2019 PNWS-AWWA Conference

Biological Filtration – Benefits and Challenges

Lynn Williams Stephens, PE

Agenda

- Background on biofiltration
- How to develop a Filter Management Plan
- Pilot testing case studies
  - Toronto: cold weather biological filtration
  - Lake Oswego: surface water treatment pilot

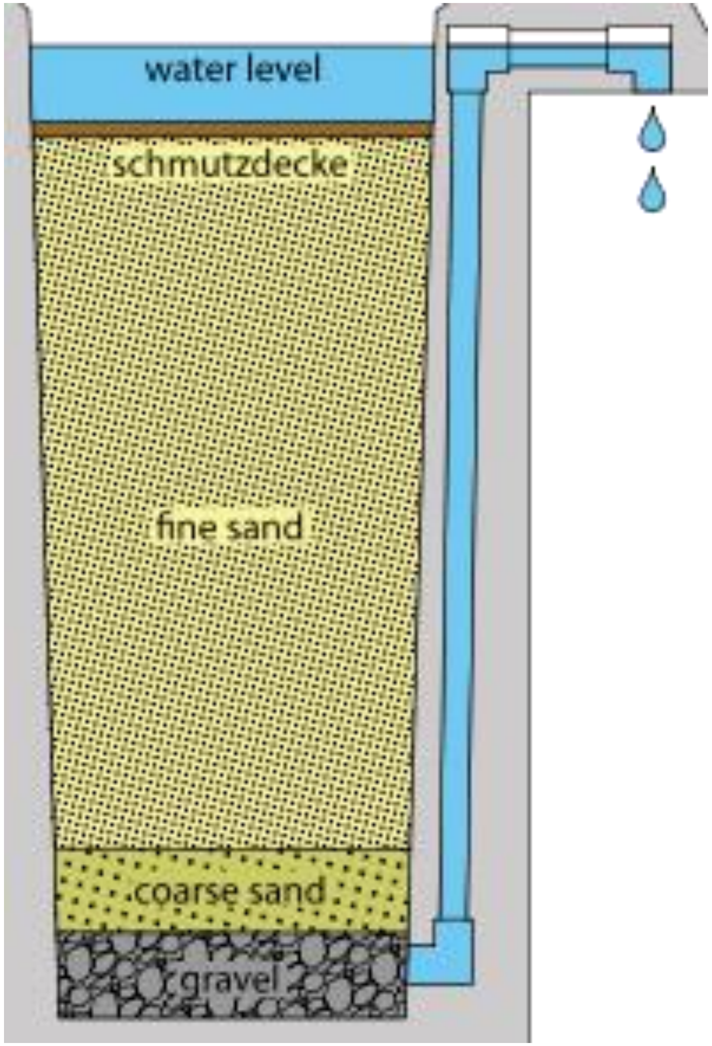
Biological Filtration Definition

Biological treatment within a filter at a drinking water treatment facility is an operational practice of managing, maintaining, and promoting biological activity on granular media in the filter to enhance the removal of organic and inorganic constituents before treated water is introduced into the distribution system.

2016 AWWA Biological Drinking Water Treatment Committee

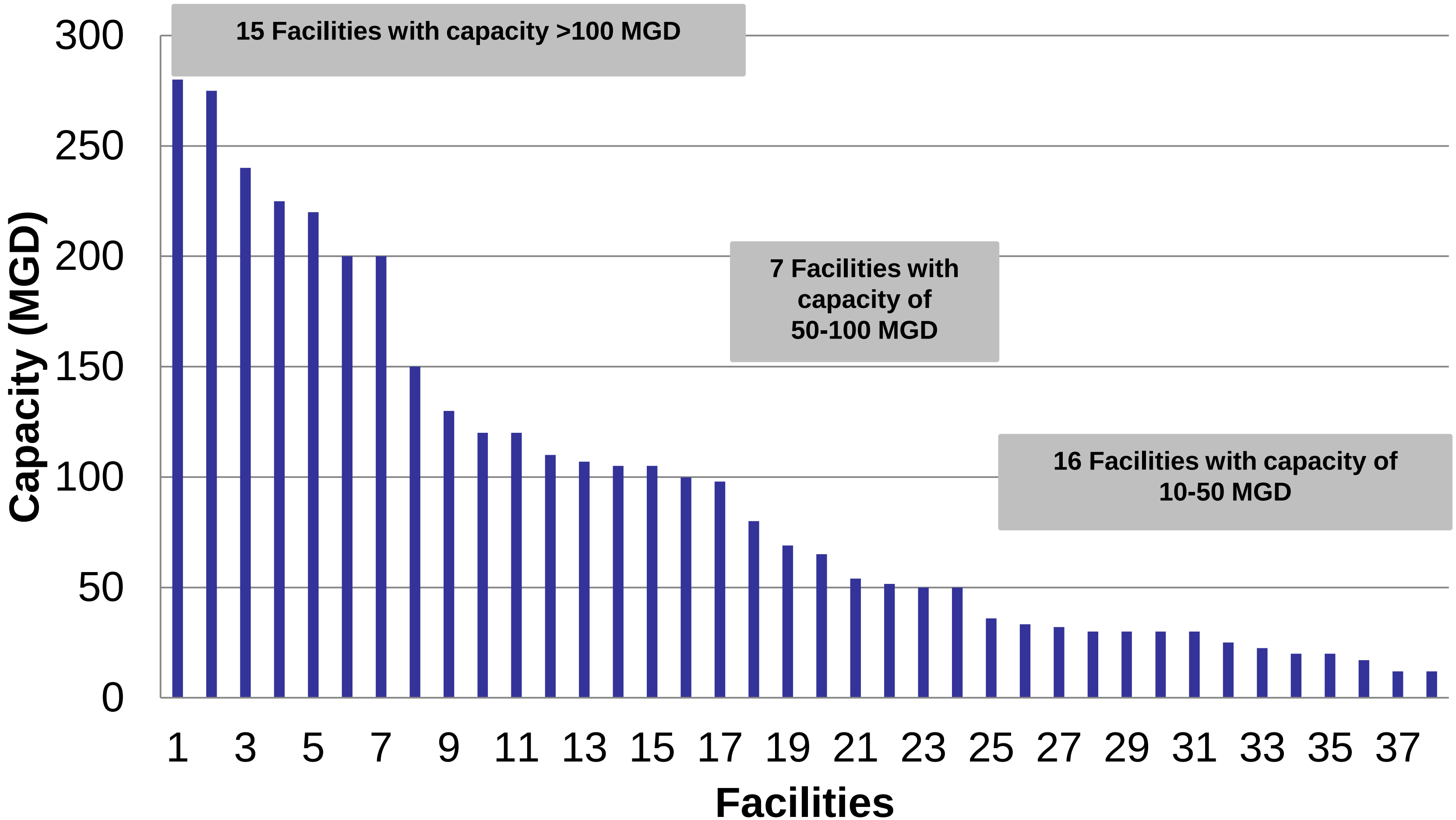
Slow Sand Biological Filtration

- Historically, biological filtration around for 100’s of years via slow sand filtration
  - Biofilm layer “*Schmutzdecke*”
- Relies on microbial activity of bacteria to degrade contaminants



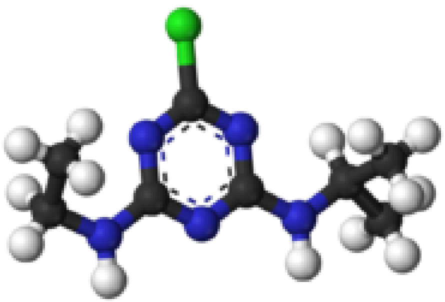
Example of Slow Sand Filtration

Current Practices with Rapid Rate Biofiltration

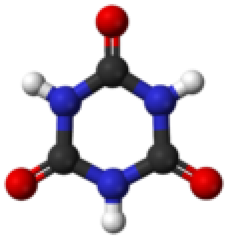


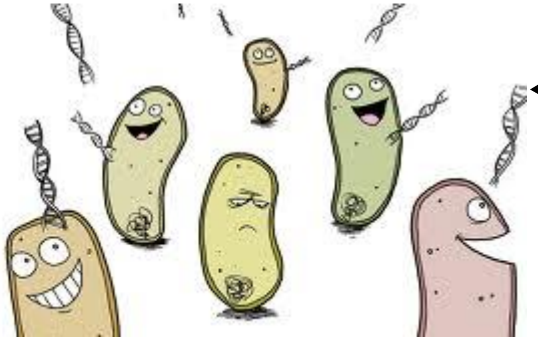
Source: WRF 4459 – Development of a Biofiltration Knowledge Base

