NOTE: Federal Register reference: National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule; Proposed Rule [Federal Register: August 11, 2003, Volume 68, Number 154, Page 47639-47795]

PROVISIONS OF THE LT2ESWTR RELEVANT TO THE DESIGN AND OPERATION OF UV DISINFECTION SYSTEMS

In August, 2003, the USEPA published the proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) (USEPA, 2003) which primarily targets *Cryptosporidium*. The rule regulates many critical aspects of the design and operation of UV systems for drinking water. These are summarized below. The reader should be aware that some of the requirements may change upon final promulgation of the rule.

General. EPA believes that UV disinfection is effective for inactivating *Cryptosporidium* and *Giardia* at economical doses, but is much less effective against viruses. EPA also believes that research has shown that UV disinfection does not significantly increase the formation of DBPs and does not believe that nitrate formation by hydrolysis of nitrate in UV systems will cause nitrate concentrations close to the MCL. However, EPA is concerned that the selection or modification of disinfectants to limit DBPs may cause less effective disinfection against some microorganisms. For example, a shift to UV disinfection exclusively for primary disinfection in order to reduce DBPs could increase the risk from viruses. This is addressed in the rule by requiring at least two disinfectants for unfiltered systems. It should also be noted that the earlier surface water treatment rule (SWTR) requirement of 3 log removal/inactivation of *Giardia lamblia* and 4 log removal of viruses must still be achieved.

Treatment Requirements for Filtered Systems. Surface water systems using filtration will be classified into one of four risk bins depending on their average source water *Cryptosporidium* concentration as shown in Table IV-2.

LT2ESWTR Table IV-2. Bin classification table for filtered systems

If your average *Cryptosporidium* concentration[1] is...	Then your bin classification is...
Cryptosporidium <0.075/L	Bin 1
0.075/L ≤ Cryptosporidium < 1.0/L	Bin 2
1.0/L ≤ *Cryptosporidium* < 3.0/L	Bin 3
Cryptosporidium ≥ 3.0/L	Bin 4

[1] All concentrations shown in units of oocysts/L

Further details on sampling are discussed in the LT2ESWTR rule.

Systems will receive *Cryptosporidium* log inactivation credit for treatment in place as listed in Table

IV-3. The credits for conventional, slow sand, and diatomaceous earth (DE) filtration plants are based on average removals achieved by plants that are in compliance with the SWTR, Interim Enhanced Surface Water Treatment Rule (IESWTR), and Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) as compared to former rules which were based on minimum expected values. EPA assigned a 2.5 log inactivation credit to direct filtration plants, which lack a sedimentation process, but could not assign an average removal credit for membranes, bag filters, and cartridge filters due to variability among products.

LT2ESWTR Table IV-3. *Cryptosporidium* treatment credit towards LT2ESWTR requirements

Plant type	Conventional treatment (includes softening)	Direct filtration	Slow sand or diatomaceous earth filtration	Alternative filtration technologies Treatment
Credit[1]	3.0 log	2.5 log	3.0 log	Determined by State[2]

[1]Applies to plants in full compliance with the SWTR, IESWTR, and LT1ESWTR as applicable
[2]Credit must be determined through product or site specific assessment

The *Cryptosporidium* LT2ESWTR treatment requirements versus risk bins are shown in Table IV-4.

LT2ESWTR Table IV-4. (*Cryptosporidium*) treatment requirements per LT2ESWTR bin classification

If your bin class-ification is...	And you use the following filtration treatment in full compliance with the SWTR, IESWTR, and LT1ESWTR (as applicable), then your additional treatment requirements are...			
	Conventional filtration treatment (includes softening)	Direct filtration	Slow sand or diatomaceous earth filtration	Alternative filtration technologies
Bin 1	No additional treatment	No additional treatment	No additional treatment	No additional treatment
Bin 2	1 log treatment[1]	1.5 log treatment[1]	1 log treatment[1]	As determined by the State[1,3]
Bin 3	2 log treatment[2]	2.5 log treatment[2]	2 log treatment[2]	As determined by the State[2,4]
Bin 4	2.5 log treatment[2]	3 log treatment[2]	2.5 log treatment[2]	As determined by the State[2,5]

[1] Systems may use any technology or combination of technologies from the microbial toolbox.
[2] Systems must achieve at least 1 log of the required treatment using ozone, chlorine dioxide, UV light, membranes,

bag/cartridge filters, or bank filtration.
[3]Total *Cryptosporidium* removal and inactivation must be at least 4.0 log.
[4]Total *Cryptosporidium* removal and inactivation must be at least 5.0 log.
[5]Total *Cryptosporidium* removal and inactivation must be at least 5.5 log.

Water treatment plants can achieve the additional *Cryptosporidium* treatment credits required in Table IV-4 by various ways including:

- implementing pretreatment processes such as presedimentation or bank filtration,
- developing a watershed control program,
- applying additional treatment processes such as UV light, ozone, chlorine dioxide, or membranes,
- obtaining additional credit for existing treatment by achieving very low filter effluent turbidity or demonstrating performance.

Section IV.C and especially Table IV-7 of the LT2ESWTR discusses and lists the additional *Cryptosporidium* treatment credit given to a variety of treatment and control options. This is called the 'microbial toolbox.' Systems in Bin 2 can use combination of options from the microbial toolbox, whereas systems in Bins 3 and 4 must achieve an additional 1 log removal with ozone, chlorine dioxide, UV light, membranes, bag filtration, cartridge filtration, or bank filtration.

