Future-Proofing Slow Sand Filtration

Adding Ancillary Technologies to a Time-Tested Science to Solve Modern Day Drinking Water Challenges

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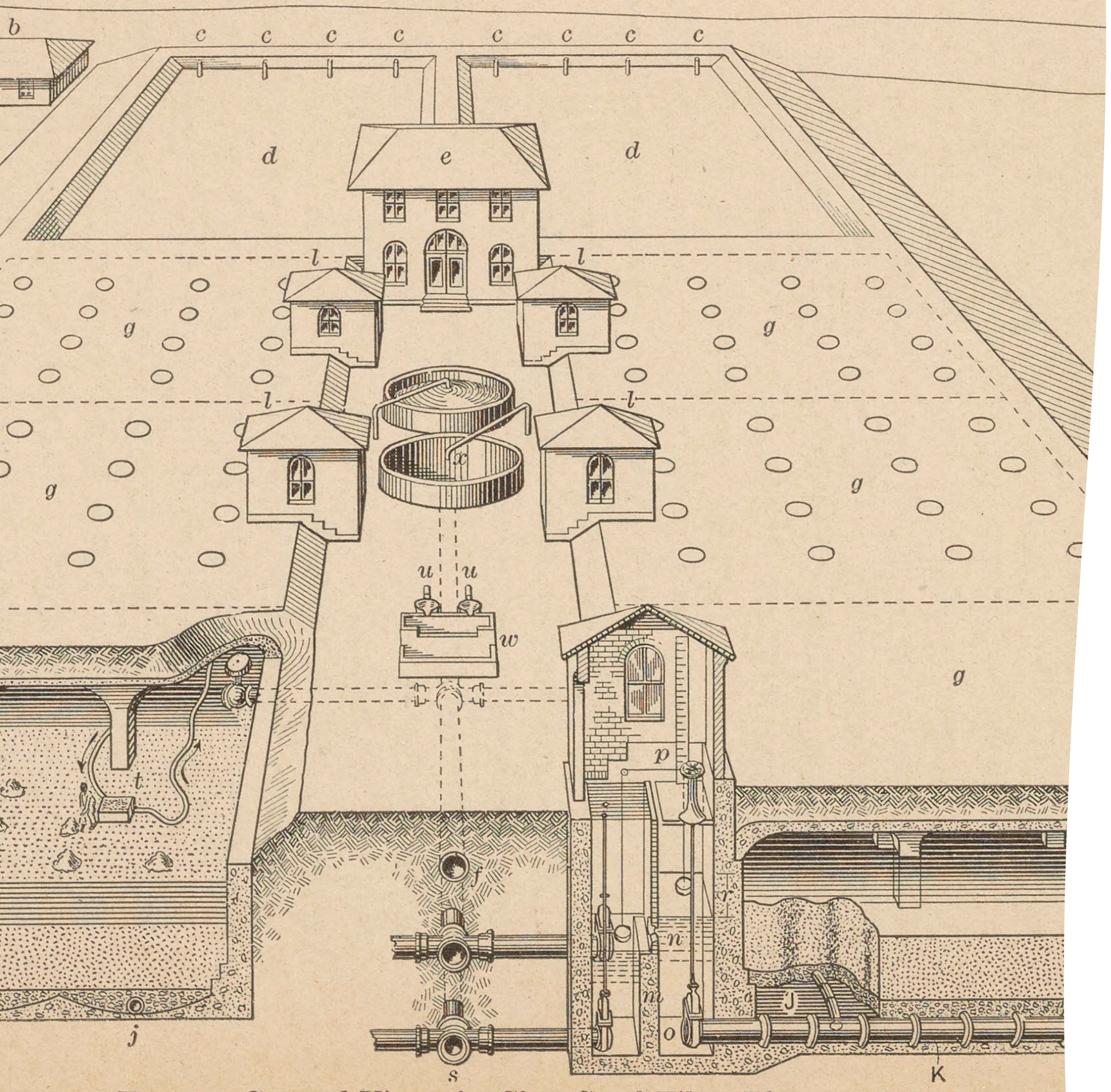


Fig. 4.—General View of a Slow Sand Filter Plant.

Slow Sand Filtration

A Timeless Technology

1829 First slow sand filtration system constructed for the Chelsea Water Company in London, England for the express use of producing drinking water.

1872 First documented use in the U.S. in Poughkeepsie, NY, used until 1962..

Despite dropping off with the advent of new technologies like cartridge, rapid rate filtration and membranes, slow sand remains a viable choice especially for small and remote communities

What can Slow Sand Filtration do?

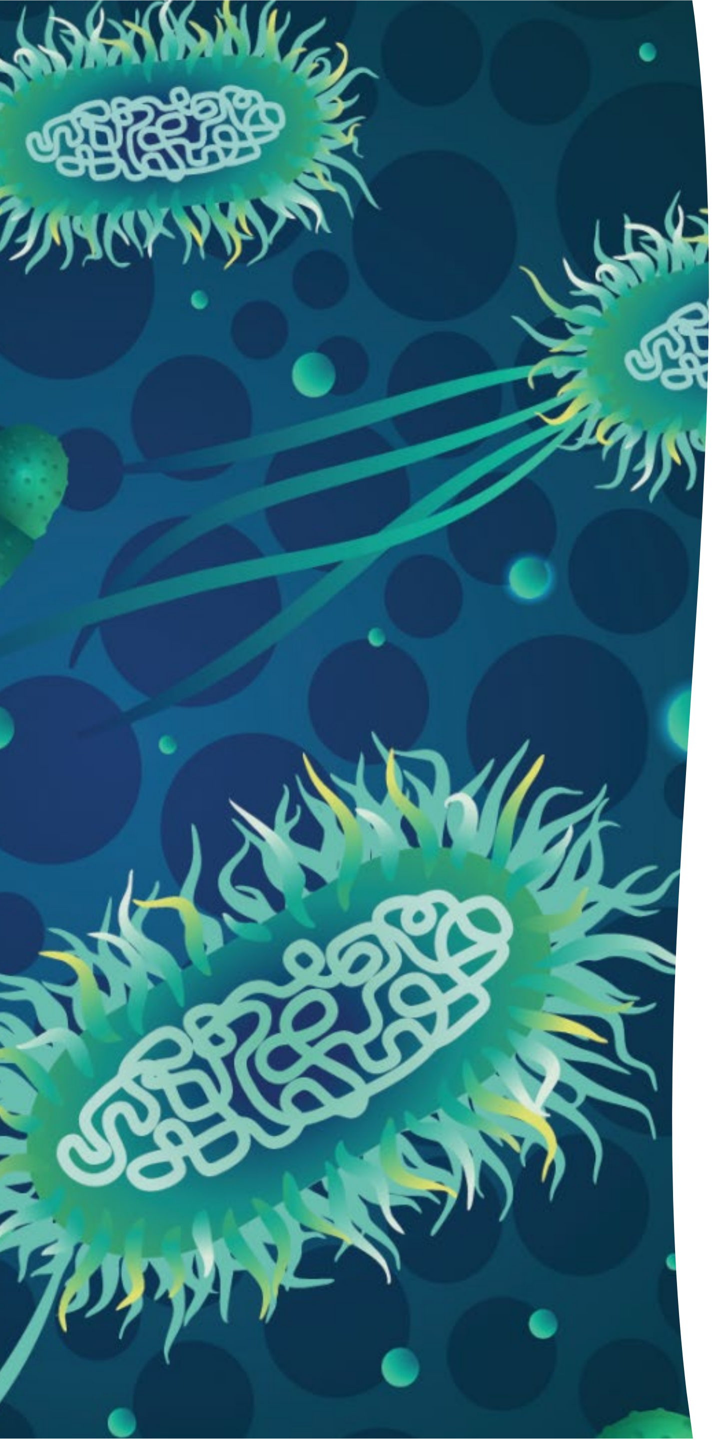
- Meet or exceed regulator requirements for filtration for raw water that falls within treatable water parameters.
- Operate with low energy consumption, minimal operator requirements, low operating costs, and without chemical inputs.
- Operate without specialized or high-level expertise.
- Operate without chemical waste.
- Withstand supply-chain interruptions.

