THM Removal Strategies for Water Tanks and Reservoir

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Agenda

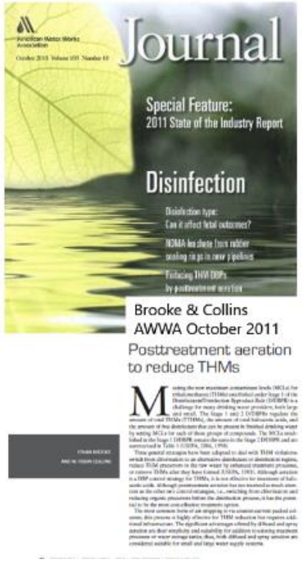
- Trihalomethanes
  - Background
  - THM Formation
- Aeration as a means of THM removal
- Case Studies

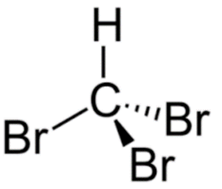
Trihalomethanes (THMs) – Long history of contaminant regulation

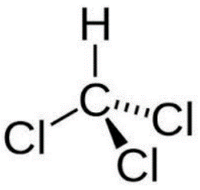
Canada’s regulations:

- 100 ppb MAC of Total Trihalomethanes (TTHM)
- 16 ppb MAC of Bromodichloromethane (BDCM)

based on a sample locational running annual average (LRAA)







International Agency for Research on Cancer

World Health Organization

** HAA5 – Haloacetic Acids cannot be mitigated through aeration techniques*

There are four general strategies to deal with THMs: change disinfectant (to chloramines), reduce NOM (naturally occurring organic material), reduce water age, or remove THMs after they form