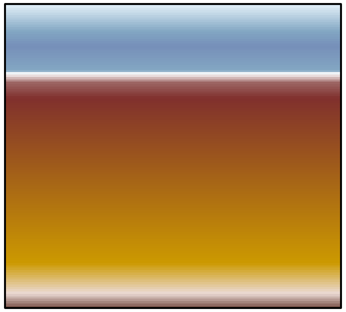
Overview of Ozonation and Biofiltration



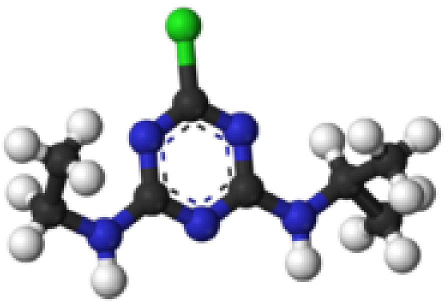
$+ O_3 =$



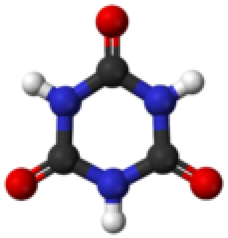


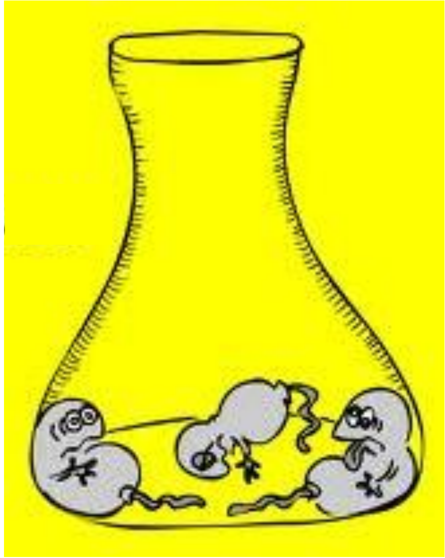


Overview of Ozonation and Biofiltration

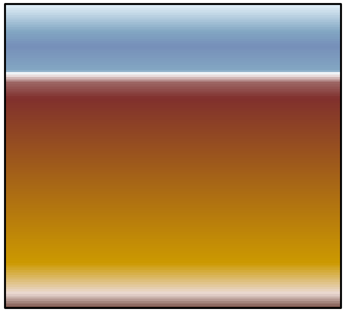


+ O_3 =



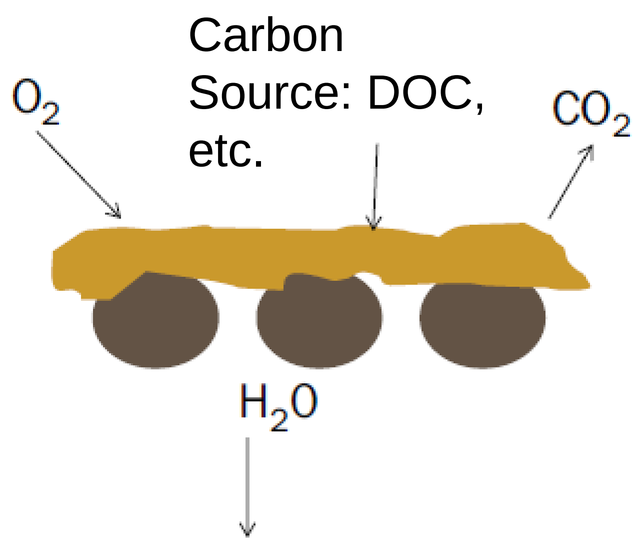


Cl_2



Microbial Oxidation – How does it work?

- Based on redox chemistry
- Surface water and groundwater condition

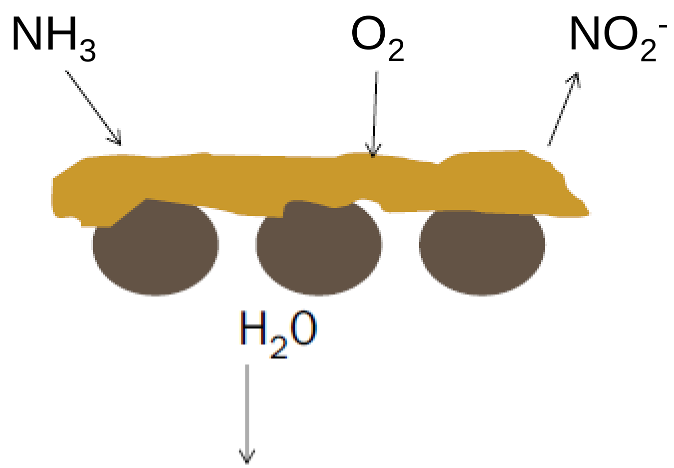


0_2: -4 charge

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

Microbial Oxidation – Removal of Nitrate and Perchlorate

- Based on redox chemistry
- Typically surface water or groundwater condition



NH_3 : +1 charge

$$4NH_3 + 7O_2 \rightarrow 4NO_2^- + 6H_2O$$

Application and Benefits

- Application
  - Surface and groundwater
  - Aerobic and anoxic
  - Organics – T&O compounds, AOC, DOC, CECs, DBP reduction
  - Inorganics - ammonia, nitrate, nitrite, iron, manganese, arsenic, perchlorate, selenium
- Benefits
  - Removal of multiple contaminants
  - Biostability of DWDS
  - Minimal chemical addition
  - Minimal energy addition
  - No waste products

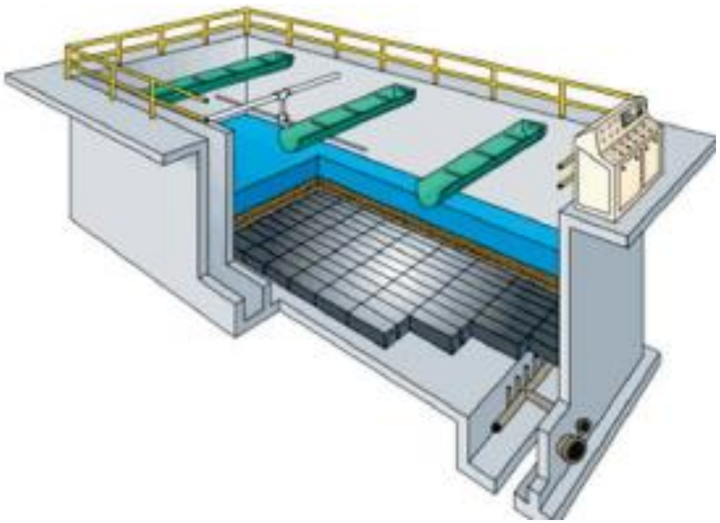
Removal of Contaminants by Biofiltration using Inert Media

High >85%	Moderate		Low 0-15%
	50-85%	15-50%	
Benzo[a]pyrene	Acetaminophen	Caffeine	Atenolol
DDT	Aldicarb	DEET	Carbamazepine
Fluoxetine	Chlorobenzene	Erythromycin	Meprobamate
Formaldehyde	Clofibric Acid	Diclofenac	Primidone
Ibuprofen	Dimethoate	Gemfibrozil	Sucralose
Molinate	Naproxen	**Geosmin**	Sulfamethoxazole
P-Toluenesulfonic Acid	Phenol	**MIB**	TCEP
Saxitoxin C2	Triclosan	Trimethoprim	Trichloromethane

Source: Dickenson, E., Wert, E., Verdugo, E., Greenstein, K., Brown, J., Schneider, O., Marfil-Vega, R., Summers, R. S. 2017. Simultaneous Removal of Multiple Contaminants Using Biofiltration. Water Research Foundation 4559.

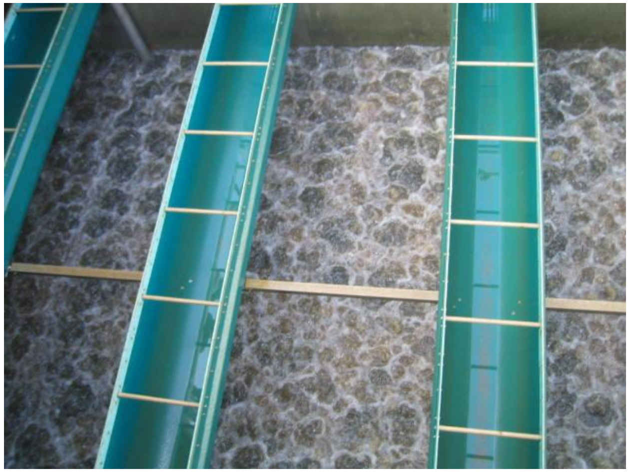
Engineered Rapid Rate Biofiltration

- Media selection
  - GAC media to increase surface area for biomass
  - Deep beds
- Pretreatment
  - Ozonation prior to filtration to promote biological oxidation of contaminants
- May add external carbon source and phosphate addition to increase biological growth
- Underdrain design
- Backwash strategy
- Disinfection strategy



