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Colorado Department of Public Health and Environment

October 11, 2011

To: Public Water Systems

Subject: Acceptance of Ultraviolet (UV) Disinfection as a technology for meeting the primary disinfection requirements for *Giardia lamblia*, *Cryptosporidium*, and virus inactivation as specified in the *Colorado Primary Drinking Water Regulations* (CPDWR)

To Whom It May Concern;

The Water Quality Control Division (the Division) in consultation with industry and academic subject matter experts in the field of UV Disinfection has reviewed currently operating UV disinfection systems, vendor data, industry best practices, relevant literature, and related regulatory guidance from the United States Environmental Protection Agency (http://www.epa.gov/ogwdw/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf) in order to address requirements of Article 1.11.2 and Article 7 of the *Colorado Primary Drinking Water Regulations* (CPDWR).

The Division hereby finds that UV Disinfection can be successfully used to comply with the log inactivation requirements of Article 7 of the CPDWR. The technology meets or exceeds the requirements of the *State of Colorado Design Criteria for Potable Water Systems* and is accepted for use as a technology to meet the log inactivation requirements for *cryptosporidium* and/or *Giarida Lamblia* subject to the performance conditions outlined in Table 1 and the Additional Design Criteria given in Table 2.

This acceptance addresses the following types of disinfection systems:

- UV Disinfection for inactivation of *Giardia*, *cryptosporidium*, and viruses.

This acceptance applies only to the use of UV Disinfection for compliance with Article 7 of the CPDWR (the surface water treatment rules). It does NOT constitute construction approval for installation or use at individual public water systems. Therefore:

Public water systems must submit plans for individual review and approval to use this technology. Each submittal will be reviewed for approval on a case-by-case basis by the Division as required by Article 1.11.2 of the CPDWR.

Table 1. UV Disinfection Design Submittal Requirements:

Design Requirements for UV Disinfection	
Parameter	**Requirement**
Raw water quality data*	- UV transmittance (UVT) – must span different seasonal conditions where applicable (Winter, runoff, summer) - Turbidity (must be less than 5 NTU) - Manganese < 0.03 mg/L - Iron < 0.3 mg/L

Disinfection goal	System MUST specify which organism is being targeted for inactivation and what log inactivation credit is necessary (eg. 1.0 log *Giardia* for direct filtration plants)
Validation report	MUST be provided to the State during plans review AND must be kept onsite at the facility for review during sanitary surveys.
Dose-monitoring approach	Either "UV Intensity Setpoint" or "Calculated Dose"
Hydraulics	Either – 5 pipe diameters straight pipe upstream of UV (in addition to the length of straight pipe used in validation) OR Identical inlet and outlet conditions to the validated conditions
Desired flow rate (MGD)	System should indicate its design flow rate for this reactor – the Division will approve UV reactors up to their max validated flow given raw water quality conditions (UVT) Instantaneous flow measurement is REQUIRED on all UV installations being used for log-inactivation credit.
Lamp cleaning strategy	Specified during design and called out in the operations and maintenance manual.
Monitoring equipment calibration	Appropriate monitoring equipment for flow, UVT, UV intensity, raw water turbidity must be specified in the design of the UV facility.

***The term 'raw water' means the water entering the UV reactor – could be raw, settled, or filter effluent**

Table 2: UV Disinfection Additional Design Criteria:

Additional Design Criteria
1. Bypass piping to divert water around the UV Disinfection will not be approved. 2. A means to restrict or control flow for each UV Reactor shall be provided. 3. A means to measure the flow through each UV Reactor shall be provided.
Additional Monitoring Requirements
1. The water system shall monitor the UV reactor based upon the dose-monitoring approach specified in the approval letter. Appendix A discusses the monitoring and recordkeeping requirements for each strategy. 2. Monitoring frequencies shall comply with Figure A.2. 3. The water system shall keep an Operations and Maintenance manual for the specific UV reactor installed available onsite for operational use and also for review during a sanitary survey. 4. The water system shall keep records of the following operational parameters (to be reviewed during a Sanitary Survey): a. Summary of flows through the reactor for each month (daily peak flow must be tracked). b. Monthly off spec flow percentage (see figure A.3) c. Monthly summary of dose monitoring (lamp status MUST always be included): i. Either: Monthly calculated dose data summarizing the minimum dose for each day that the unit was in operation (see figure A.4), this includes UVT measurements and minimum daily dose delivered

ii. Or: Monthly intensity setpoint summary verifying UV intensity (see figure A.5) and daily minimum intensity and maximum flow measured.

d. Records of lamp run times, cleaning frequencies, sensor calibrations (per manufacturer specs) must be maintained and available for review. See figures 6.6 – 6.8 of the UVDGM.

Please direct any further correspondence regarding this acceptance to:

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If you have any questions or comments, please call Tyson Ingels at 303-692-3002.

Sincerely,

Tyson Ingels, P.E.
Lead Drinking Water Engineer
Engineering Section
Water Quality Control Division

ec: CDPHE-WQCD-ES
CDPHE-WQCD-CA

APPENDIX A

The dose monitoring approach for UV compliance is described in the UV Disinfection Guidance Manual (USEPA 2006 - http://www.epa.gov/ogwdw/disinfection/lt2/pdfs/guide_lt2_uvguidance.pdf). Section 3.5 of the manual describes the two dose monitoring strategies typically employed by UV manufacturers. Table 3.6 summarizes the two approaches and is shown in Figure A.1 below:

Table 3.6. Dose-monitoring Approaches – Key Characteristics

Dose-monitoring Strategy	Parameter Used as the Operational Setpoint	Parameters Monitored During Operations to Confirm Dose Delivery
UV Intensity Setpoint Approach	UV Intensity	Flow rate Lamp status UV intensity
Calculated Dose Approach	Calculated or Validated dose [1]	Flow rate Lamp status UV intensity UVT

[1] As noted in Section 3.4.1, the calculated dose is estimated using a dose-monitoring equation. For the Calculated Dose Approach, the validated dose is equal to the calculated dose divided by a Validation Factor, which accounts for biases and experimental uncertainty.