TIME

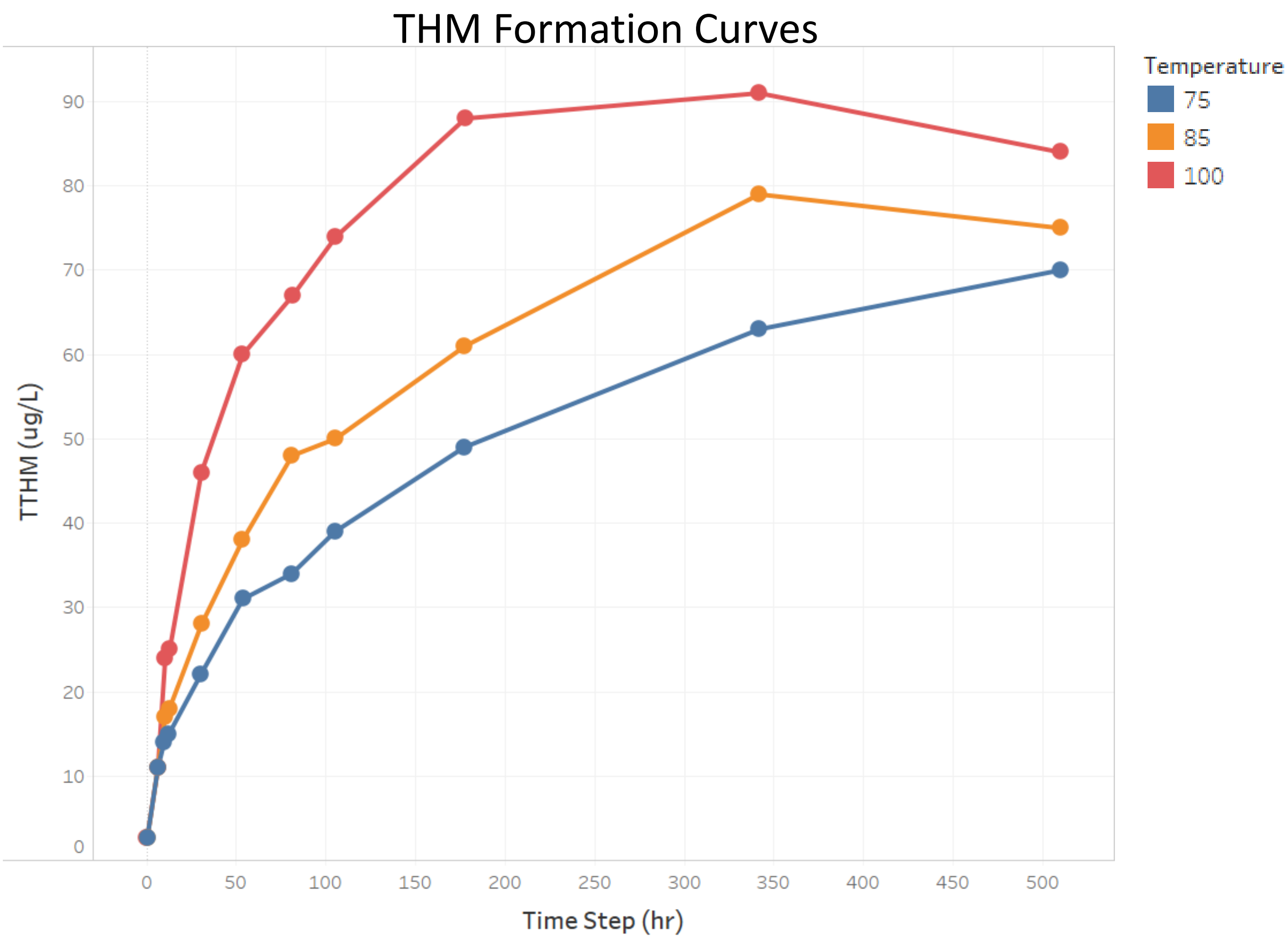
+  = 

Free Chlorine (Cl)

Natural Organic Matter (NOM)

Disinfection Byproducts (DBP)

THMs form faster at higher temperatures



There are four general strategies to deal with THMs: change disinfectant (to chloramines), reduce NOM (naturally occurring organic material), reduce water age, or remove THMs after they form

In-tank aeration removes THMs by aeration after they form

TIME

+

=

Free Chlorine (Cl)

Natural Organic Matter (NOM)

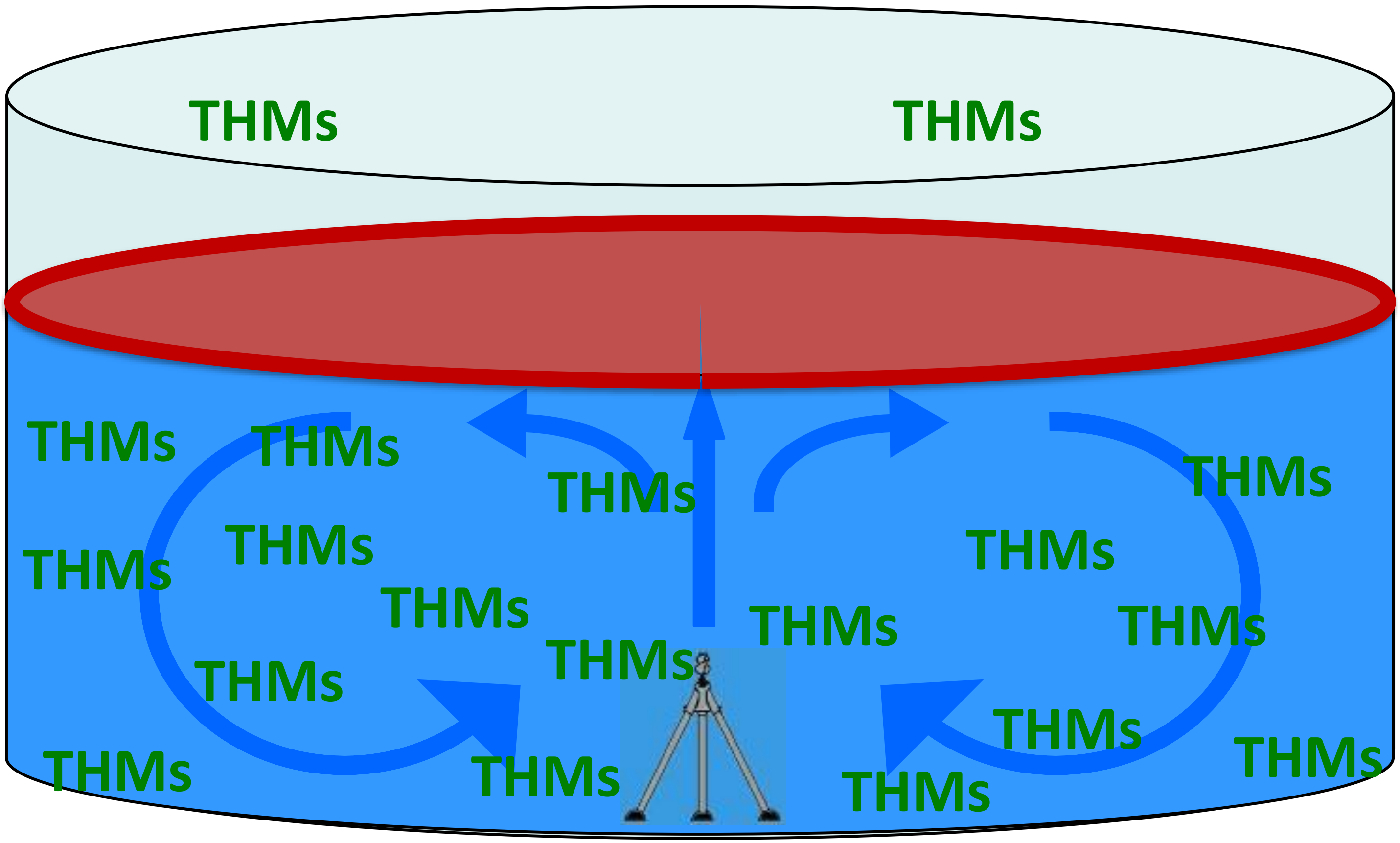
Disinfection Byproducts (DBP)

