Reduction of THMs Within Storage Tanks Using Aeration

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Goals for today:

- Review DBPs, THMs and conventional approaches
- Explain the science of in-tank aeration
- Review latest case studies
- Explain when in-tank aeration is best at the clearwell versus in the distribution system
- Q&A

Typical Approach to DBP reduction

- Lower the organic matter in raw water
  - GAC, Miex, Filtration, RO (get the organics OUT!)
  - Improve raw water source (new source?)
- Reduce the chemistry of disinfection
  - Change primary disinfection (ozone, UV, etc.)
  - Change secondary disinfection (chloramines)

Problem: All these options are VERY expensive!
(big changes to your water system)

Have you heard of In-tank Aeration?

Aeration to remove THMs is not new…

Table 1. Simulated Aquarium Test

Aeration reduced THMs 85 percent in Solano Irrigation District's aquarium test.

Date	Time	Sample Location	THM Result	Difference
10/25/2006	10:10	Aquarium before aeration	151 µg/L	-85%
10/25/2006	12:55	Aquarium after aeration	23.2 µg/L	

Table 2. Full-Scale Storage Tank Test

Aeration at SSWA's Gregory Hill Storage Tank reduced THMs 70 percent.

Date	Time	Sample Location	THM Result	Difference
1/5/2007	11:00	Tank before aeration	120 µg/L	-70%
1/15/2007	10:20	Tank after aeration	36.4 µg/L	

NOVEL APPROACHES TO TRIHALOMETHANE MANAGEMENT

Paper Presented by :

Dr Rino Trolio

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Water Corporation (WA)

69th Annual Water Industry Engineers and Operators' Conference
Bendigo Exhibition Centre
5 to 7 September, 2006

Figure 2: *Aeration at Denmark Horsley Road Reservoir*

Installation of the continuous aeration system in Horsley Road Reservoir, resulted in a reduction in the average THM concentrations value from 218 µg/L to 73 µg/L.

Treatment

Storage Tank Aeration Eliminates
Trihalomethanes

In anticipation of the Stage 2 Disinfection Byproducts Rule's more stringent requirements, a California water association found a simple solution for eliminating treatment by-products.

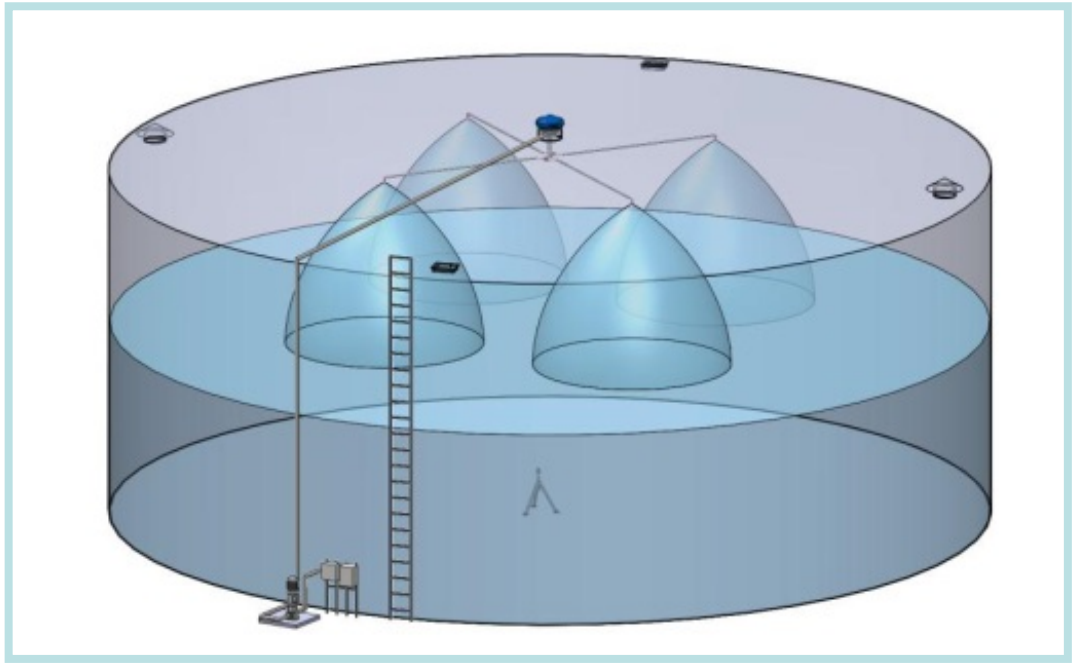
Treatment

Aeration Decreases THMs

After considering several treatment options, a small system in Northern Ontario turned to aeration to reduce trihalomethanes in its municipal drinking water system.

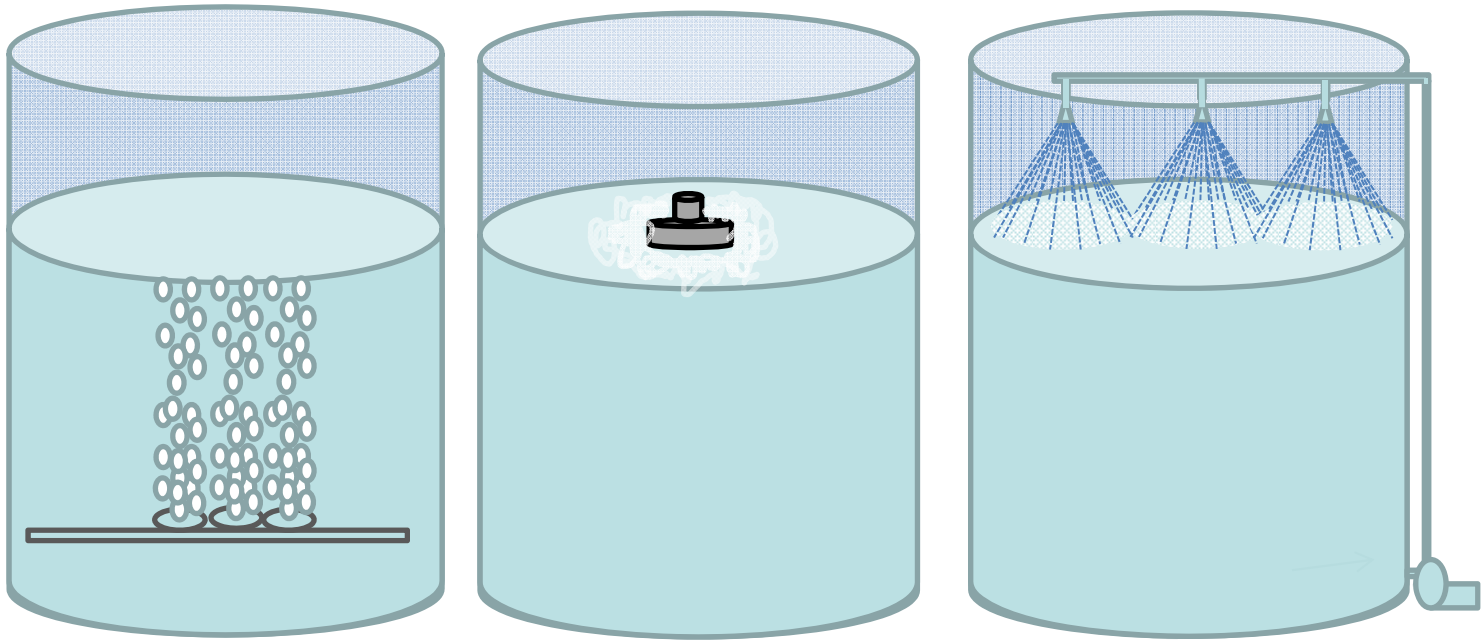
Aeration has been PROVEN to work

Post-treatment Aeration can reduce THMs



Deal with THMs where they are highest in your system

Different In-tank Aeration Technologies for different applications



Bubble aeration Surface aeration Spray aeration

Any of these technologies can be made to work… but capital and energy costs vary greatly

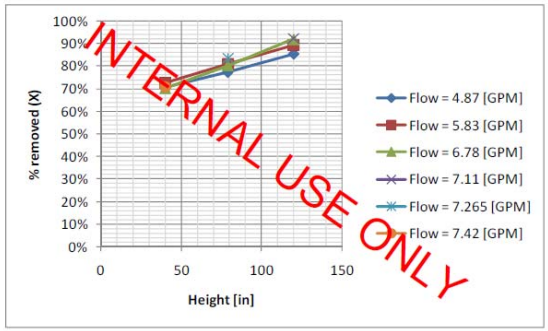
What is the TRS?

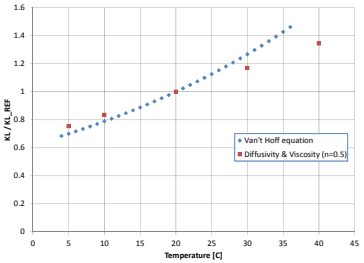
- TRS = Trihalomethane Removal System
- Partnership between PAX and Utility Service Group
- A portfolio of technologies:
  - Spray nozzles, Mixers, Surface Aerators, Ventilation– and future tools (Hardware)
  - Design software, Computer models (Software)
  - Experience, databases, engineering (Know-how)
- An integrated approach to THM reduction
  - TRS factors in operational choices and their effects on THM levels

TRS is a fully engineered, fully installed solution customized to EACH tank, with a performance guarantee

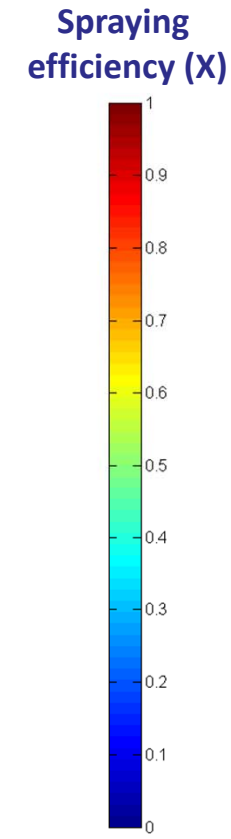
How did we develop the TRS?

- 2 years spent analyzing published and unpublished case studies on aeration for THM reduction
- 1.5 years spent measuring mass transfer coefficients for specific aeration technologies (lab and field studies)
- Optimized spray nozzle designs
- Trials (and tribulations!)

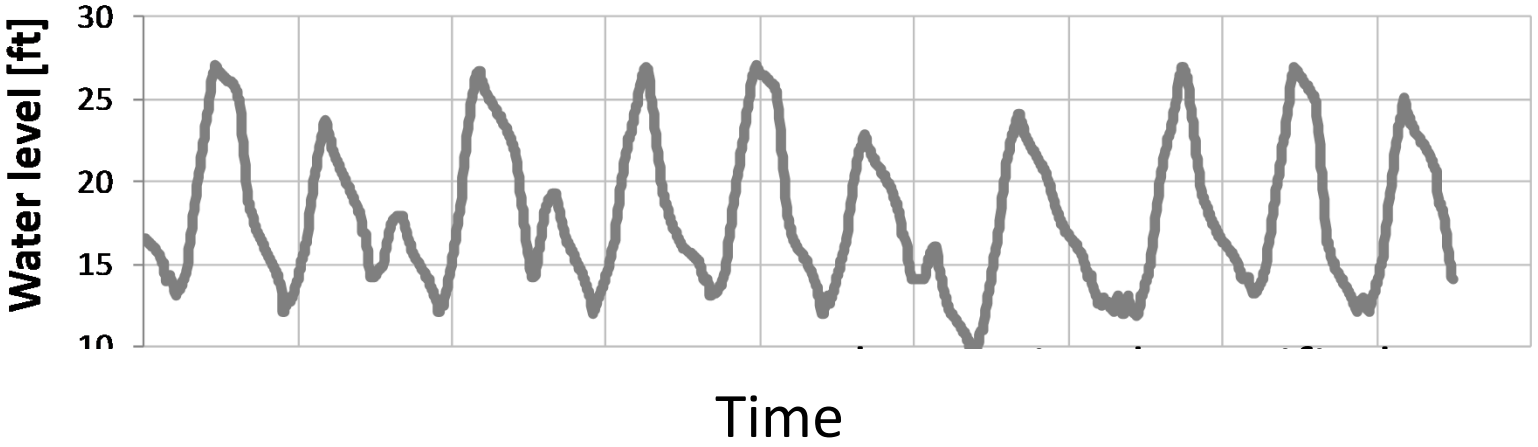




Spray Aeration: Droplet Size Dependent

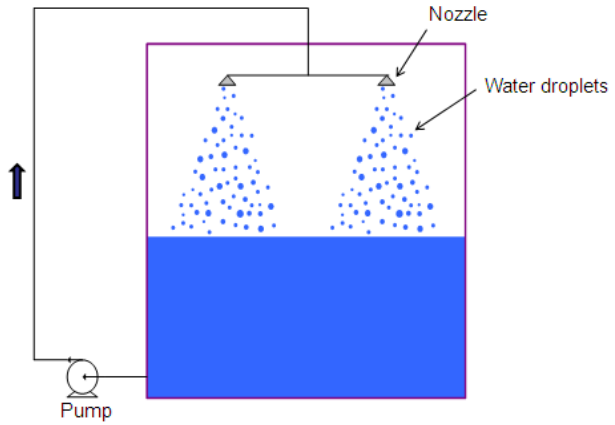


Tank Hydraulics and Fill Cycles



NEPTUNE™ Toolbox

Water sprayed at the top of the tank to strip DBPs into air



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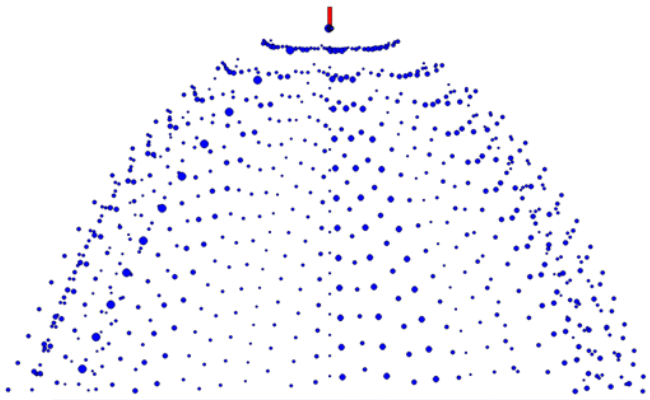
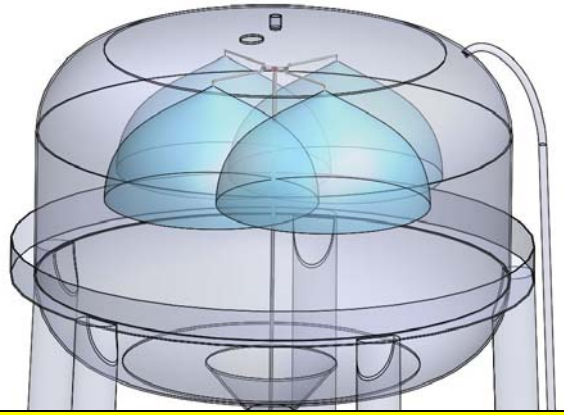
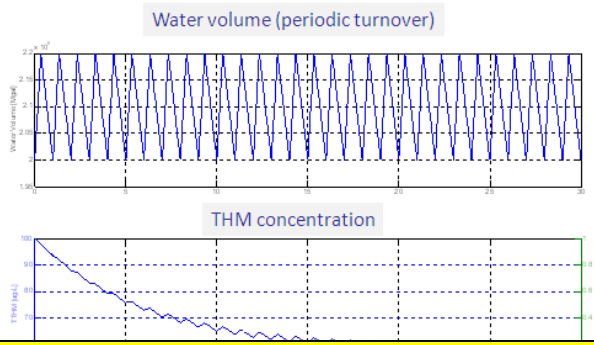
Spray efficiency model