Raw Water Parameters

Slow Sand Filtration alone has historically been limited in terms of the raw water quality it can effectively filter to meet regulation.

With the addition of anxillary technologies is capable of treating more than the preconceived limits from fresh surface water sources.

- Turbidity: >20 NTU reduced to <0.3 NTU
- True Colour: 50 TCU reduced to <5 TCU
- Dissolved Organic Carbon: 10 mg/L reduced to <5 mg/L
- UV Transmittance: 50% increased to 90%
- Iron: 3.0 mg/L reduced to detection limits
- Manganese: 1.0 mg/L reduced to detection limits



Protozoan Cyst/Oocyst Removal

- Cryptosporidium oocyst removals:
  - 4.0-4.7 log (Anderson Huck & Cleary 2005)
  - 4.0 log (DeLoyde, 2007)
  - 4.7 log (Hijnen et al, 2007)
  - 5.3 log (Dullemont et al, 2006)
- Giardia cyst removal generally better than Cryptosporidium oocyst removal
- Cyst/oocyst removal occurs in the upper layers of the slow sand filter
- Very low risk of breakthrough
- Addition of pre-ozonation provides a high level of disinfection

Taste and Odours

Conventional Slow Sand Filtration has a FAIR ability to remove taste and odour.

Enhanced Slow Sand Filtration is EXCELLENT at removing taste and odour.

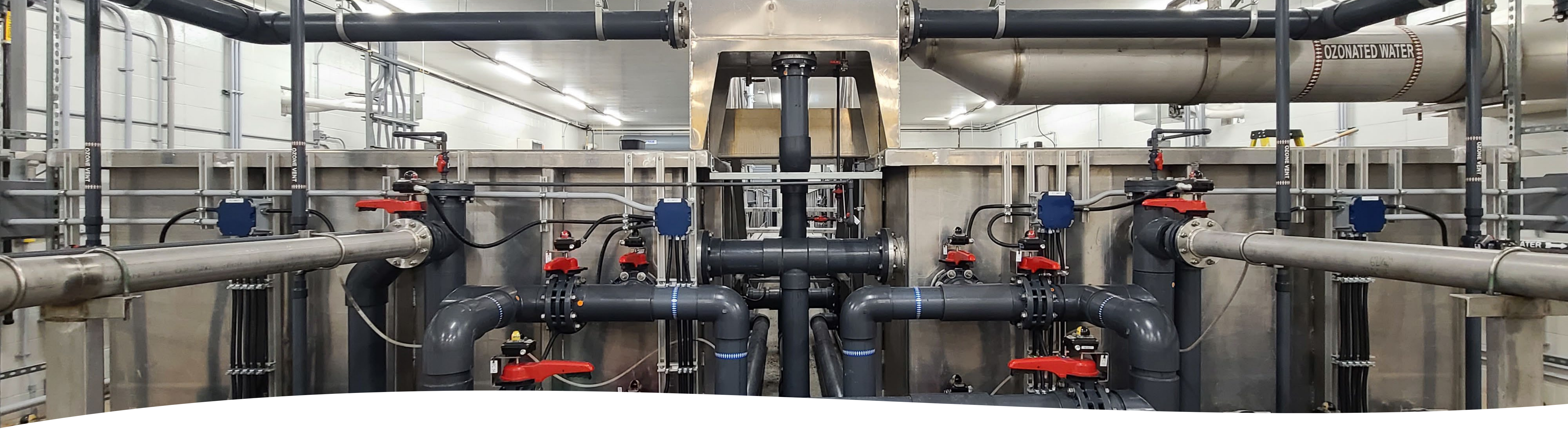
Regardless of the chemistry, if it smells weird and it tastes weird, nobody wants to drink it.

- Geosmin/2-MIB removed from 25 ng/L to threshold odour level with biologically-active GAC filters
- 100 ng/L influent concentrations of geosmin reduced by ~60%
- 100 ng/L influent levels of 2-MIB reduced by ~40%

Modified Slow Sand Filtration

Adding auxillary technologies balances the needs of modern drinking water with the robust simplicity of slow sand