THMs are volatile … just like CO_2

- THMs would rather be in gas phase than liquid phase
- THMs can build up in the headspace of a tank if its not actively ventilated, stopping THM volatilization

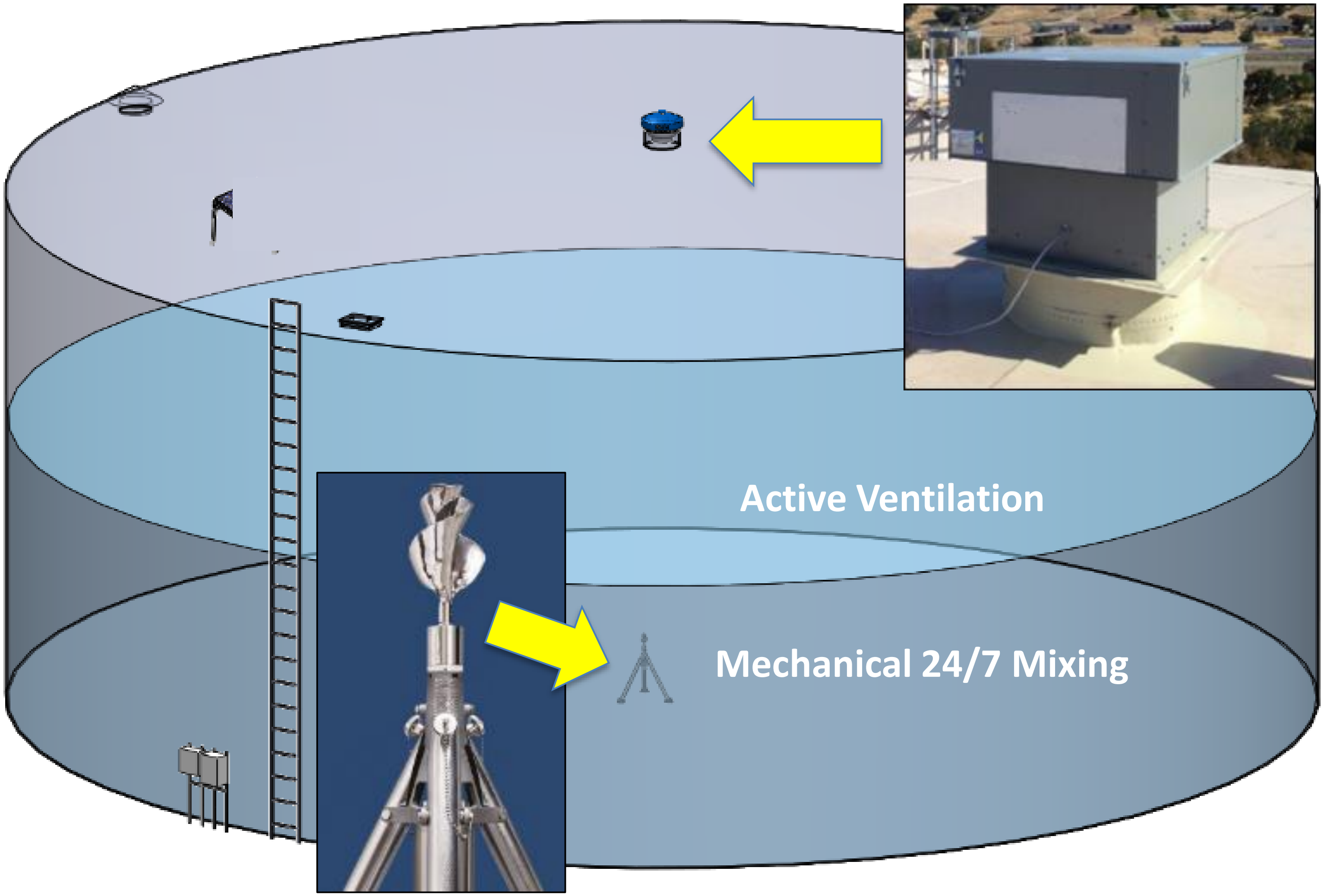
"Headspace"

