Stantec

Memo

To:	Dale McTaggart, P. Eng. Regional District of North Okanagan	From:	Miles Yi, Reno Fiorante Stantec
File:	111700554	Date:	December 22, 2016

Reference: Duteau Creek WTP Protozoa Monitoring, Dissolved Air Floating Removal and UV Disinfection Review

Background

Stantec is engaged by Regional District of North Okanagan to conduct the following review at Duteau Creek Water Treatment Plant (DCWTP),

1. Current *Giardia lamblia* and *Cryptosporidium parvum* sampling and testing program;
2. *Giardia* and *Cryptosporidium* monitoring requirement by BC Ministry of Health and US EPA Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR);
3. Literature review of protozoa removal by Dissolved Air Floatation (DAF).
4. Protozoa inactivation by ultraviolet (UV) treatment

Stantec has reviewed a number of regulatory and scientific publication and DCWTP operating data pertinent to the subject matter. This Technical Memorandum summarizes the findings and recommendations of the review.

Giardia and Cryptosporidium sampling program and result

According to the 2012 Water Utility Master Plan, a protozoa sampling program was conducted between August 1999 and December 2001. The total number of samples and sampling frequency were unknown. The location for the raw water sampling was at the Duteau Creek Headgates Building from the raw water line, same as the current total coliform and E.coli sampling location.

This previous sampling program reported 1 positive assay for *Cryptosporidium* of 0.2 oocysts per 100 liters (hence 0.002 oocysts/liter); and 6 positive assays for *Giardia* of average 0.45 cysts per 100 liters (hence 0.0045 cysts/ liter).

Currently the District is conducting a monthly protozoa sampling program at two locations, with raw water sampling at Duteau Creek Headgates Building (from the raw water line) and treated water at Dissolved Air Floated Effluent (from the DAF recycled water lines to the Saturators). The program was initiated in July 2015 and currently has approximately 11 monthly data.

The recent data show high *Giardia* cysts counts in raw water ranging from 50 to 743 cysts per 100 liters (or 0.5 - 7.43 cysts/liter); and one positive *Cryptosporidium* oocysts sample at the raw water for 2.9 oocysts per 100 L (or 0.029 oocysts/liter).

The data also show effective treatment by the DAF process, ranging from 99.38% (or 2.2 logs) to 100% removal of *Giardia* cysts (with limitation by the available analytical method). For the one positive *Cryptosporidium* oocysts sampling in the raw water in May 2016, the DAF treatment efficiency was found with no detectable oocysts in the treated effluent.

The table below summarizes the current protozoa sampling results and DAF treatment efficiencies.

Table 1 Current *Giardia* cysts monitoring results and DAF treatment efficiencies

	Raw/Headgates cysts /100L	Post DAF cysts/100L	Removal %	Log Removal	Detection Limit (oo)cysts / 100L	
					Raw	Post DAF
21-Jul-15	64	0.4	99.38%	2.20	2.00	0.40
17-Aug-15	81.7	0	> 99.51%	> 2.31	1.08	0.40
14-Sep-15	225	0	> 99.85%	> 2.82	1.09	0.34
19-Oct-15	466	0	> 99.97%	> 3.46	1.00	0.16
16-Nov-15	743	1.4	99.81%	2.72	0.99	0.36
14-Dec-15	245.5	0	> 99.92%	> 3.09	0.99	0.20
18-Jan-16	324.32	0	> 99.91%	> 3.05	1.35	0.29
15-Feb-16	191.7	0	> 99.70%	> 2.53	2.08	0.57
14-Mar-16	259.8	0	> 99.78%	> 2.67	1.03	0.56
18-Apr-16	50	0	> 98.18%	> 1.74	1.28	0.91
16-May-16	61.9	0	> 99.50%	> 2.30	2.94	0.31
13-Jun-16	51.4	0	> 99.57%	> 2.37	0.68	0.22
11-Jul-16	27.1	0				
15-Aug-16	9.6	0				

Note:
1. A value of "0" means below detection limit.

Table 2 Current *Cryptosporidium* oocysts monitoring results and DAF treatment efficiencies

	Raw/Headgates oocysts /100L	Post DAF oocysts/100L	Removal %	Log Removal	Detection Limit (oo)cysts / 100L	
					Raw	Post DAF
21-Jul-15	0	0	-	-	2.00	0.40
17-Aug-15	0	0	-	-	1.08	0.40
14-Sep-15	0	0	-	-	1.09	0.34
19-Oct-15	0	0	-	-	1.00	0.16
16-Nov-15	0	0	-	-	0.99	0.36
14-Dec-15	0	0	-	-	0.99	0.20
18-Jan-16	0	0	-	-	1.35	0.29
15-Feb-16	0	0	-	-	2.08	0.57
14-Mar-16	0	0	-	-	1.03	0.56
18-Apr-16	0	0	-	-	1.28	0.91
16-May-16	2.9	0	> 89.31%	> 0.97	2.94	0.31

13-Jun-16	0.7	0	> 68.57% [2]	> 0.50 [2]	0.68	0.22
11-Jul-16	0	0				
15-Aug-16	0	0				

Note:

1. A value of "0" means below detection limit.
2. For low raw water (oo)cysts data, the percentage and log removal are no longer valid due to the limitation set by the detection limits. For example, the numbers shown are the results comparing the detection limits of raw water and treated effluent only.