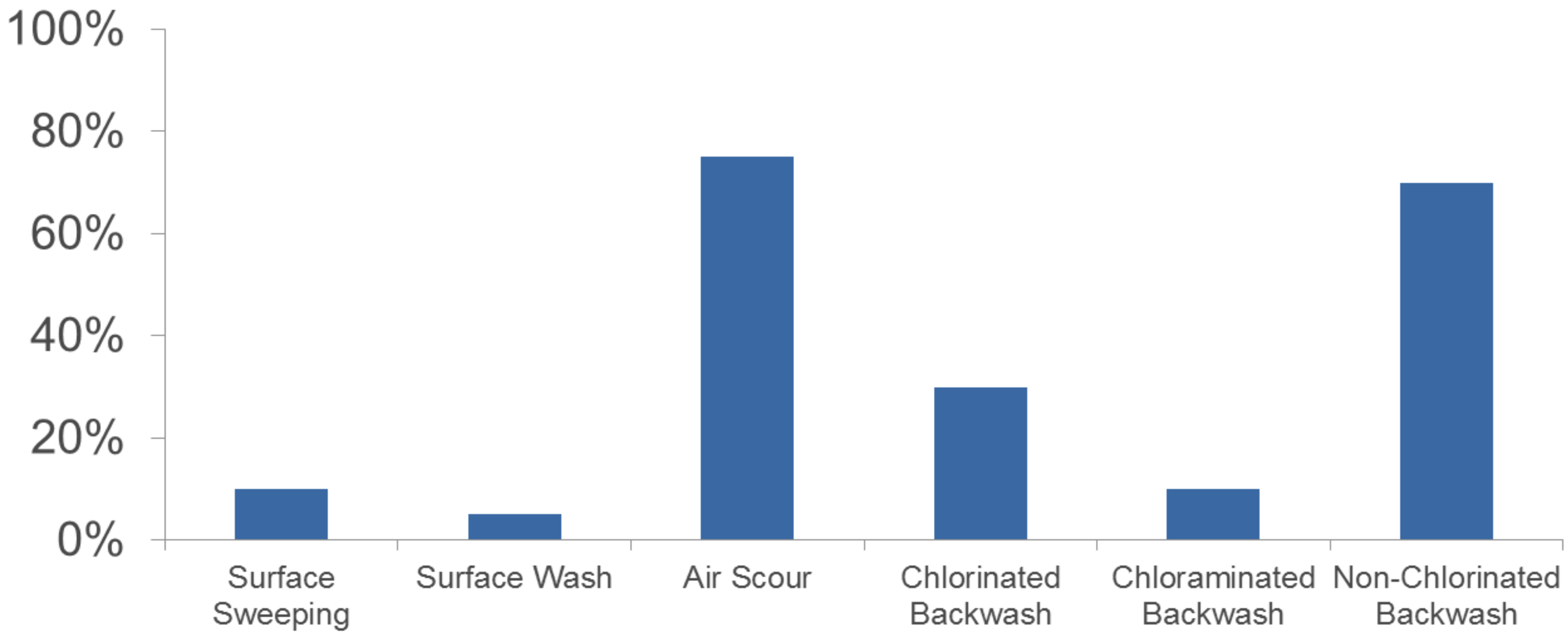
Backwashing Options for Biological Filters

- Probable backwashing intervals at 24 hours
- Simultaneous air and water (collapsed pulsing condition), followed by a standard water fluidization; not found to be detrimental to AOC reduction (many utilities)
- Non-chlorinated backwash water (most common)
- Chlorinated backwash (some still use)
  - Chlorine does decrease biomass
  - BOM removal much less affected
  - Chlorine in air/water improves initial turbidity spike, improves headloss



Source: Hooper, J. 2015. Monitoring Tools for Biological Filtration. ACE Workshop.

Backwashing Strategies by 21 Utilities with Biological Filters



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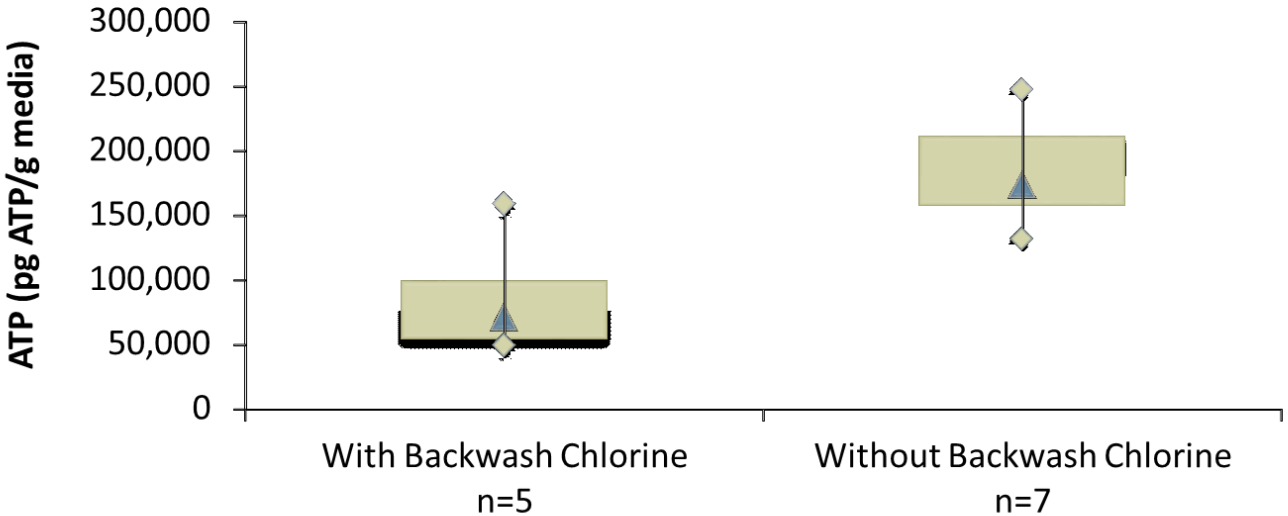
Bacterial population roughly doubled when backwashing with unchlorinated water



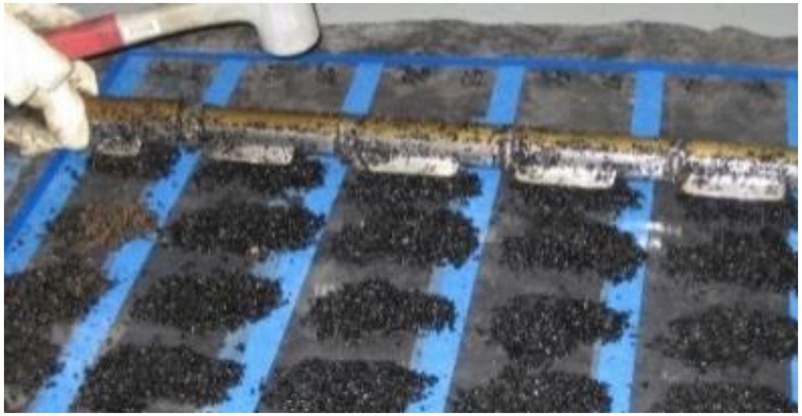
Temperature = 13-20°C
Ozone Dose = 0.8-1.0 mg/L
Filtration Rate = 3.1-3.7 gpm/ft^2
Backwash Chlorine Dose = 2-3 mg/L

Temperature = 13-20°C
Ozone Dose = 0.7-1.1 mg/L
Filtration Rate = 2.1-3.6 gpm/ft^2
Backwash Chlorine Dose = none

Source: Hooper, J. 2015. Monitoring Tools for Biological Filtration. ACE Workshop.

What are the concerns/challenges?

- Can have increased headloss due to biomass accumulation
- Can have reduced Unit filter run volumes (UFRVs)
- Design considerations
- Promoting bacteria in drinking water
- Blackbox



Steps to Understand Biofiltration

1. Define filter objectives
2. Develop Filter Management Plan
3. Develop baseline
4. Reassess Filter Management Plan

Filtration Monitoring and Control Tools

Control
• Filter loading rate/EBCT • Backwash timing/ rates • Filter run time • Chlorinated vs. unchlorinated backwash • Oxidant dose and type (ozone, chlorine, peroxide)

Filtration Monitoring and Control Tools

Control	Operational
• Filter loading rate/EBCT • Backwash timing/ rates • Filter run time • Chlorinated vs. unchlorinated backwash • Oxidant dose and type (ozone, chlorine, peroxide)	• Head loss and headloss profiling • Unit filter run volumes • Chlorine demand • Visual inspection

Filtration Monitoring and Control Tools

Control	Operational	Water Quality

• Filter loading rate/EBCT
• Backwash timing/ rates
• Filter run time
• Chlorinated vs. unchlorinated backwash
• Oxidant dose and type (ozone, chlorine, peroxide)
	• Head loss and headloss profiling
	• Unit filter run volumes
	• Chlorine demand
	• Visual inspection
		• Desired contaminant removal (organics and/or inorganics)
		• Dissolved oxygen uptake
		• Organic specific:
		    • Biodegradable dissolved organic carbon (BDOC)
		    • Assimilable organic carbon (AOC)
		    • Carboxylic acids
		• Nutrients
		• Temperature

Filtration Monitoring and Control Tools

Control	Operational	Water Quality	Biological

• Filter loading rate/EBCT
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		  • Carboxylic acids
		• Nutrients
		• Temperature
			• Adenosine triphosphate (ATP)
			• Heterotrophic plate counts (HPCs)
			• Extracellular polymeric substances (EPS)
			• Microbial Assessments (i.e. polymerase chain reaction [PCR])

Filter Management Plan

	Monitoring Tool	Normal Operations (Baseline)	Trouble-shooting
Operational	Headloss	Continuously	Continuously
	UFRV	Continuously	Continuously
	Turbidity and/or particle counts	Continuously	Continuously

Filter Management Plan

Monitoring Tool		Normal Operations (Baseline)	Trouble-shooting
Operational	Headloss	Continuously	Continuously
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	Turbidity and/or particle counts	Continuously	Continuously
Water Quality	TOC/DOC or UV254	Weekly	Daily
	Temperature	Continuously	Continuously
	Carboxylic acids	Monthly	Weekly