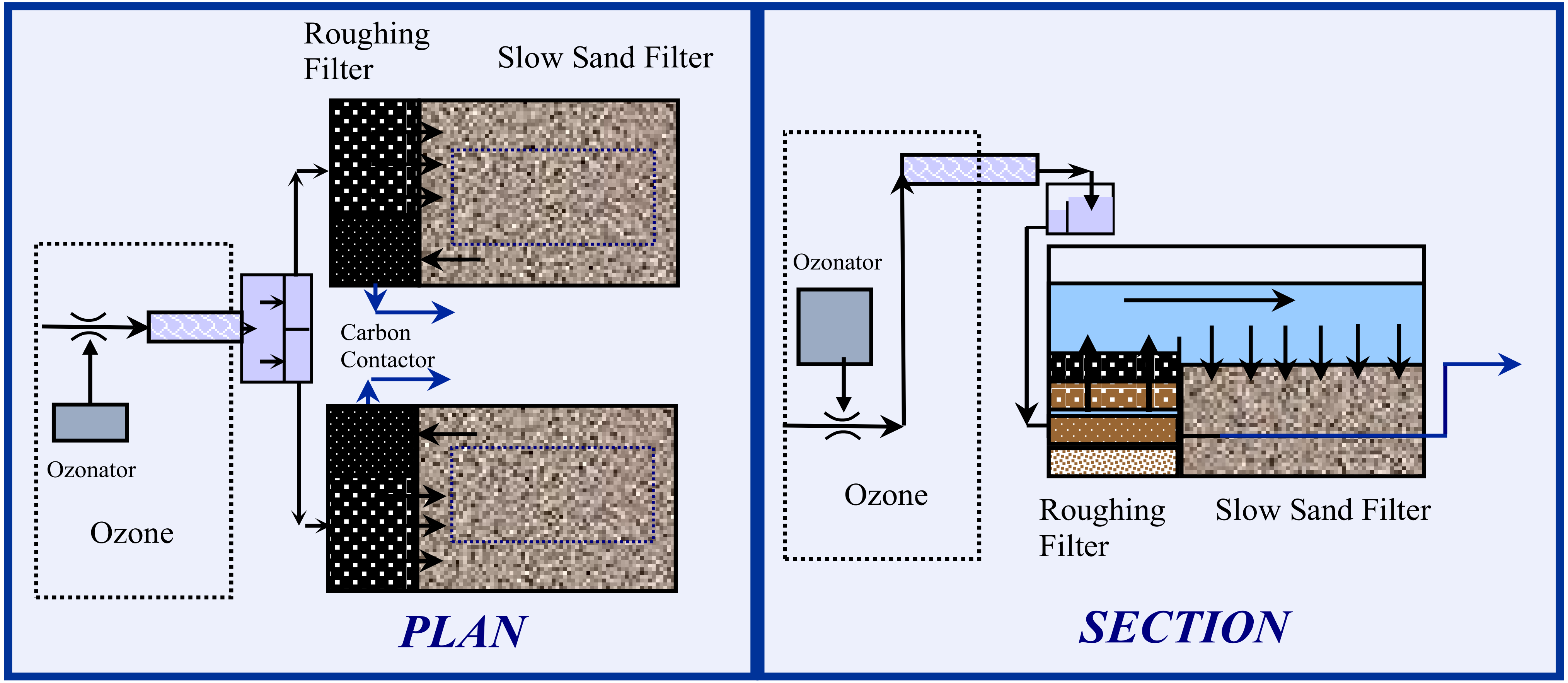
- Ozone Pre-Treatment
- Roughing Filter
- Granular Activated Carbon (GAC)
- Ion Exchange
- Advanced Oxidation Process (AOP)



The evolution of our system

- Foundational biological slow sand filter
- Addition of Roughing Filter
- Carbon Contactor
- Ozone Pre-Treatment

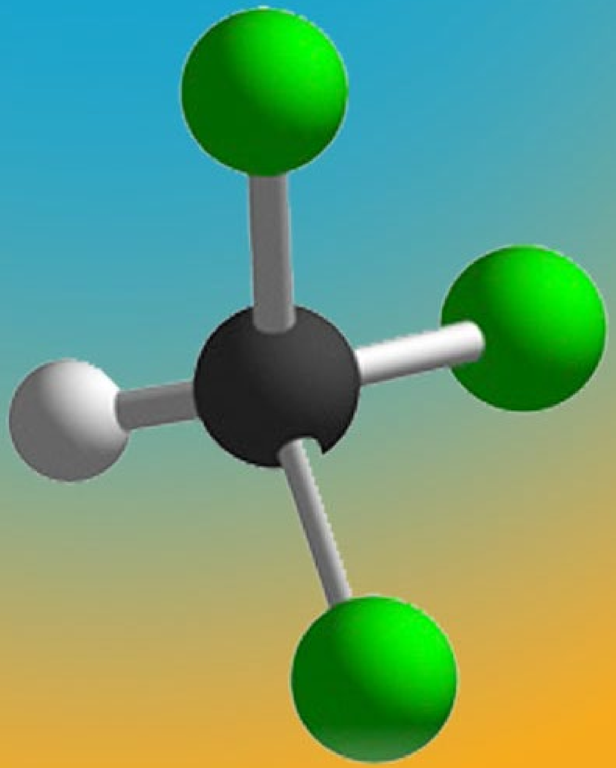
Figure 1. - Components of The Multi-Stage Filtration Process



The Results

Enables treatment of poor-quality source water

- Pre-Ozonation
  - Converts DOC to AOC; Oxidizes Fe, Mn
  - Powerful Disinfectant
- Roughing filter with GAC cap
  - Extends range of raw water turbidity
  - Removal of AOC (or BDOC) following ozonation is very important
  - Removal of chlorine and ozone residual
- Ozone plus biological filtration will remove Geosmin/MIB to below threshold detection levels
- Effective for a broad spectrum of pathogens and contaminants
- Removal of pathogens, pharmaceuticals, endocrine disrupting compounds, personal health care products and other health and nuisance compounds