Total Coliform and E. coli sampling program and result

Currently, Total coliform and E. coli are sampled and tested on a weekly basis on Tuesday at the Headgates Sampling Station, post DAF effluent, and DCWTP Reservoir outlet (finished water). All these Tuesday samples are sent to external lab (CARO) for analysis as part of the RDNO QA/QC program.

In addition, sampling is done on Thursday at the DCWTP Reservoir outlet as well, and analysis is completed internally at the RDNO lab. All finished water data (from both Tuesday and Thursday samplings) show conformance to the regulatory requirement for no detectable total coliform and E.coli.

The results of the weekly raw water and DAF effluent sampling for total coliform and E.coli are summarized below.

Table 3 Current Total Coliform monitoring results and DAF treatment efficiencies

	Raw/Headgates CFU/100 mL	Post DAF CFU/100 mL	Removal %	Log Removal	Detection Limit CFU / 100mL	
					Raw	Post DAF
11/16/2015	120	2	98.33%	1.78	1	1
11/24/2015	46	-	-	-	1	1
12/01/2015	110	-	-	-	1	1
12/08/2015	39	1	97.44%	1.59	1	1
12/14/2015	39	1	97.44%	1.59	1	1
12/21/2015	13	< 1	> 92.31%	> 1.11	1	1
12/29/2015	74	1	98.65%	1.87	1	1
01/05/2016	58	1	98.28%	1.76	1	1
01/12/2016	28.5	1	96.49%	1.45	1	1
01/18/2016	42	< 1	> 97.62%	> 1.62	1	1
01/26/2016	61	< 1	> 98.36%	> 1.79	1	1
02/02/2016	100	1	99.00%	2.00	1	1
02/09/2016	32	< 1	> 96.88%	> 1.51	1	1
02/15/2016	96	1	98.96%	1.98	1	1
02/23/2016	53	1	98.11%	1.72	1	1
03/01/2016	230	2	99.13%	2.06	1	1
03/08/2016	58	< 1	> 98.28%	> 1.76	1	1

03/14/2016	40.5	1	97.53%	1.61	1	1
03/22/2016	330	3	99.09%	2.04	1	1
03/29/2016	41	< 1	> 97.56%	> 1.61	1	1
04/05/2016	96	1	98.96%	1.98	1	1
04/12/2016	29	< 1	> 96.55%	> 1.46	1	1
04/18/2016	29	< 1	> 96.55%	> 1.46	1	1
04/26/2016	83	< 1	> 98.80%	> 1.92	1	1
05/03/2016	57	< 1	> 98.25%	> 1.76	1	1
05/10/2016	57	< 1	> 98.25%	> 1.76	1	1
05/16/2016	48	< 1	> 97.92%	> 1.68	1	1
05/24/2016	> 160	2	> 98.75%	> 1.90	1	1
05/31/2016	360	1	99.72%	2.56	1	1
06/06/2016	> 590	4	> 99.32%	> 2.17	1	1

Table 4 - Current E.coli monitoring results and DAF treatment efficiencies

	Raw/Headgates CFU/100 mL	Post DAF CFU/100 mL	Removal %	Log Removal	Detection Limit CFU / 100mL	
					Raw	Post DAF
11/16/2015	4	< 1	> 75.00%	> 0.60	1	1
11/24/2015	8	-	-	-	1	1
12/01/2015	< 1	-	-	-	1	1
12/08/2015	1	< 1	-	-	1	1
12/14/2015	9	< 1	> 88.89%	> 0.95	1	1
12/21/2015	4	< 1	> 75.00%	> 0.60	1	1
12/29/2015	1	< 1	-	-	1	1
01/05/2016	2	< 1	-	-	1	1
01/12/2016	1	< 1	-	-	1	1
01/18/2016	2	< 1	-	-	1	1
01/26/2016	13	< 1	> 92.31%	> 1.11	1	1
02/02/2016	65	< 1	> 98.46%	> 1.81	1	1
02/09/2016	24	< 1	> 95.83%	> 1.38	1	1
02/15/2016	50	1	98.00%	1.70	1	1
02/23/2016	14	1	92.86%	1.15	1	1
03/01/2016	98	2	97.96%	1.69	1	1
03/08/2016	12	< 1	> 91.67%	> 1.08	1	1
03/14/2016	24.5	1	95.92%	1.39	1	1
03/22/2016	330	3	99.09%	2.04	1	1
03/29/2016	36	< 1	> 97.22%	> 1.56	1	1
04/05/2016	56	< 1	> 98.21%	> 1.75	1	1
04/12/2016	9	< 1	> 88.89%	> 0.95	1	1