Example of model output





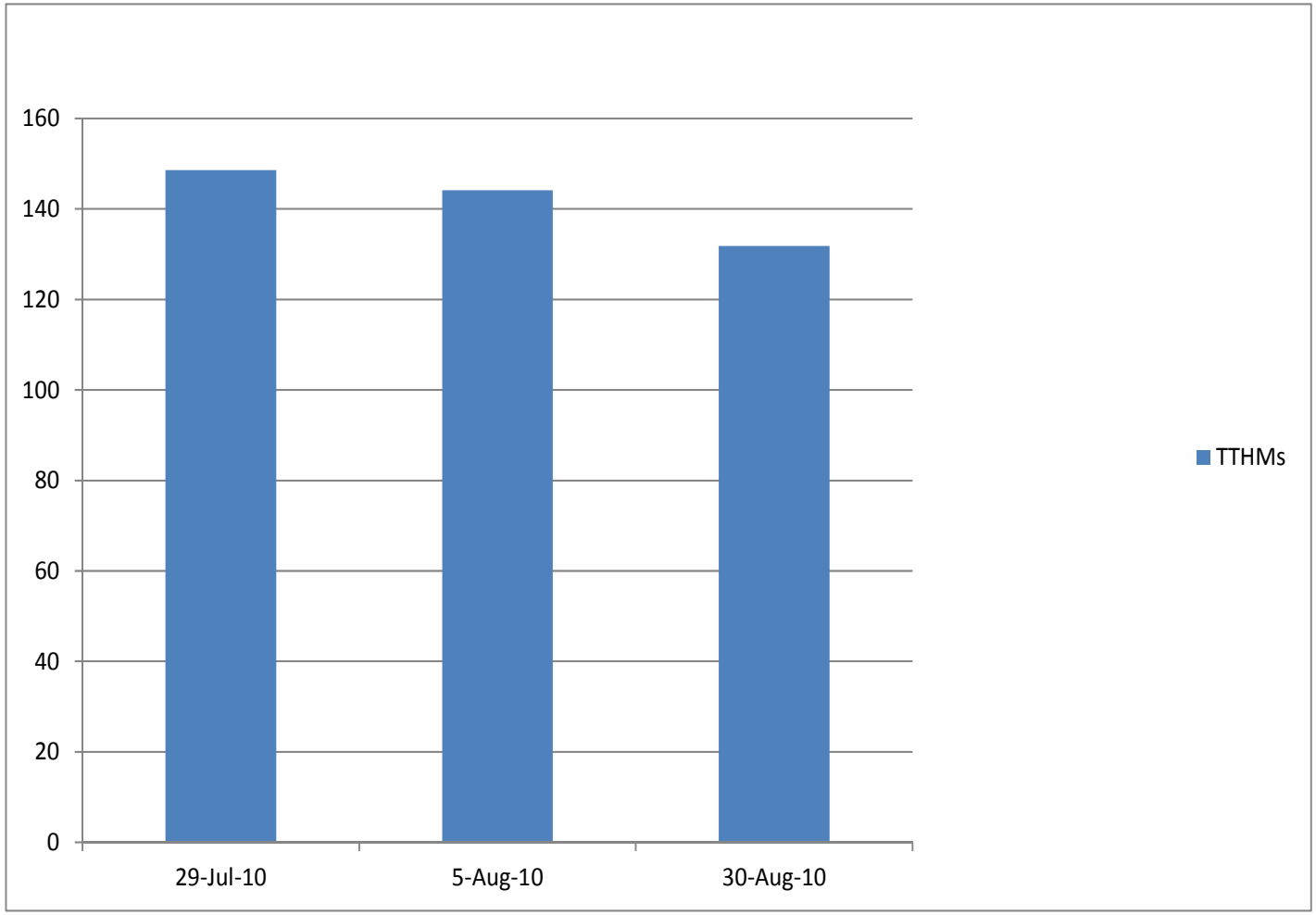
We can provide analytical support to evaluate and optimize the aeration designs of others, and we can design for new and existing tanks

TRS Case Studies

Ryan Ranch tank (Monterey, CA)

- 0.5MG, 72’ dia., 16’ h – end of line, low turnover
- Max 50 µg/L THM levels outside Ryan Ranch
- Ryan Ranch THM levels average 140 µg/L in tank
- **Estimate w/o intervention: 140 µg/L**
- To avoid violation (RAA < 80 µg/L), sample needs to be around 50 µg/L in Q3-2011
- Low Cl – periodic dosing onsite
- Others proposed sprayer aeration system ($350K)
- Limited power at tank site

Historic TTHMs – Ryan Ranch Tank



The TRS goals and design

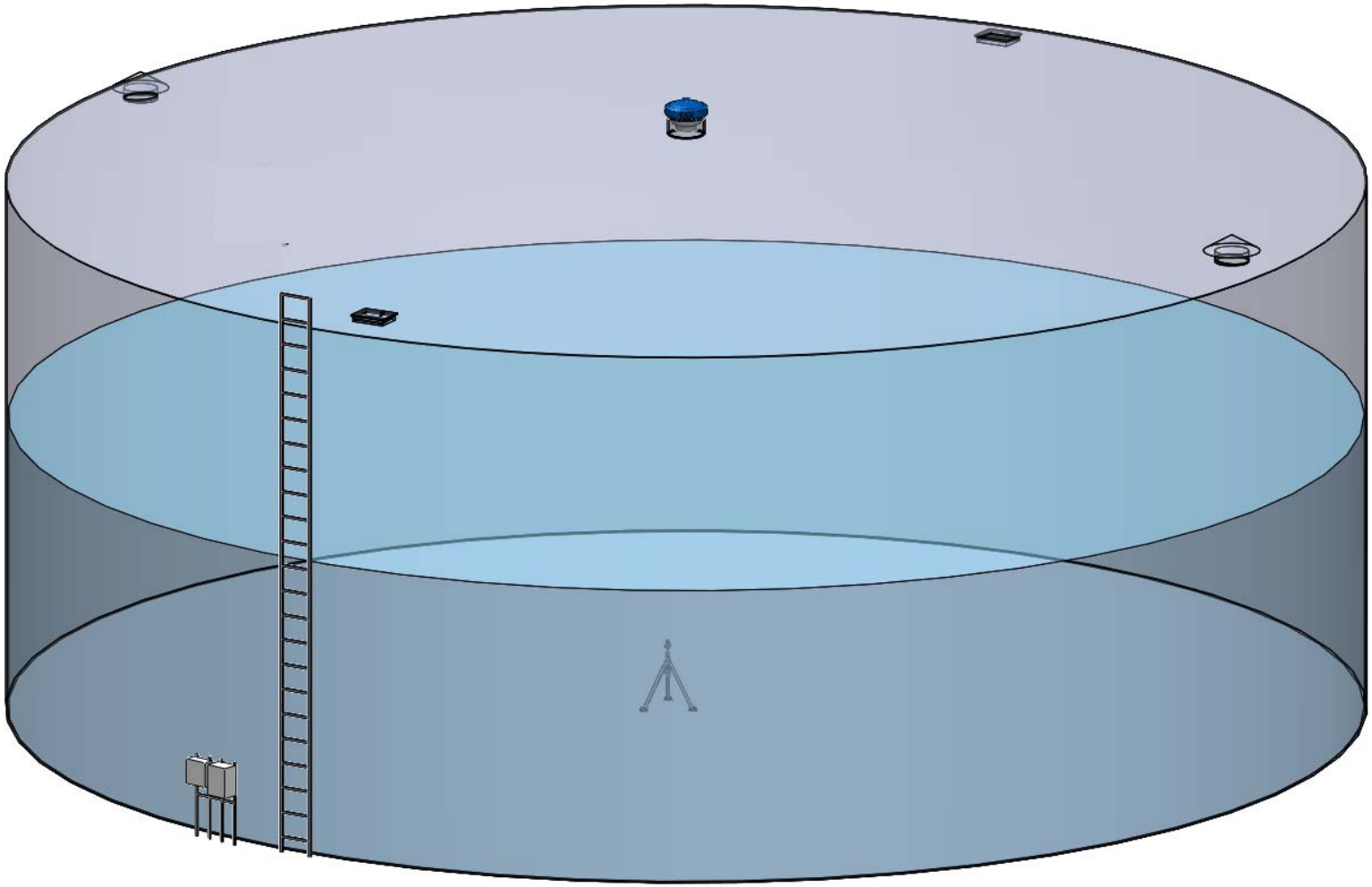
Goals

- Lower Cl demand
  - Eliminate stratification
  - Clean tank
- Remove THMs
  - Aeration
  - Goal: 60% reduction
- Use as little power as possible