Filter Management Plan

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Water Quality	TOC/DOC or UV254	Weekly	Daily
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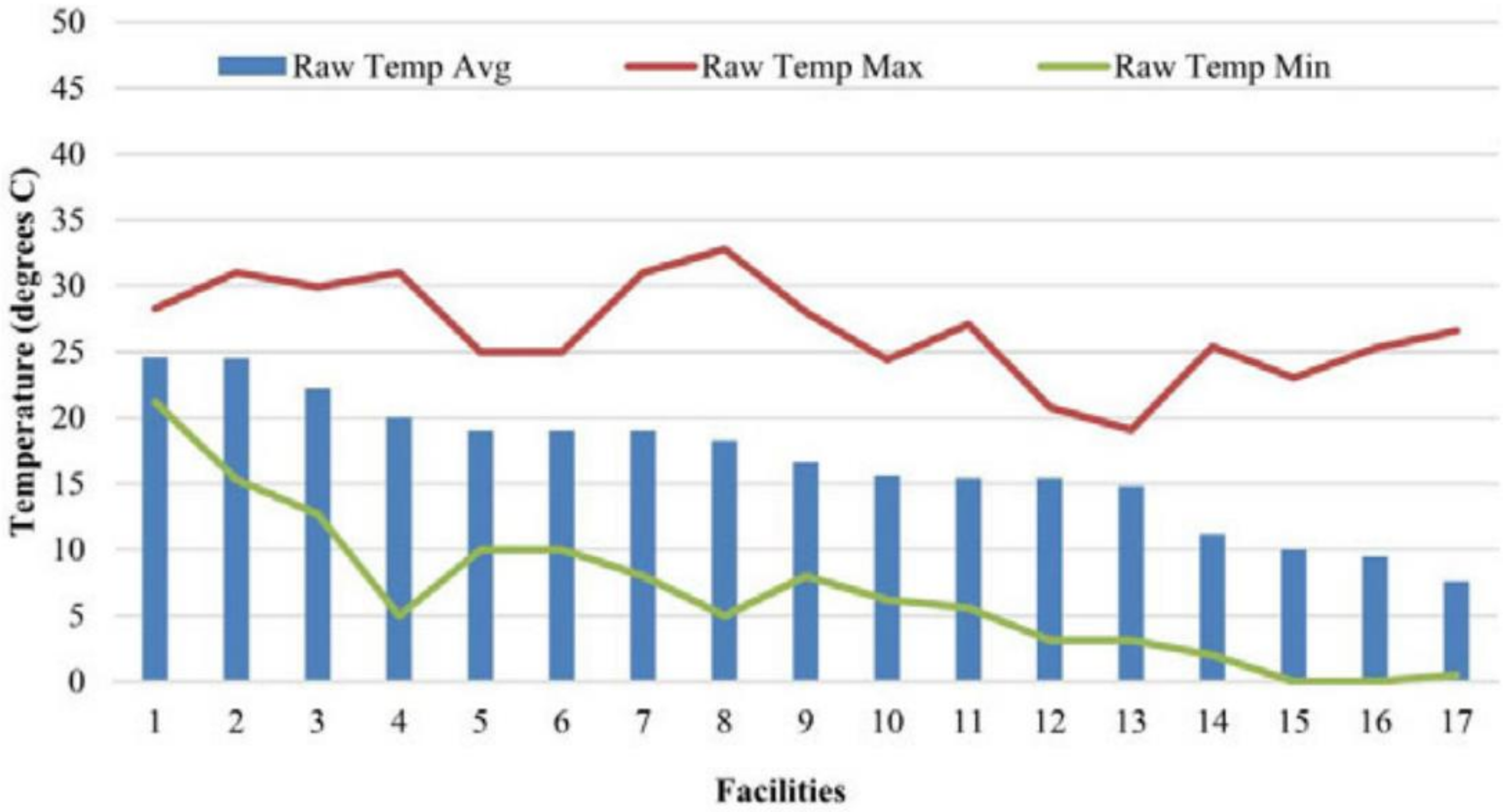
	Carboxylic acids	Monthly	Weekly
Biological	Dissolved Oxygen Uptake	Continuously	Continuously
	ATP	Monthly	Weekly

Many Successful Utilities with Low Temperatures

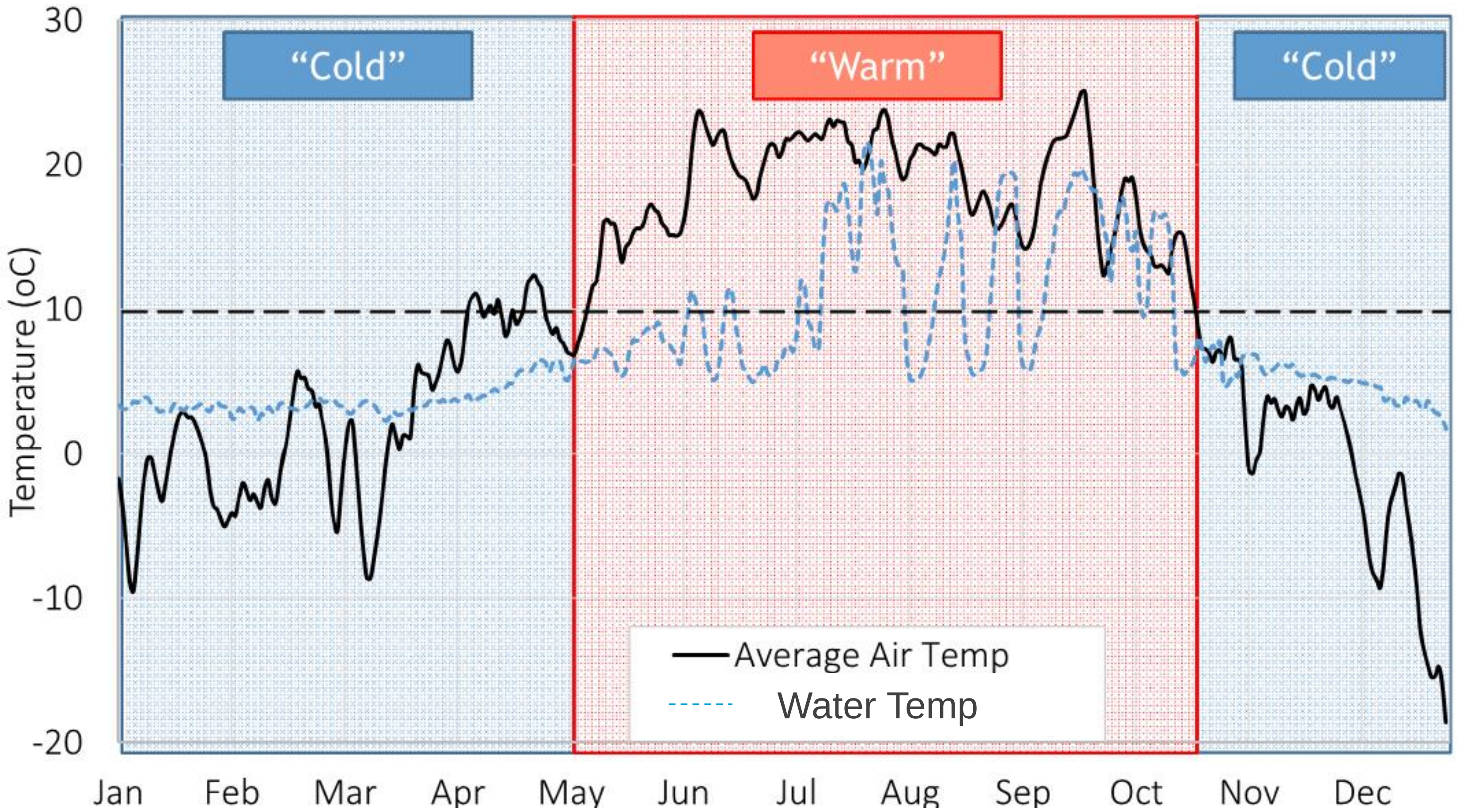


Source: WRF 4459

Case Study:
Toronto Pilot Study - Biofiltration in Cold Temperatures

Source: Michael J. McKie, Liz Taylor-Edmonds, Susan Andrews, and Robert Andrews. 2018 Water Quality Technology Conference, Workshop: Implementing Drinking Water Biofiltration in Cold Weather Conditions

Lake Ontario



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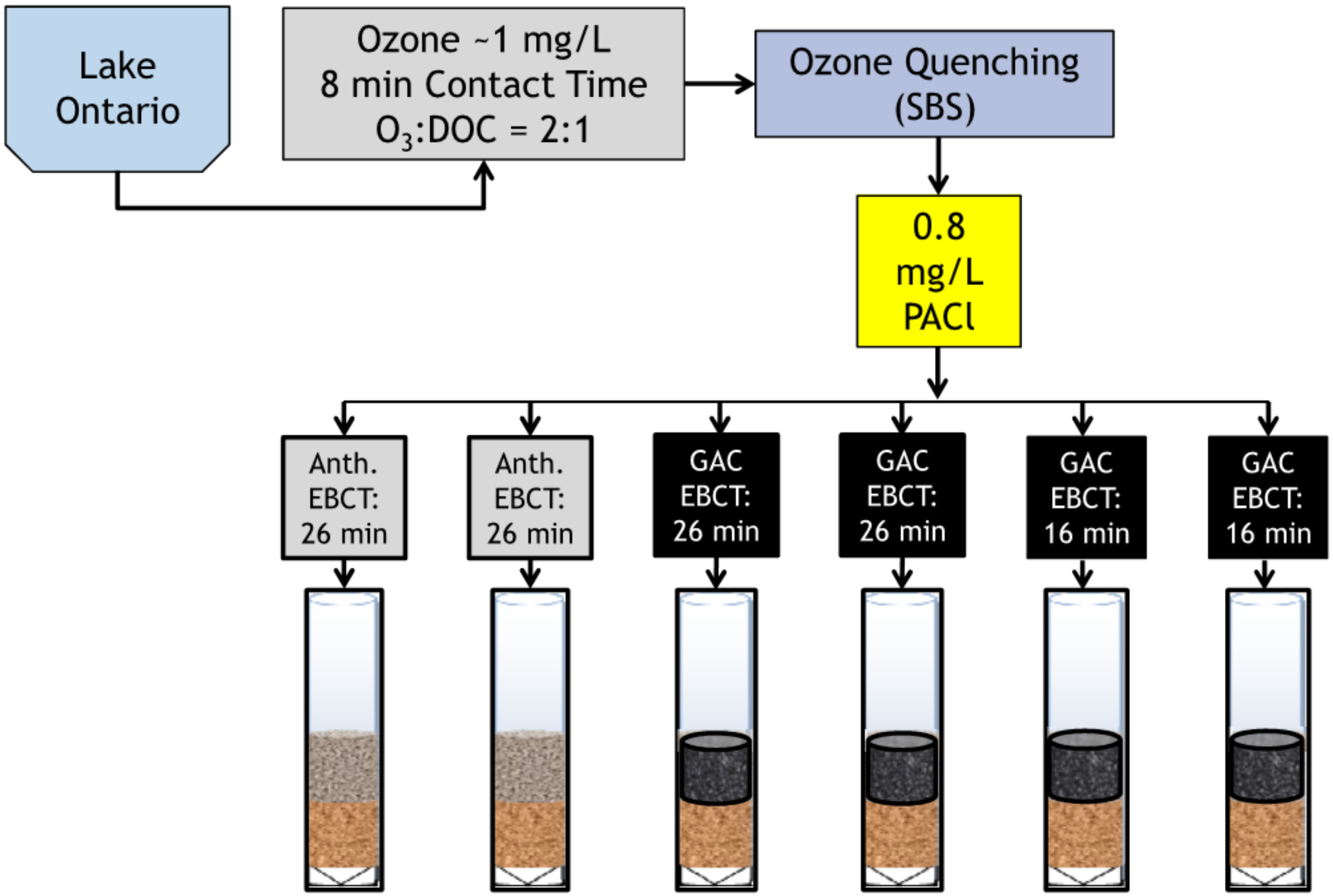