Active mixing allows THM's to bridge the diffusional barrier into an active headspace

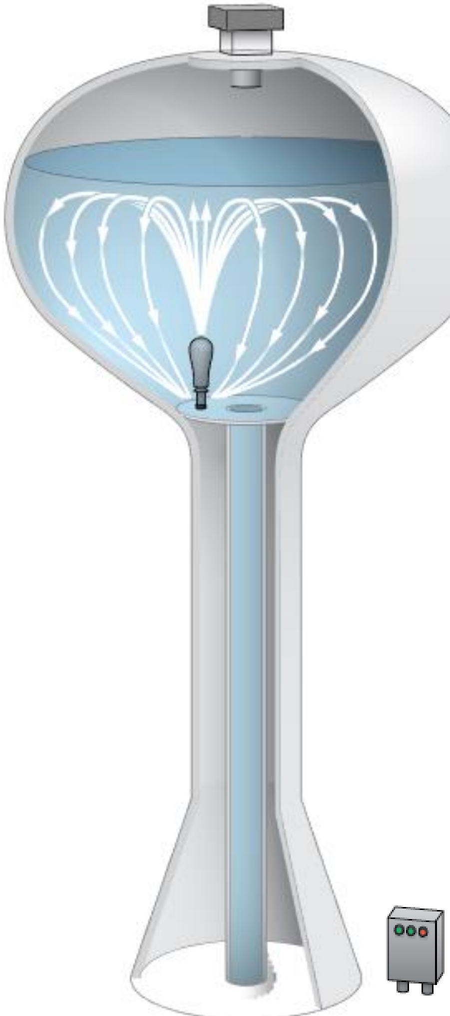


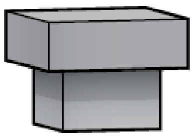
But you need <u>STRONG</u> mixing

Adding active ventilation breaks Henry's Law equilibrium in tank head-space

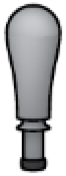


Mixer + Active Ventilation: ideal for tanks with high residence time*





Active Ventilation



Active Mixer

- Mixer + Active Ventilation relies on the tank mixer to continually introduce water with high THM concentration to the air-water interface at the water surface. The longer the water is in the tank, the more opportunity for mass transfer
- Ideal economic stepping-stone to additional removal levels with more aeration

**High residence time or high detention time creates opportunities for THM formation and should be ideally avoided in system design*