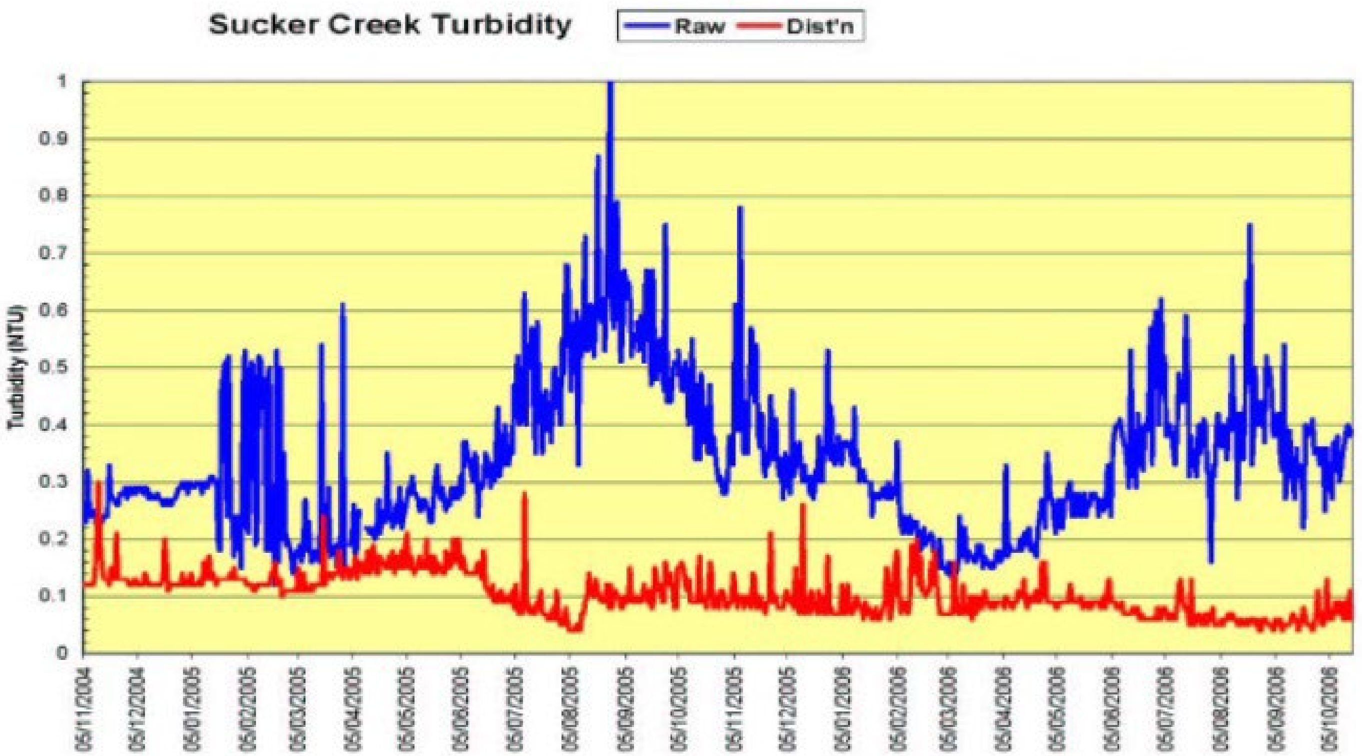


Disinfection By-Products

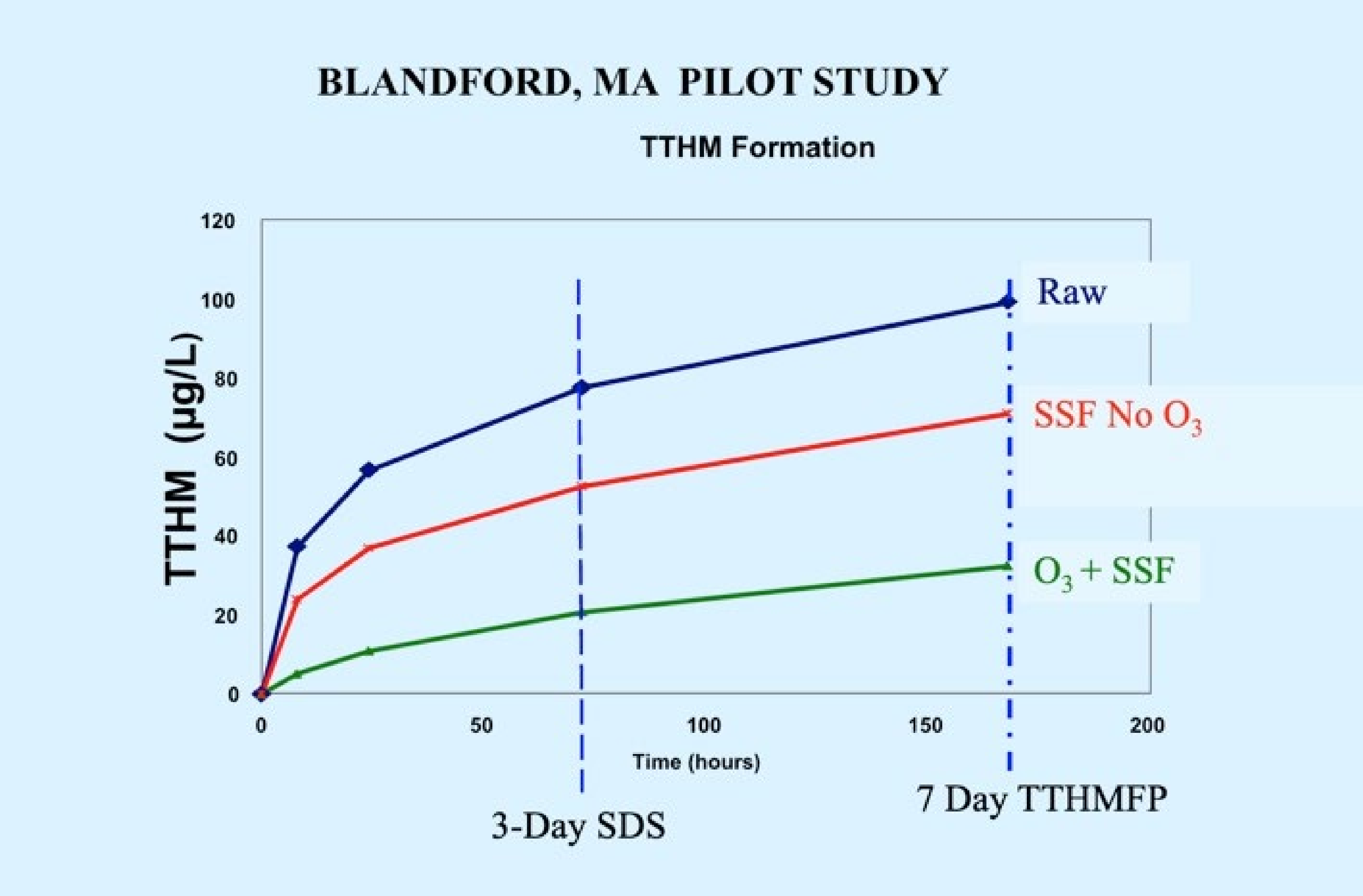
Removal of AOC (or BDOC) following ozonation is very important.

- Can lead to regrowth
- May increase DBPs
- Biological treatment is very effective
- DOC removals using ozone + biofiltration similar in efficiency to alum coagulation
- Excellent DBP precursor removal