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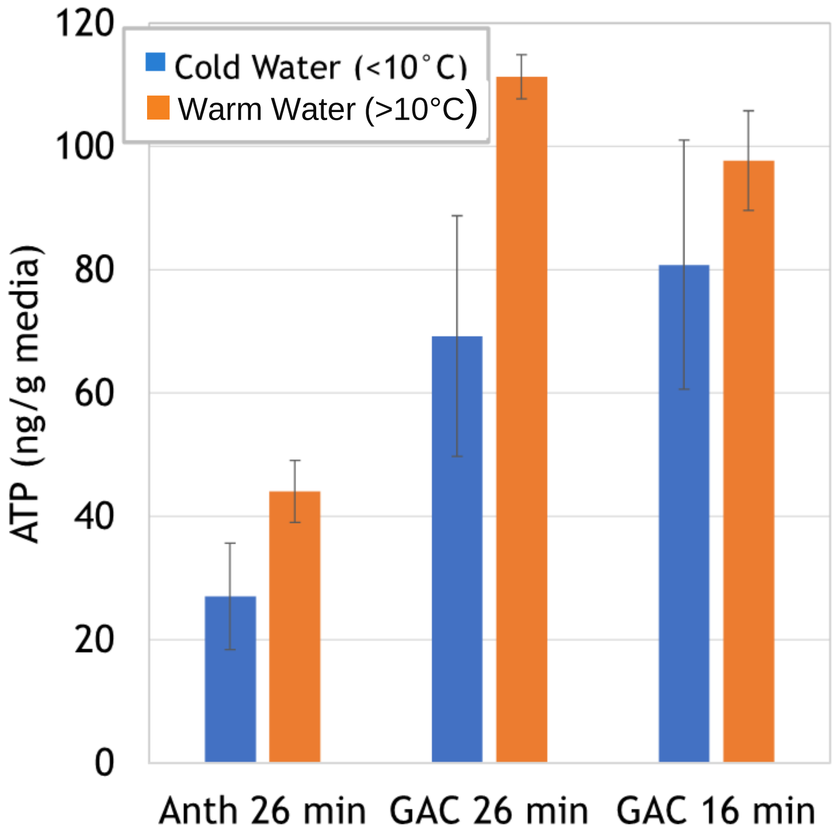
Cold Temperatures Decrease ATP Levels



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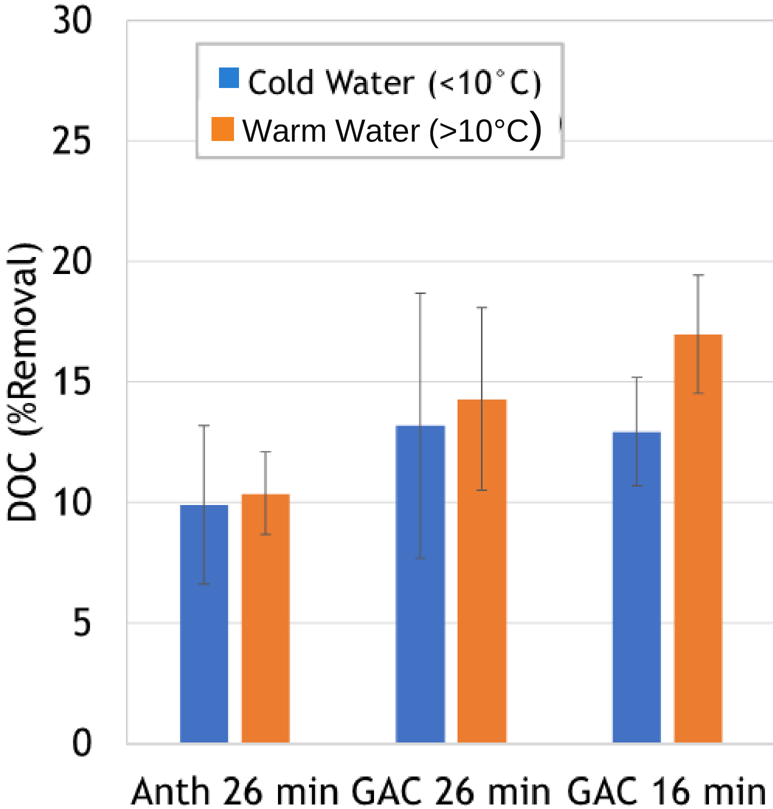
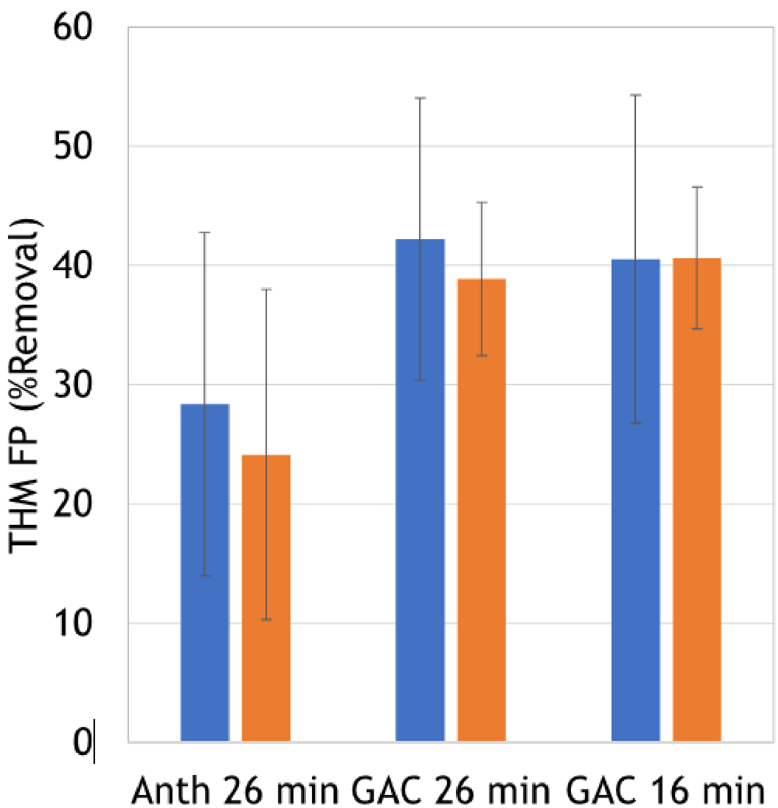
Cold water still achieved good DOC Removals