04/18/2016	20	< 1	> 95.00%	> 1.30	1	1
04/26/2016	4	< 1	> 75.00%	> 0.60	1	1
05/03/2016	4	< 1	> 75.00%	> 0.60	1	1
05/10/2016	2	< 1	-	-	1	1
05/16/2016	5.5	< 1	> 81.82%	> 0.74	1	1
05/24/2016	25	< 1	> 96.00%	> 1.40	1	1
05/31/2016	22	< 1	> 95.45%	> 1.34	1	1
06/06/2016	120	< 1	> 99.17%	> 2.08	1	1

In order for the percentage and log removal be meaningful, the raw water microbial level needs to be high and the treated effluent detection limit needs to be low. As such, some of the data points with low raw water microbial counts are not included. For example, with raw water E.coli counts of 1 (or 2) and the treated effluent of less than 1 CFU/100mL (detection limit), the calculation of percentage and log removal is no longer meaningful.

For these data points and in fact all data points, the focus should be the actual low to non-detectable microbial results from the DAF effluent. It demonstrates the robust performance in DAF treatment.

A summary of the weekly raw water total coliform and E.coli data at the Duteau Creek Headgates for year 2014, 2015 and year to date 2016 are presented in the table below.

Table 6 – Summary of the weekly Total Coliform and E.coli raw water (at Duteau Creek Headgates) monitoring results

Total Coliform			
Year	2014	Yr 2015	YTD 2016
Total Number of Samples	48	48	12
Samples > 100 MPN/100 mL	20	19	4
% Samples > 100 MPN/100 mL	41.67%	39.58%	33.33%
E.Coli			
Year	2014	2015	2016
Total Number of Samples	49	48	12
Samples > 20 MPN/100 mL	14	18	7
% Samples >20 MPN/100 mL	28.57%	37.50%	58.33%

It should be noted that the USEPA regulations (SWTR, IESWTR and LT1ESWTR) for Filtration Avoidance Criteria specify the source water microbial quality requirement for "representative samples immediately prior to the first point of disinfectant application". This is similar to the BC Ministry of Health Filtration Exclusion criteria for turbidity monitoring "immediately before disinfectant". It is apparent that the post DAF sampling location is critical in evaluating DCWTP for filtration exclusion. This represents the actual water quality prior to disinfection, which consistently meets the filtered water quality targets including turbidity below 0.3 NTU for 95% of samples.

Even though total coliform and E.coli are not direct indicators for protozoa, they are widely accepted as an indicator for water quality conditions (for potential for health risks, Health Canada, 2012). As

discussed above, the monitoring of DAF treated effluent water is of similar importance to the filtered water monitoring in a filtration plant.

Regulatory *Giardia* and *Cryptosporidium* monitoring requirement

Sampling Duration and Frequency

The BC Ministry of Health guidelines (*2012 - Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia*) does not appear to stipulate a specific protozoa monitoring requirement.

The Health Canada guidelines (2012 - Guidelines for Canadian Drinking Water Quality – Guideline Technical Document – Enteric Protozoa: *Giardia* and *Cryptosporidium*) state that routine and targeted monitoring for *Giardia* and *Cryptosporidium* should be part of the source water assessment, but did not specify details such as in monitoring frequency, location, reporting.

The 2006 USEPA Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) establishes very specific requirements and timeline for conformance. Under LT2ESWTR, the monitoring includes

1. an initial two years of monthly sampling (minimum 1 sample / month) and reporting for *Cryptosporidium* (for unfiltered system, plus E.coli and turbidity for filter system); and

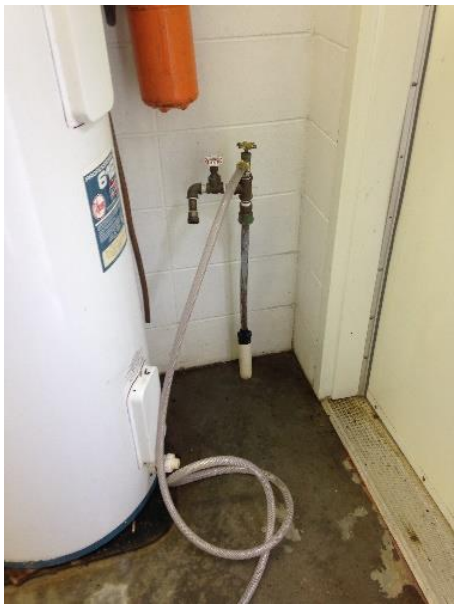
2. a second round of monitoring six years after completing the initial round.