Typical Filtered Turbidity



TTHMFP Reduction



Gull Bay (KZA) First Nation WTP

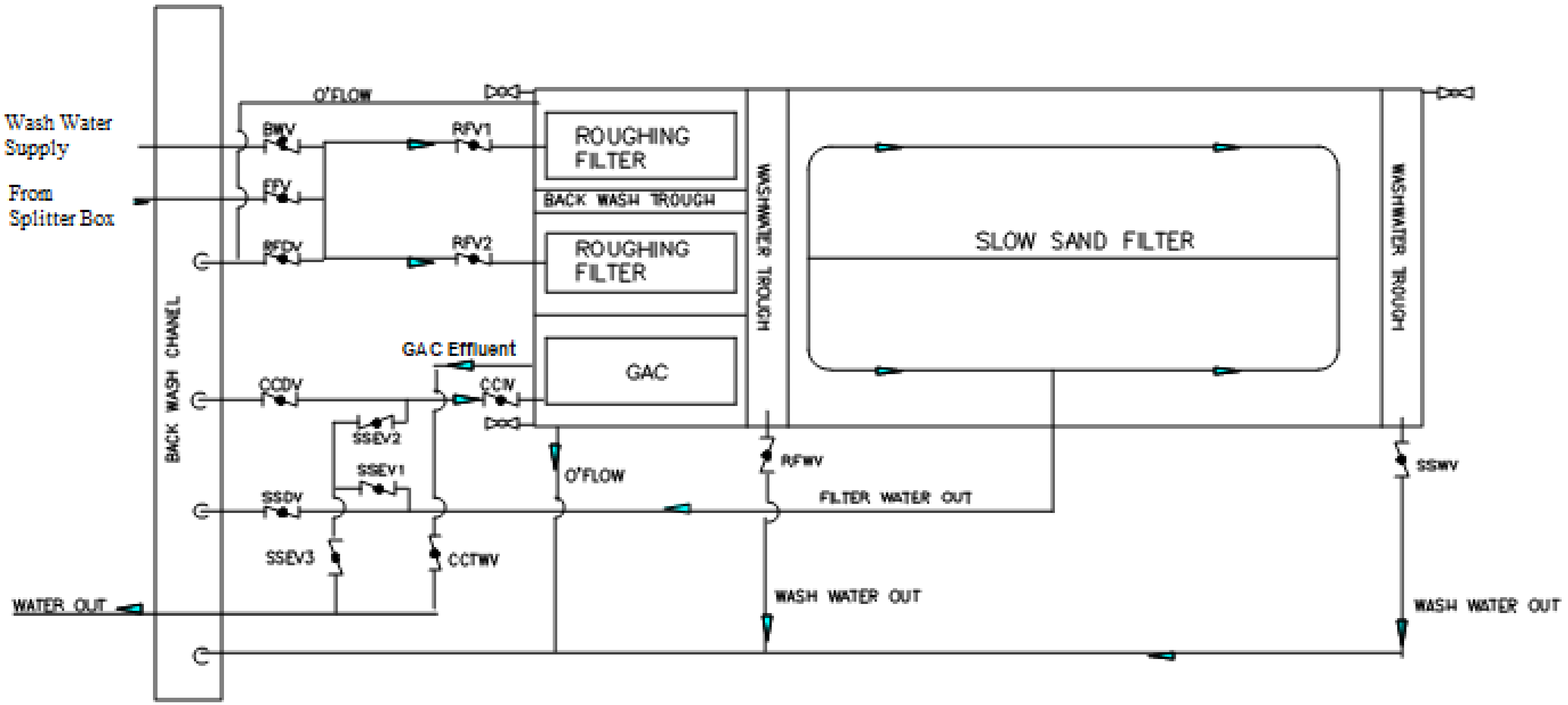
Gull Bay (KZA) First Nation WTP

- Constructed in 2021
- Source Water: Lake Nipigon
  low colour, low turbidity, high organic carbon
- Design Capacity: 600 m3/day
- Design Ozone Capacity: 280 g/h
- Design Ozone Dose (applied): 10 mg/L
- Design Ozone Contact Time: 5 mins
- Design RF Rise Rate: 2.0 m/h
- Design SSF Filtration Rate: 0.4 m/h

