
Log Reduction for
Drinking Water Production
What's In It for You?
June 30, 2020
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Webinar
moderator
Billie Emas
is a Sales Associate at the American Water Works Association.
Billie Emas is the Sales Associate to the NE and SE territories in the Sales Department at AWWA. She has been with AWWA for six months and she has been corresponding and building relationships with the members, advertisers, exhibitors and sponsors with AWWA. She has over 20 years of experience marketing, sales, event planning and membership. Billie has a BS in Business Administration from Bowling Green State University.
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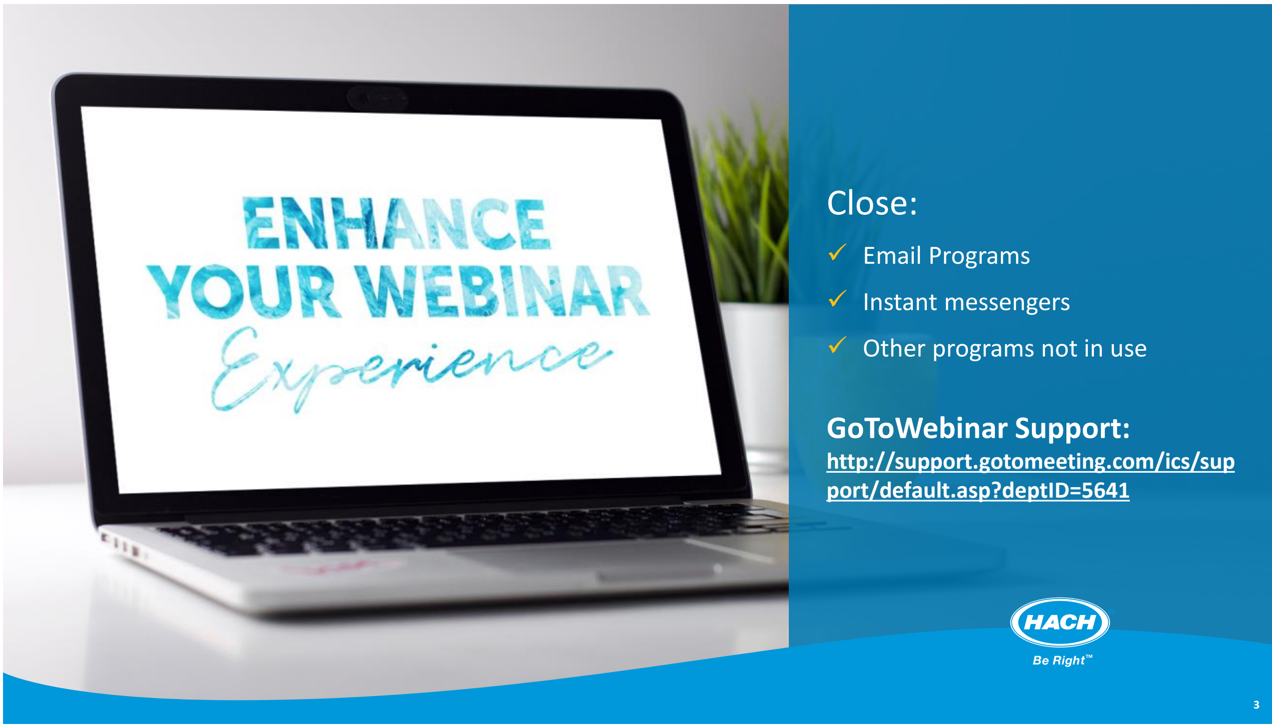
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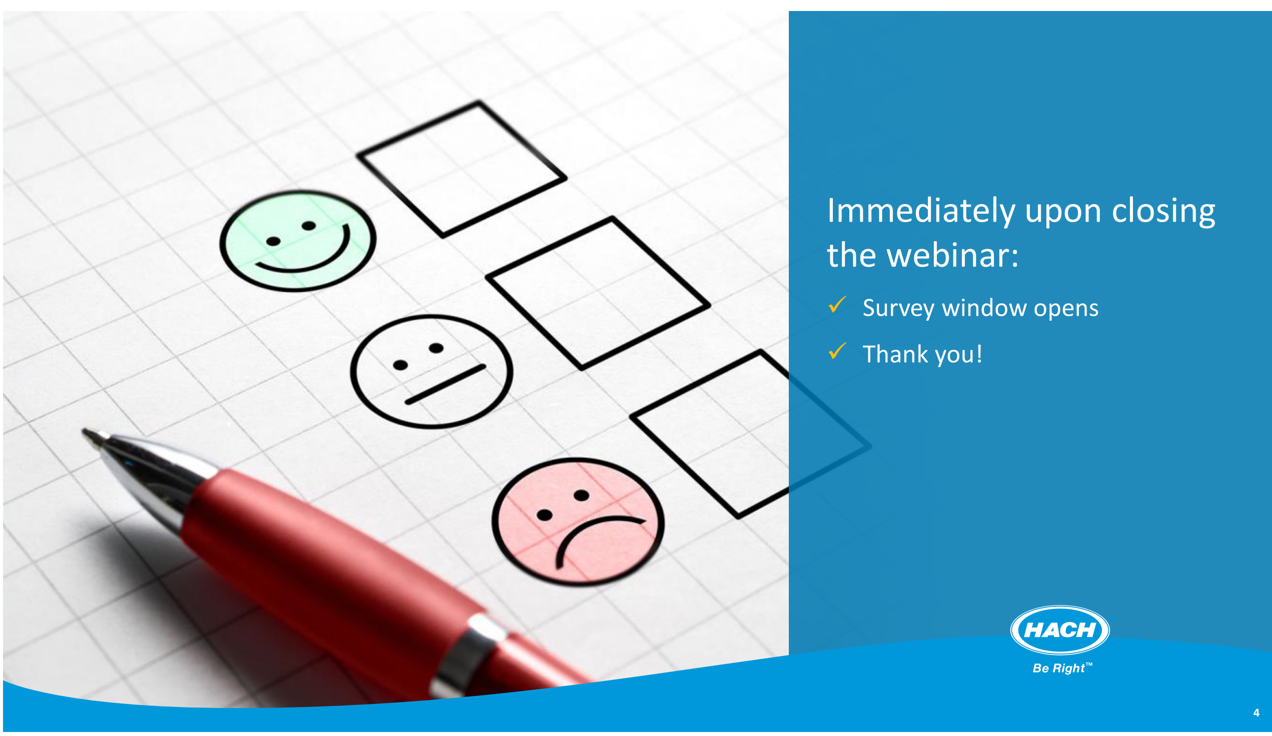
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Presenters