LT2ESWTR has also established a Monitoring Avoidance requirement stating the source water are not required under LT2 Rule "if the system will provide a total of at least 3-log inactivation, equivalent to meeting the requirements for unfiltered system with a mean concentration of greater than 0.01 oocysts/L in 40 CFR § 141.712 [40 CFR § 141.701(d)(2)]."

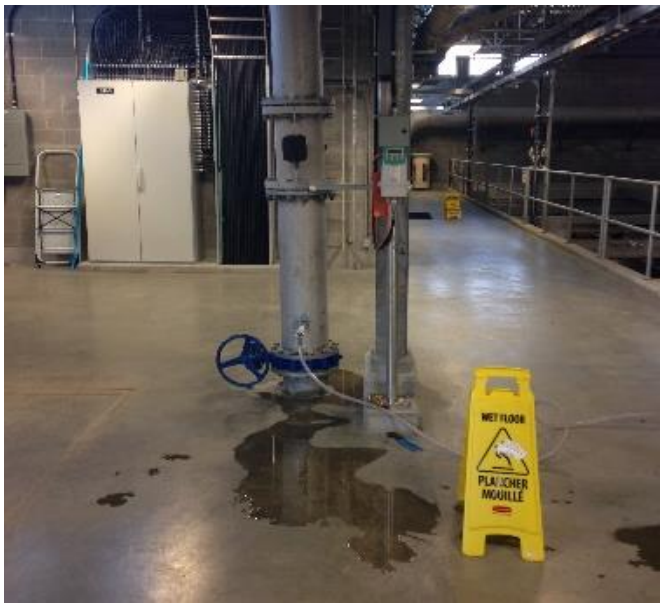
Sampling Location

For source water monitoring, the sampling location for LT2 Rule is at each plant intake / raw water line sampling tap prior to chemical treatment. If the plant does not have a sampling tap, the collection point could be "as close to the intake as is feasible, at a similar depth and distance from shore". The Health Canada guidelines (2012 GCDWQ) also stated the raw water sample to be collected near and at the depth of the intake point. The intention is to have the samples representative to the raw water influent to the treatment plant.

Currently, the DCWTP collects raw water sample at the Duteau Creek Headgates Building raw water line(standpipe sampling tap). This location meets LT2 Rules and Health Canada recommendation.



Duteau Creek Headgates Building Raw Water Line Sample Tap Location



DCWTP DAF Effluent Sample Tap Location

For the post-DAF sampling, the sampling location is at the DAF recycle flows (pump discharge lines to the DAF saturators). The samples from the DAF effluent recycle pump discharge lines are representative to the DAF effluent.

Analytical Methods

The LT2 Rules allow two methods for *Cryptosporidium* analysis, EPA Method 1622 and EPA Method 1623. Method 1623 is the most widely used method due to the advantage that it provides both *Giardia* and *Cryptosporidium*. It is also referenced in the Health Canada guidelines.

During the sampling, separation and concertation processes, there could be signification losses of (oo)cysts. Thus the laboratory QA/QC process and recovery efficiencies are very important in the validity of the data. The QA/QC and recovery efficiency results should be regularly and frequent reported along with the actual *Giardia* and *Crypto* results.

Currently, the District and Greater Vernon Water have on-going QA/QC program to ensure the prevision and standard of water sampling and analysis. The QA/QC control data and recovery efficiencies are also reported in every laboratory result report sheets from the certified lab (example below).

Giardia and Cryptosporidium Analysis Report Sheet — **Confidential Report**

Hyperion Research Ltd.
1008 Allowance Ave. SE, Medicine Hat, AB T1A 3G8
Telephone (888) 529-0847 Fax (403) 5290852 hyperion@telusplanet.net
www.hyperionlab.ca

CALA

To: Connie Kruger
Regional District of North Okanagan
9848 Aberdeen Rd.
Coldstream BC
V1B 2K9
250.550-3680
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Sample Date:	13-Jun-16
Sample Type:	Raw
LIMS:	
Volume Filtered (L):	146
Rec'd within 96h?:	Yes
Arrival Temp <20 °C?:	Yes

Project #:	
Upload to DB?:	
Field pH:	7.20
Field Temp °C:	12.7
Field Turb (NTU):	1.24
Sample Location:	Headgates

The methodology used to produce this report conforms to USEPA Method 1623 unless indicated otherwise below. Based on the validation data, the method is fit for its intended use Hyperion Research Ltd. is accredited for this analysis by CALA under the ISO/IEC 17025 standard.