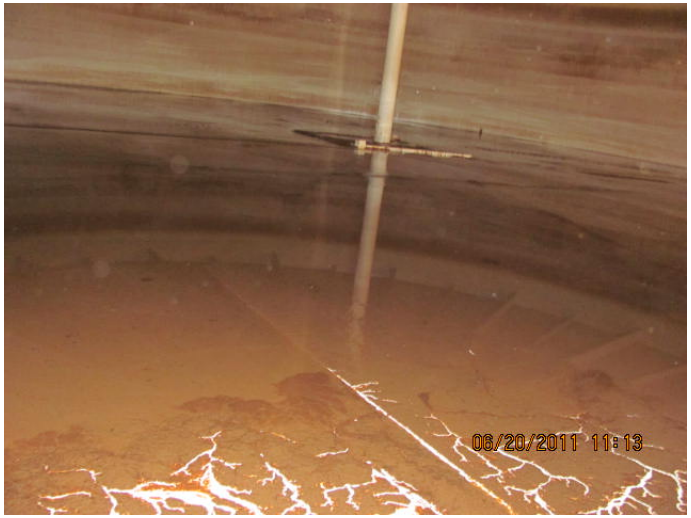
Design

- Wash-out
- Chemical clean
- 1 PWM-400 mixer
- 1 PAX PowerVent fan

Design for Ryan Ranch TRS



TRS installation: Chemical cleaning

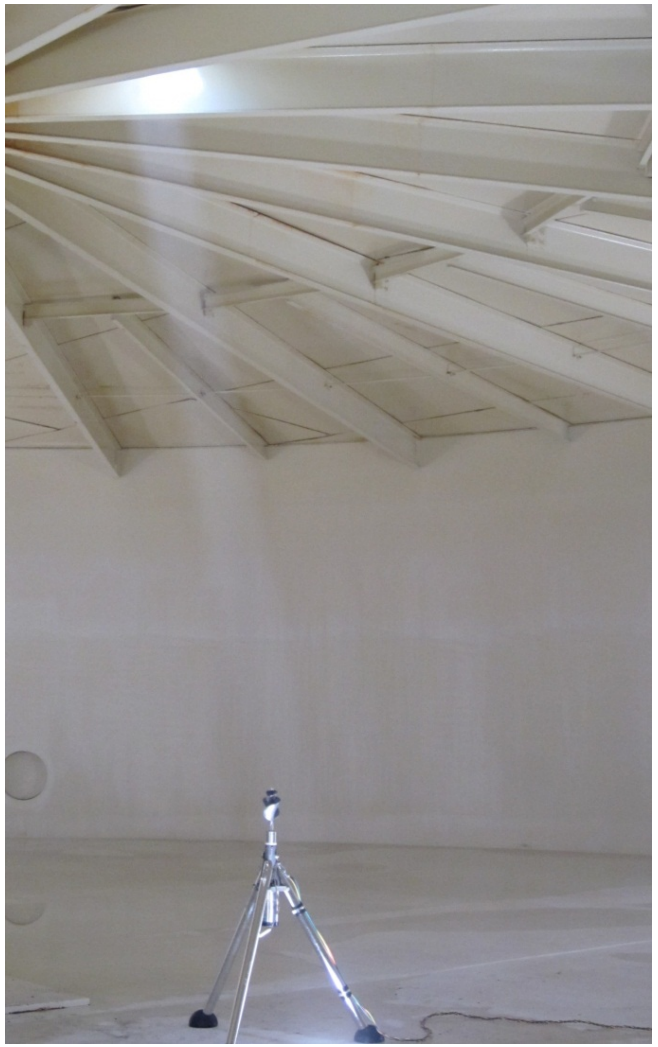


TRS Installation: Interior coatings repair

TRS Installation: PAX PowerVent™ Installation

TRS Installation: Mixer Installation

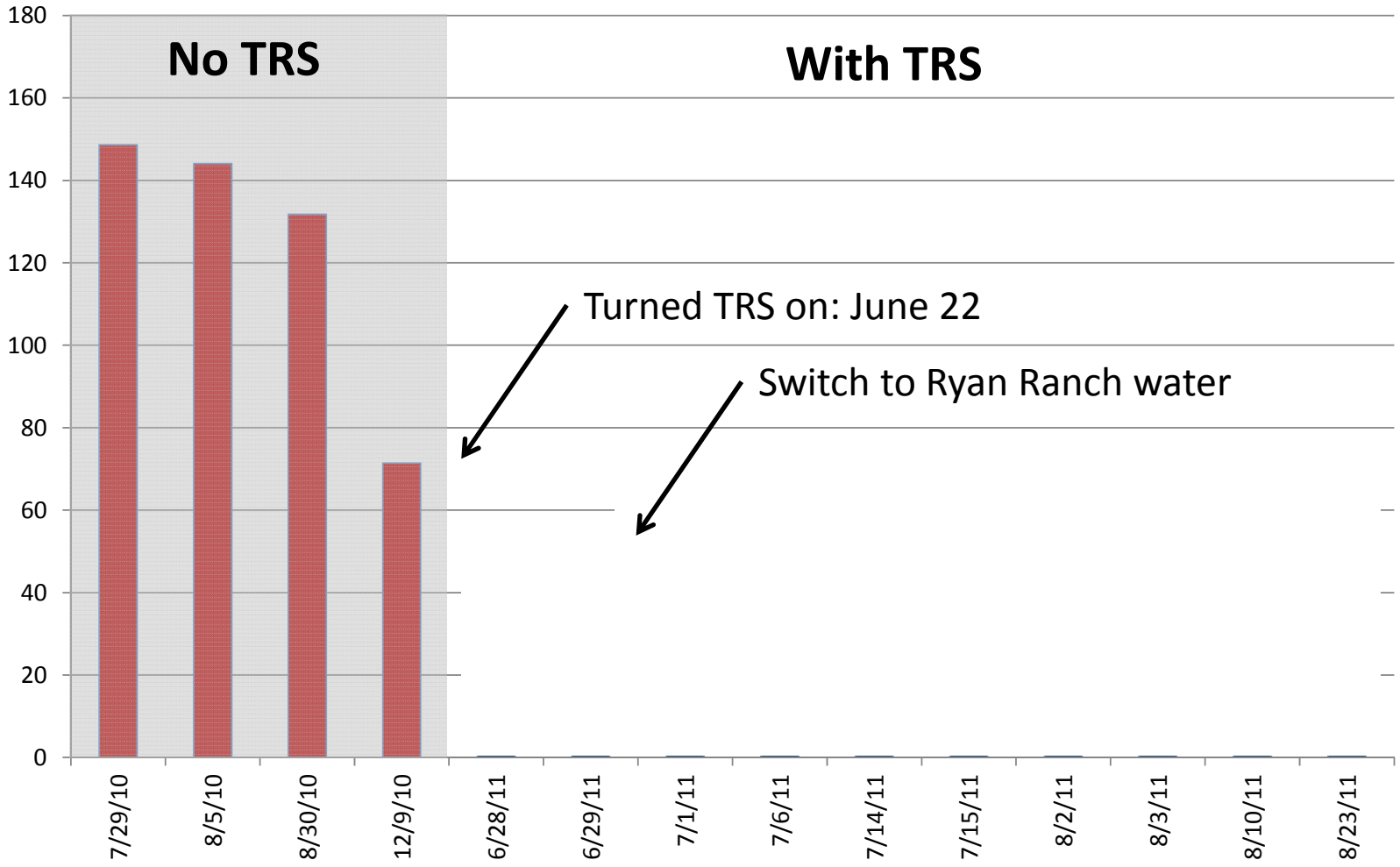
Initial results of Q3 compliance test

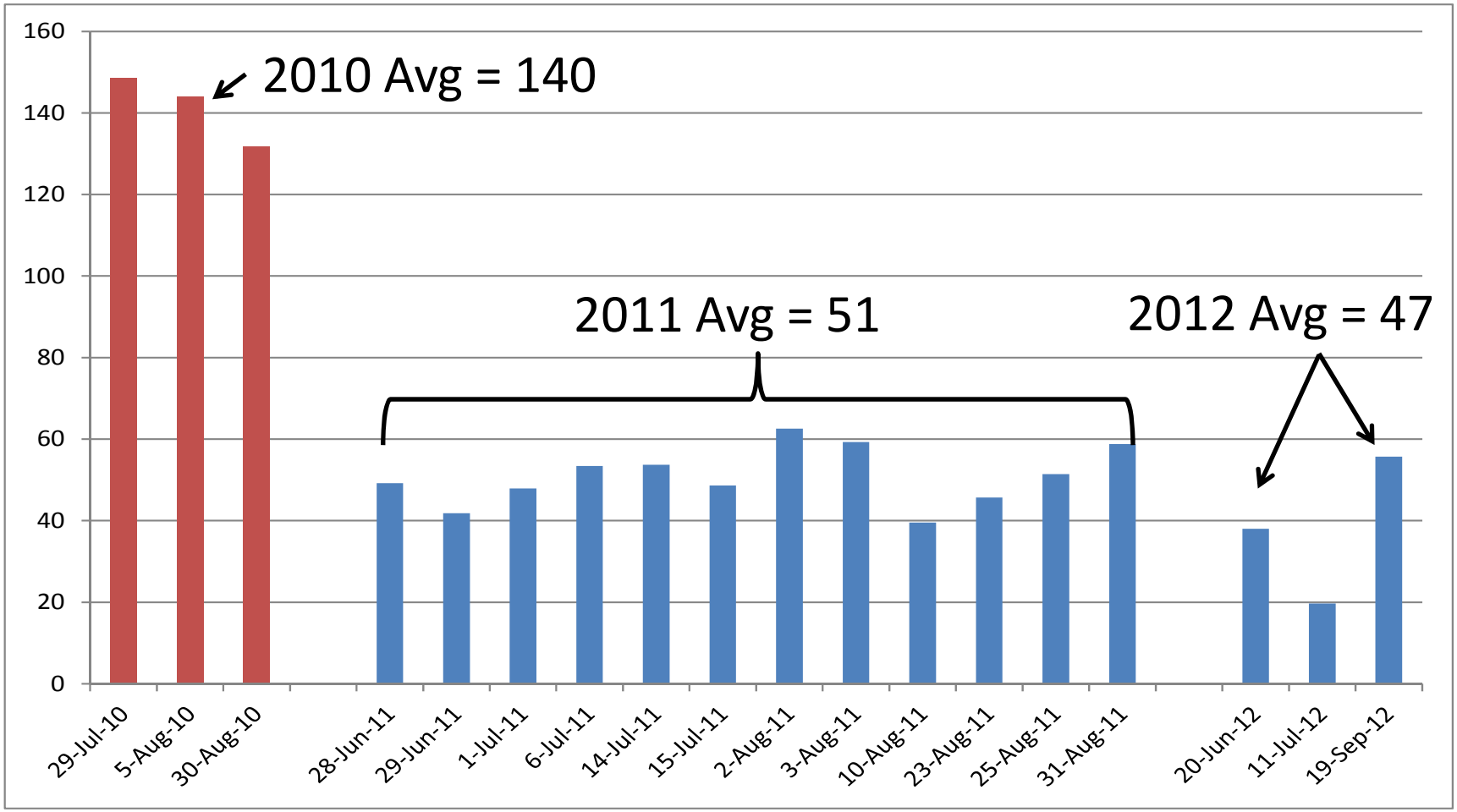


Post-TRS

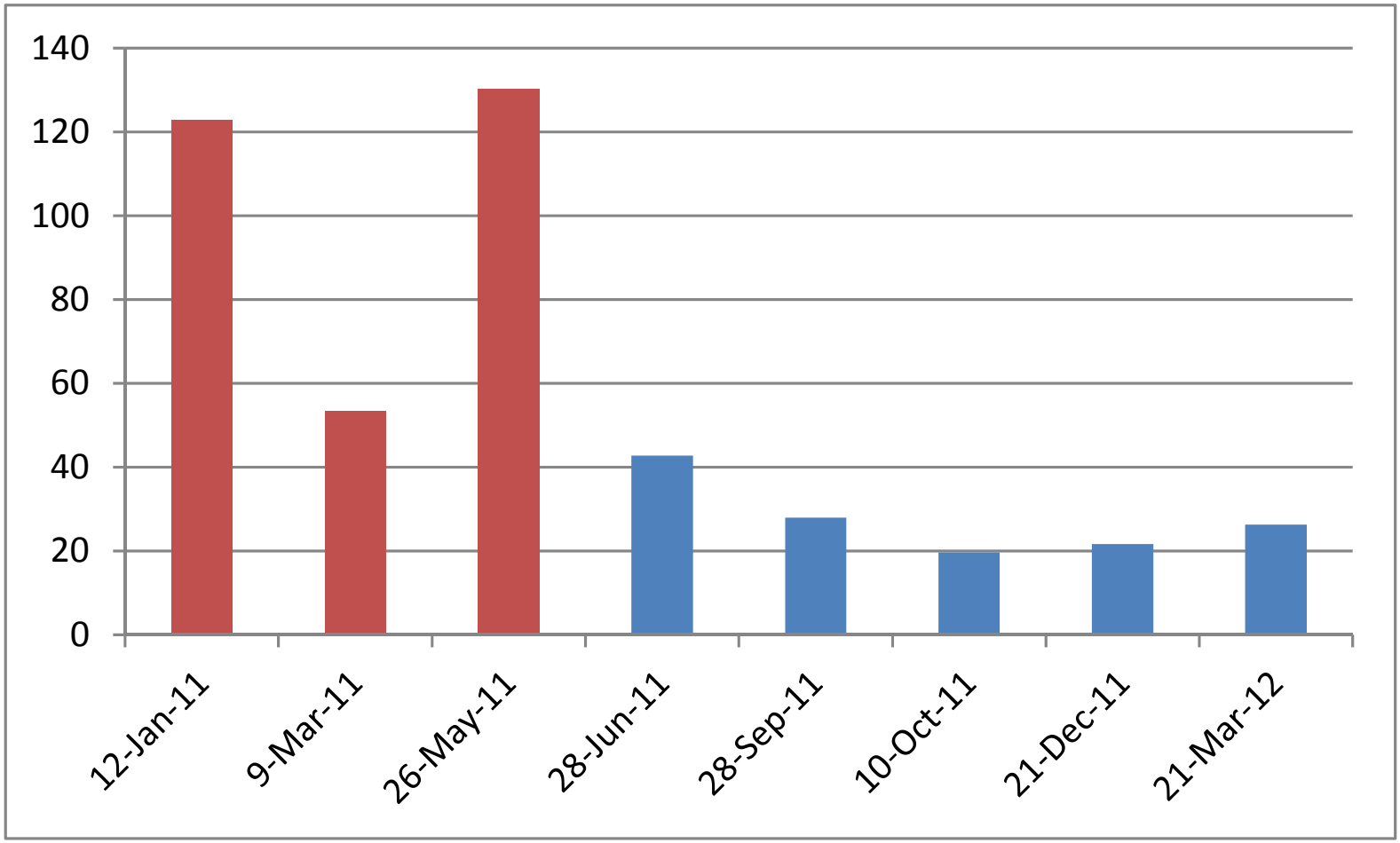
Q3 Sample result = 49.2 µg/L

RAA = 79.3 µg/L

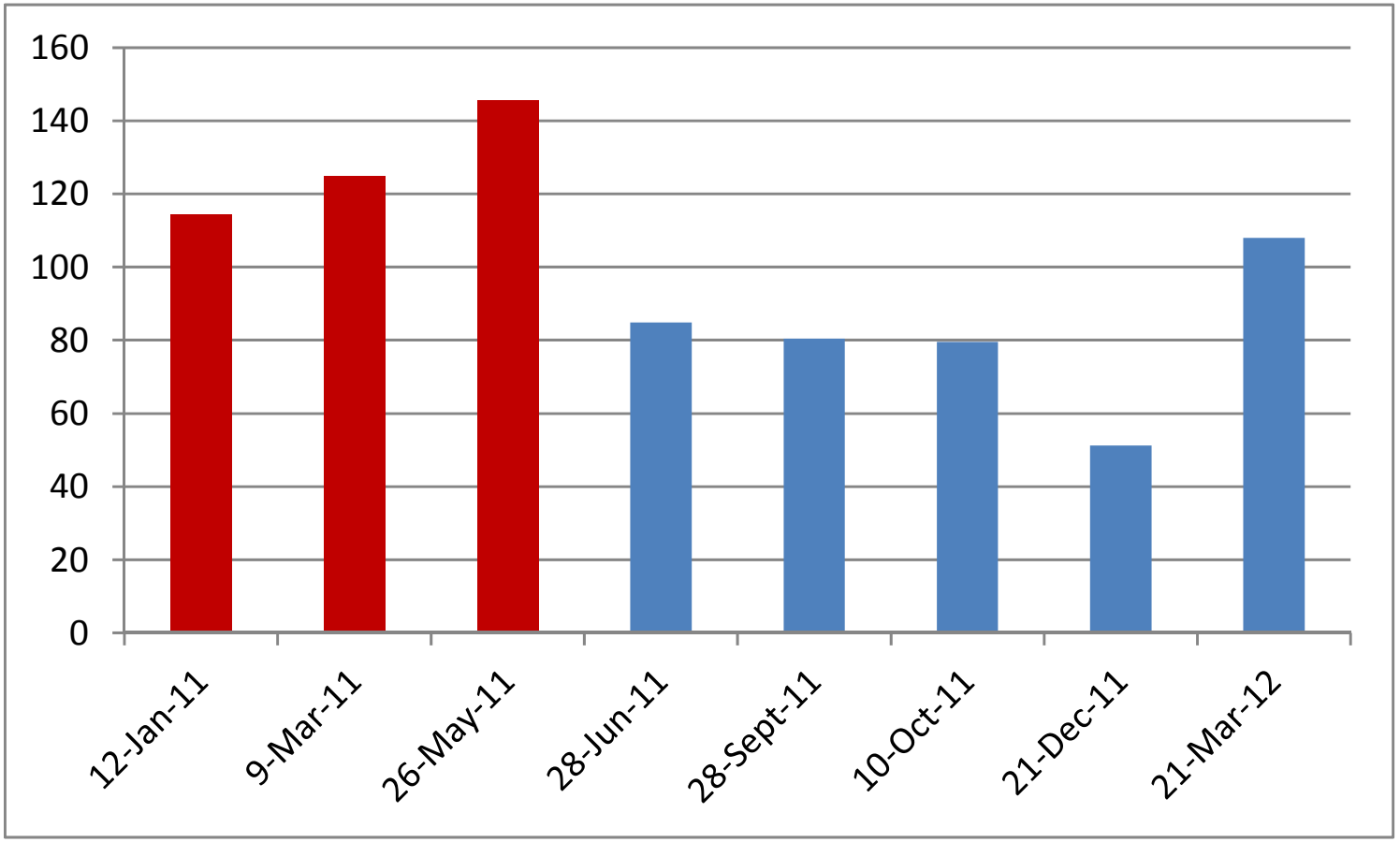

No TRS
With TRS
Turned TRS on: June 22
Switch to Ryan Ranch water
180
160
140
120
100
80
60
40
20
0
7/29/10
8/5/10
8/30/10
12/9/10
6/28/11
6/29/11
7/1/11
7/6/11
7/14/11
7/15/11
8/2/11
8/3/11
8/10/11
8/23/11