Travis Scurlock
Water Resources Senior Lead Operator, Parker Water & Sanitation District
(303) 841-4627
tscurlock@pwsd.org

Jacob Stephani
Technical Coordinator –
Soldier Canyon Water Treatment Authority
(970) 482-3143
jstephani@soldiercanyon.com

Dr Vadim Malkov
Principal Product Applications Manager – Hach
+1 970 663 1377 x2689
vmalkov@hach.com

Carlos Williams
Applications Development Manager – Hach
970.663.1377 x2181
cawillia@hach.com

Greg Fleck
Global Product Manager – Hach
970.663.1377 x2353
greg.fleck@hach.com

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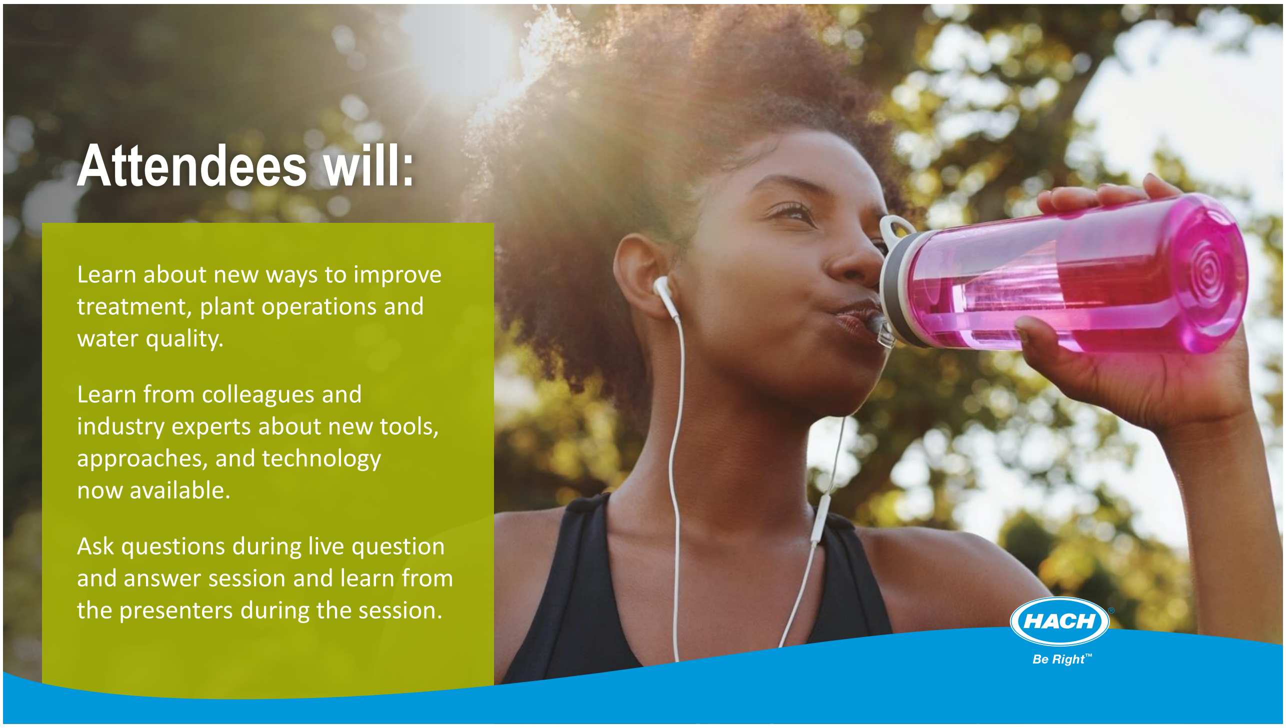
Attendees will:
Learn about new ways to improve treatment, plant operations and water quality.
Learn from colleagues and industry experts about new tools, approaches, and technology now available.
Ask questions during live question and answer session and learn from the presenters during the session.
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Greg Fleck
Global Product Manager – Hach
970.663.1377 x2353
greg.fleck@hach.com
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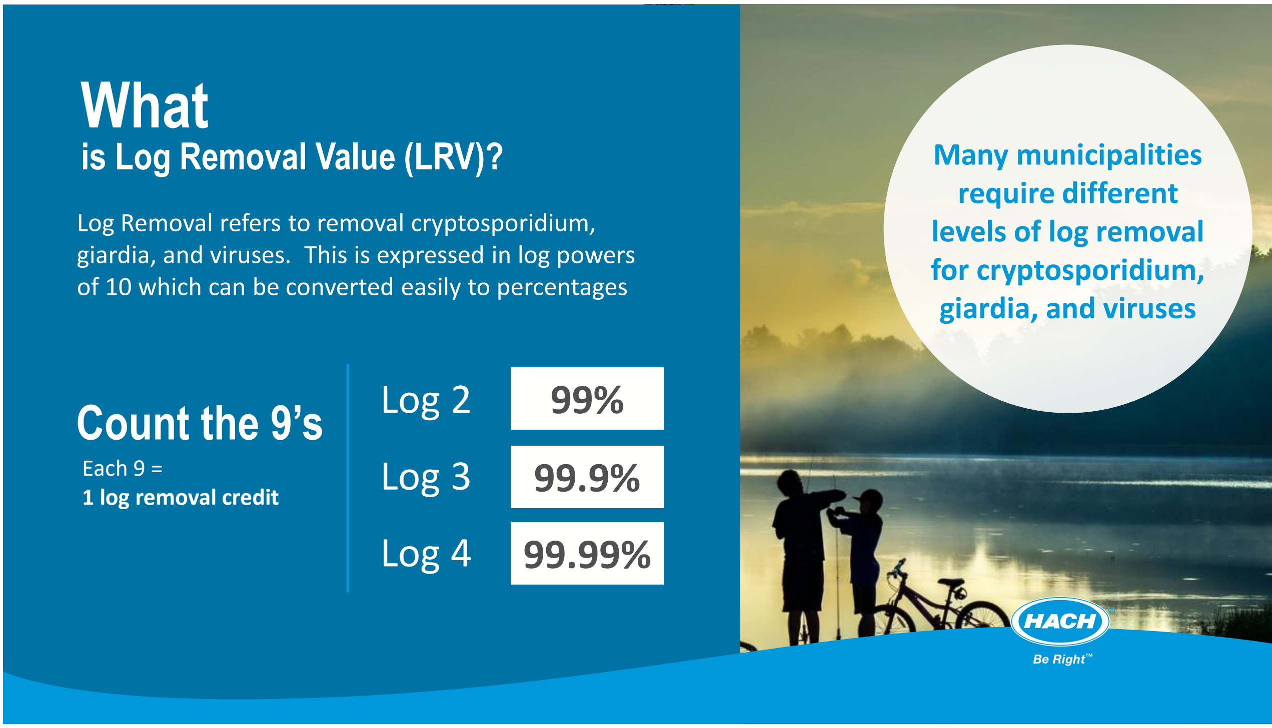
What
is Log Removal Value (LRV)?
Log Removal refers to removal cryptosporidium, giardia, and viruses. This is expressed in log powers of 10 which can be converted easily to percentages
Count the 9's
Each 9 =
1 log removal credit
Log 2
99%
Log 3
99.9%
Log 4
99.99%