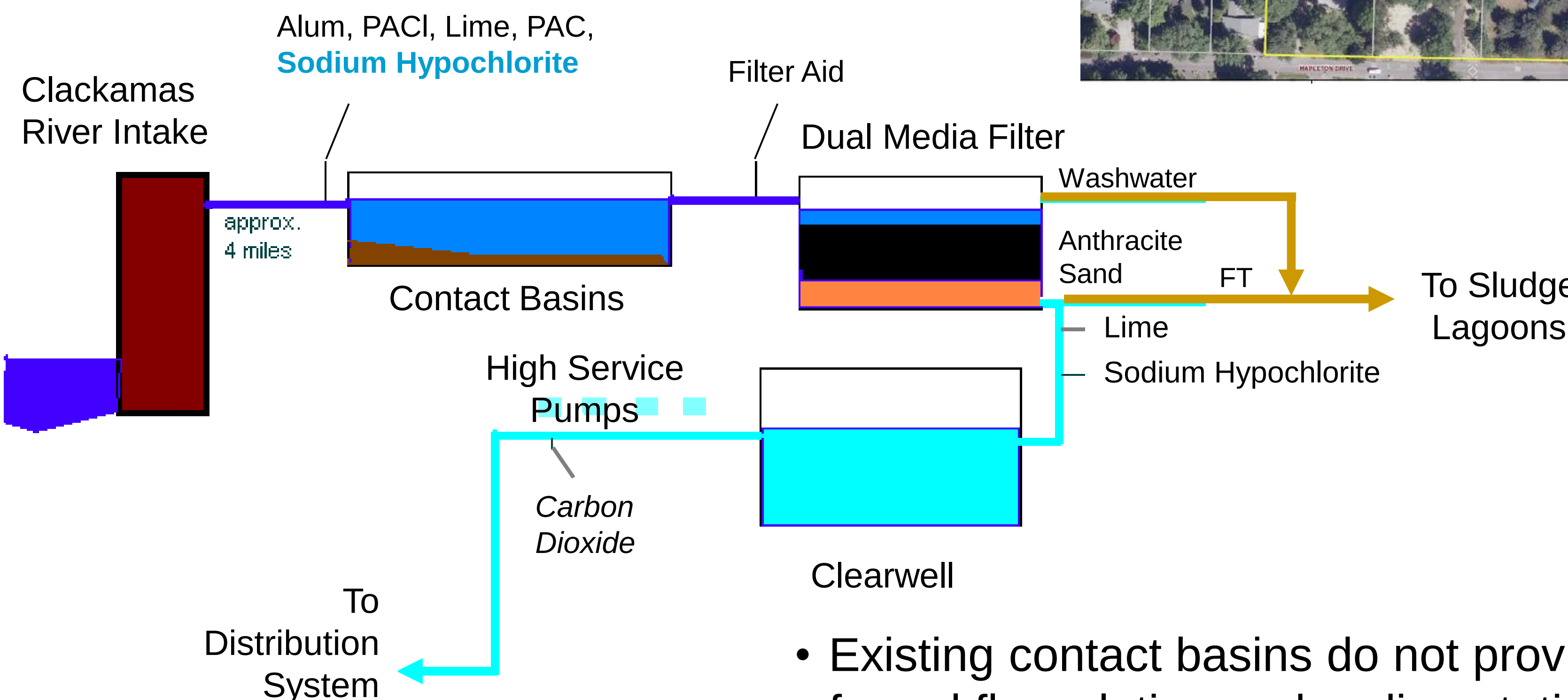




Source: Michael J. McKie, Liz Taylor-Edmonds, Susan Andrews, and Robert Andrews. 2018 Water Quality Technology Conference, Workshop: Implementing Drinking Water Biofiltration in Cold Weather Conditions

Case Study: Lake Oswego-Tigard Water Partnership, Oregon

Existing Direct Filtration Plant

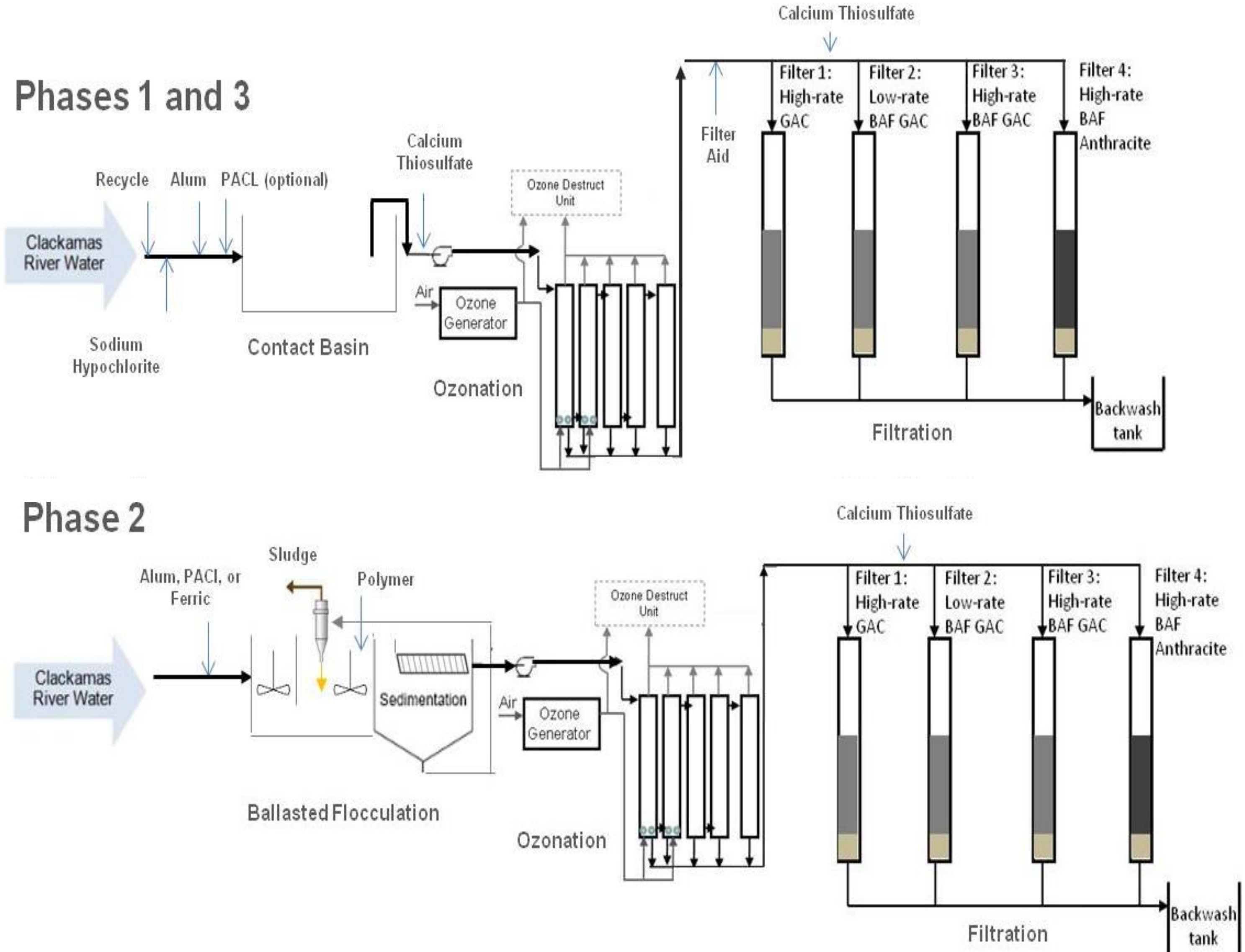


- Existing contact basins do not provide formal flocculation and sedimentation
- *Seasonal algal taste and odors issue*

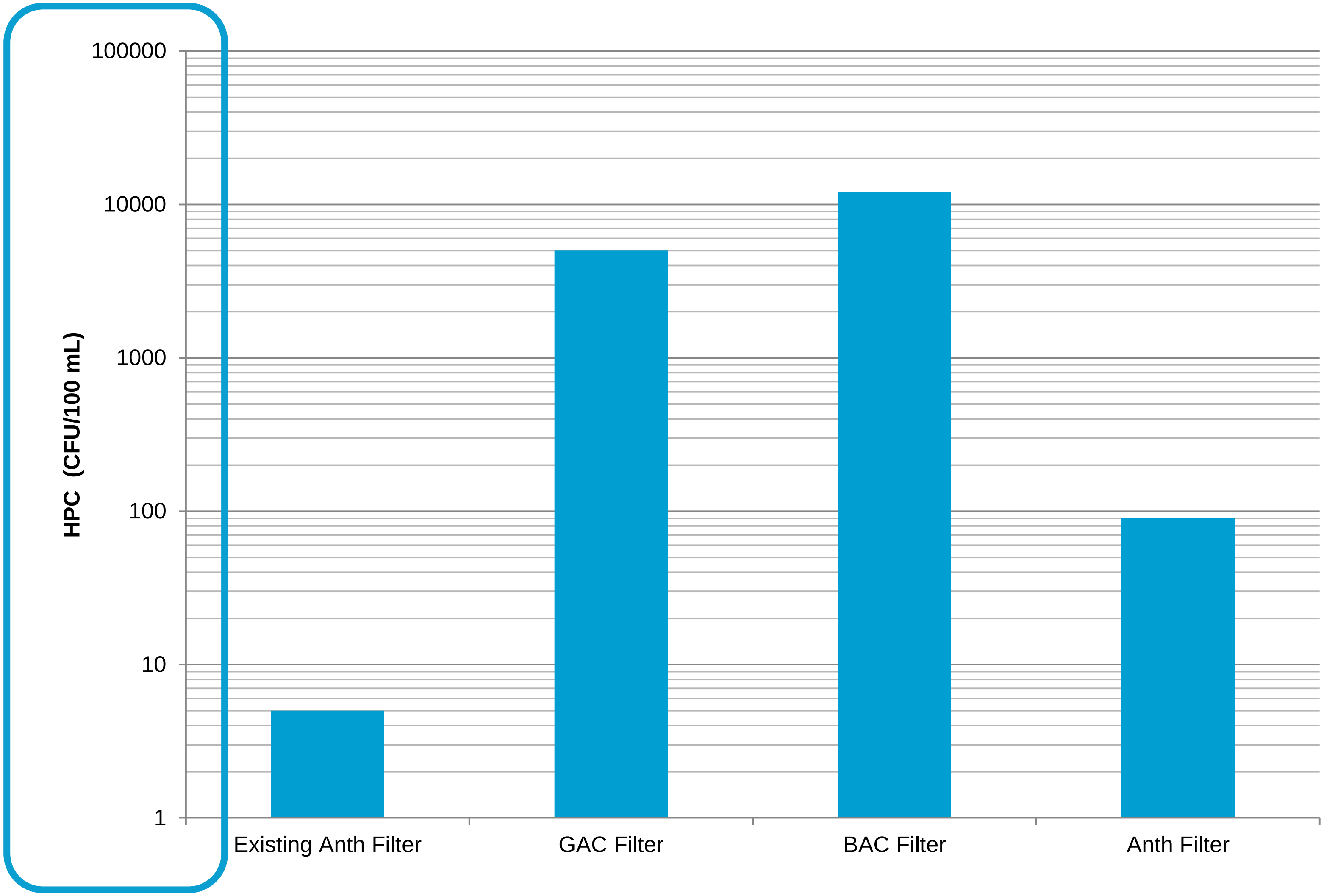
Expansion Treatment Alternative

- Liquid Stream Treatment Process
  - Ballasted flocculation
  - Ozonation
  - Biological filtration