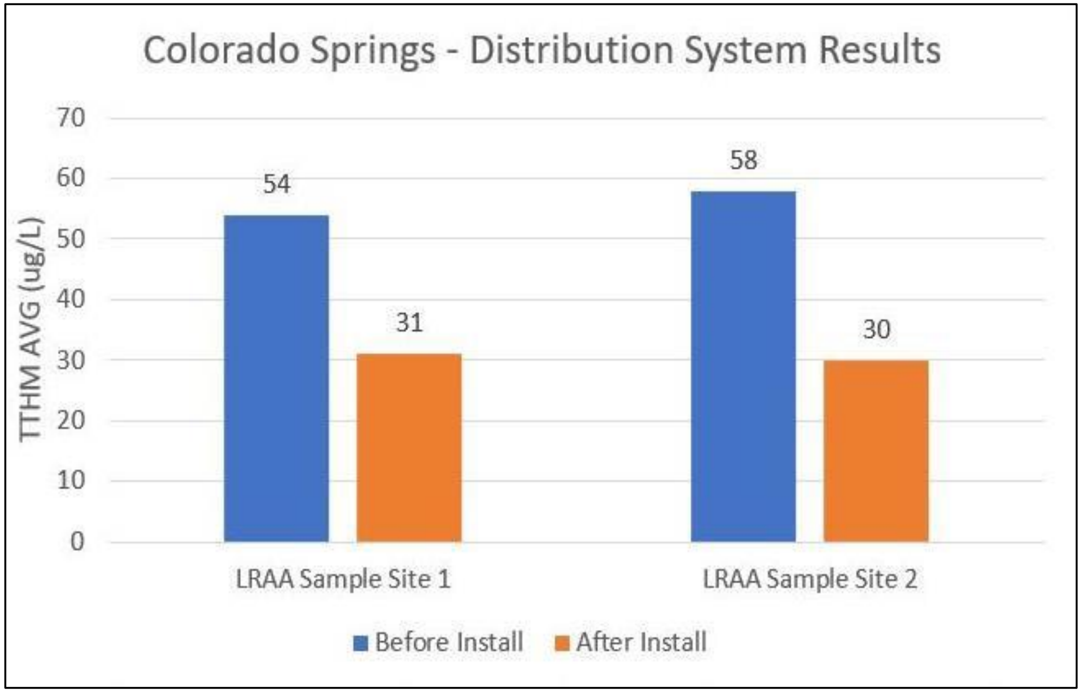
Colorado Springs Utilities

Case Study

- Despite mountain runoff, periodic problems with THM formation
- Numerous tactics employed over the years including flushing, treatment modifications, reducing water levels, on-site boosting to limit chlorine entry levels
- Decided to try network aeration to reduce THMs
- Designed to reduce THMs by 25%
- Installation without taking tank down during a 60-day window in winter

Tank at 7,500 foot elevation

Despite extreme weather, the installation was completed in three days and resulted in 42% and 48% reductions in THMs at sample locations



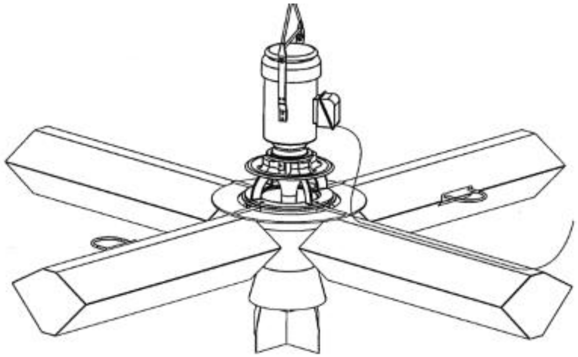
Active Ventilation 0.5 HP

Mixer 0.5 HP

Colfax: 0.3 MG, 1.0 MG clearwells (4 day detention) – Tank Mixer + Active Ventilation

Colfax: 0.6 MG Ball Park Tank (10 day detention) end of the line - higher detention times result in higher removal rates

In addition to active mixing and ventilation, surface aeration may be needed depending on tank operational parameters