Many municipalities require different levels of log removal for cryptosporidium, giardia, and viruses
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Why
do we monitor Log Removal?
To **prevent** waterborne disease outbreaks
LT2SWTR Requirement
At least 99.9% (3-log) removal and/or inactivation of Giardia lamblia cysts
At least 99.99% (4-log) removal and/or inactivation of viruses
At least 99% (2-log) removal of Cryptosporidium
1993 Cryptosporidium outbreak in Milwaukee caused
400,000 illnesses in two weeks
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How
do we calculate our LRV?
Removal =
Filtration
(e.g Giardia, Cryptosporidium, viruses)
Inactivation =
Disinfection
(e.g. Giardia, Cryptosporidium, viruses)
Removal +
Inactivation =
System Log
Removal Credits
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Carlos Williams
Applications Development
Manager – Hach
970.663.1377 x2181
cawillia@hach.com
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Sample Calculation - CT

Determine *Giardia* $CT_{99.9}$ from CT Table given Temperature = 0.5°C, pH = 6 s.u., Free chlorine residual = 0.8 mg/L

Chlorine Conc. (mg/L)	Temperature <= 0.5°C						
	pH						
	<=6.0	6.5	7	7.5	8	8.5	9
<=0.4	137	163	195	237	277	329	390
0.6	141	168	200	239	286	342	407
0.8	145	172	205	246	295	354	422
1.0	148	176	210	253	304	365	437

$CT_{99.9}$ = 145 minutes•mg/L

Step 3-B: Calculate *Giardia lamblia* Log Inactivation

Giardia Log Inactivation = 3 log × (CT_{CALC} / $CT_{99.9}$)