Process Schematic

Processes

- Pre-Ozonation
- Roughing Filtration
- Slow Sand Filtration
- GAC Contactor



Results During Commissioning

61 %

REDUCTION

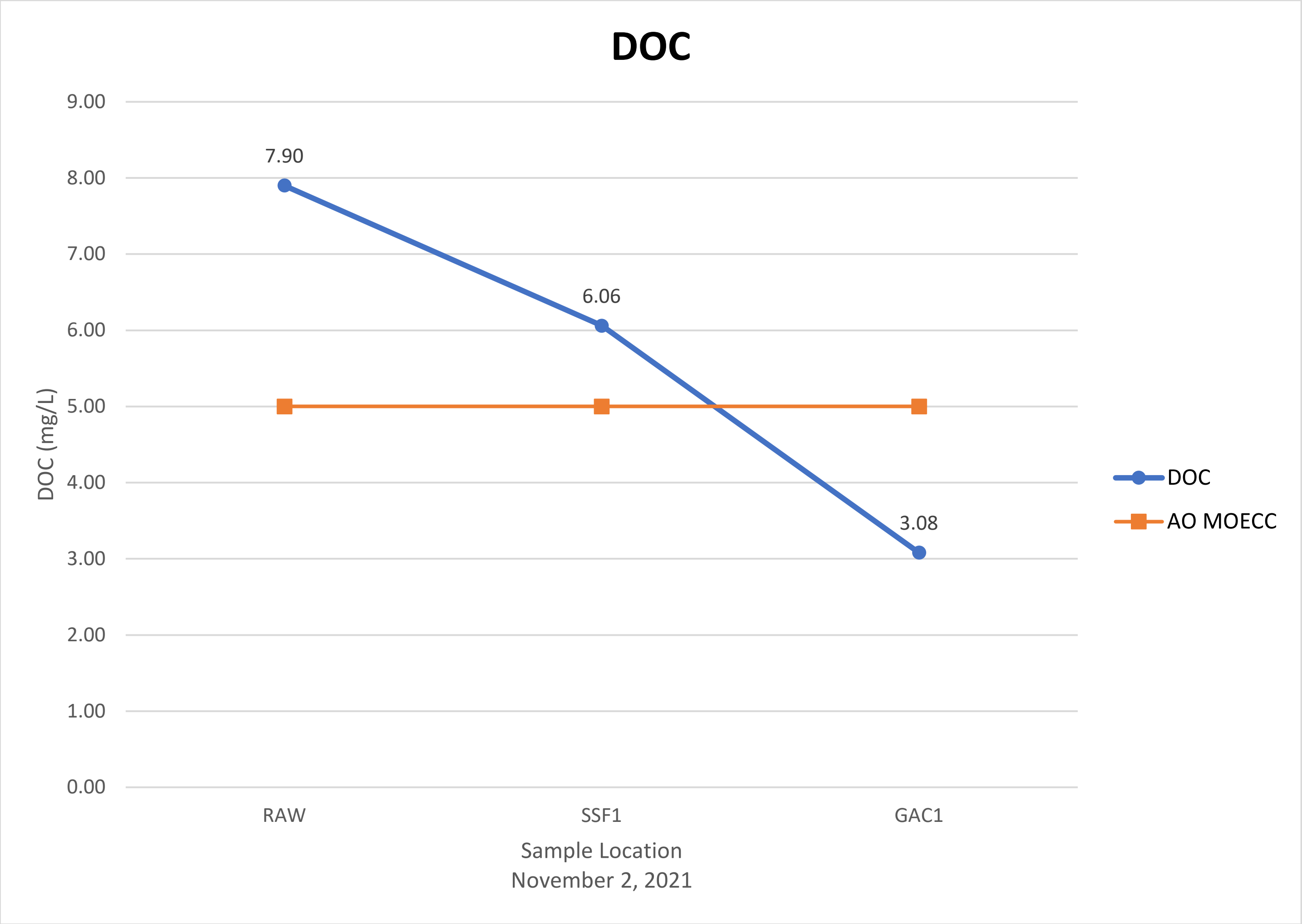
Dissolved Organic Carbon

Raw: 7.9 mg/L

Post SSF1: 6.1 mg/L

Post GAC1: 3.1 mg/L

Sample Date: Nov 2, 2021



85 %

REDUCTION

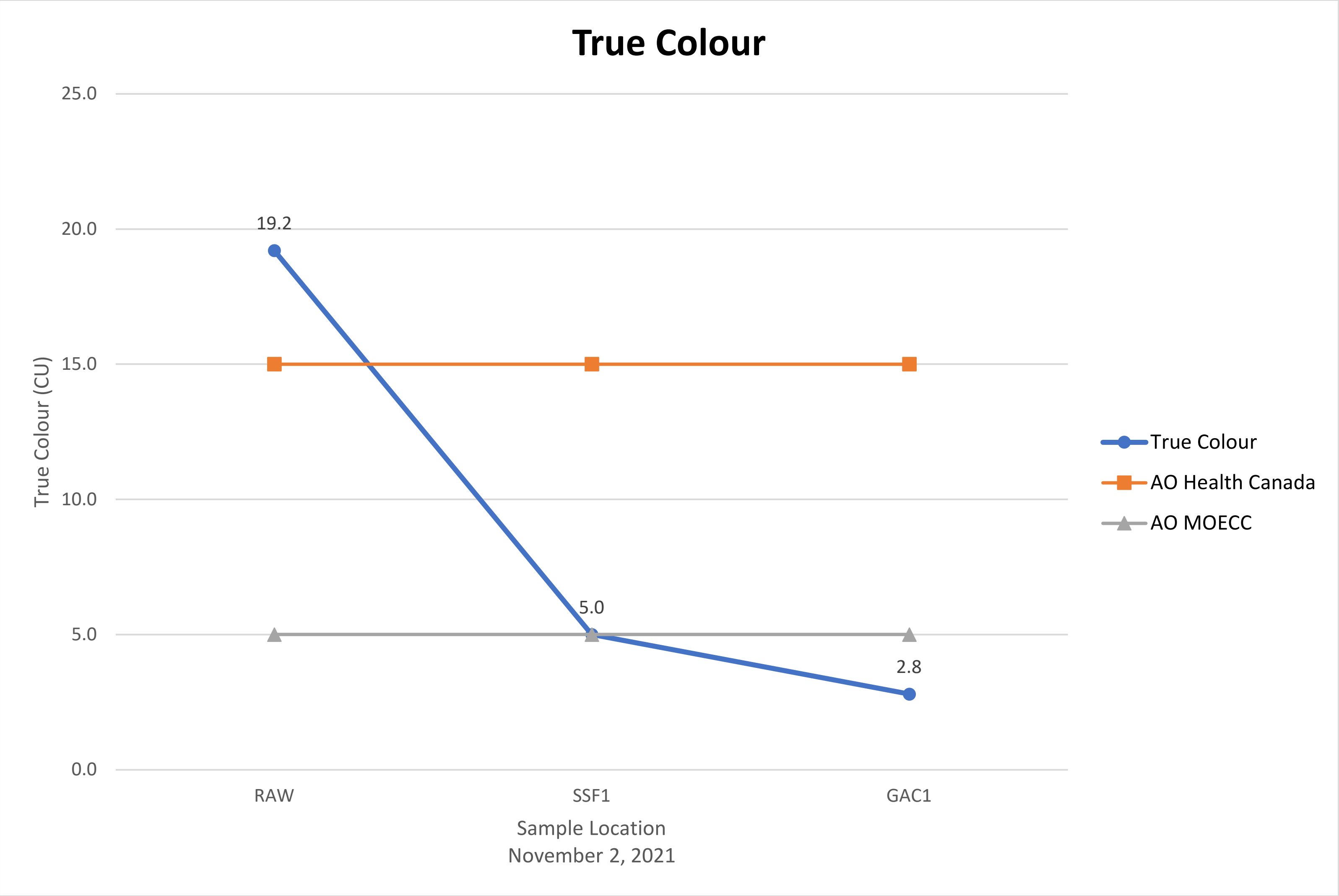
True Colour

Raw: 19.2 TCU

Post SSF1: 5 TUC

Post GAC1: 2.8 TCU

Sample Date: Nov 2, 2021



30 %

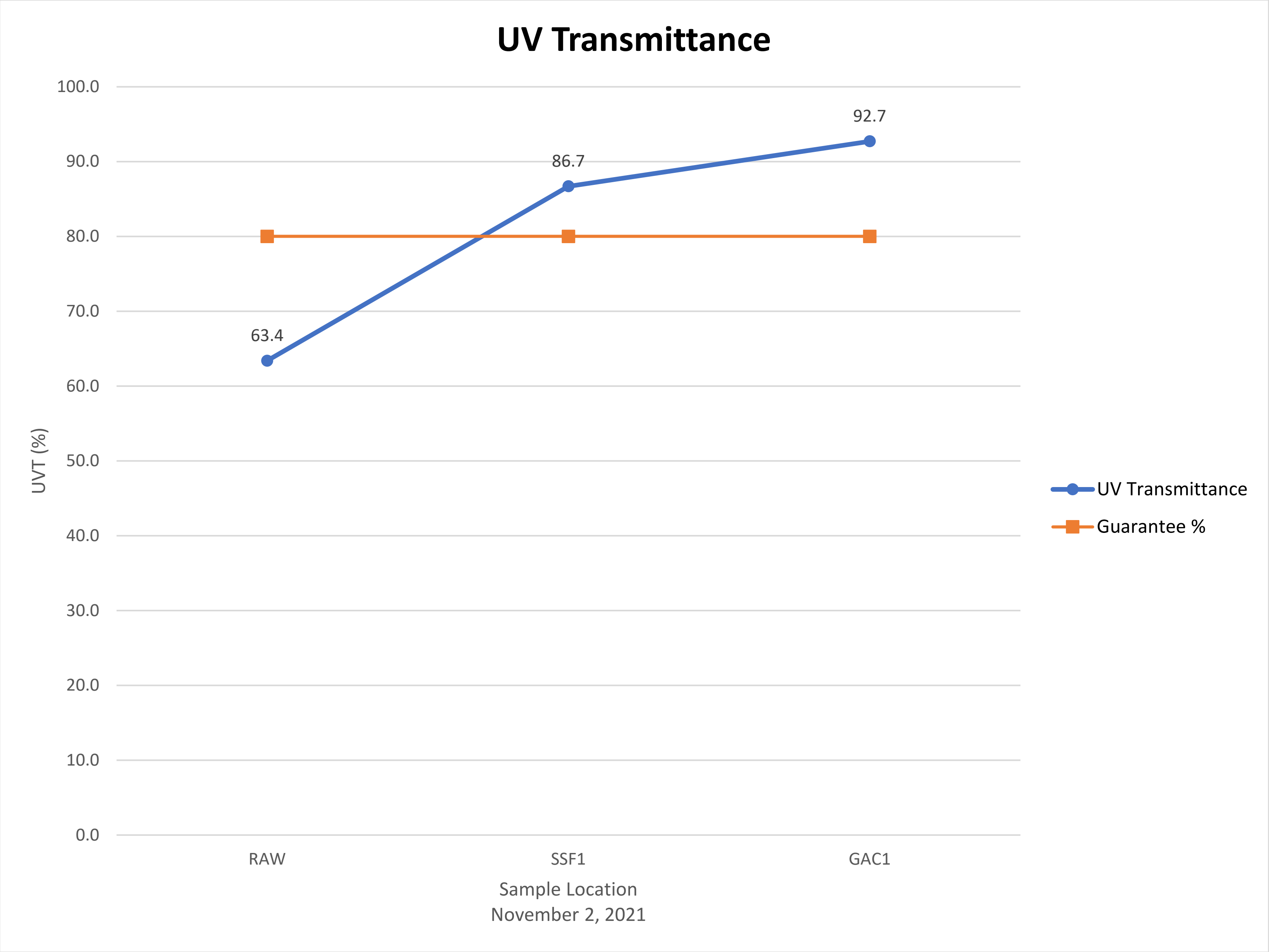
INCREASE TO UVT

Raw: 63.4%

Post SSF1: 86.7%

Post GAC1: 92.7%

Sample Date: Nov 2, 2021



72 %

REDUCTION

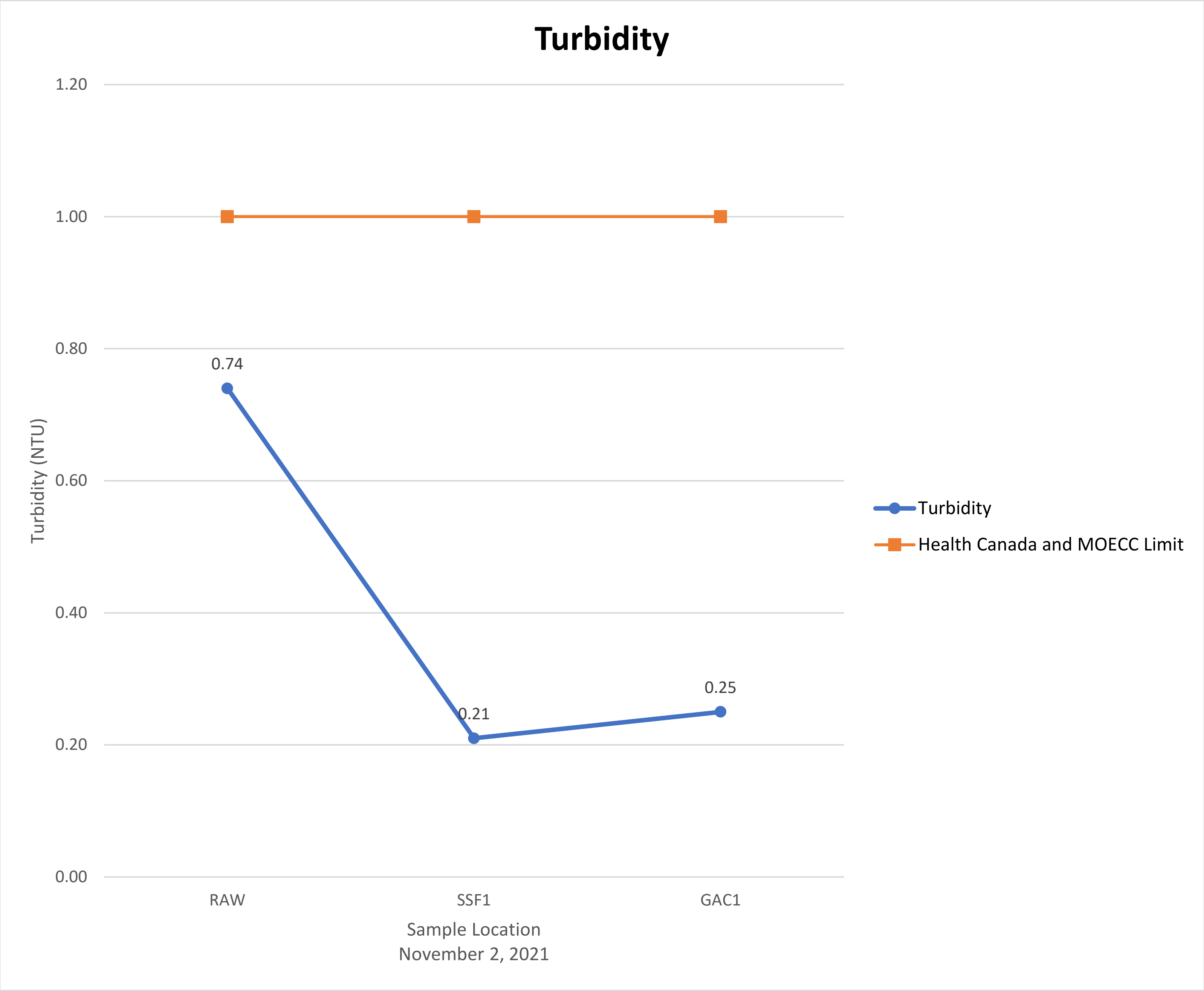
Turbidity

Raw: 0.74 NTU

Post SSF1: 0.21 NTU

Post GAC1: 0.25 NTU

Sample Date: Nov 2, 2021

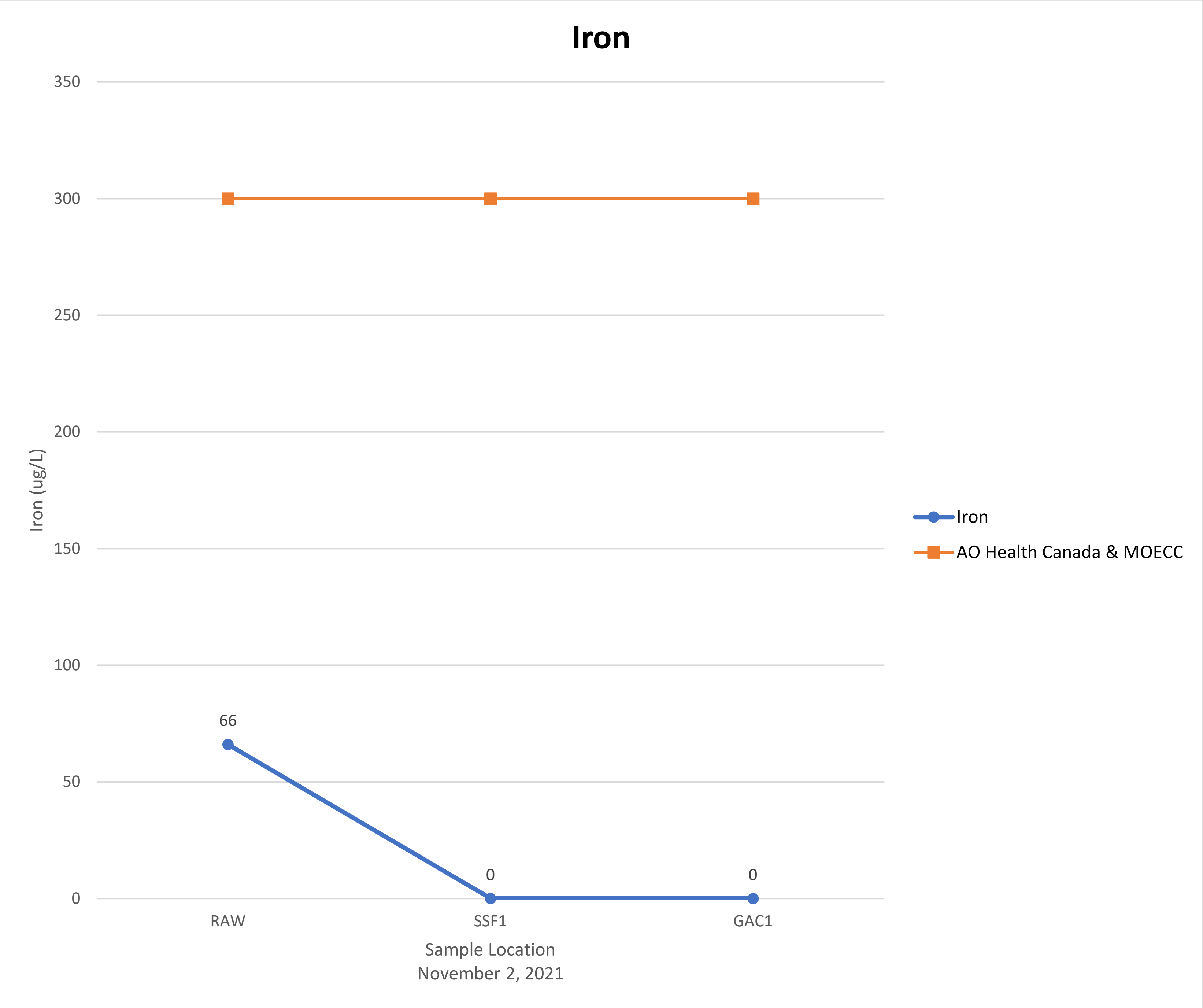


Iron Reduction

Raw: 66 ug/L

SSF1: <50 ug/L (below detection limit)

GAC1: <50 ug/L (below detection limit)



Gull Bay (KZA) First Nation WTP

May 2022 Water Quality Event Notified:

Raw Water Quality (Sampled June 1, 2022):

- DOC = 13.0 mg/L
- UVT = 31.8 %
- True Colour = 68.5 TCU
- Iron = 213 ug/L

What happened and how was this effecting the performance of the MS Filter System?

Possible Causes for the change in water quality:

- Major Forest Fire events that summer
- Flooding the following spring

Other issue effecting water quality found during investigations:

- Iron Bacteria in Low Lift Well

Why is the change in water quality effecting the MS Filter System Performance?

- Iron bacteria will eat up the ozone
- Ozone Pretreatment was not designed to handle organic loads of these levels.
- With insufficient pretreatment, this will lead to filters “clogging” quicker, and not being able to achieve our targeted ozone residuals.