Raw Counts in Sample Equivalent Volume

# CYSTS/OOCYSTS	*Giardia*	*Crypto.*
DAPI+/empty: Probably Dead	56	0
DAPI-/Probably Alive	19	1

Detection Limit: 0.68 cysts or oocysts/100L

The detection limit is calculated assuming a minimum of 1 cyst or oocyst observed in the Sample Equivalent Volume

RESULTS

Giardia	51.4	cysts/100 L
Cryptosporidium	0.7	oocysts/100 L

- A value of '0' really means below the detection limit
- These results apply to this sample only.

Processing Data

Date/Time Received:	6/14/2016 1:40:00 PM
Sample Temp. on arrival °C:	10.2
Lab ID:	56096
Filter Type:	Filta-Max
Date/Time Conc:	6/15/2016 11:00:00 AM
Concentration Analyst:	CS
IMS System:	DynaBeads GC Combo
IMS Lot No:	1752496
Pellet Vol (mL):	0.4
Resusp Vol (uL):	100
MAb Conjugate:	Giardi-a-Glo; Crypt-a-Glo
Monoclonal Antibody Lot No:	C34 G32
Control G:	4
Control C:	4
Date/Time Stained:	6/16/2016 12:00:00 PM
Staining Analyst:	CS
Microscope Analyst:	KW
Vol Used (uL):	100
Sample Equivalent Volume (L):	146.0

Comments:

Method 1623 Quality Control Data

	Lab Water Spike 2015		Matrix Spike 2014	
	% Recovery	RSD	% Recovery	RSD
Giardia	52.3	34.7	49.1	27.5
Cryptosporidium	58.5	44.9	51.9	20.1

These data indicate ongoing precision and recovery from monthly spiked water samples.

Analyst:

Peter M. Wallis, Ph.D.

Effective Date: 6 Feb. 2002 Revision Date: 22 January 2016 Version 1.2 Document # HR0008 Report Date: 6/17/2016 11:57:12 AM Page 2 of 2

The current monthly protozoa monitoring program at Duteau Creek WTP meets the LT2 monitoring requirements.

Literature review of protozoa removal by Dissolved Air Floatation (DAF)

The on-going monthly protozoa monitoring program provides a set of first-hand full scale operational data demonstrating the DAF removal / treatment efficiency of protozoa (presented in the Table 1 and 2 above). Even though the numbers of data points are limited, it shows that overall the removal efficiencies are significant and consistent with the reported values from literatures.

Fench et al. (2000) summarized 138 data points in the literature in a modeling effort for *Cypto* removal by DAF process in drinking water treatment. It was found that DAF was effective in removing up to 4-log of *Cypto oocysts* (see Figure 1 below from Fench et al. 2000).

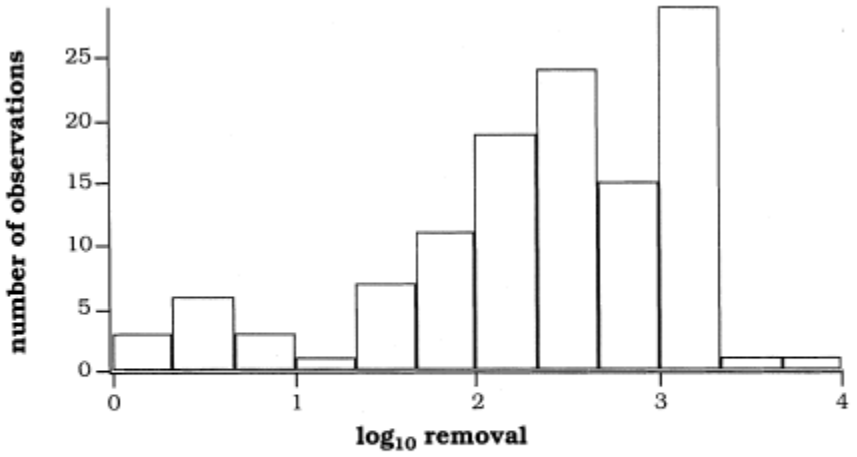

Fig. 1. Summary of log removals of oocysts reported for DAF processes. (Fench et al., 2000)

Edzwald et al. (2004) studied the Cryptosporidium oocysts removal by DAF and plate settler under various conditions with zero to 10% waste filter backwash water recycles. They found DAF processes achieved about 2-log oocysts removal for both summer and winter season with or without recycle of filter backwash wastewater. Plate settler achieved less removal (1 – 1.9 log) and varied between seasons.