Figure A.1: Dose monitoring approaches summarized in the UVDGM

In either case monitoring frequencies are critical to ensuring the required amount of water is being treated within specifcations. Therefore, the Division is requiring the following monitoring frequencies for UV parameters (figure A.2).

Table 6.7. Recommended Recording Frequency for Required Monitoring Parameters

Parameter	Recommended Recording Frequency	Notes
Off-specification Alarm	Minimum of every 5 minutes	Recording should continue until the alarm condition has been corrected.
UV Intensity	Every 4 hours	The UV intensity must be greater than or equal to the validated setpoint.
UVT[1]	Every 4 hours	The UVT must be greater than or equal to the minimum UVT validated.
Validated Dose[1]	Every 4 hours	The validated dose must be greater than or equal to the D_{Req}.
Lamp Status	Every 4 hours	Lamps should be energized if water is flowing through the UV reactor.
Flow Rate	Every 4 hours	The flow rate should be less than or equal to the maximum flow tested in validation.
Production Volume	Off-specification events and monthly total	The production volume needs to be recorded so the off-specification compliance calculation can be completed.
Calibration of UV Sensors	Monthly	The calibration of the UV sensor should be monitored as described in Section 6.4.1.1.
Calibration of On-line UVT Analyzer[1]	Weekly[2]	The calibration of the UVT analyzer should be monitored as described in Section 6.4.1.2.[1]

[1] Required only if necessary for the dose-monitoring strategy (i.e., the Calculated Dose Approach).
[2] Frequency could be reduced as described in Section 6.4.1.2.

Figure A.2: Required recording frequencies for systems practicing UV Disinfection. The Division recommends the system also monitor in accorance with Table 6.8 of the UVDGM.

Less than 5% of the volume treated by the UV reactor on an monthly basis can be off specification. The system must keep records daily and that data must feed into a summary report which calculates the percentage of water that is off specification (off-spec) for the month. In the event that the water system produces more than 5% off spec water, the water system MUST notify the Divsion within 10 days. This will be a violation of Article 7 of the Colorado Primary Drinking Water regulations. Figure A.3 shows the example summary form from the UVDGM. Water systems may use this form or an equivalent and records must be available for review during a Sanitary Survey.

Reporting Period: _____
System/Treatment Plant: _____
PWSID: _____
Signature of Principal Executive: _____ Date: _____
Officer or Authorized Agent: _____ Date: _____

			Off-Specification Data	
Unit Number	Total Run Time (hrs)	Total Production (MG)	Number of Off-Specification Events	Total Off-Specification Volume (MG)
Total				

Compliance Certification

Total Volume of Off-Specification Water Produced (MG) [A] _____
Total Volume of Water Produced (MG) [B] _____
Total Off-Specification Water Produced (% of Volume of Water Produced) ([A]/[B]*100) _____

Facility Meets Off-Specification Requirement (< 5% of Volume on a Monthly Basis) (Y/N) _____

Of the _____ sensors, _____ have been checked for calibration and _____ were within the acceptable range of tolerance.

The Following Reactors had a Sensor Correction Factor

Reactor Number	Sensor Correction Factor

Figure A.3: Summary of off-spec water for a UV facility per the UVDGM (page 6-41)

Water system MUST also keep daily records of the dose montoring strategy that is performed at the facility. Parameters that must be monitored are summarized in figure A.2. Figures A.4 and A.5 show example summary forms from the UVDGM that detail each required parameter on a daily basis. If water systems choose not to use these summary forms, then they must design a form that tracks the eqivalent information.

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): _____

$$\text{Validated Dose} = \frac{\text{Calculated Dose}}{\text{VF} \times \text{CF}}$$

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)

Operational Data			Dose Requirements	Data at Daily Minimum Validated Dose					UV Dose Adequacy Determination	Total Off-Specification
Day	Run Time (hrs)	Total Production (MG)	$D_{req'd}$[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)	UVT (%)	Validated Dose > $D_{req'd}$ ([D] > [A]) (Y/N)	Total Off-Specification Volume (MG)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
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23										
24										
25										
26										
27										
28										
29										
30										
31										
Min										
Max										
Total										

[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 is 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
[5] Off-specification worksheet (Figure 6.5) should be used to calculate daily off-specification volume. If UVT, flowrate, and/or Validated Dose off-specification occur simultaneously, the off-specification time should only be counted once

Figure A.4: Summary of calculated dose monitoring form for a UV facility per the UVDGM (page 6-42)

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: _____
Intensity Setpoint: _____

Operational Data						Intensity Requirements			Daily Minimum Intensity		Total Flow Off-Specification
			Flow Rate								
Day	Run Time (hrs)	Total Production (MG)	Min (mgd)	Ave (mgd)	Max (mgd)	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)	Total Flow Off-Specification[3] (MG)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
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Min											
Max											
Total											

[1] Sensor CF will be 1 is no CF is used.
[2] UVT measurements are not required but could be useful in addressing operational issues.
[3] Off-specification worksheet (Figure 6.5) should be used to calculate daily off-specification volume. If UV intensity or flowrate off-specification occur simultaneously, the off-specification time should only be counted once

Figure A.5: Summary of intensity setpoint monitoring form for a UV facility per the UVDGM (page 6-43)