- With higher organics in the water, this will use up the Granular Activated Carbon very quickly.

What has happened since:

- Water samples in the Bay were taken and the intake was raised to a height where iron bacteria is not believed to be an issue
- Low Lift Well was cleaned and a new cleaning protocol to prevent bacteria was initiated
- Continuous sampling protocol to monitor the Raw and Treated Water DOCs and other parameters, to assist with a future upgrade.
- Ozone Stress Test to verify full operation of equipment

Water Quality Results After Changes

Raw Water – Pre GAC-Swap (Jan 23,2024):

- DOC = 8.58 mg/L
- UVT = 52.8 %
- True Colour = 29.0 TCU

Raw Water – Post GAC Swap (Jan 25,2024): :

- DOC = 9.34 mg/L
- UVT = 51.8 %
- True Colour = 28.1 TCU

Pre-GAC Swap SSF2:

- DOC = 3.9 mg/L
- UVT = 84.1%
- True Colour = 5.75 TCU

Post-GAC Swap SSF2:

- DOC = <0.5 mg/L
- UVT = 95.1 %
- True Colour = <2 TCU

Since January 2024 GAC Replacement

- Water Sampling Program Ongoing
- Existing ozone system (with no pre-treatment upgrade to date) operating manually in order to utilize the spare equipment for more ozone dosing.
- GAC being used up at a fast rate due to insufficient pre-treatment
- Flow rate is being monitored and decreased when needed to provide as much pre-treatment as possible
- RAW DOC recorded at over 18 mg/L being treated to below 5 mg/L.

What has been constant throughout the issues at the WTP?

- The Operators (Steve, Marcel, Carlos and Gary) have done an amazing job to continuously provided excellent water quality throughout
- MS Filter Systems Inc. has provided support and assistance (on site and remote) when required

Recommendation