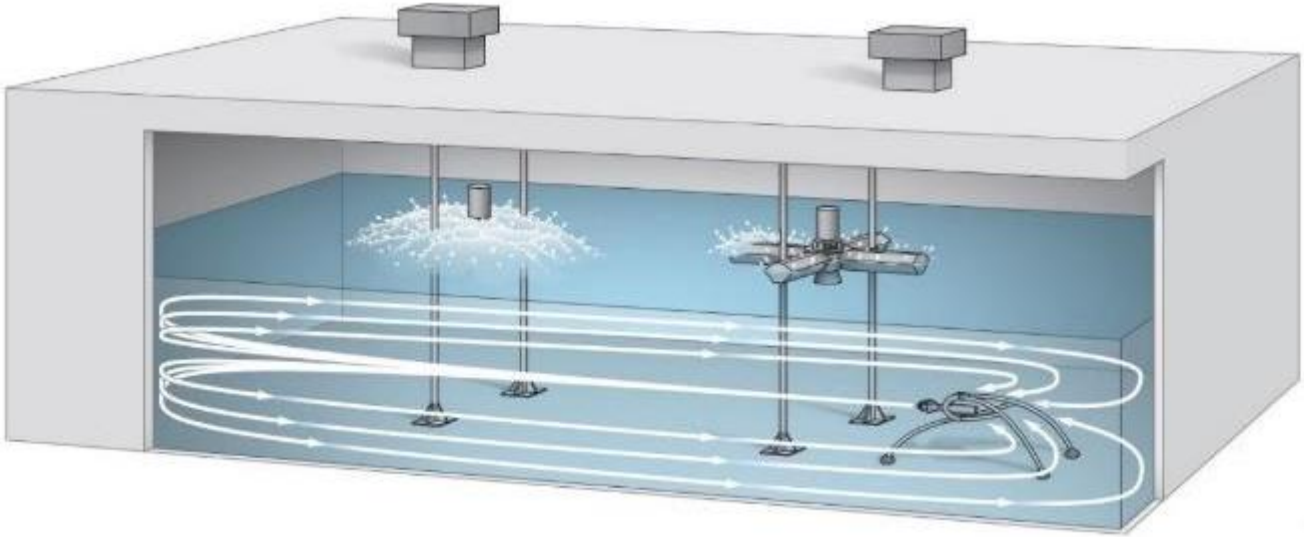


<u>Mixer</u>: Continually introduces THM laden water to the air-water interface

<u>Active Ventilation</u>: Blows fresh air into the tank, exhausting THM laden air and providing the driving force for mass transfer

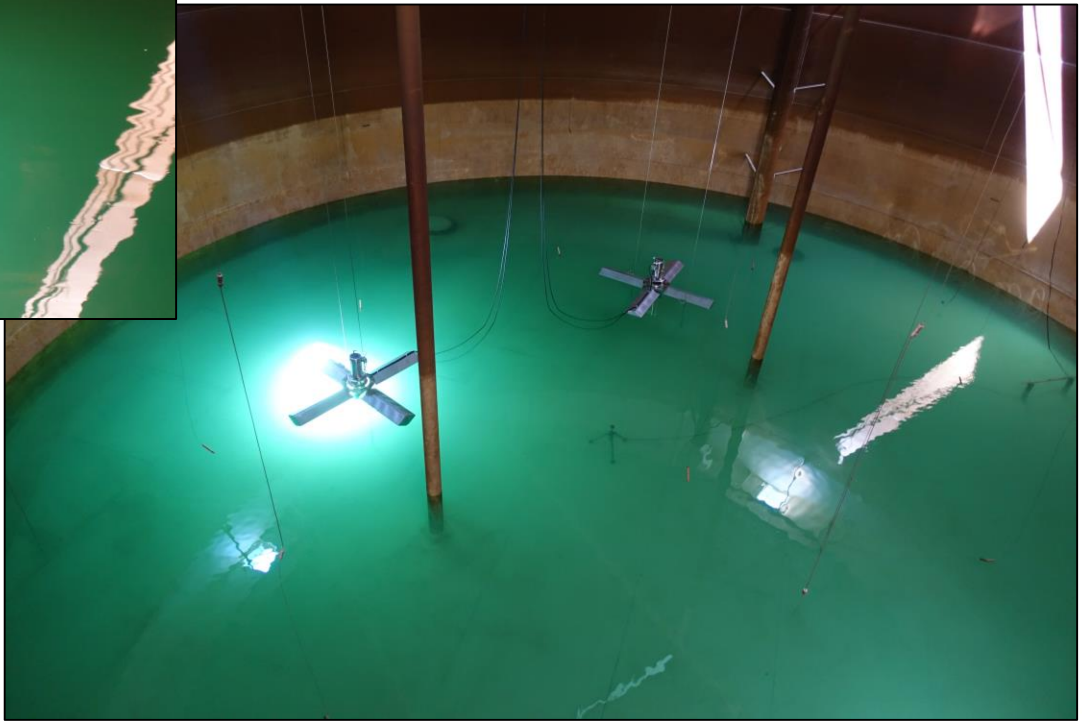
<u>Air-water interface</u>: Surface aeration equipment increases available water surface area for additional mass transfer