Giardia Log Inactivation = 3 log × (CT_{CALC} / $CT_{99.9}$)
Giardia Log Inactivation = 3 log × (65 minutes•mg/L / 145 minutes•mg/L)
***Giardia* Log Inactivation = 1.34 log**

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Log Removal / Inactivation

Log Removal	Initial Quantity (%)	Removal (%)	Amount Removed (%)	What's left (%)
1	100	90	90	10
2	10	90	9	1
3	1	90	0.9	0.1
4	0.1	90	0.09	0.01
5	0.01	90	0.009	0.001

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CT Tables

All values in tables are in minutes•mg/L

Table A: 3 Log CT ($CT_{99.9}$) Values for *Giardia* Cysts by free chlorine

Chlorine Conc. (mg/L)	Temperature <= 0.5°C							Temperature = 5°C							Temperature = 10°C						
	pH							pH							pH						
	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9
<=0.4	137	163	195	237	277	329	390	97	117	139	166	198	236	279	73	88	104	125	149	177	209
0.6	141	168	200	239	286	342	407	100	120	143	171	204	244	291	75	90	107	128	153	183	218
0.8	145	172	205	246	295	354	422	103	122	146	175	210	252	301	78	92	110	131	158	189	226
1.0	148	176	210	253	304	365	437	105	125	149	179	216	260	312	79	94	112	134	162	195	234
1.2	152	180	215	259	313	376	451	107	127	152	183	221	267	320	80	95	114	137	166	200	240
1.4	155	184	221	266	321	387	464	109	130	155	187	227	274	329	82	98	116	140	170	206	247
1.6	157	189	226	273	329	397	477	111	132	158	192	232	281	337	83	99	119	144	174	211	253
1.4	55	65	78	94	114	137	165	41	49	58	70	85	103	123	27	33	39	47	57	69	82
1.6	56	66	79	96	116	141	169	42	50	59	72	87	105	126	28	33	40	48	58	70	84
1.8	57	68	81	98	119	144	173	43	51	61	74	89	108	129	29	34	41	49	60	72	86
2.0	58	69	83	100	122	147	177	44	52	62	75	91	110	132	29	35	41	50	61	74	88
2.2	59	70	85	102	124	150	181	44	53	63	77	93	113	135	30	35	42	51	62	75	90
2.4	60	72	86	105	127	153	184	45	54	65	78	95	115	138	30	36	43	52	63	77	92
2.6	61	73	88	107	129	156	188	46	55	66	80	97	117	141	31	37	44	53	65	78	94
2.8	62	74	89	109	132	159	191	47	56	67	81	99	119	143	31	37	45	54	66	80	96
3.0	63	76	91	111	134	162	195	47	57	68	83	101	122	146	32	38	46	55	67	81	97

All values in tables are in minutes•mg/L

Table A: 3 Log CT ($CT_{99.9}$) Values for *Giardia* Cysts by free chlorine

Chlorine Conc. (mg/L)	Temperature <= 0.5°C							Temperature = 5°C							Temperature = 10°C						
	pH							pH							pH						
	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9
<=0.4	137	163	195	237	277	329	390	97	117	139	166	198	236	279	73	88	104	125	149	177	209
0.6	141	168	200	239	286	342	407	100	120	143	171	204	244	291	75	90	107	128	153	183	218

Table B: 4 Log CT ($CT_{99.99}$) Values for viruses by free chlorine

Temperature °C	pH	
	6-9	10
0.5	12	90
5	8	60
10	6	45
15	4	30
20	3	22
25	2	15

Tables reproduced from

U.S. EPA. 2003. *LT1ESWTR Disinfection Profiling and Benchmarking Technical Guidance Manual.* EPA 816-R-03-004, http://www.epa.gov/safewater/mdbp/pdf/profile/lt1profiling.pdf

For more information

EPA's LT1ESWTR web site: http://www.epa.gov/safewater/mdbp/lt1eswtr.html

CDPHE WQCD web site: http://www.cdphe.state.co.us/wq/

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Potential options are:

1. Texas TCEQ approach
2. California IPR approach (12/10/10 log removals for virus/Crypto/Giardia)
3. the use of an Expert Panel

Regulations are Clear for Indirect Potable Reuse in California

Pathogen Removal from Raw Sewage to Potable Water

- 12-log Virus (99.9999999999%)
- 10-log Giardia
- 10-log Cryptosporidium

Water Quality

- Maximum TOC of 0.5 mg/L of wastewater origin
- Maximum TN 10 mg/L
- Advanced oxidation for direct injection projects – 0.5-log 1,4-dioxane

Other Public Health Protection for the rest of the country

Pathogens Criteria

- Choose pathogen control criteria for DPR.

