

plant. The Toolbox Guidance Manual, available in draft with today's proposal, provides guidance on methodologies for

determining CT values and estimating log inactivation for different

disinfection reactor designs and operations.

TABLE IV-19.—CT VALUES FOR *Cryptosporidium* INACTIVATION BY OZONE

Log credit	Water Temperature, °C ¹									
	≤0.5	1	2	3	5	7	10	15	20	25
0.5	12	12	10	9.5	7.9	6.5	4.9	3.1	2.0	1.2
1.0	24	23	21	19	16	13	9.9	6.2	3.9	2.5
1.5	36	35	31	29	24	20	15	9.3	5.9	3.7
2.0	48	46	42	38	32	26	20	12	7.8	4.9
2.5	60	58	52	48	40	33	25	16	9.8	6.2
3.0	72	69	63	57	47	39	30	19	12	7.4

¹ CT values between the indicated temperatures may be determined by interpolation.

TABLE IV-20.—CT VALUES FOR *Cryptosporidium* INACTIVATION BY CHLORINE DIOXIDE

Log credit	Water Temperature, °C ¹									
	≤0.5	1	2	3	5	7	10	15	20	25
0.5	319	305	279	256	214	180	138	89	58	38
1.0	637	610	558	511	429	360	277	179	116	75
1.5	956	915	838	767	643	539	415	268	174	113
2.0	1275	1220	1117	1023	858	719	553	357	232	150
2.5	1594	1525	1396	1278	1072	899	691	447	289	188
3.0	1912	1830	1675	1534	1286	1079	830	536	347	226

¹ CT values between the indicated temperatures may be determined by interpolation.

The system may demonstrate to the State, through the use of a State-approved protocol for on-site disinfection challenge studies or other information satisfactory to the State, that CT values other than those specified in Tables IV-19 or IV-20 are adequate to demonstrate that the system is achieving the required log inactivation of *Cryptosporidium*. Protocols for making such demonstrations are available in the Toolbox Guidance Manual.

b. *How was this proposal developed?* EPA relied in part on analyses by Clark *et al.* (2002a and 2002b) to develop the CT values for ozone and chlorine dioxide inactivation of *Cryptosporidium* in today's proposal. Clark *et al.* (2002a) used data from studies of ozone inactivation of *Cryptosporidium* in laboratory water to develop predictive equations for estimating inactivation (Rennecker *et al.* 1999, Li *et al.* 2001) and data from studies in natural water to validate the equations (Owens *et al.* 2000, Oppenheimer *et al.* 2000). For chlorine dioxide, Clark *et al.* (2002b) employed data from Li *et al.* (2001) to develop equations for predicting inactivation, and used data from Owens *et al.* (1999) and Ruffell *et al.* (2000) to validate the equations.

Another step in developing the CT values for *Cryptosporidium* inactivation in today's proposal involved consideration of the appropriate

confidence bound to apply when analyzing the inactivation data. A confidence bound represents a safety margin that accounts for variability and uncertainty in the data that underlie the analysis. Confidence bounds are intended to provide a high likelihood that systems operating at a given CT value will achieve at least the corresponding log inactivation level in the CT table.

Two types of confidence bounds that are used when assessing relationships between variables, such as disinfectant dose (CT) and log inactivation, are confidence in the regression and confidence in the prediction. Confidence in the regression accounts for uncertainty in the regression line (*e.g.*, a linear relationship between temperature and the log of the ratio of CT to log inactivation). Confidence in the prediction accounts for both uncertainty in the regression line and variability in experimental observations—it describes the likelihood of a single future data point falling within a range. Bounds for confidence in prediction are wider (*i.e.*, more conservative) than those for confidence in the regression. Depending on the degree of confidence applied, most points in a data set typically will fall within the bounds for confidence in the prediction, while a significant fraction will fall outside the bounds for confidence in the regression.

In developing earlier CT tables, EPA has used bounds for confidence in the prediction. This was a conservative approach that was taken with consideration of the limited inactivation data that were available and that reasonably ensured systems would achieve the required inactivation level. The November 2001 draft of the LT2ESWTR included CT tables for *Cryptosporidium* inactivation by ozone and chlorine dioxide that were derived using confidence in prediction (USEPA 2001g). However, based on comments received on those draft tables, along with further analyses described next, EPA has revised this approach in today's proposal.

The underlying *Cryptosporidium* inactivation data used to develop the CT tables exhibit significant variability. This variability is due to both experimental error and potential true variability in the inactivation rate. Experimental error is associated with the assays used to measure loss of infectivity, measurement of the disinfectant concentration, differences in technique among researchers, and other factors. True variability in the inactivation rate would be associated with variability in resistance to the disinfectant between different populations of oocysts and variability in the effect of water matrix on the inactivation process.