Betancourt and Rose (2000) reviewed a number of publications on DAF performance for *Crypto* removal and the results are in general agreement with the two papers cited above; and quoted "DAF process is much more effective than sedimentation for removal of protozoan cysts" (Betancourt and Rose, 2000).

Overall, both sedimentation and dissolved air floatation could provide between 1 to 3 log of removal in Giardia and Crypto (oo)cysts, and the performance varied with filter backwash wastewater recycle ratio, flocculation time, pH and turbidity. Fench et al. (2000) provided a fitting model describing the relations of the factors (below):

> Log removal = 5.110 + 0.228 (% recirculation) – 1.808 (turbidity) + 0.4552 (turbidity^2)- 0.693 (pH) + 0.0594 (floc time, mins)
>
> *(By Fench et al., 2000, with R2 value of 0.64 and an error mean square of 0.49)*

The USEPA regulation in Surface Water Treatment Rules (SWTR), LT1 or LT2 Rules does not address DAF removal credit for *Giardia* and *Cryptosporidium*, likely because DAF has less application than conventional sedimentation. The LT2 provides 0.5 log *Crypto* removal credit to the sedimentation process in general if it meets the following criteria

- in continuous operation and treats all flow;
- continuous coagulation;
- achieves a monthly mean reduction of 0.5 log or greater in turbidity or particulate removal.

Health Canada (2012) also referenced a recent review of pilot and full-scale study data and concluded that "coagulation, flocculation and sedimentation processes were associated with a 1.6 log Cryptosporidium removal credit (range of 0.4 – 3.7 log) and a 1.5 log Giardia removal credit (range of 0 – 3.3 log)."

The DAF process, generally considered a variation to the sedimentation process, is capable of meeting the LT1 and LT2 Rules criteria, and often performs better compared to conventional sedimentation processes under the same conditions. It should be recognized that DAF should at a minimum receive the same *Giardia* and *Cryptosporidium* log removal credits that are provided to sedimentation processes.

Health Canada (2012) adapted a similar system to the USEPA LT1 and LT2 Rules in log removal credit for physical treatment processes. Similarly, it is mainly on the credits to various types of filtration methods (see table below from Health Canada 2012). All other physical treatment processes would need Demonstration and Challenge Testing as per the next section.

Table 7. *Cryptosporidium* and *Giardia* removal credits for various treatment technologies meeting the turbidity values specified in the Guidelines for Canadian Drinking Water Quality[a]

Treatment barrier	*Cryptosporidium* removal credit[b]	*Giardia* removal credit[c]
Conventional filtration	3 log	3 log
Direct filtration	2.5 log	2.5 log
Slow sand filtration	3 log	3 log
Diatomaceous earth filtration	3 log	3 log
Microfiltration and ultrafiltration	Demonstration and challenge testing[d]	Demonstration and challenge testing[d]
Nanofiltration and reverse osmosis	Demonstration and challenge testing[d]	Demonstration and challenge testing[d]

[a] Health Canada (2012b)
[b] Values from the LT2ESWTR (U.S. EPA, 2006a), p. 678.
[c] Values based on review of Schuler and Ghosh, 1990, 1991; AWWA, 1991; Nieminski and Ongerth, 1995; Patania et al., 1995; McTigue et al., 1998; Nieminski and Bellamy, 2000; U.S. EPA 2003; DeLoyde et al., 2006; Assavasilavasukul et al., 2008
[d] Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.

Demonstration and Challenge Testing

According to LT2ESWTR, "where a system can demonstrate that a plant, or a unit process within a plant consistently achieves a *Cryptosporidium* treatment efficiency greater than the presumptive credit specified in the LT2ESWTR, the state may allow the system to receive a higher *Cryptosporidium* treatment credit for the compliance with the LT2ESWTR (40 CFR 141.718(c))". Per USEPA, the Demonstration of Performance (or DOP) credits can be granted for any process, including inactivation processes.

The DOP process involves development and approval of the DOP evaluation criteria and testing matrix; DOP implementation; as well as Data analysis and reporting.

In order to demonstrate a relatively high log removal (3-log or higher), the DOP often needs to use alternative indicators or surrogate parameters because the naturally occurring (background) Crypto

levels are not high enough to demonstrate; and spiking crypto in a full scale operation is not practical due to the potential health concern.

With the same considerations, the selected surrogate needs to meet the following criteria,

1. Natural occurring (preferably), with high background concentration;
2. Do not pose health risks;
3. Can be detected at low concentration (after treatment);
4. Conservative in terms of treatment / removal compared to *Crypto*;
5. Does not increase or decrease by other methods (re-growth or indigenous reduction) than the treatment under investigation.