160
140
120
100
80
60
40
20
0
2010 Avg = 140
2011 Avg = 51
2012 Avg = 47
29-Jul-10
5-Aug-10
30-Aug-10
28-Jun-11
29-Jun-11
1-Jul-11
6-Jul-11
14-Jul-11
15-Jul-11
2-Aug-11
3-Aug-11
10-Aug-11
23-Aug-11
25-Aug-11
31-Aug-11
20-Jun-12
11-Jul-12
19-Sep-12

Upper Ragsdale (Compliance point)



Quarterly TTHMs – Harris Court (dead end)



Case Study: Ryan Ranch tank

Lowering THM Levels and Achieving Stage 2 DBP Rule Compliance with In-Tank Aeration

By Peter S. Fiske, Ph.D., and Leslie Jordan

Across California and Nevada, implementation of the Stage 2 Disinfectants and Disinfection By-product Rule is spurring utilities to explore a range of strategies for improving water quality in their water systems. Many utilities are investigating ways of lowering total organic carbon (TOC) in their water or altering treatment plant processes to reduce the production of disinfection byproducts (DBPs). Unfortunately, many of these treatment plant changes are large capital projects that will take several years to complete.

The most common DBP, trihalomethanes or THMs, is a function of both raw water quality AND disinfectant levels and water age. Thus, some utilities are also examining ways in which operational and technological changes in their distribution system can lower DBP levels. In many cases, high THM levels are present in only one part of a water distribution system, most commonly where water age is the highest or source water quality is a challenge. By deploying new technologies in distribution system water storage tanks, a few utilities have discovered that THM levels can be brought under control.

Monterey, California, is a seaside town that enjoys cool weather, picturesque beaches and, for the most part, excellent water quality. However, one part of the system, the Ryan Ranch Business Park, faced water quality challenges. Ryan Ranch was fed by three wells separate from the rest of the Monterey system, and treated water was stored in a single 500,000 gallon above-ground, steel storage tank. While raw water TOC levels were low, the well water was known to contain elevated levels of bromide.

Beginning in 2010, TTHM levels spiked, and the running annual average for the Ryan Ranch system rose dramatically (Figure 1). The dominant THM species was bromoform. After accumulating three quarters of elevated levels, water quality managers calculated that they needed to achieve a TTHM level of less than 50 ppb for the June 2011 measurement for the locational running annual average (LRAA) to remain in compliance. Historical estimates suggested that without a major intervention, actual TTHM levels at that time would be around 140 ppb.

The precise causes of the dramatic increase in TTHMs in the Ryan Ranch tank were uncertain, but several factors likely contributed to the problem:

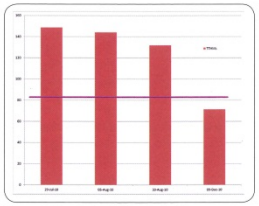


Figure 1. Historic TTHM levels (ppb) per quarter at Ryan Ranch. Locational running annual averages were expected to exceed the MCL in Q2 2011.

The combination of high temperatures and low turnover likely led to thermal stratification during some of the year. Thermal stratification leads to high water age and high rates of residual consumption, both of which can elevate THM levels.

The use of source water high in bromine likely stimulated the formation of brominated THM species such as bromoform.

The tank had been periodically washed out, but it had not been chemically cleaned to

Figure 2a. Interior conditions of the Ryan Ranch tank prior to TRS.

Figure 2b. Locations where the interior coatings had failed in the Ryan Ranch tank (these were repaired).

Figure 2c. Application of the chemical cleaning agent to remove organic and inorganic deposits on interior surfaces.

THM Levels, Continued from page 21

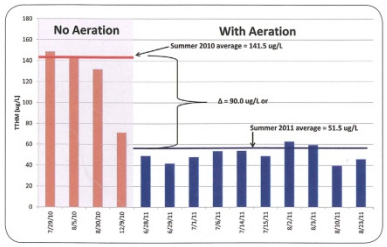


Figure 3. TTHM levels at the Ryan Ranch tank in 2010 before installation of the TRS (red) and 2011 after installation of the TRS (blue).

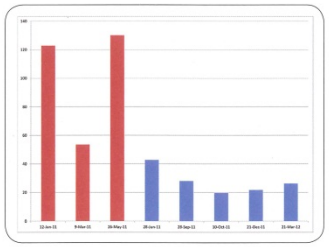


Figure 4. TTHM levels at the Upper Ragsdale Court sample location before installation of the TRS (red) and after (blue).

cleaning all likely worked together to lower disinfectant consumption, lower temperatures and physically remove THMs formed in the tank. By applying an integrated approach to THM reduction, operators at Monterey were able to achieve a successful result.

Peter S. Fiske, CEO, Pax Water Technologies, received his Ph.D. in Geological and Environmental Sciences from Stanford University and is the author of over 20 peer-reviewed articles. He has technical expertise in the fields of chemistry, fluid mechanics and physics.

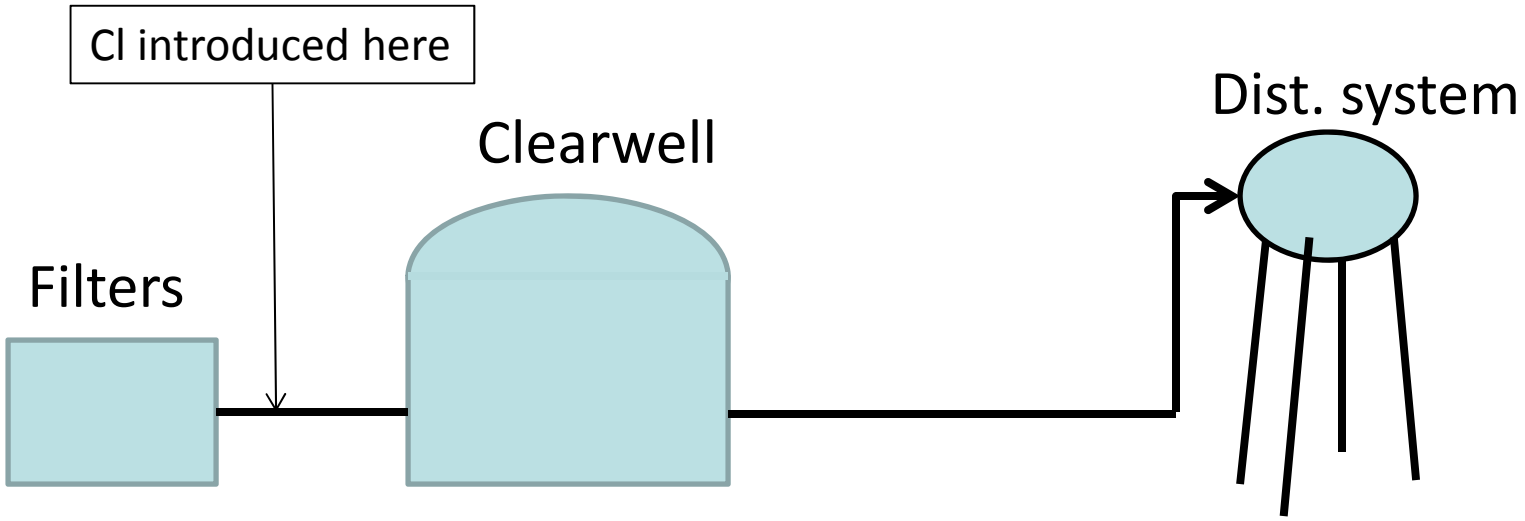
Leslie Jordan, Water Quality/Environmental Compliance Superintendent, California American Water, Monterey, has 26 years of experience in the water industry, and has had operations and management roles in water quality and environmental compliance.

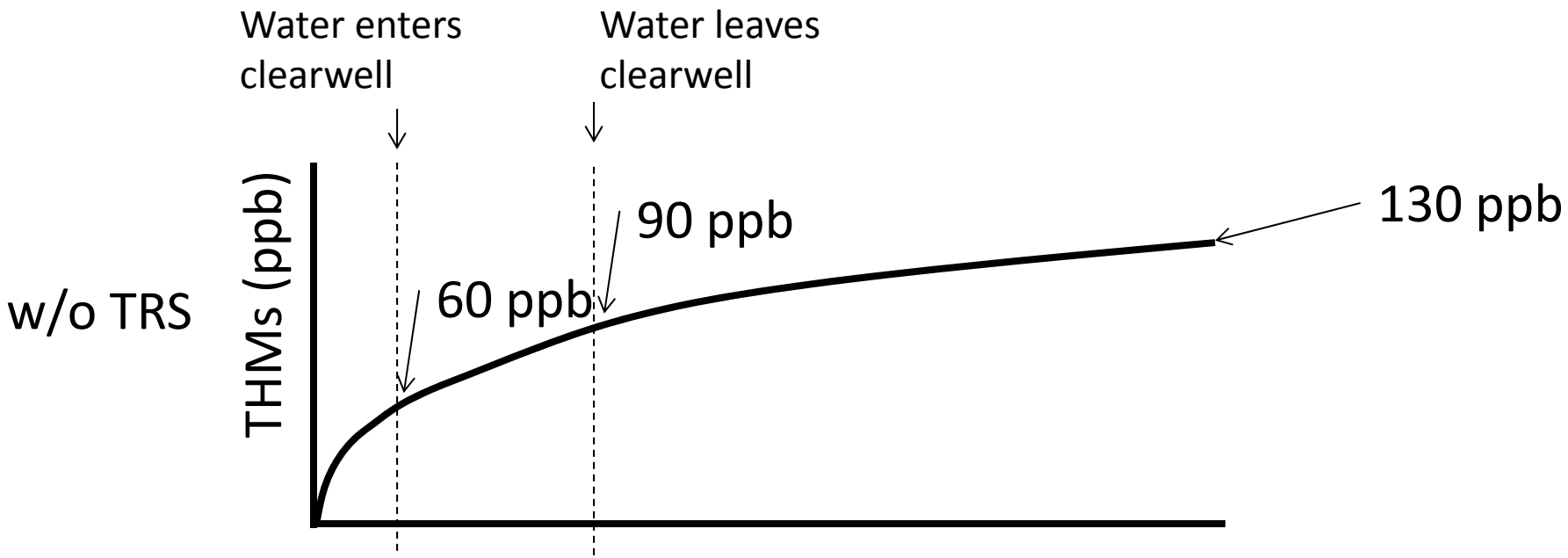
Source Magazine
(CA/NV AWWA Magazine)
Winter, 2014 (V. 27, no. 1)
p. 20-23

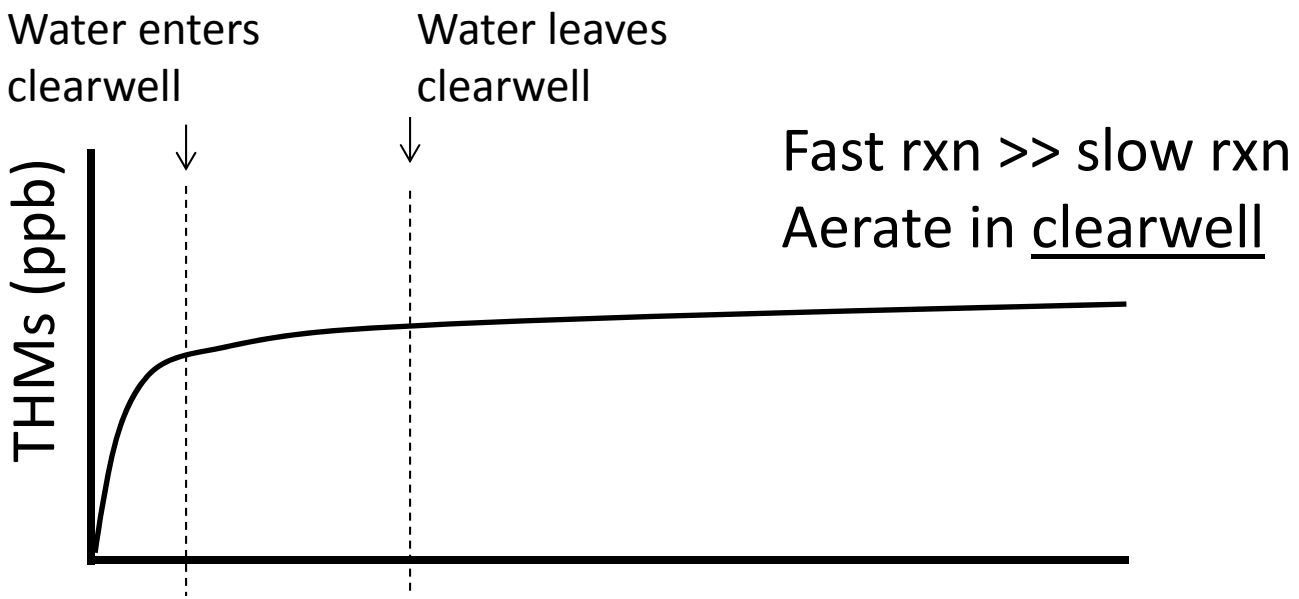
Is it better to address THMs in clearwell or in distribution system tanks? Depends:

- Rate of THM formation potential
- Physical limitations (available headspace in tank)

THMs grow with time… but not steadily




Water enters clearwell
Water leaves clearwell
w/o TRS
THMs (ppb)
60 ppb
90 ppb
130 ppb


Water enters clearwell
Water leaves clearwell
THMs (ppb)
Fast rxn >> slow rxn
Aerate in clearwell

Case Study: Madison, NC - Clearwell

TRS sprayer manifold mounted in clearwell

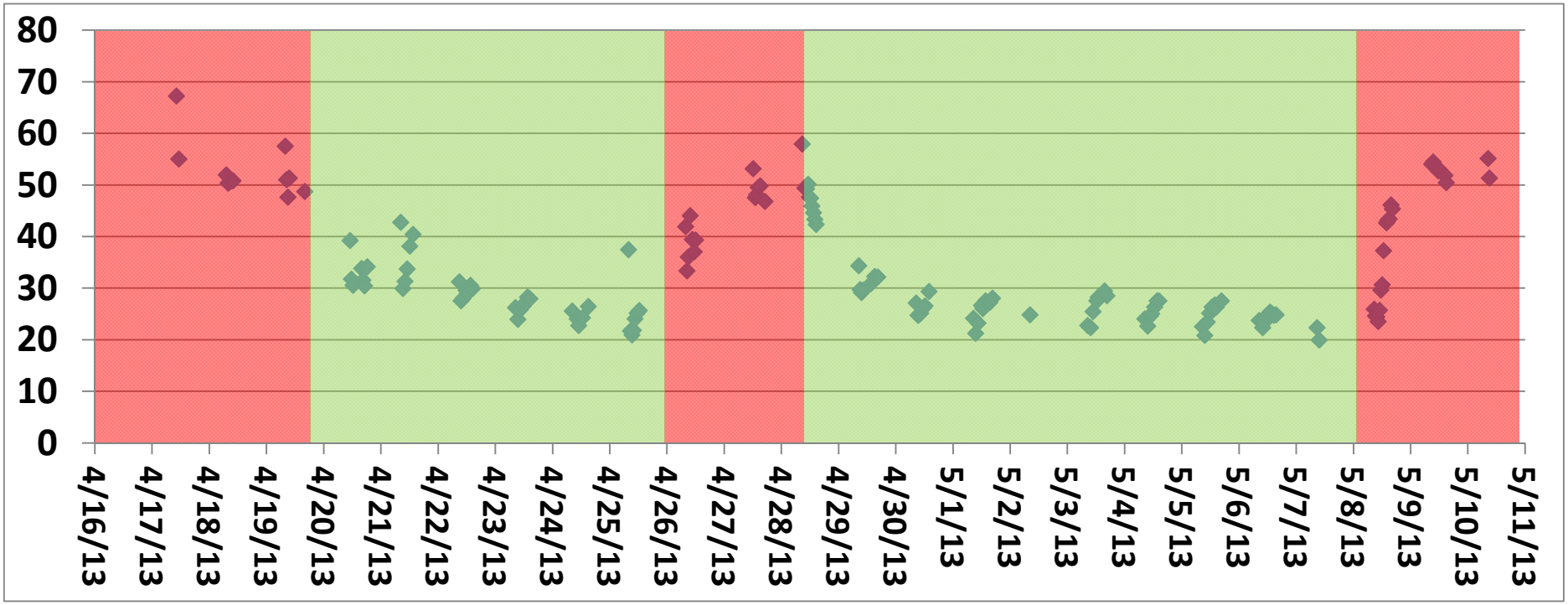
PAX Mixer in Clearwell

Clearwell after TRS installation

Parker Hannifin THM Analyzer

- 30-minute species-specific analysis
- Portable, easy to use
- Requires UHP grade helium

Madison, NC Clearwell: TTHMs (ppb) versus time



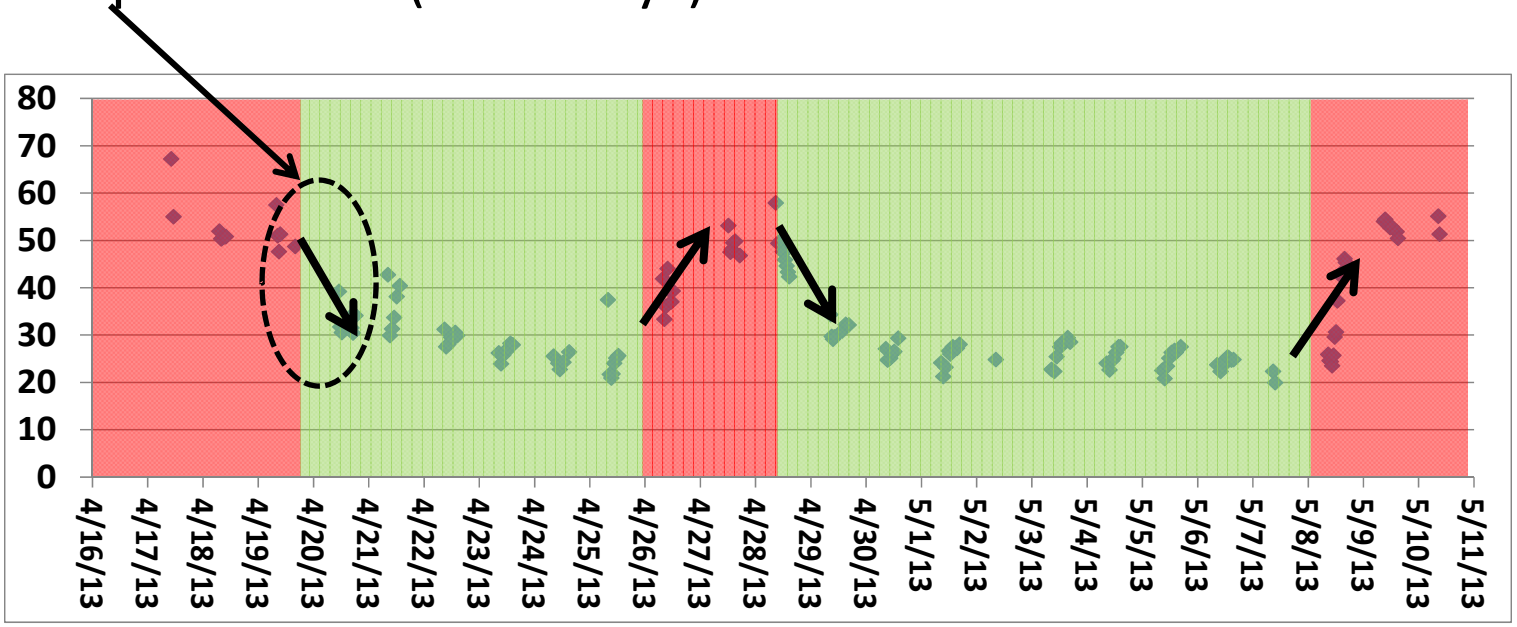
TRS off

TRS on

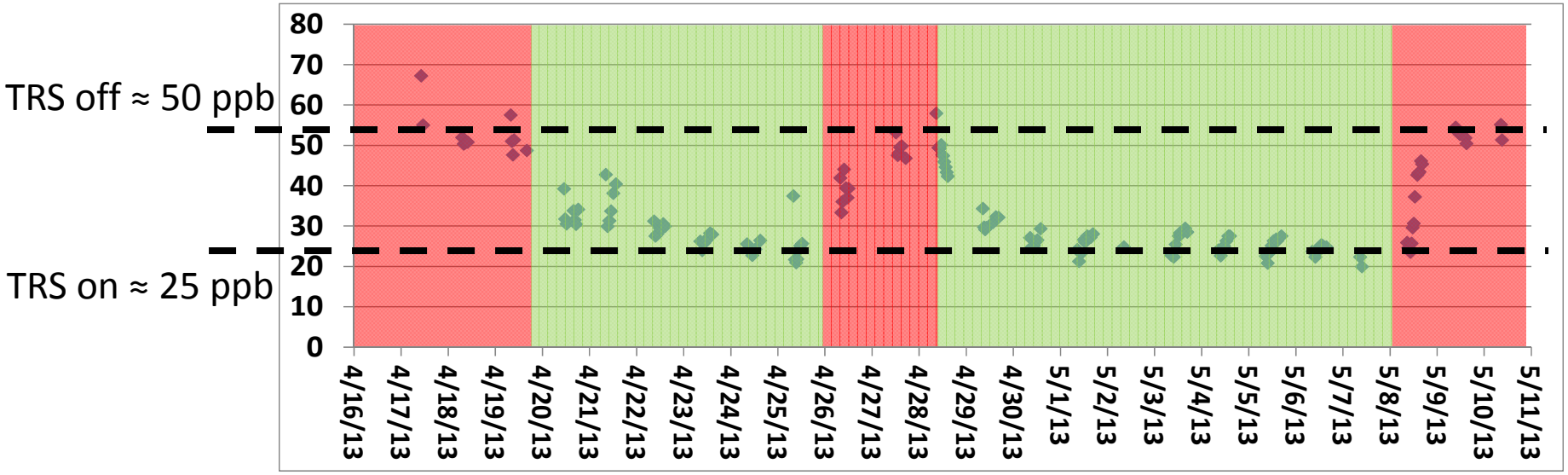
Data collected by Madison staff using Parker Hannifin THM Analyzer

Madison, NC Clearwell: Recorded TTHM Data

Periods of equilibration (~ 1-2 days)