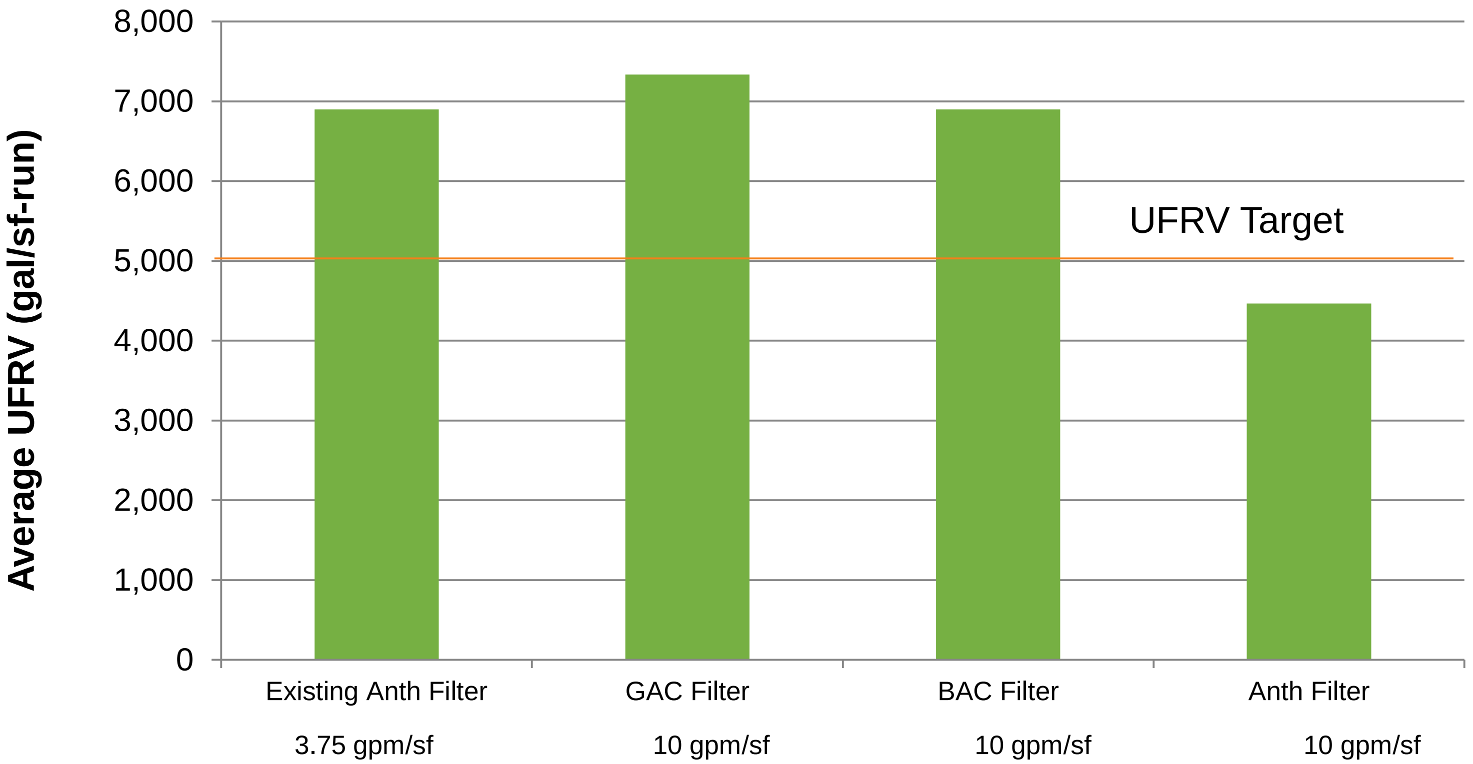
Pilot Plant Configuration



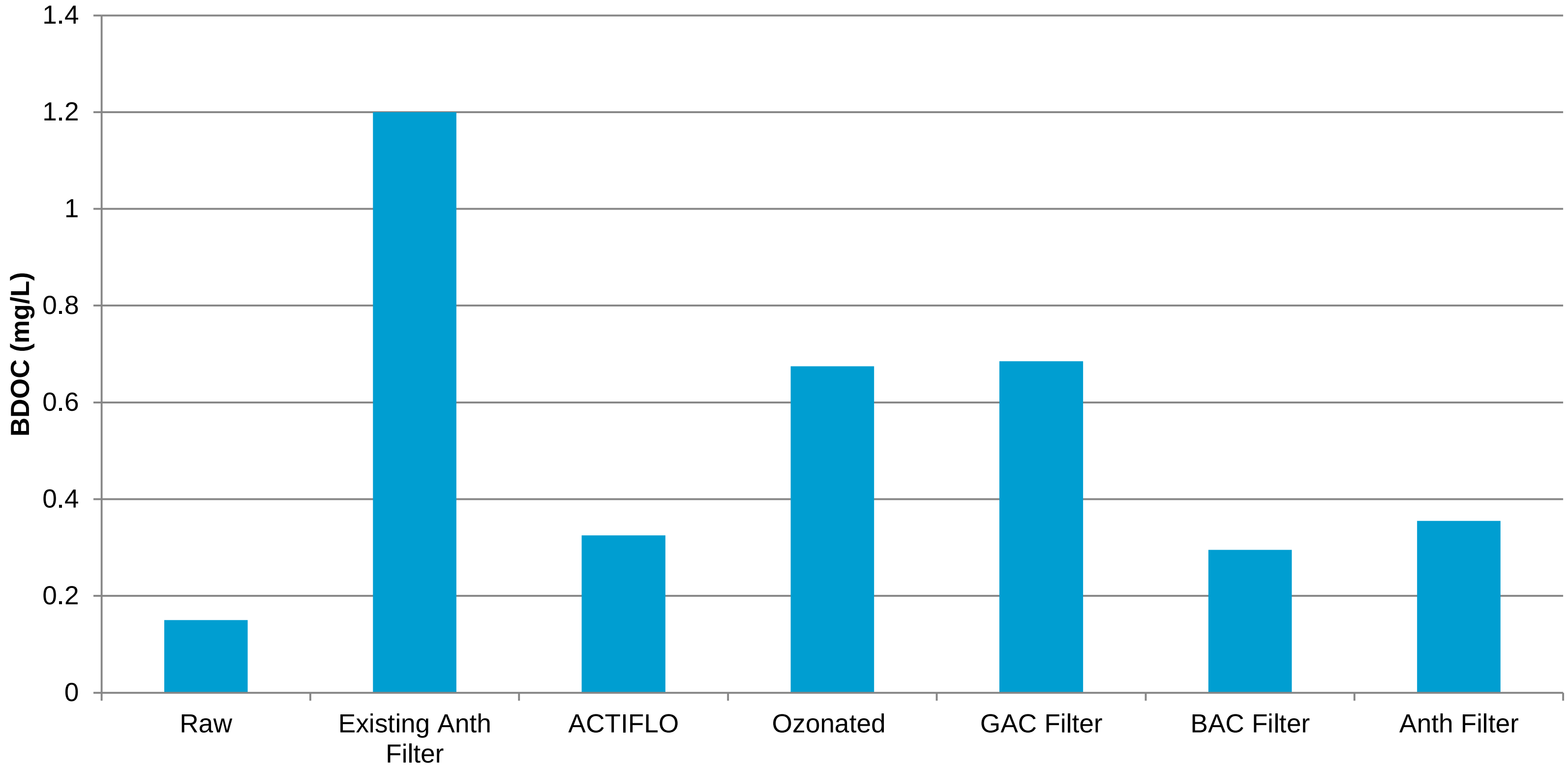
Greatest HPC levels in BAC Filter



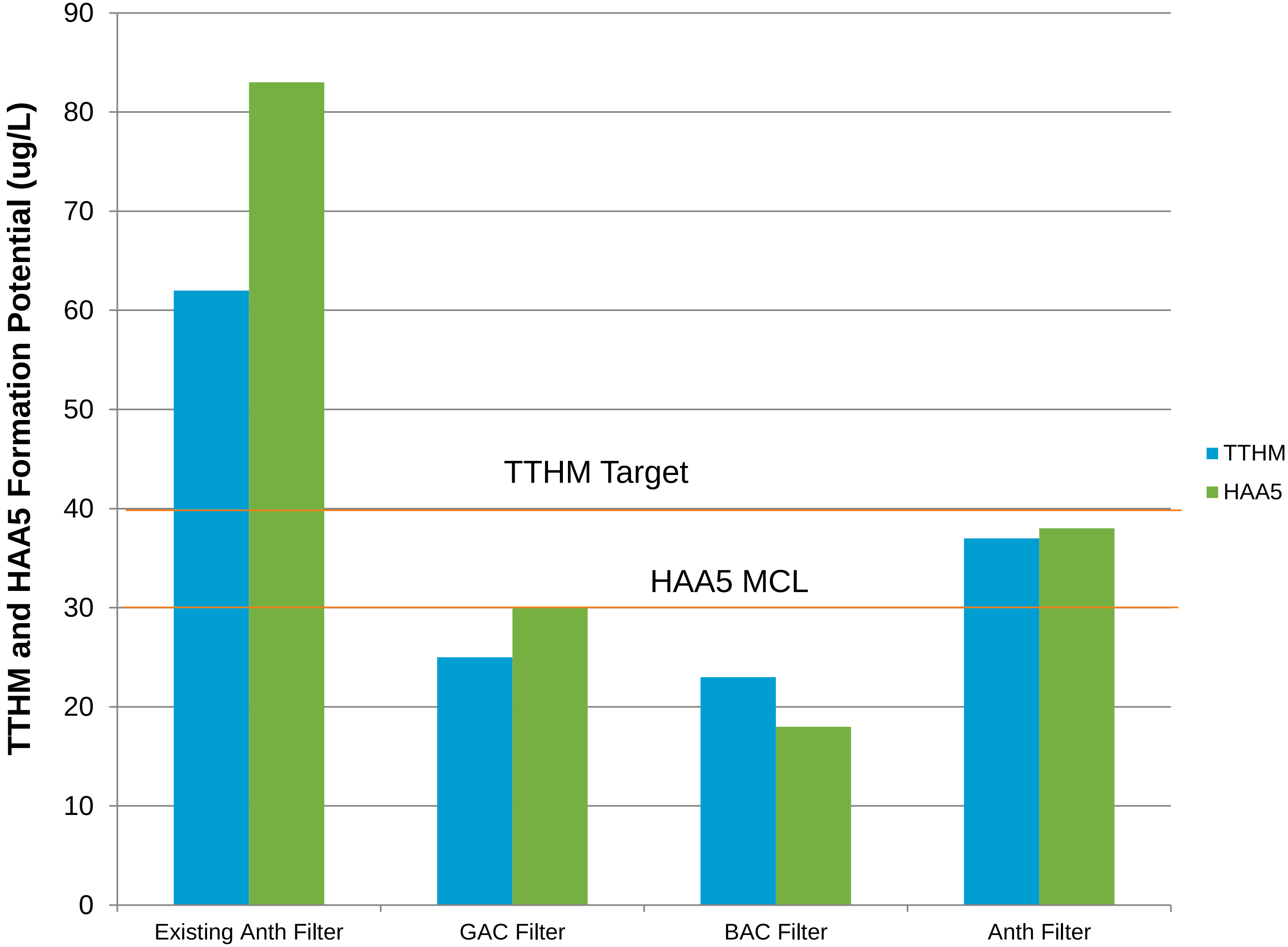
Filter Productivity



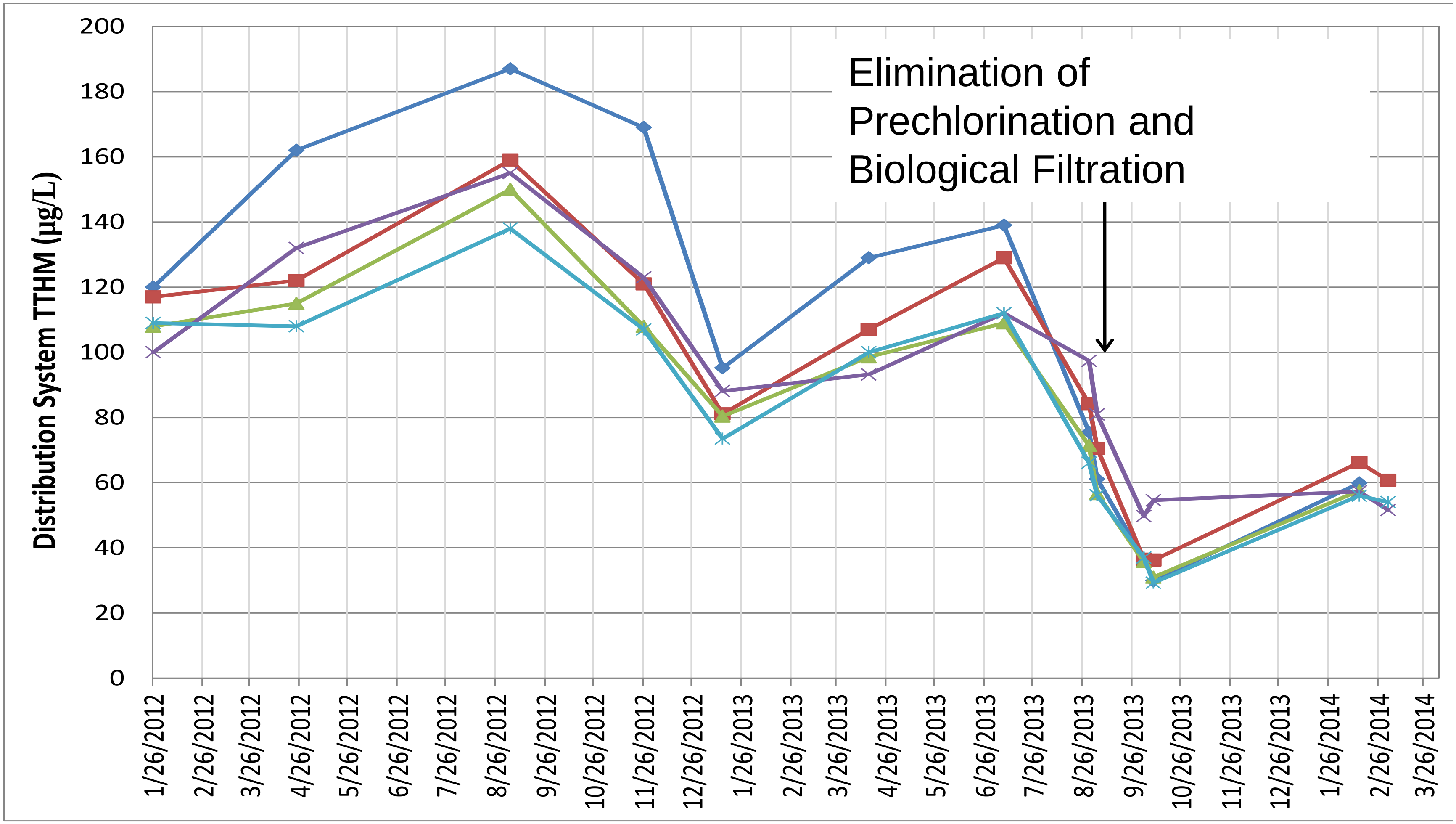
Average BDOC Remaining



DBP SDS Testing Results



Eliminating Prechlorination and adding BAC reduces TTHMs



Summary

- Many successful cold water biofiltration plants
- From pilot at Lake Oswego WTP, ozonation followed by biological filtration effectively reduced disinfection by-products while achieving effective performance
- Non-chlorinated GAC had increased biological activity and improved bed life, but increased headloss
- Biological filtration is a process to maximize contaminant removal
- Intentional about the biofilter optimization
- Develop a Filter Management Plan to increase understanding and to choose monitoring parameters that work for your system

Do you want to learn more?

- Biological Drinking Water Treatment Committee
- Ten State Standards
  - Anoxic biological treatment
  - **Biologically active filters for surface waters**
  - Aerobic groundwater treatment

- Water Research Foundation Biological Filtration Knowledge Area
  - **#4719 – Biofiltration Guidance Manual, expected late 2019/early 2020**

Questions? Comments?

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Mini water plant to test new huge plant

Test machinery will give information to make new plant safe, cost-effective

By CLIFF NEWELL
Staff Reporter

Everyone knows how big the Lake Oswego-Tigard Water Partnership is. Some day it will produce up to 32 million gallons of drinking water a day.

But the project is starting out small. Two key parts of a miniature water plant — ozonation and filtration units — were installed on Sept. 6 at the city of Lake Oswego's water treatment plant in West Linn.

