
If yes, ...
 - Did % SP for any membrane unit ever exceed the DEP-specified maximum for more than 4 consecutive hours? _____ If yes, ...
 - What was the date and duration of this **treatment technique violation**? _____
- Was the accuracy of the continuous monitoring equipment verified during the month? _____
- Was direct integrity testing, with a resolution $\leq 0.01 \mu\text{m}$ and a sensitivity ≥ 4 logs, conducted on each membrane unit daily and whenever the % SP exceeded the DEP-specified maximum for > 15 minutes? _____ If yes, ...
 - Was any test result outside the control limit? _____ If yes, ...
 - How many test results were outside the control limit and what corrective action was taken? _____

Exhibit J-4: Additional MOR Sheet for GWSs Using Ultraviolet (UV) Disinfection, with the UV Intensity Setpoint Approach, for FDEP-Approved Four-Log Virus Treatment

Reporting Period: _____			Maximum Validated Flow Rate: _____		
System/Treatment Plant: _____			Minimum Validated UVT: _____		
PWSID: _____			Target Log Inactivation: _____		
UV Reactor: _____			Target Pathogen: _____		
Process Train: _____			Intensity Setpoint: _____		
Operator Signature: _____					
Date: _____					

Operational Data			Intensity Requirements			Daily Minimum Intensity		Total Operation Time Outside Validated Operating Conditions, hours
Day	Flow Rate		Intensity Setpoint (W/m ²) [A]	Sensor Correction Factor ¹ [B]	Adjusted Intensity Setpoint (W/m ²) ([A] * [B]) [C]	Daily Minimum Intensity (W/m ²) [D]	Minimum Daily Intensity > Adjusted Intensity Setpoint ([D] > [C]) (Y/N)	
	Min (mgd)	Ave (mgd)						Max (mgd)
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								

¹ Sensor CF will be 1 if no CF is used.

- Did the reactor ever operate outside validated operating conditions during the reporting month? ____ If yes, did the reactor ever operate outside validated operating conditions for more than 4 consecutive hours? ____ If yes, what was the date and duration of this **treatment technique violation**? _____
- Was the calibration of the UV sensors verified during the month? ____

Exhibit J-5: Additional MOR Sheet for GWSs Using Ultraviolet (UV) Disinfection, with the Calculated Dose Approach, for FDEP-Approved Four-Log Virus Treatment

Reporting Period: _____
 System/Treatment Plant: _____
 PWSID: _____
 UV Reactor: _____
 Process Train: _____
 Operator Signature: _____
 Date: _____

Maximum Validated Flow Rate: _____
 Minimum Validated UVT: _____
 Target Log Inactivation: _____
 Target Pathogen: _____
 Dose Required (D_{req'd}): _____
 Validation Factor (VF): _____

Validated Dose = $\frac{\text{Calculated Dose}}{\text{VF} \times \text{CF}}$
 Calculated Dose = Dose that is calculated by validated PLC algorithm
 VF = Validation factor
 CF = UV intensity sensor correction factor.
 The CF is only applied if sensors do not meet recommended criteria
 (NOTE – a CF will not be needed in most cases)

Day	Dose Requirements	Data at Daily Minimum Validated Dose					UV Dose Adequacy Determination Validated Dose > D _{req'd} ([D] > [A]) (Y/N)	Total Operation Time Outside Validated Operating Conditions, hours
		D _{req'd} ¹ (mJ/cm ²) [A]	Sensor Correction Factor ² [B]	Calculated Dose ³ (mJ/cm ²) [C]	Daily Minimum Validated Dose ⁴ ([C][VF][B]) (mJ/cm ²) [D]	Flow Rate (MGD)		
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								

¹ D_{req'd} is the dose required for the target log inactivation without a VF or Sensor CF applied and can be found in the UVDGM Table 1.4.
² Sensor CF will be 1 if no CF is used
³ Calculated dose is calculated using the dose algorithm in the PLC.
⁴ The Validated Dose is the dose based on the calculated dose that is normalized on the Validation Factor and Correction Factor

- Did the reactor ever operate outside validated operating conditions during the reporting month? ____ If yes, did the reactor ever operate outside validated operating conditions for more than 4 consecutive hours? ____ If yes, what was the date and duration of this **treatment technique violation**? _____
- Was the calibration of the UV sensors and UVT analyzers verified during the month? ____

Exhibit J-6: Additional MOR Sheet for GWSs Using Conventional Filtration Treatment, Including Lime Softening; Direct Filtration; or Microfiltration Preceded by Coagulation for FDEP-Approved Four-Log Virus Treatment

DAILY DATA SHEET FOR FILTERED SYSTEMS (For system use only)					
Month _____		System/Treatment Plant _____			
Year _____		Filtration Technology _____			
		PWSID _____			
Date	Maximum Filtered Water Turbidity		3	4	5
	Combined Filter Effluent (CFE)		No. of Turbidity Measurements	No. of Turbidity Measurements ≤ 1 NTU	No. of Turbidity Measurements > 1 NTU
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					
Totals:					

- Did the CFE turbidity ever exceed 1 NTU during the reporting month? _____ If yes, ...
 - Was the CFE turbidity monitored at least every 4 hours until it returned to a value ≤ 1 NTU? _____
 - Did the CFE turbidity ever exceed 1 NTU for more than 4 consecutive hours? _____ If yes, ...
 - What was the date and duration of this **treatment technique violation**? _____

- Was continuous turbidity monitoring used during the reporting month? _____ If yes, ...
 - Was the calibration of the continuous turbidity monitoring equipment verified during the month? _____

Exhibit J-7: Additional MOR Sheet for GWSs Using Slow Sand Filtration or Diatomaceous Earth Filtration for FDEP-Approved Four-Log Virus Treatment

DAILY DATA SHEET FOR FILTERED SYSTEMS (For system use only)					
Month _____		System/Treatment Plant _____			
Year _____		Filtration Technology _____			
		PWSID _____			
Date	Maximum Filtered Water Turbidity		No. of Turbidity Measurements	No. of Turbidity Measurements <= 5 NTUs	No. of Turbidity Measurements > 5 NTU
	Combined Filter	Effluent (CFE)			
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					
Totals:					

- Did the CFE turbidity ever exceed 5 NTUs during the reporting month? _____ If yes, ...
 - Was the CFE turbidity monitored at least every 4 hours until it returned to a value \leq 5 NTUs? _____
 - Did the CFE turbidity ever exceed 5 NTUs for more than 4 consecutive hours? _____ If yes, ...
 - What was the date and duration of this **treatment technique violation**? _____
- Was continuous turbidity monitoring used during the reporting month? _____ If yes, ...
 - Was the calibration of the continuous turbidity monitoring equipment verified during the month? _____