Surface aeration is a good method to treat THMs in tanks, especially where detention time is short



- Surface Aeration is energy efficient relative to other mass transfer techniques
- Adding surface aerators to a tank is relatively easy
- Maintaining surface aerators in a tank can be a problematic due to tank access and weight/size
- Cost of energy usually outweighs the capital cost of the equipment over time – pay attention to power requirements
- Often a design will be phased with mixers and ventilation in first phase and if additional removal is required, surface aerators can be added in subsequent phase

Surface aerator installations are straightforward and do not require extensive tank modifications (crane is required)



Manitoba Canada – Plumas Clearwell

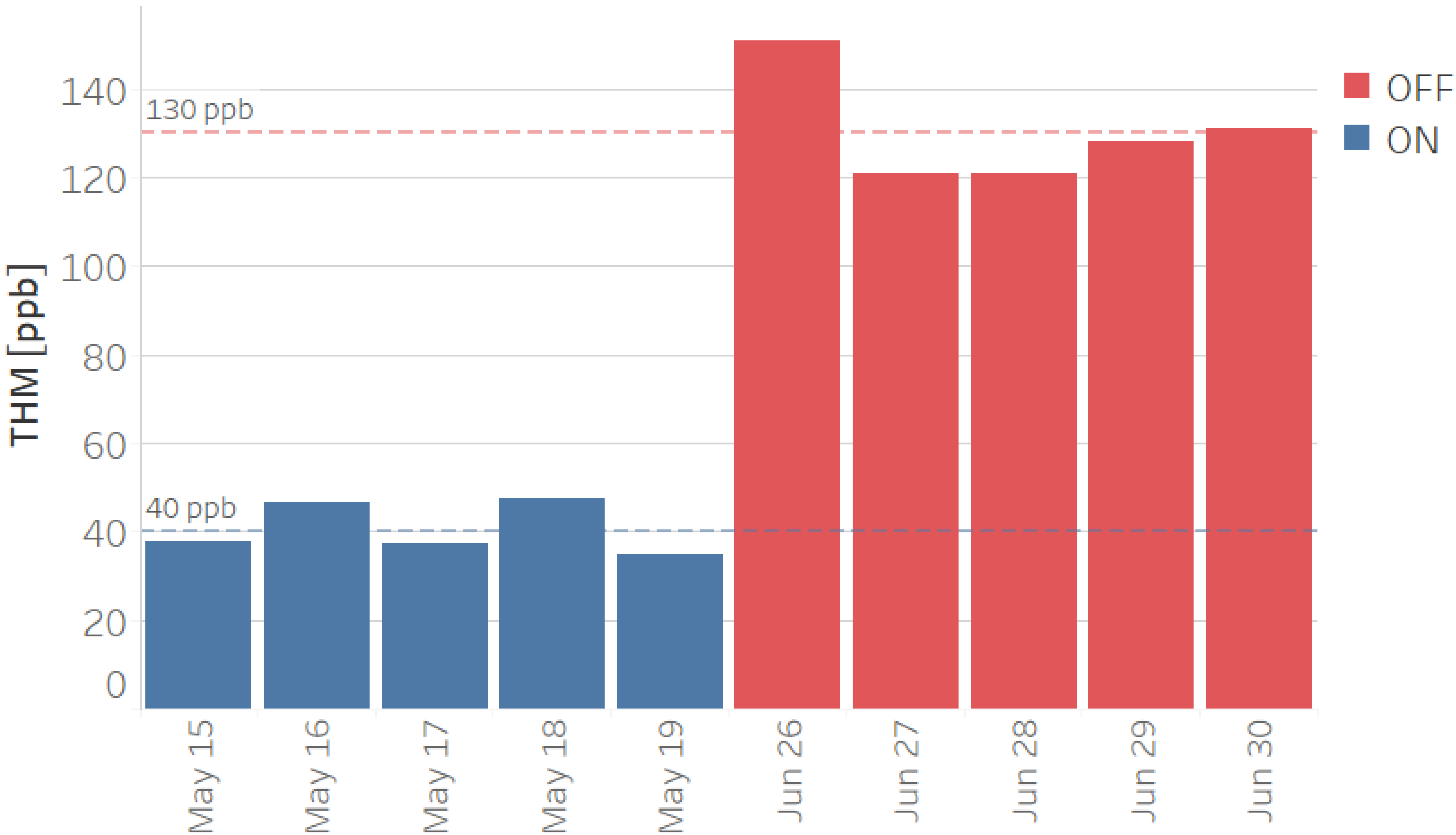
Case Study

- Full scale pilot study – initially
- RFP issued June 2016
- 70% TTHM removal target
- Year round treatment
- Full water chemistry analysis
- System startup November 2016
- Clearwell under building install location

Below grade clearwell – installation of one surface aerator (guides) + mixer

Active Ventilation with in-line duct heater

Validation results = 70% removal



Conclusion

- In-tank aeration is a safe, effective, and proven means of lowering THM levels in finished water
- Active mixing and ventilation are necessary to initiate aeration process in-tank.
- Surface aeration may be needed and will vary based on tank geometry, volume of water, turnover, and THM formation curve for that network.

Questions?

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Henry's Law constants dictate the percentage of THM's that can saturate the tank head-space – ***in equilibrium***

THM species	Henry's law constant @ 20 °C
Chloroform	0.13 (87% in water)
Bromodichloromethane	0.08
Chlorodibromomethane	0.04
Bromoform	0.02 (98% in water)

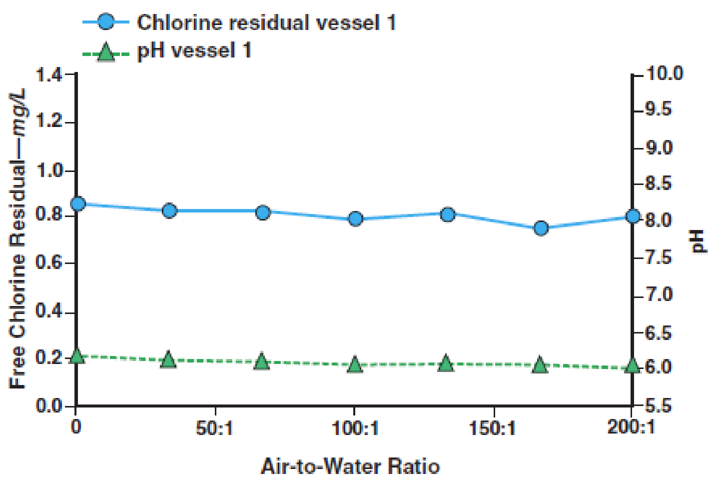
Chloroform is the most "volatile" (easiest to remove)

Bromoform is the least "volatile" (hardest to remove)

Chlorine is not lost during the aeration process

$HOCl \leftrightarrow H^+ + OCL^-$

- Hypochlorite speciates based on pH
- Hypochlorite ion is not volatile – not a gas
- Hypochlorous acid is “thermodynamically stable” even at low pH. (See Brooke & Collins AWWA 2011)
- Drops in chlorine residual after aeration are temporary, and related to deactivation of bio-film due to mixing



A computer-aided titrator was used to maintain the pH at 6.1.