The main reason the little plant is necessary is that the state requires pilot studies.

But the mini water plant will set the stage for the major plant by providing a huge amount of information that will be used to assure that the new operation provides plentiful, safe water in the most cost-effective way.

"Our operators will get invaluable experience," said Lynn

"This won't be like a wrecking ball. It's more like microsurgery. The sequence must be very tight."

— Jane Heisler, on refining the design of an expanded water treatment plant

and see how best to remove taste, odors and contaminants."

The mini plant will treat 250,000 gallons of water a day through March 2012. The new processes for reducing byproducts will be compared to the processes now used at the existing plant.

"We will have seven months to fully understand the water quality characteristics of three seasons," ...d. "We'll have a report ... spring. It will allow the ...nd plant staffs to under- ... the new plant will

...ER PLANT, page A3

STAFF PHOTO / VERN UYETAKE
Lynn Williams and Tyler McCune show off part of the pilot filtration unit at the West Linn water treatment facility.

Water plant:

Continued from page A1

improve water quality."

Knowledge gained will be money saved. Williams estimates the pilot project will result in the water partnership saving millions of dollars in the future.

Even before the pilot project begins, the city of Lake Oswego is working to get West Linn's Robinwood neighborhood ready for the new water treatment plant. Heading this effort is communications director Jane Heisler, who has jumped from one huge public works project — the Lake Oswego Interceptor