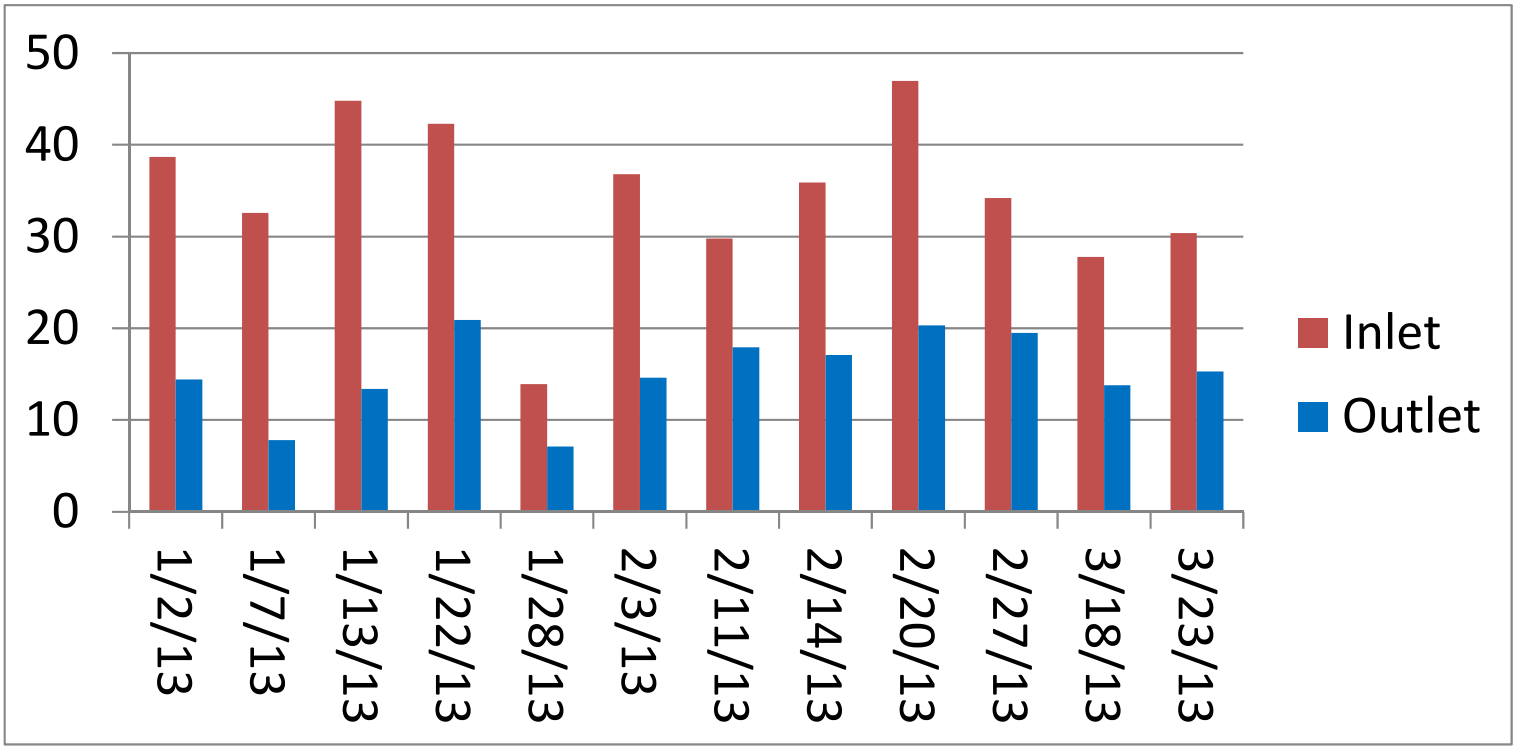


Madison, NC Clearwell TRS: Roughly 50% THM removal



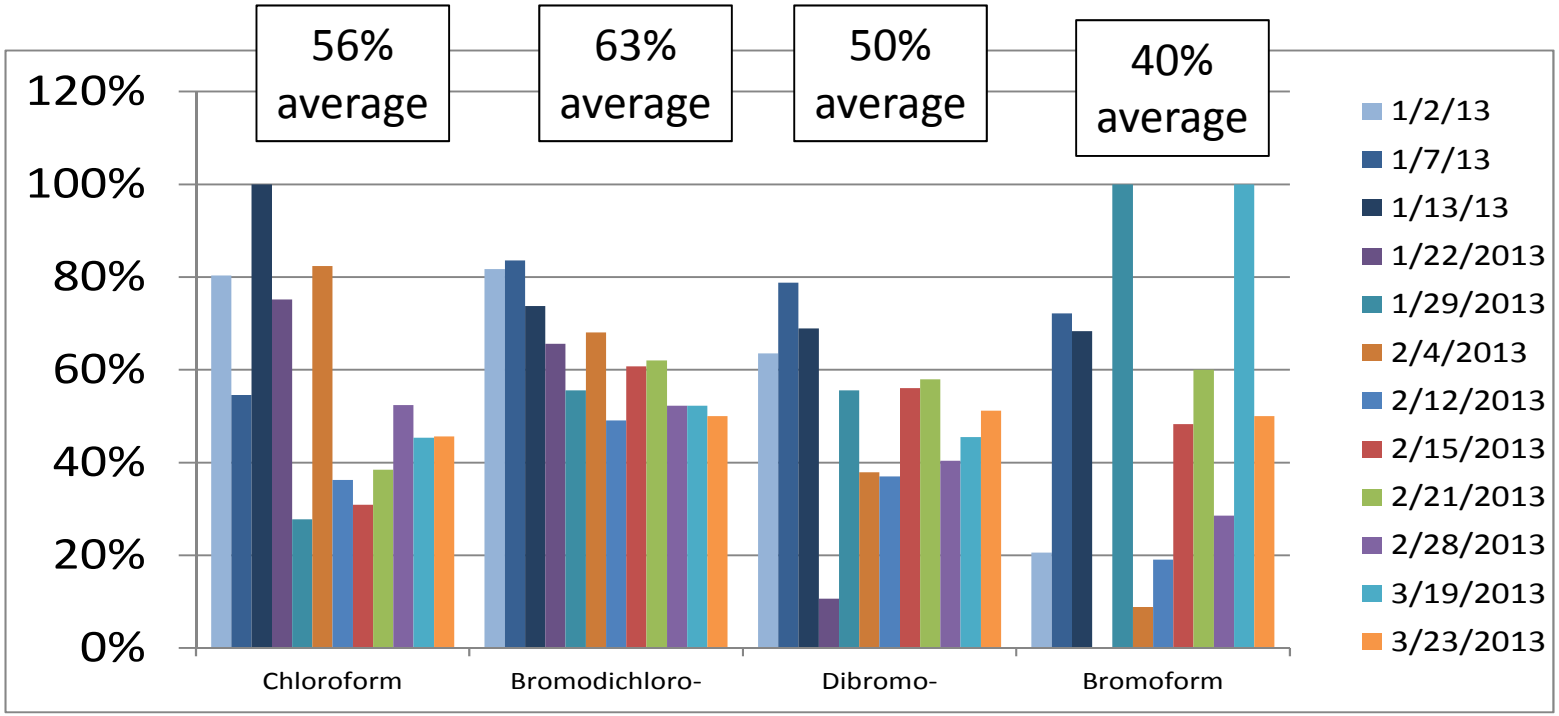
Madison, NC elevated tank

THM reduction post-TRS



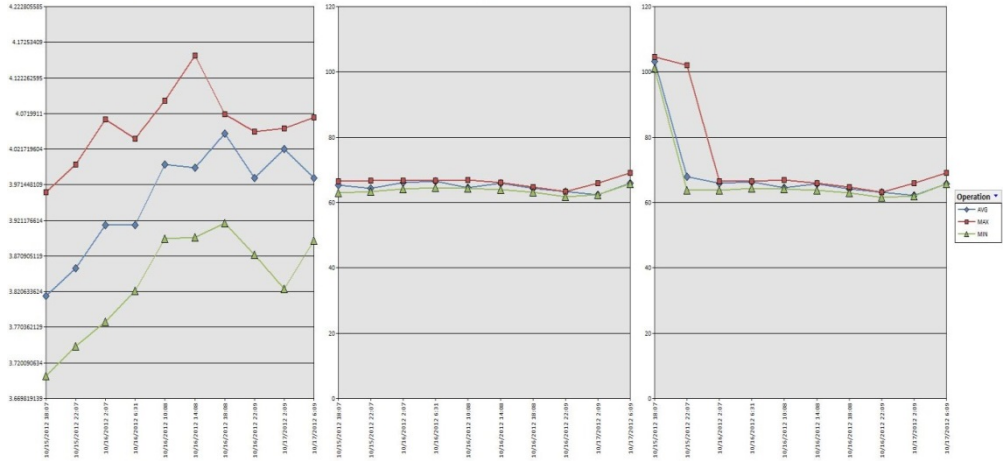
Average = 55% reduction

Unlike bubble aeration systems (and surface aeration?) – spray aeration removes ALL THM species at nearly the same rate

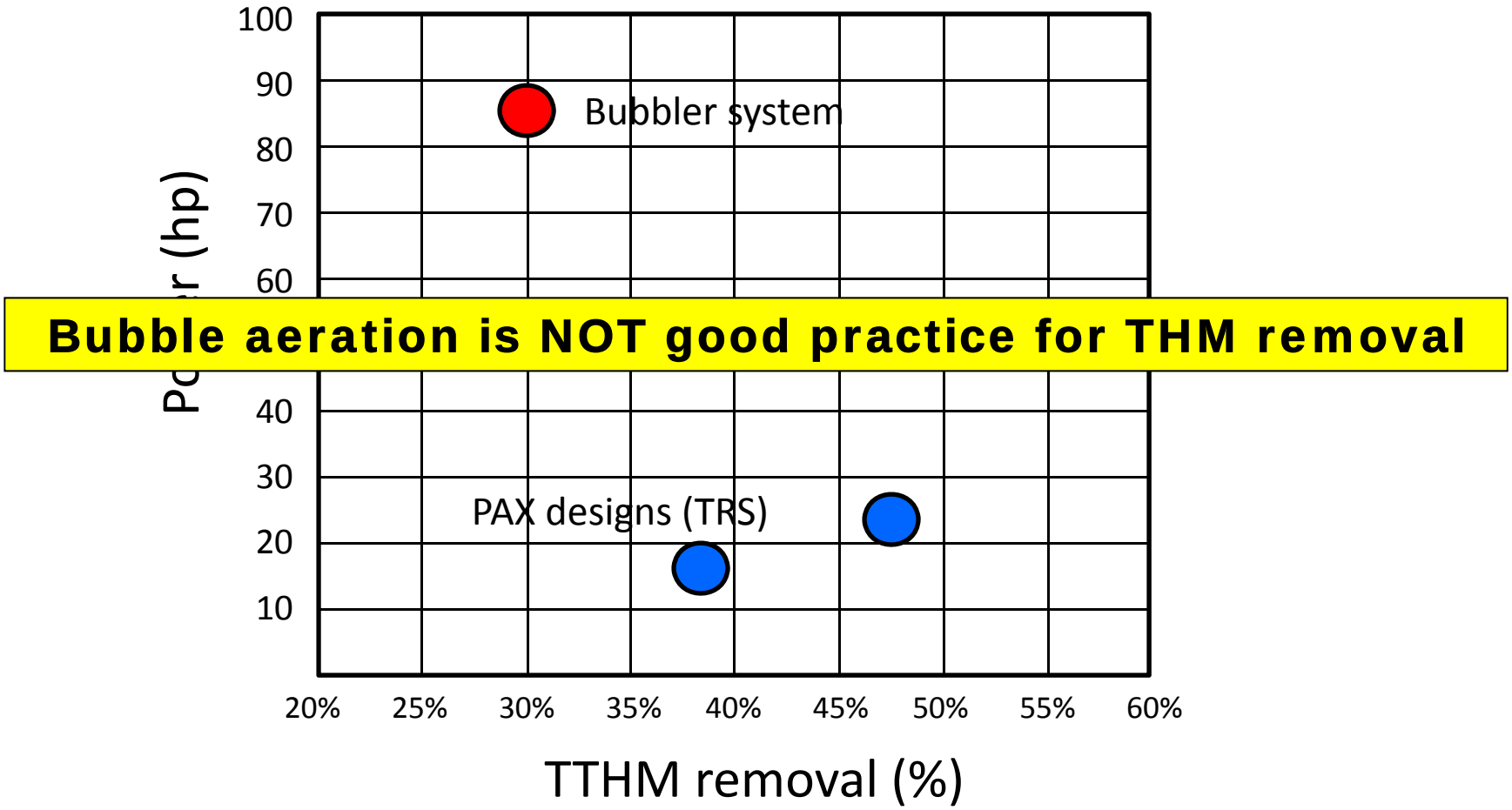


How do we assure TRS remains on and functional?

- Wireless, remote monitoring system
  - Inlet and Outlet pressure
  - Flow
  - Current to all subsystems
- Alerts sent to PAX and customer

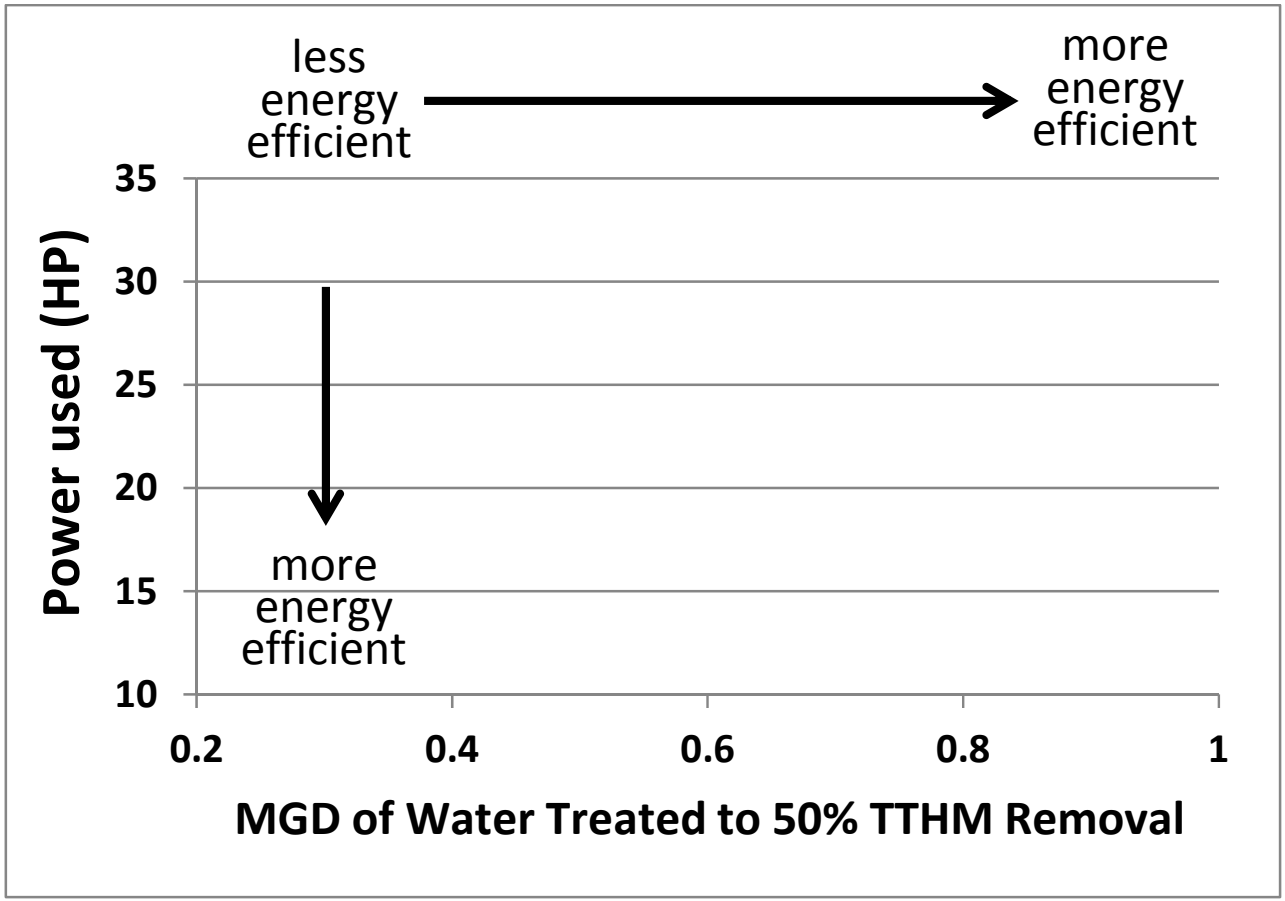


Other Technology vs. Spray Aeration (XX County, VA)



Bubble aeration is NOT good practice for THM removal

Evaluate Aeration Technologies on Energy Efficiency per MGD Treated

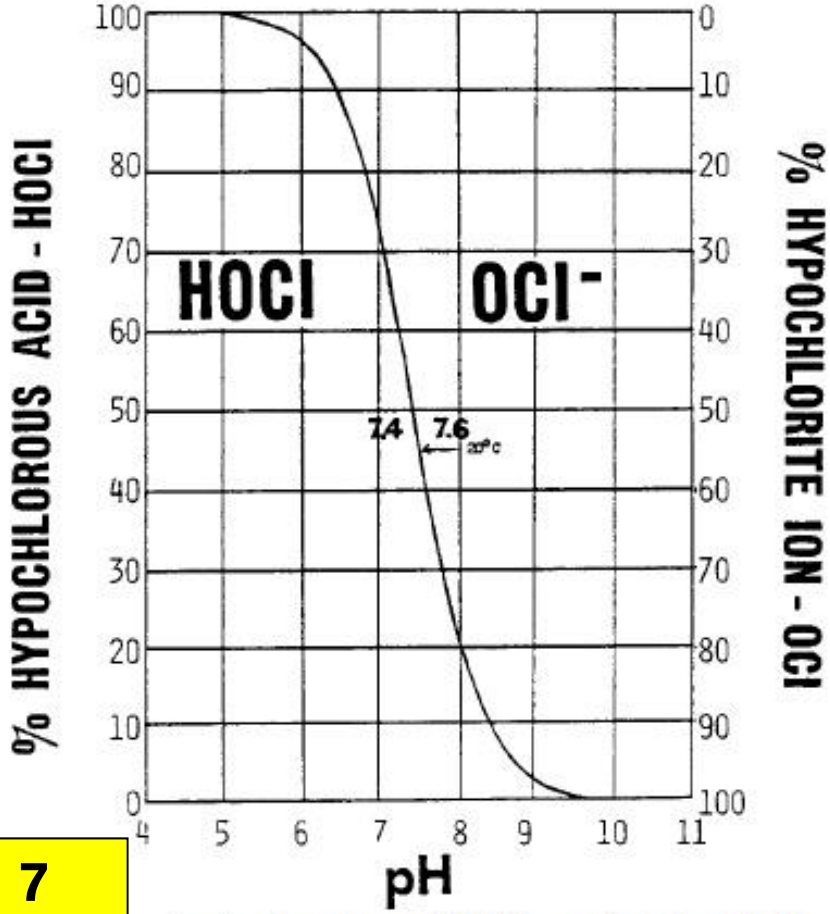


Effects of aeration on water chemistry What would you expect?