Chemicals Criteria:

Tier 1: Meet water MCLs

Tier 2: Monitoring could be required for unregulated chemicals (including CECs)

Tier 3: Surrogates or unregulated chemicals that are useful for evaluating treatment

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Example Pathogen Log Reduction Credits (Potable water reuse example)

Process	Monitoring	Log Reduction Credits		
		V	G	C
Secondary treatment	Study needed	0 - 1.9	0 - 0.8	0 - 1.2
MF or UF	Daily PDT	0[a]	4.0	4.0
RO	Online EC	1.5	1.5	1.5
UV-AOP	Intensity sensors	6	6	6
ESP with free chlorine, CL_2,	Online Cl_2	6	3	0
Total		**13.5**	**14.5**	**11.5**

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State Primacy and Application Driven

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Parker Water & Sanitation District Experience

Travis Scurlock

Water Resources Senior Lead Operator Rueter-Hess Water Purification Facility

Parker Water & Sanitation District, Parker, CO

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PWSD Rueter-Hess Drinking Water Plant

Population served: 56,000
Demand: Winter 3.5 MGD/Summer- 22 MGD
Treatment plant capacity: 10 MGD
Groundwater Well capacity: 26 MGD

Supplied by Rueter-Hess Reservoir

- ✓ 75000 Ac/ft capacity
- ✓ 164 ft total depth
- ✓ 1200 surface acres

Reservoir water is a blend of water from Cherry Creek, alluvial wells, and tertiary treated effluent from PWSD water reclamation facility.

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Achieving the LRV – Front End

The treatment begins with a Source Water Monitoring Panel on the raw water

- Accelerated sedimentation (Actiflo Turbo)
- Secondary ballasted sand process (Actiflo Carb)
- Exceptional TOC removal

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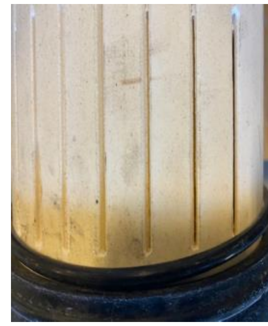
Achieving the LRV - Filtration

The 4-log virus inactivation by disinfection

- Pre-oxidation
- Post-chlorination



Filtration by ceramic membranes:

- ✓ 3-log Giardia
- ✓ 3-log Cryptosporidium

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Achieving the LRV - Disinfection

Pre-oxidation:

- Permanganate
- Chlorine Dioxide
- Pre-Chlorination (Free Chlorine)

Post-chlorination:

- The chlorine is monitored at the combined filter effluent (CFE) for appropriate concentration before entering the DCB.
- Minimum of 0.55 mg/L free chlorine residual must be maintained at exit from disinfection contact basin (DCB).

Originally used a Hach CLF10:

- Varying pH and iron fouling caused inaccurate readings and extra maintenance
- Replaced it with a CL17

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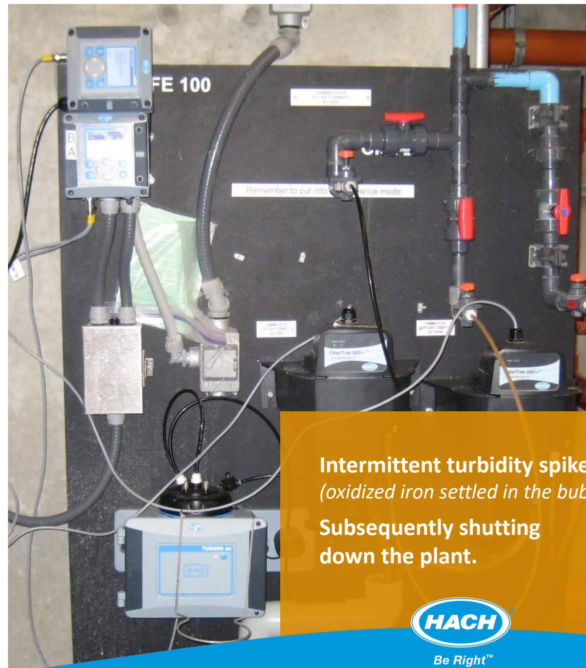
Achieving the LRV - Turbidity

Turbidity compliance point at the CFE

Originally monitored with Hach FT660sc turbidimeters

Tested new TU5400sc turbidimeter



Intermittent turbidity spikes
(oxidized iron settled in the bubble traps)

Subsequently shutting down the plant.

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Achieving the LRV - Turbidity

Turbidity compliance point at the CFE

Originally monitored with Hach FT660sc turbidimeters

Tested new TU5400sc turbidimeter

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Achieving the LRV – Turbidity & Chloramination

Chose the TU5400sc turbidimeters
Helps to ensure proper filter operation for the log removal.

CL17 for free chlorine compliance before ammonia addition (post DCB)

Three 5500sc AMC analyzers (Ammonia/Monochloramine):

Monitor the finished/treated water from the treatment plant.

WISE treated water source.

The combined flow as it enters the distribution system.