The USEPA reviewed two potential surrogates, aerobic bacteria spores and microspheres, in LT2 Rules Toolbox Guidance Manual for conventional treatment (coagulation, flocculation, sedimentation and filtration), quoting a number of literature research works.

Among them, Nieminski and Bellamy (2000) presented an extensive research and survey program studying 24 potable water systems and 12 possible surrogates to the target pathogens of *Giardia*, *Cryptosporidium* and enteric viruses. The result of the study shows no "ideal" surrogate for predicting (or corresponding) the occurrence and treatment of protozoa due to the low protozoa occurrence and the analytical constraints in low level detection of the treated water. However, the findings also lead to the recommendation of aerobic spores and particle counts as effective surrogates to evaluate the physical removal performance of the treatment processes. The two tables below summarize some of key characteristics of the candidate surrogates.

TABLE 1 **Candidate surrogate parameters**

Potential Surrogate	Natural Occurrence in Surface Water	Removal Similar to Pathogens	Analysis Turn-around Time, Simplicity, and Costs	Candidate Surrogate
Turbidity	Yes	Site-specific	Quick, simple, inexpensive	Yes
Particles > 2 µm	Yes	Yes?	Quick, simple, relatively inexpensive	Yes
Streaming-current potential	Yes	Treatment-specific	Quick, simple, relatively inexpensive	Used as baseline
Total and fecal coliform	Yes	No	Quick, simple, inexpensive	Used as baseline
Heterotrophic plate count	Yes	Treatment-specific	Quick, simple, inexpensive	Yes
Anaerobic bacterial spores and *Clostridium perfringens*	Yes, very low	Unknown	Quick, complicated, inexpensive	Yes
Aerobic bacterial spores and *Bacillus subtilis*	Yes	Yes	Quick, simple, inexpensive	Yes
Micrococcus luteus	Yes, low?	Unknown	Quick, simple, inexpensive	Preliminary
Somatic coliphage	Yes	Unknown	Quick, complicated, expensive	Yes
f-specific coliphage	Yes	Unknown	Quick, complicated, expensive	Yes

TABLE 3 **Raw water microbiological quality results**

Pathogen or Surrogate	Number	Detects *percent*	Median	25th Percentile	95th Percentile
Giardia—per 100 L	137	79	21	5	224
Cryptosporidium—per 100 L	137	59	5	2	66
Enteric viruses—*per 100 L*	12	75	5	1	465
Heterotrophic plate count—*per 100 mL*	211	99	15,000	3,800	462,200
Escherichia coli—per 100 mL	143	64	4	1	129
Total coliform—*per 100 mL*	176	85	39	6	4,496
Fecal coliform—*per 100 mL*	149	65	4	1	214
Aerobic spores—*per 100 mL*	242	100	1,820	528	25,280
Bacillus—per 100 mL	243	93	130	33	3,330
Anaerobic spores—*per 100 mL*	160	94	10	5	120
Clostridium—per 100 mL	160	92	6	2	78
PhiX174 phage—*per 100 mL*	62	71	8	1	2,414
Male-specific 2 phage—*per 100 mL*	62	56	3	1	689
Turbidity—*ntu*	195	100	3	1	33
Particles > 2 µm—*per mL*	68	100	8,937	5,675	360,633

The aerobic spores and particle counts meet the criteria described above for surrogates, and thus should be considered for DOP process for the DAF at the DCWTP. However, all other water quality parameters, such as, turbidity, protozoa, total coliform and E.coli should also be closely monitored in an effort to evaluate the overall treatment performance.

Per LT2 Rules, the DOP monitoring should be included in the monitoring program to assess the DAF performance at the DCWTP with a minimum weekly frequency for 52 consecutive weeks. More frequent monitoring may be required at critical operating conditions, such as peak flow, high turbidity (or deteriorated raw water quality) etc.

UV Disinfection and Log Inactivation Credit

In UV disinfection, there are three critically important parameters that determine the level of disinfection. They are UV light intensity, exposure / contact time, and target microbial response to UV light.

For *Giardia* and *Cryptosporidium,* the microbial response to UV light is well established. The LT2 Rules provides specific dose requirement for log inactivation credits, as illustrated in the LT2 table below. It applies to both filtered system **and to unfiltered systems** (*LT2ESWTR, 40 CFR 141.720(d)(1)*).

Exhibit 13.1 UV Dose Requirements – millijoules per centimeter squared (mJ/cm^2)[1]

Target Pathogens	Log Inactivation							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

[1] 40 CFR 141.720(d)(1).

In order to obtain log inactivation credit under LT2 Rules, the UV system must be validated and monitored as described in *40 CFR 141.720(d)(2) Reactor validation testing* and *40 CFR 141.720(d)(3) Reactor monitoring*.