- Aeration removes Cl (?)
  - Residual Cl should drop
- Aeration removes CO_2
  - pH should rise

Chlorine loss? Depends on pH

- HOCl is volatile: dominant species @ pH < 7
- OCl^- is an ion and non-volatile: dominant species @ pH > 7



Ionization curve of HOCl as a function of pH.

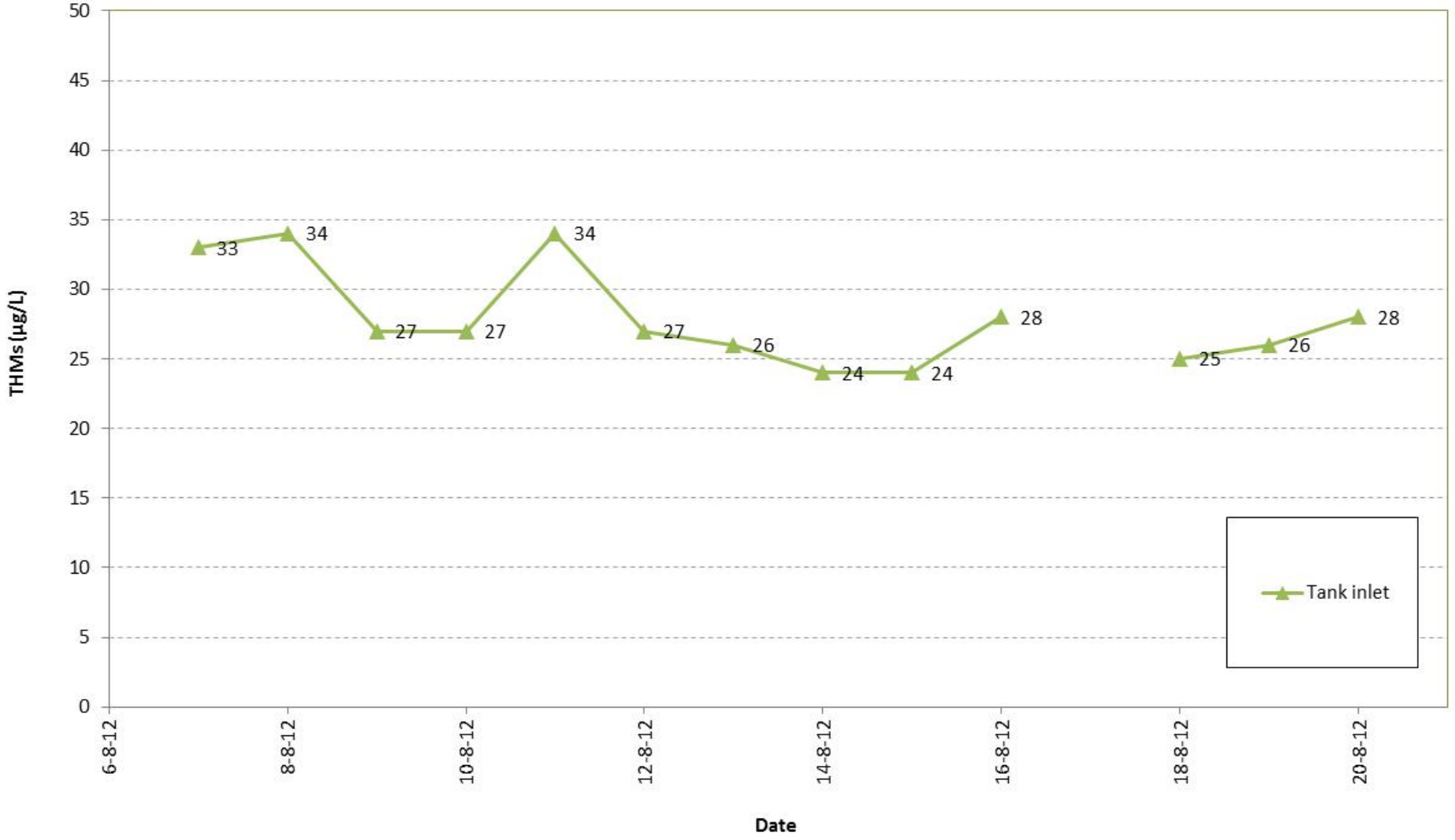
Chlorine loss low at pH > 7

Aeration, THMs and water chemistry

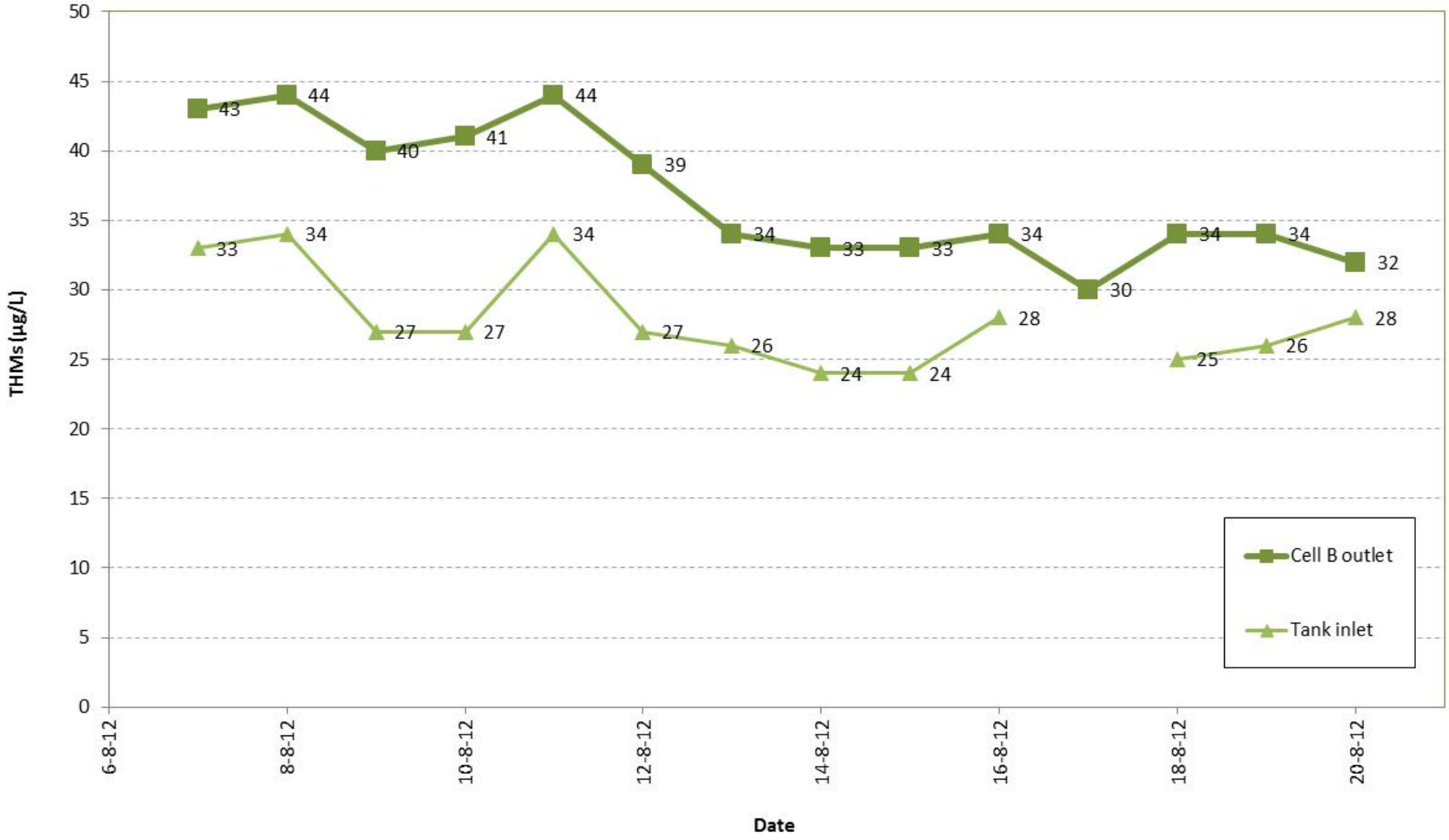
- 1 MG concrete tank
- Split into two identical cells
- AMS-100 On-line THM analyzer