- Upgrade the Ozone System using the data from the continuous sampling program and an onsite verification study

Looking to the Future

Solving the problems we face today

In an effort to further reduce the organics to reduce the disinfection byproducts in treated water, we are actively exploring 2 options for modular technologies

- Advanced Oxidation Process (AOP)

  A pre-treatment to be used in conjunction with ozone

- Ion Exchange

  Post-treatment added after the pre-ozonation and slow sand processes

Ion Exchange

- The potential use of a tertiary fixed Ion Exchange bed is under investigation. The high quality of the slow sand filter effluent makes a simple fixed bed setup feasible, much like a water softener.
- Biological Ion Exchange needs to be considered based on studies showing years between regeneration.
- The benefits are:
  - High removal percentage of dissolved organics.
  - Relatively simple operation.
- The issues are:
  - Significant salt consumption
  - Sodium in the finished water
  - High sodium content in the regeneration brine discharge

Advanced Oxidation Process (AOP)

- Ozone is a powerful oxidant but in combination with either Hydrogen Peroxide or Ultraviolet produces an even more powerful oxidant which can significantly enhance the oxidation of dissolved organics.
- Further research is required on the optimum ozone contact time followed by the AOP to optimize organics oxidation for subsequent biological removal.
- Hydrogen Peroxide at relatively low concentrations (10 to 20%) is a simple feed system and does not produce a wastewater residual.
- Positive results from a trial at the Lindsay Ontario WTP.

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