Derivation of Log Removal Values for the Addendum to A Framework for Regulating Direct Potable Reuse, presenting an early draft of the anticipated criteria for DPR

Giardia cysts, *Cryptosporidium* oocysts, and enteric virus have been selected as the reference pathogens for the direct potable reuse regulation. *Giardia* cysts, *Cryptosporidium* oocysts, and enteric virus are used in the regulation of indirect potable reuse in California. They are also the pathogens regulated in the Federal and California surface water treatment regulations and, therefore, must be addressed in potable reuse regulation because municipal wastewater can be considered a surface water.

To avoid underestimating virus risk, Norovirus was used to determine the required log reduction for enteric virus. Norovirus is the most common cause of acute gastroenteritis in the United States, is found in high concentrations in raw wastewater, is a highly infectious virus, and has the greatest potential to exceed a 1:10,000 annual risk of infection, equivalent to 2.7E-07 daily risk of infection (CDPH, 2018; Eftim et al., 2017; Kirby et al., 2015). This approach is consistent with the approach used to determine the tolerable virus concentration in drinking water, where Rotavirus was used (Regli et al., 1991). As Norovirus are not readily culturable, data from molecular methods are considered appropriate for use to estimate the concentration of infectious Norovirus in raw wastewater (Gerba et al., 2017; Gerba et al., 2018; Soller et al., 2018).

Exposure to pathogenic microorganisms is controlled in the draft regulation by requiring a total of 16 log enteric virus, 10 log Giardia cyst, and 11 log Cryptosporidium oocyst reduction between the raw wastewater and finished drinking water [§64669.45(b)(2), (3), and (7)]. Each 1-log reduction is the reduction of the organism density by a factor of ten. These log reductions were determined by identifying the highest organism density that could be expected in raw municipal sewage and calculating the reduction necessary to achieve the allowable densities in drinking water as determined by the U.S. Environmental Protection Agency (U.S. EPA) or using accepted dose-response relationships. The allowable drinking water densities are calculated to limit the annual risk of infection to 1 in 10,000 (equivalent to 2.7E-07 daily risk of infection). Water consumption of 2 liters per day, 365 days per year is used in the calculation.

All validated treatment barriers between the raw sewage and finished drinking water may be credited toward the total log reduction required. Table 1 includes the values used in the calculation of the required log reductions.

Table 1

	Enteric virus	*Giardia*	*Cryptosporidium*
Raw sewage maximum density	1E09 virus GC/L [a]	1E05 cysts/L [b]	1E04 oocysts/L [c]
Tolerable drinking water density	3.3E-07 virus/L [d]	6.8E-06 cysts/L [e]	1.4E-07 oocysts/L [f]
Ratio of drinking water to sewage density	3.3E-16	6.8E-11	1.4E-11
Required log reduction	16	10	11

(a) The maximum Norovirus concentration in gene copies per liter (GC/L) based on a literature review and meta-analysis presented by Eftim et al. (2017), Table 2.

(b) The high cyst concentrations found in untreated wastewater presented in Asano et al., Water Reuse, Metcalf and Eddy, 2007, Table 3-7.

(c) An oocyst concentration based on Norway (Robertson et al., 2006) and Melbourne (Tetra Tech, 2011) data, rounded up.

(d) Calculated using the dose-response model described by Teunis et al. (2008), page 1471.

(e) Calculated using the exponential dose-response model described Regli et al. (1991), Table 1.

(f) Calculated using the beta-Poisson dose-response model described by Messner et al. (2016), Table II.

The 2016 Expert Panel called for achieving reliability by "[u]sing a treatment train…with multiple, independent treatment barriers (i.e., redundancy) that meet performance criteria *greater than* (emphasis added) the public health threshold $\log_{10}$ reduction value (LRV) goals established for microorganisms" (Olivieri et al., 2016, p. 3, executive summary). For the treatment train to reliably provide microbiologically safe drinking water, the treatment train must be designed to include extra log reduction capacity beyond the required log reductions.

A treatment train has sufficient log reduction capacity to reliably achieve the required log reductions when it is designed for a total of 20 log enteric virus, 14 log Giardia cyst, and 15 log Cryptosporidium oocyst reduction between the raw wastewater and finished drinking water [§64669.45(a)]. These log reductions were determined by conducting a quantitative microbial risk assessment of a treatment train and applying a conservative critical treatment failure scenario for each reference pathogen, calculating the resulting risk of infection associated with the failure scenario, and then adjusting the total log reduction value (LRV) required to be provided by the treatment train to ensure the calculated risk of infection does not exceed a daily threshold of 2.7E-07 (equivalent to a 1:10,000 annual risk of infection).

The failure scenario is analyzed using a quantitative microbial risk assessment tool called DPRisk, developed in a research study overseen by The Water Research Foundation and funded by the State Water Board that incorporates a probabilistic analysis of treatment train performance (PATTP) to determine the pathogen exposure concentration. The PATTP allows for failure scenarios to be modeled. The tool calculates the risk of infection based on the pathogen exposure from water consumption and the applicable dose-response curve for the reference pathogen. A final draft of the study report provides an overview of the research scope, DPRisk tool guidance, and training presentations (Pecson et al., 2020). For more information on the DPRisk tool, please visit the State Water Board DPR website under the "DPR Research" section.

A conservative critical failure scenario includes a set of health protective assumptions. The scenario modeled is as follows: (a) the critical treatment process identified is the advanced oxidation process using ultraviolet light (UV/AOP), which is capable of providing a maximum 6-log reduction for each reference pathogen; (b) the critical failure of the UV/AOP is a power interruption that shuts down all UV lamps; and (c) a reasonable UV/AOP failure duration of 15 minutes is applied to the scenario based on standard design of UV/AOP treatment which typically includes a supervisory control system that continuously monitors and controls the quality of the power supply, condition of the UV lamp ballast, UV lamp output, and other electrical components, such that any treatment failure is identified and controlled accordingly within minutes or seconds; and (d) the critical failure is an infrequent to rare occurrence, which is characterized in this analysis as occurring once per year. Table 2 includes the scenario modeled and the calculation of the minimum design requirement.

Table 2

	Enteric virus	*Giardia*	*Cryptosporidium*
Required log reduction to ensure microbiologically safe drinking water	16	10	11
Critical treatment train failure scenario modeled:			
- Critical Process	UV/AOP	UV/AOP	UV/AOP
- Maximum loss of LRV	6 log	6 log	6 log
- Process failure magnitude	100% (loss of all 6 logs)	100% (loss of all 6 logs)	100% (loss of all 6 logs)
- Process failure duration	15 minutes	15 minutes	15 minutes
- Process failure frequency	Once a year	Once a year	Once a year
Excess log capacity needed to achieve a 2.7E-07 daily risk of infection with failure scenario	4	4	4
Minimum required design LRV	20	14	15

For additional information regarding pathogen control and log removal values, please refer to the State Water Board's [website for DPR](#), the reports associated with the investigation on the feasibility of developing uniform water recycling criteria for direct potable reuse ([SWRCB, 2016](#)), and the framework for regulating direct potable reuse ([SWRCB, 2019](#)).

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