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Pre-filter &
Post-filter Treatment
Jacob Stephani
Technical Coordinator – Soldier
Canyon Water Treatment Authority
(970) 482-3143
jstephani@soldiercanyon.com
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Northern
Colorado
Soldier Canyon Water
Treatment Plant
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Soldier Canyon Water Treatment Plant, Fort Collins, CO – Facts

Wholesale Treatment Plant built in 1962, owned by and supplies drinking water to three districts:

- Fort Collins/Loveland Water District (FCLWD)
- North Weld County Water District (NWCWD)
- East Larimer County Water District (ELCO)
  - Rated at 50 MGD (undergoing Plant Expansion to 60 MGD – due 2021)
  - Production Range: 9 to 44 million gallons of water per day
  - SCFP treated 7.43 Billion gallons in 2019

Raw Water Sources: Horsetooth Reservoir and Cache La Poudre River via Pleasant Valley Pipeline

- Raw flow can be a combination of Horsetooth water and Pleasant Valley water (April – October)

On Site Water Storage:

Four Above-Ground Clearwell Tanks = 11 MGD Total

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Treatment process and disinfection credit

Conventional Water Treatment

Oxidation | Coagulation | Flocculation | Sedimentation | Filtration | Disinfection | Corrosion Control

Chlorine Dioxide: first chemical added to the raw water (pre-oxidant, generated, fed prior to coagulation)

Does not create regulated Disinfection Byproducts

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Disinfection

Pre-Clearwell residual is monitored in two locations:

- End of the CFE channel where the water enters the pipe leading to the Clearwell Tanks: CL17 in the Laboratory
- Right before entering the Clearwell Tanks: CL17 + beta CL17sc

Post-Clearwell residual: CL17 and CL10

- Both measure the residual existing in the Clearwell Tanks and entering the Distribution system

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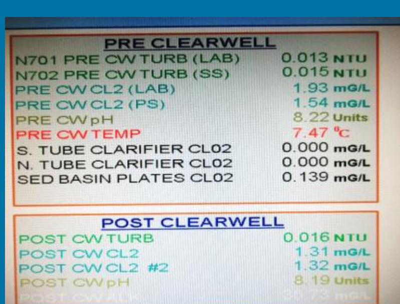
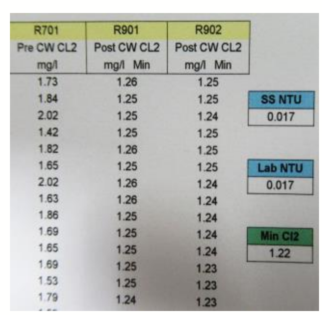
Chlorine Analysis



All four chlorine analyzers tied into SCADA

- two Pre-Clearwell
- two Post-Clearwell



R701	R901	R902
Pre CW CL2 mg/l	Post CW CL2 mg/l Min	Post CW CL2 mg/l Min
1.73	1.26	1.25
1.84	1.25	1.25
2.02	1.25	1.24
1.42	1.25	1.25
1.82	1.26	1.25
1.65	1.25	1.25
2.02	1.26	1.24
1.63	1.26	1.24
1.86	1.25	1.24
1.69	1.25	1.24
1.65	1.25	1.24
1.69	1.25	1.23
1.53	1.25	1.23
1.79	1.24	1.23

SS NTU	Lab NTU	Min Cl2
0.017	0.017	1.22

Great value of redundancy

- Robust automated compliance reporting
- No need for manual sampling if an analyzer goes down

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Log-Reduction Credits

Record of Approved Water Works
Determines Log-Removal required based on your system and technologies utilized

Source Water BIN Classification: BIN 1

Type of Filtration: Conventional

	Crypto	Giardia	Virus
Minimum Treatment Required	2.0-log	3.0-log	4.0-log
Removal Credit Granted	3.0-log	2.5-log	2.0-log
Inactivation Required	**-1.0-log**	**0.5-log**	**2.0-log**

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Daily Calculation of Log-Reduction Credits for *Giardia lamblia* and Viruses

Enter Baffling Factor for Stage 1:	0.70	**Enter** Baffling Factor for Stage 4:	0.30
Enter Baffling Factor for Stage 2:	0.10	**Enter** Baffling Factor for Stage 5:	0.70
Enter Baffling Factor for Stage 3:	0.50	**Enter** Baffling Factor for Stage 6:	0.10

System Characteristics and Log-Reduction Credits for: Soldier Canyon Filter Plant

January 2020

Day	Treatment Stage	Disinfectant	Residual Conc. (mg/L)	pH	Temp. (Celsius)	Peak Flow (GPM)	Vol. Min. (gal)	Vol. Eff. (gal)	T10 (min)	CT Actual	Log-Reduction (*Giardia*)	Log-Reduction (viruses)
1	Headworks	Chlorine Dioxide	0.30	7.66	4.4	11,035	3,660	2,562.0	0.2	0.1	0.01	1.66
	Floc Influent	Chlorine Dioxide	0.05	7.66	4.4	11,035	52,762	5,276.2	0.5	0.0	0.01	1.66
	Floc Basin	Chlorine Dioxide	0.05	7.66	4.4	11,035	537,124	268,562.0	24.3	1.2	0.11	1.73
	Sed Basin	Chlorine Dioxide	0.05	7.66	4.4	11,035	381,480	114,444.0	10.4	0.5	0.05	1.69
	Pipe to Clearwell	Free Chlorine	1.32	8.44	4.9	11,035	24,748	17,323.6	1.6	2.1	0.02	0.86
	Clearwell	Free Chlorine	1.20	8.21	4.9	11,035	5,605,006	560,500.6	50.8	61.0	.72	.22
	System TOTAL										**0.93**	**36.81**
2	Headworks	Chlorine Dioxide	0.28	7.59	4.3	11,000	3,660	2,562.0	0.2	0.1	.01	.66
	Floc Influent	Chlorine Dioxide	0.05	7.59	4.3	11,000	52,762	5,276.2	0.5	0.0	0.01	1.66
	Floc Basin	Chlorine Dioxide	0.05	7.59	4.3	11,000	537,124	268,562.0	24.4	1.2	0.11	1.73
	Sed Basin	Chlorine Dioxide	0.05	7.59	4.3	11,000	381,480	114,444.0	10.4	0.5	0.05	1.69
	Pipe to Clearwell	Free Chlorine	1.41	8.62	4.5	11,000	24,748	17,323.6	1.6	2.2	0.02	0.90
	Clearwell	Free Chlorine	1.24	8.24	4.5	11,000	5,953,528	595,352.8	54.1	67.1	.76	.28
	System TOTAL										**0.97**	**38.91**