Unfiltered system treatment technique requirements for *Cryptosporidium*. All unfiltered systems using surface water or ground water under the direct influence of surface water must meet the following requirements:

- achieve at least 2 log (99%) inactivation of *Cryptosporidium* of water entering the distribution system,
- monitor for Cryptosporidium in the source water,
- achieve at least 3 log Cryptosporidium inactivation if the concentration of *Cryptosporidium* exceeds 0.01 oocysts/L,
- achieve at least 3 log inactivation of *Giardia lamblia* and 4 log of viruses as per existing requirements,
- meet disinfection requirements using a minimum of two disinfectants (allowable disinfectants are ozone, ultraviolet (UV) light, and chlorine dioxide) (For example, a system could achieve 2 log inactivation of Cryptosporidium and Giardia with UV disinfection and an additional 1 log inactivation of *Giardia* and 4 log inactivation of viruses with chlorine.),
- each disinfectant by itself must achieve the inactivation for at least one of the three pathogens (viruses, crypto, giardia),
- must continue to meet disinfectant residual requirements in distribution system,
- if using UV light disinfection, must follow the UV disinfection continuous monitoring requirements as specified elsewhere in the LT2EWSTR and must record periods when any reactor operates outside of validated conditions,
- ensure at least 99 percent (or 99.9 percent if required) inactivation of Cryptosporidium in at

least 95 percent of the water delivered to the public every month.

Log inactivation credit vs UV dose. The UV dose or fluence is the product of the UVlight intensity and the exposure time, which is analogous to CT for chemical disinfectants. Delivered UV dose is the experimentally determined dose that a UV reactor achieves based on the inactivation of a microorganism measured during a bioassay challenge test. Please see the reactor validation section of this module for more details.

EPA developed the dose tables in the LT2ESWTR rule using a statistical evaluation of available dose-response data from bench scale studies using LP mercury vapor lamps. LP lamp data allow UV dose to be accurately quantified because LP lamps emit light primarily at a single wavelength (254 nm) whereas MP lamps emit polychromatic wavelengths that vary in intensity and effectiveness.

The Microbial Toolbox of the LT2ESWTR gives the additional log inactivation credit assigned to various control and treatment options. For UV disinfection, Table IV-21 below shows the inactivation credit given for *Crypto*, *Giardia*, and viruses for various UV doses. Importantly, these doses are for 254 nm as delivered from a LP mercury vapor lamps. The doses can be applied to other lamp types such as MP lamps through reactor validation testing. The doses are intended for post-filter application in a filtration plant and for systems meeting filtration avoidance criteria. The virus doses are based on adenovirus because it is the most resistant of viruses studied and is a widespread pathogen. However, it should be noted that the proposed draft *EPA UV Disinfection Guidance Manual* (2003) validation protocol applies safety factors to these doses, which increases the delivered UV dose to be verified during validation.

LT2ESWTR Table IV-21. UV dose requirements for *Cryptosporidium, Giardia lamblia,* and virus inactivation credit

Log credit	*Cryptosporidium* UV dose (mJ/cm^2)	*Giardia lamblia* UV dose (mJ/cm^2)	Virus UV dose (mJ/cm^2)
0.5	1.6	1.5	39
1.0	2.5	2.1	58
1.5	3.9	3.0	79
2.0	5.8	5.2	100
2.5	8.5	7.7	121
3.0	12	11	143
3.5	NA	NA	163
4.0	NA	NA	186

The actual log credit assigned to a specific UV reactor at a treatment is determined by validation testing.

UV Reactor validation testing. A system must demonstrate that their UV reactor can deliver the required UV dose in order to receive disinfection credit for the UV reactor. Unless the State approves an alternative approach, this demonstration involves the following:

- full scale testing of a reactor which conforms uniformly to the UV reactors used by the system,
- inactivation of a test microorganism whose dose response characteristics have been quantified with a low pressure mercury vapor lamp.

Testing must determine a set of operating conditions that can be monitored by the system to ensure that the required UV dose is delivered in routine operation. At a minimum, these operating conditions must include flow rate, UV irradiance as measured by a UV sensor, and UV lamp status. The validated operating conditions determined by testing would be required to account for the following factors:

- UV absorbance of the water,
- lamp fouling,
- lamp aging,
- UV sensor accuracy,
- the residence time distribution of water within the reactor,
- failure of UV lamps or other critical system components,
- inlet and outlet piping or channel configurations of the UV reactor.

Note that the intention is to consider worst case conditions in validation.

The reason for requiring full scale testing of UV reactors is the difficulty in predicting reactor disinfection performance based on modeling or reduced scale testing. EPA also recognizes that UV reactors produce a distribution of UV doses at all times and that a single dose does not theoretically represent the reactor. However, EPA believes that assigning a single UV dose to a reactor via validation testing has practical value as an indicator of disinfection performance.

Please see the validation section of this educational module for a discussion of the validation approach recommended by the *UV Disinfection Guidance Manual* (USEPA, 2003).

Required UV Disinfection System Monitoring. UV disinfection systems must monitor parameters (e.g., flow rate, irradiance) to show that each reactor is operating within the range of conditions that have been validated to achieve the required UV dose. Any periods when the UV reactor operates outside of validated conditions must be recorded. At a minimum systems would be required to monitor for UV irradiance, flow rate, and lamp outage. Also, systems would be required to regularly calibrate UV sensors.

Operation within validated conditions. Unfiltered systems using UV disinfection and that are required to achieve 2-log inactivation of *Cryptosporidium* must demonstrate that at least 95% of the water entering the distribution system each month was treated by UV reactors operating within validated conditions.