One of the UV validation protocol that conforms to *40 CFR 141.720(d)(2)* is described in Chapter 5 of the *UV Disinfection Guidance Manual* (USEPA, 2006). For both validation and monitoring, UV transmittance (or UV absorbance) is a key parameter due to its effect in determining the UV light intensity that reaches the target microbial organism.

UVT is used to describe the behavior of UV lights through the medium. It is the percentage of UV light, as measured by UV intensity sensors, passing through the medium (water and /or quartz sleeve) over a specific distance (per LT2 Manual Equation 2.1 below).

$$\%\ UVT = 100 * \frac{I}{I_0} \qquad \text{Equation 2.1}$$

where

UVT = UV transmittance at a specified wavelength (e.g., 254 nm) and pathlength (e.g., 1 cm)

I = Intensity of light transmitted through the sample [milliwatt per centimeter squared (mW/cm^2)]

I_0 = Intensity of light incident on the sample (mW/cm^2)

In drinking water application, UVT is the most important water quality parameter in UV system design and sizing. Other parameters, such as particle size, suspended solids and turbidity, may affect UV system in wastewater treatment disinfection, but rarely have an impact in drinking water application due to the high water quality.

For example, turbidity in drinking water application is usually below 1 NTU and do not exceed 5 NTU for unfiltered system (immediately before the disinfectant) under both US SWTR and Canadian Health Guidelines. The LT2 Rules log inactivation credits for UV disinfection apply to unfiltered system meeting the turbidity requirement for filtration avoidance criteria. Health Canada (2012) has also quoted a number of researches concluding that the UV dose-response of microorganisms is not affected by variation in turbidity up to 10 NTU (Christensen and Linder, 2002; Oppenheimer et al., 2002; Mamane-Gravets and Linden, 2004; Passantino et al., 2005).

Another example is the particle size. Typically in wastewater UV application, particle size over 10 µm can cause particle shielding effect (Emerick and Darby, 1999). For drinking water application, the most common threshold used in monitoring is 2 µm.

In Duteau Creek WTP case, the turbidity after DAF treatment has been consistently below 0.3 NTU, not only exceeding filtration avoidance / exclusion criteria, but meeting filtered water quality. This provides UVT at post-DAF effluent above 85-87%, and post-reservoir above 90% which is well within the UV validation range, and better than many un-filtered water source (Metro-Vancouver Coquitlam UV facility with un-filtered water 85% design UVT; San Francisco Tesla UV treatment plant with unfiltered water 82.5% design UVT).

In summary, UV disinfection has been well established in both filtered and un-filtered water systems for protozoa inactivation. The Duteau Creek WTP post-DAF or post-reservoir effluents are suitable for UV disinfection to achieve 3-log of *Giardia* and *Cryptosporidium* inactivation.

Conclusions and Recommendations

At Duteau Creek WTP, the DAF process has proven to be robust and superior then conventional sedimentation with 5 years of full scale operating data. It has also shown significant removal in turbidity, protozoa, total coliform and E.coli.

In order to demonstrate that the DAF process performance meets the filtration exclusion criteria, the following monitoring plan is recommended,

1. Continue monthly protozoa sampling plan to provide at least 24 month of data;

2. Continue weekly monitoring of Total coliform and E.coli of the DAF effluent, to coincide with the weekly raw water microbial monitoring;

3. Continue online monitoring of turbidity at each of DAF unit effluent, combined DAF effluent;

4. Continue online monitoring of UV Transmittance (UVT) at the Combined DAF effluent and Post-Reservoir effluent;

5. Add weekly monitoring of aerobic spores, as *Giardia* and *Cryptosporidium* surrogate, at raw water and DAF effluent for Demonstrate of Performance (DOP), for at least 52 weeks;

6. Re-instate the existing online particle count equipment (or add weekly particle count monitoring for at least 52 weeks), as a secondary *Giardia* and *Cryptosporidium* surrogate, at the raw water and DAF effluent for Demonstrate of Performance (DOP).

Even the DAF process is proven to have high log removal of protozoa, UV disinfection is still recommended for the following reasons,

1. To provide a disinfection barrier for 3-log *Cryptosporidium* inactivation. Currently, the sodium hypochlorite disinfection at DCWTP is achieving 3 log or greater in *Giardia* inactivation (which is greater than 4 log virus inactivation requirement). However, chlorine is not effective in *Cryptosporidium* inactivation.

2. To meet the BC Ministry of Health - Filtration Exclusion criteria for "a minimum of two disinfection methods" and for 3-log *Giardia* and *Cryptosporidium* reduction;

3. To reduce the chlorine dosage level at the reservoir as one of the measures to reduce the DBP levels at far end of the distribution system.

We trust the above provides you with our review comments and recommendations for District's consideration.

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