Model developed for EPA based on Montana DEQ Model and AWWA's *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*

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Impacts on Log-Reduction

Current State

Disinfectant Residual	Manageable
Clearwell Tank Volume	Manageable
Peak Flow (one hour)	No Control of System Demand
Post-pH	Manageable
Temperature	No control of Nature

Better Solution to Manage Log Removal Credit

Increase contact time

Real-time LRV calculation

Visibility of LRV to operators

Increase confidence in water safety

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Dr Vadim Malkov

Principal Product
Applications Manager – Hach
+1 970 663 1377 x2689
vmalkov@hach.com

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Choosing the Right Chlorine Analyzer

Colorimetric vs Amperometric

Thought process

Analysis of the application

Main differentiators

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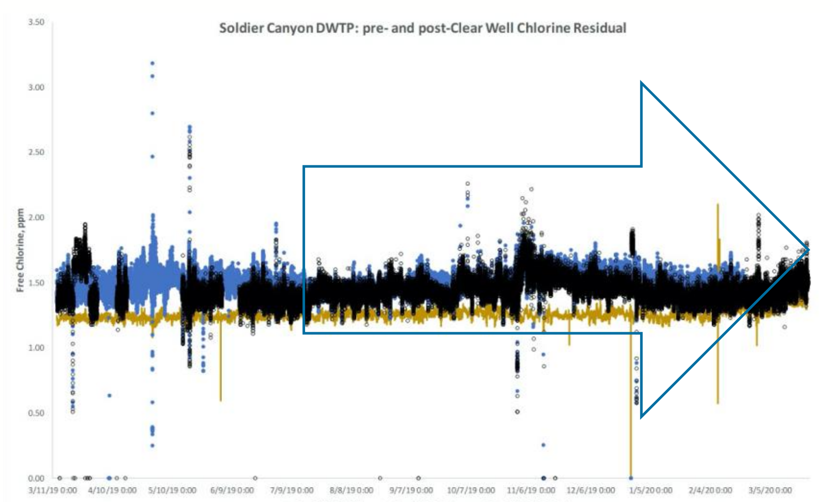
Post-chlorination at Soldier Canyon



A full year of data

Pre- and Post-Clearwell: free chlorine monitoring results

Three online analyzers

Two monitoring technologies

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Soldier Canyon: Post-chlorination monitoring results
(3/13/2019 through 3/28/2020)

Instrument & location	AVG Cl_2, mg/L	STDev	RSD, %	# points*
Pre-CW CL17	1.49	0.084	5.6%	120508
Pre-CW CL17sc	1.45	0.082	5.6%	143621**
Post-CW CLF10sc	1.26	0.041	3.2%	108583

* Data recorded at 5 min interval for CL17 and CLF10
** Since 7/18/19, at every 2.5 min

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Making a Selection
4-step process for choosing the right analyzer technology

Step 1
(Compare Basic Specifications)

Does the measurement range cover your expected values?

Does the specified pH range fit your application?

Step 2
(Evaluate Technology Key Differentiators)

What is preferred for your situation – uncompromised accuracy or speed of response?

Step 3
(Consider Detailed Instrumentation Specifications)

What nuances of the specs are most valuable for your application?

Step 4
(Keys to Application Success)

E.g. reagents discharge vs. necessity to calibrate - can your utility meet these requirements?

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Study Conclusions and References
Pre- and Post-chlorination influencing Disinfection Credit (Accuracy matters!)
Choosing the right analyzer technology is important
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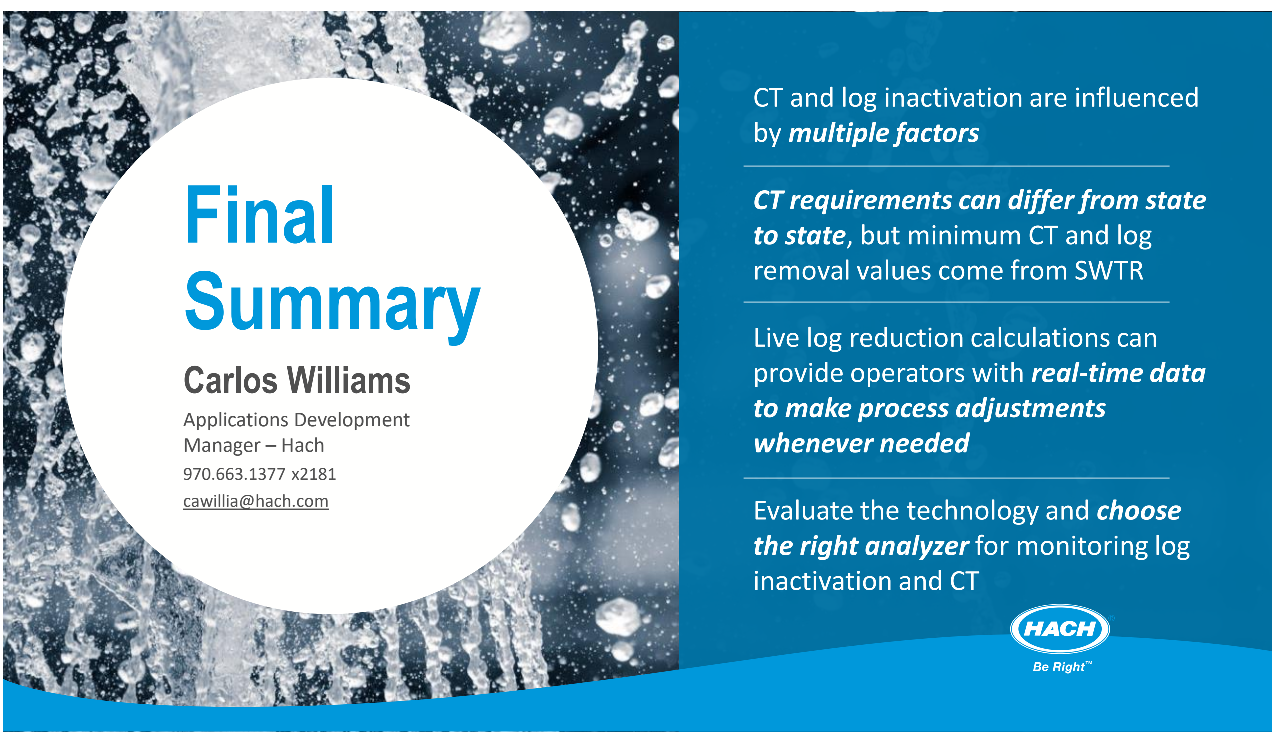
Final Summary
Carlos Williams
Applications Development Manager – Hach
970.663.1377 x2181
cawillia@hach.com
CT and log inactivation are influenced by ***multiple factors***
CT requirements can differ from state to state, but minimum CT and log removal values come from SWTR
Live log reduction calculations can provide operators with ***real-time data to make process adjustments whenever needed***
Evaluate the technology and ***choose the right analyzer*** for monitoring log inactivation and CT
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Presenter Biographies

Travis Scurlock
Water Resources Senior Lead Operator, Parker Water & Sanitation District
(303) 841-4627
tscurlock@pwsd.org

Travis Scurlock is the District's Senior Water Lead Operator for Water Resources, he has worked for PWSD for over fourteen years. In that time, Travis held positions in both water and wastewater as an operator and a lead operator. Travis not only is an excellent technical operator in the field but exemplifies the District value of outstanding customer service. Travis was nominated to receive the RMSAWWA Outstanding Distribution System Operator award due in large part to his contribution to the Water Resources Consolidation Project (WRCP). His input and leadership was instrumental in the successful switch from free chlorine to chloramines. The RMSAWWA Outstanding Distribution System Operator award covers New Mexico, Colorado and Wyoming

Jacob Stephani
Technical Coordinator – Soldier Canyon Water Treatment Authority
(970) 482-3143
jstephani@soldiercanyon.com

10 years in the Drinking Water Industry

Entered the Drinking Water Industry 10 years ago as a Plant Operator in NY, and now is the Technical Coordinator at Soldier Canyon Treatment Plant.

Greg Fleck
Global Product Manager – Hach
970.663.1377 x2353
greg.fleck@hach.com

Greg Fleck is a Global Product Manager at Hach Company and is based in Loveland, Colorado. A member of the Municipal Drinking Water team, Greg looks for ways to improve Hach's products and explore new applications in Turbidity, Disinfection, and other core drinking water parameters. While working for Hach's parent company over the past 7 years he has held roles supporting and manufacturing water quality and medical products. Greg holds Bachelor's and Master's degrees in Civil Engineering from the University of Maryland.

Dr Vadim Malkov
Principal Product Applications Manager – Hach
+1 970 663 1377 x2689
vmalkov@hach.com

Vadim B. Malkov (PhD Chemistry) joined Hach Company as an R&D chemist in 2002 and moved over to the business organization in 2008. During his tenure at Hach, Vadim has led and participated in development of several process analyzers, methods and applications. Dr. Malkov has published many papers in scientific and professional journals and presented results of his work at multiple conferences in the United States and abroad. Vadim Malkov is currently working at Hach as a Principal Product Applications Manager for Drinking Water with focus on turbidity and disinfection.

Carlos Williams
Applications Development Manager – Hach
970.663.1377 x2181
cawillia@hach.com

Carlos Williams has worked in analytical chemistry for the last 17 years in process and laboratory settings. In his time at Hach he has had the privilege of traveling across North America as well as internationally to teach and lecture on topics such instrumentation, data analysis, and chemistry to help organizations get the most out of their analytical tools. He is currently a Colorado Certified Water Professional. Carlos is based just south of Loveland, Colorado.

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