Collaborators: Ramon Ariño Tarrago
Oriol Mas Alcazar

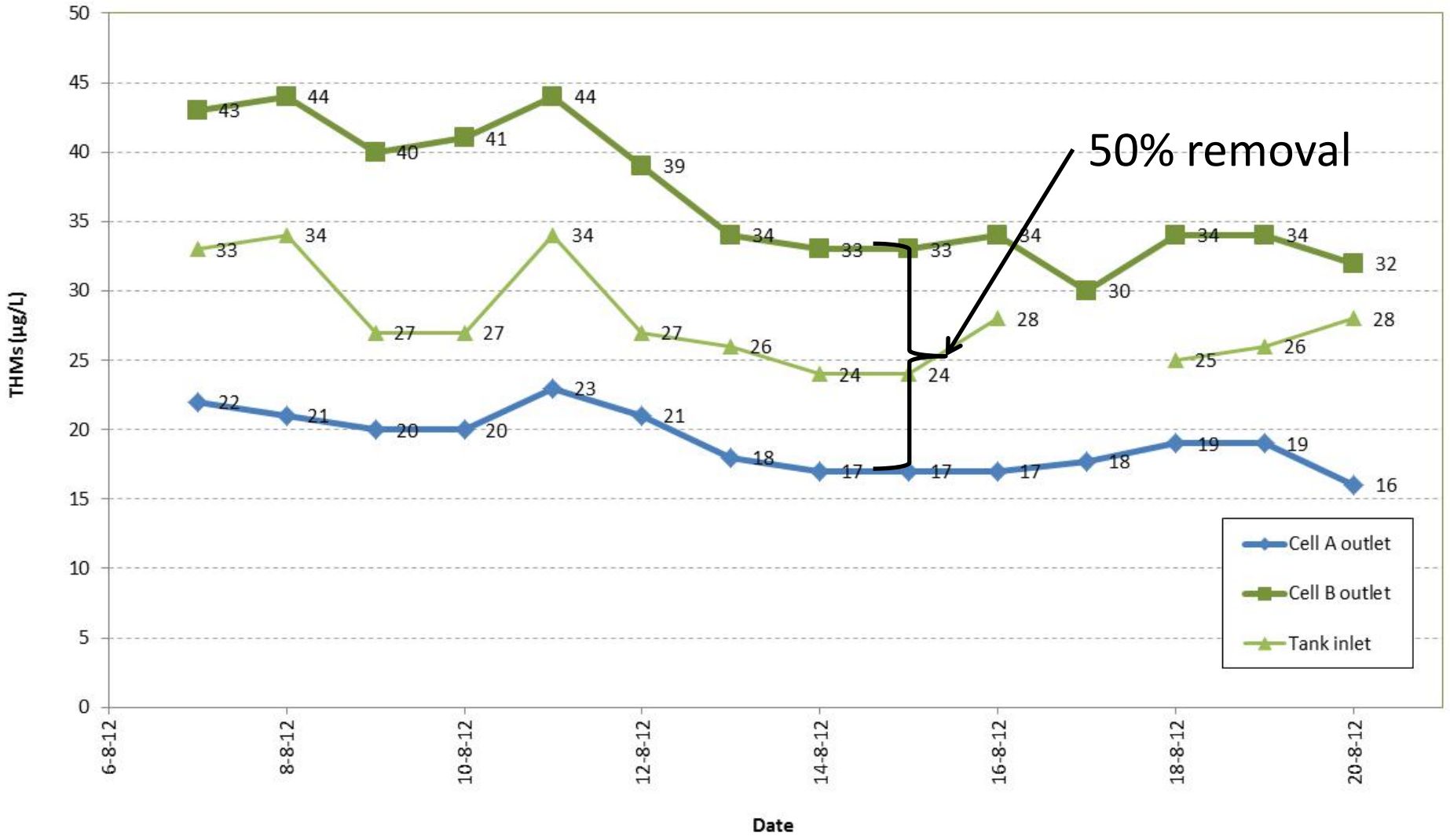
Inlet THMs

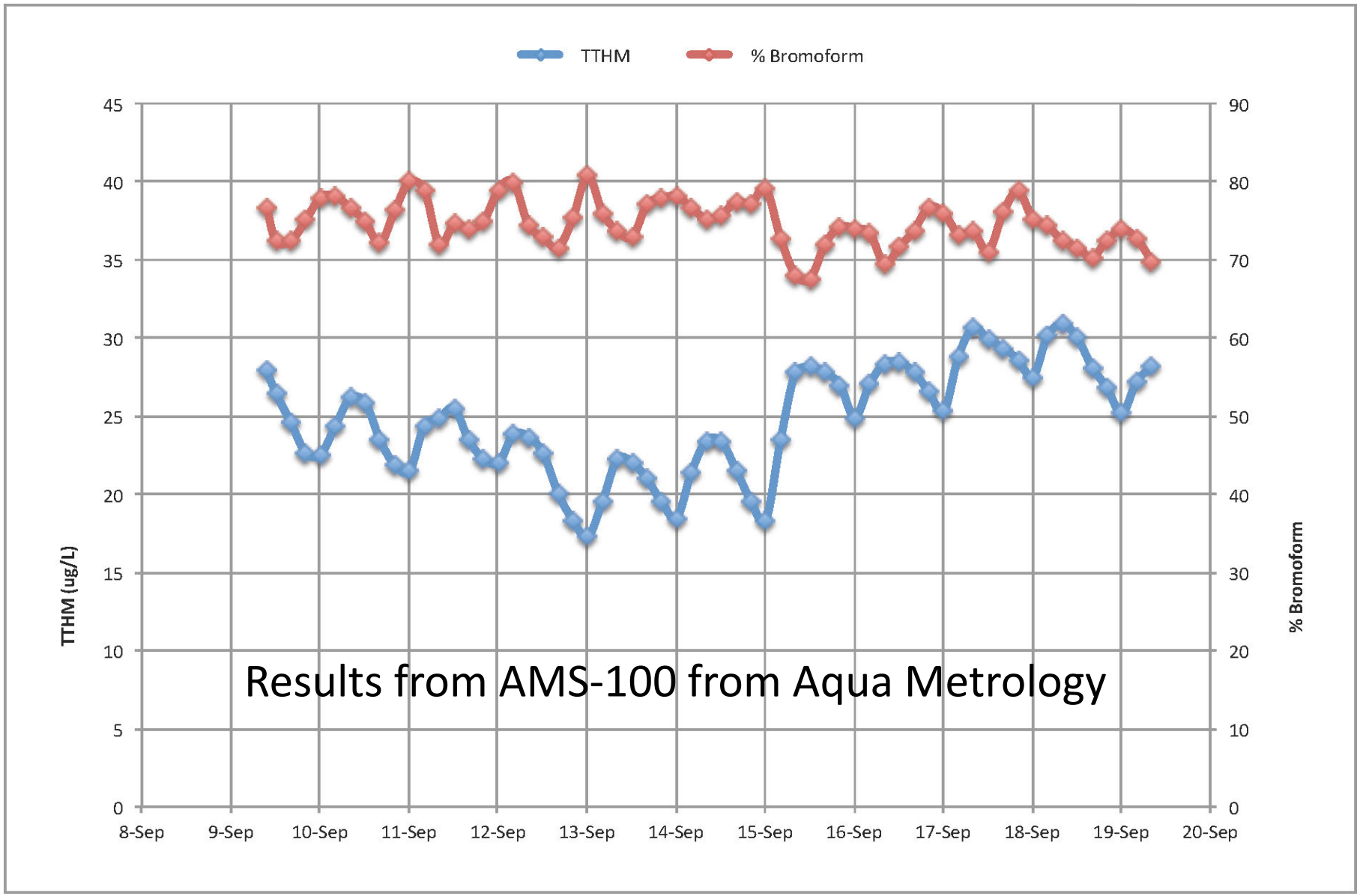

THMs (µg/L)
50
45
40
35
30
25
20
15
10
5
0
33
34
27
27
34
27
26
24
24
28
25
26
28
6-8-12
8-8-12
10-8-12
12-8-12
14-8-12
16-8-12
18-8-12
20-8-12
Date
Tank inlet

Outlet THMs: no aeration

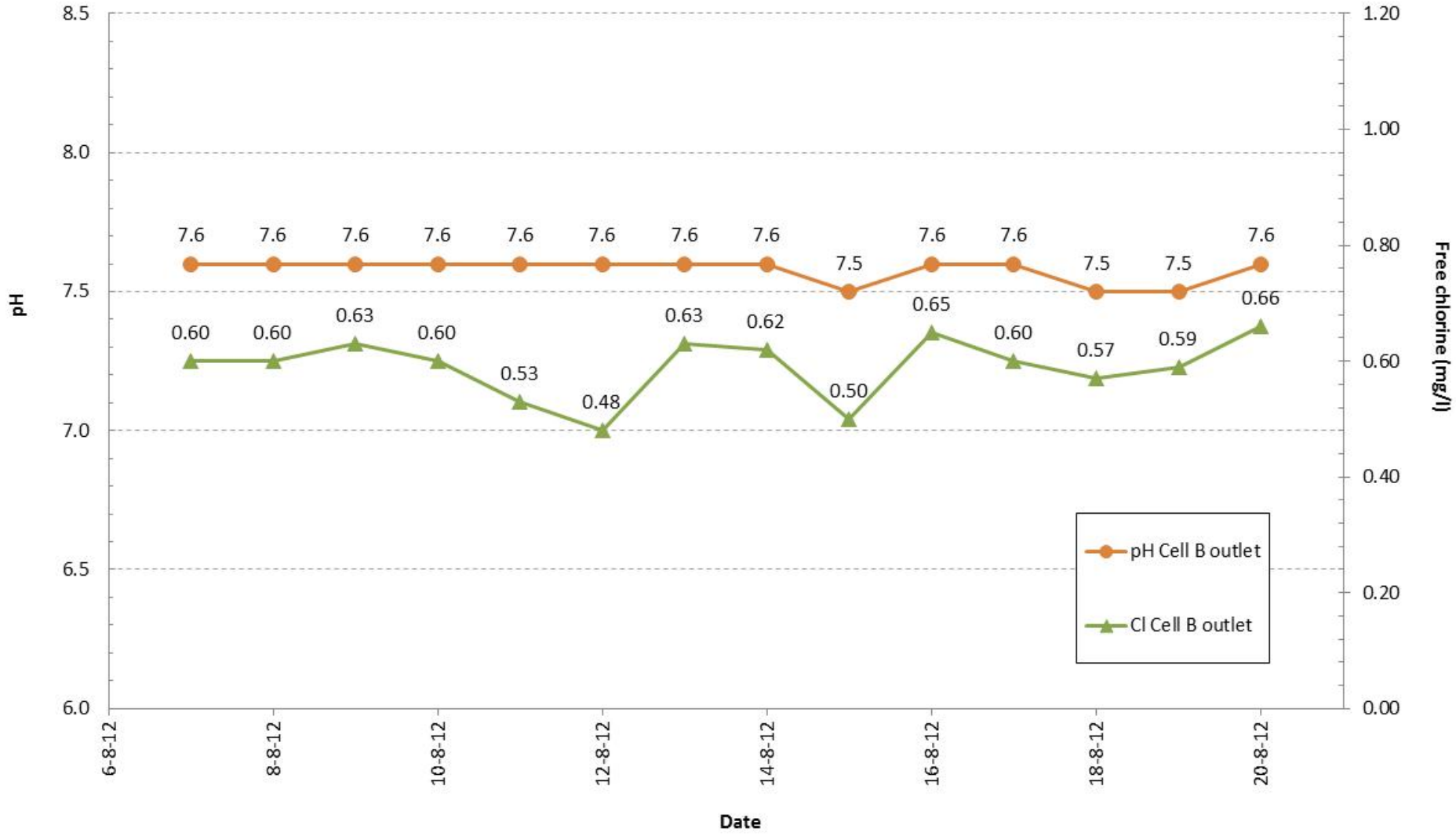


Outlet THMs: aeration vs. no aeration

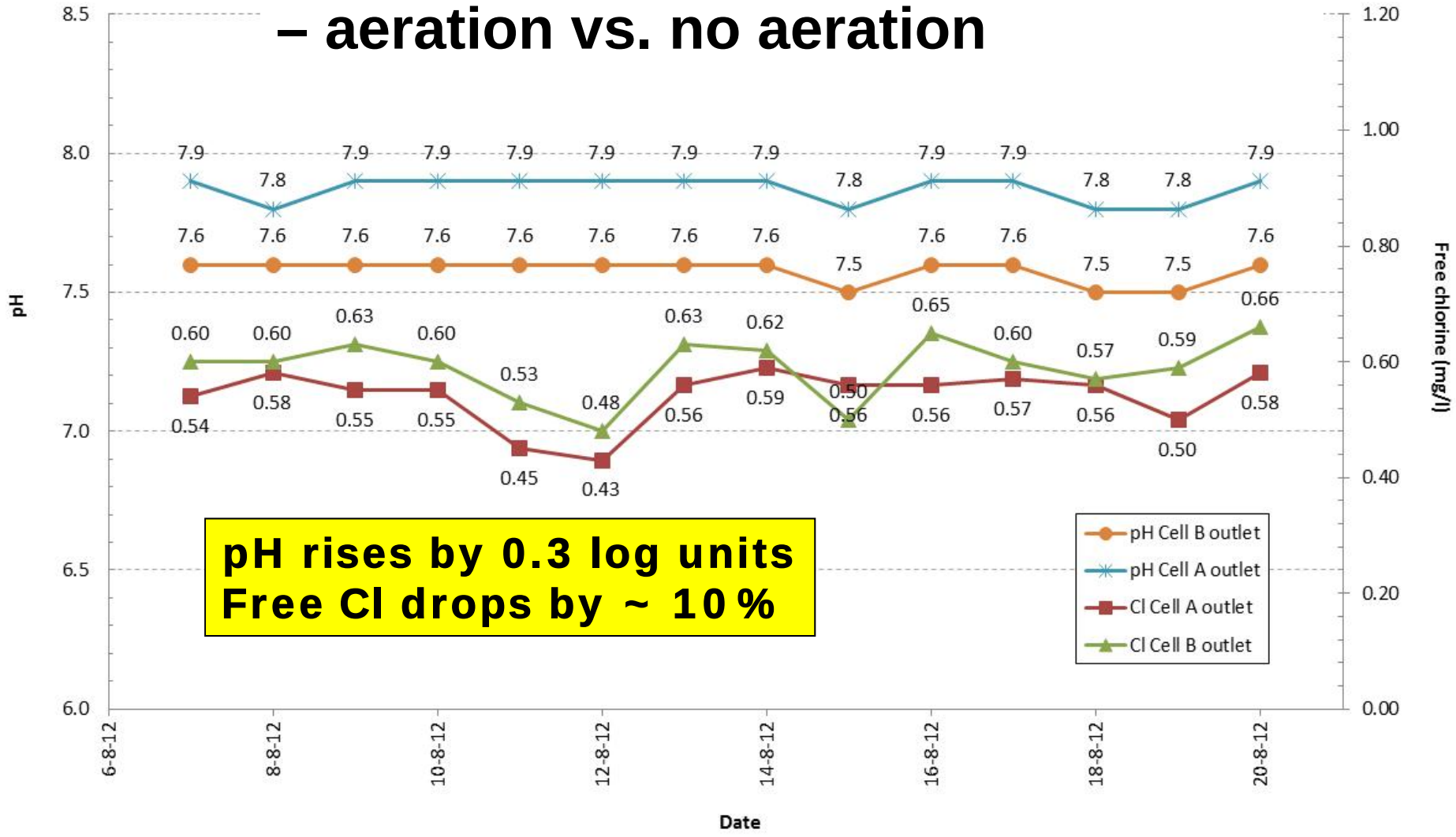



TTHM
% Bromoform
TTHM (ug/L)
% Bromoform
45
40
35
30
25
20
15
10
5
0
90
80
70
60
50
40
30
20
10
0
8-Sep
9-Sep
10-Sep
11-Sep
12-Sep
13-Sep
14-Sep
15-Sep
16-Sep
17-Sep
18-Sep
19-Sep
20-Sep
Results from AMS-100 from Aqua Metrology

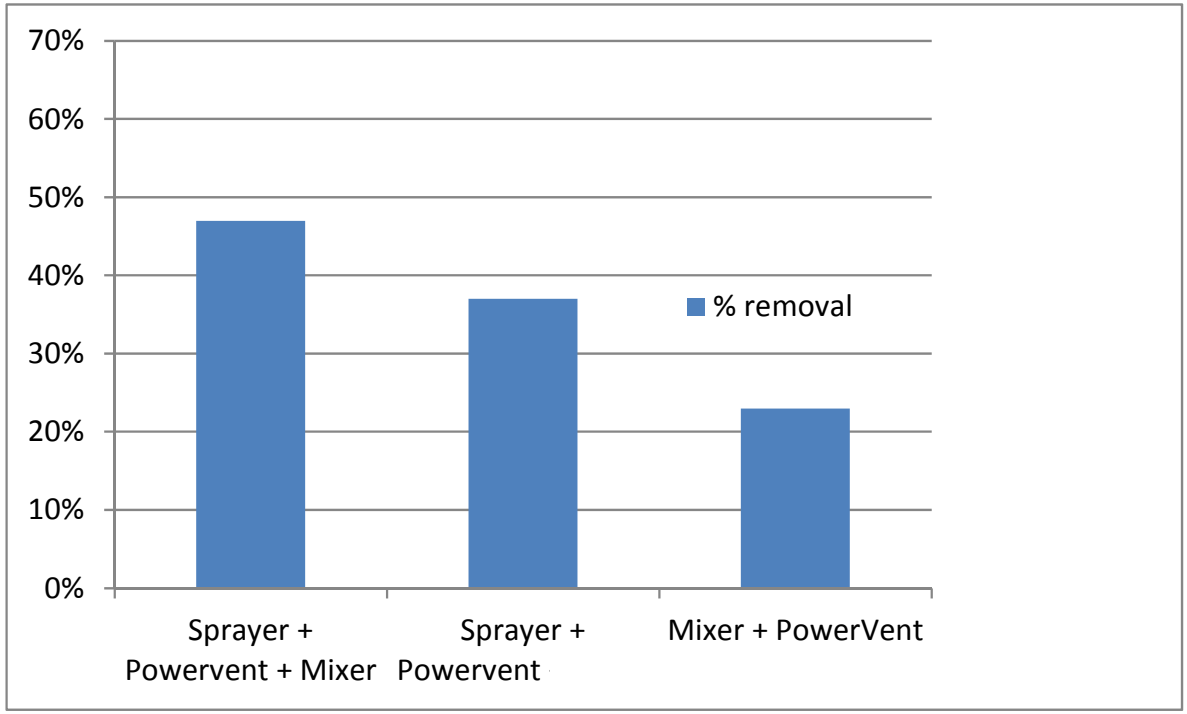
pH and Free Chlorine – no aeration



pH and Free Chlorine – aeration vs. no aeration



How do the sub-components of the TRS contribute to overall THM reduction?



Aigües de Barcelona
Department of Water Quality

Summary of today's presentation

- In-tank aeration (TRS) is a safe and effective means of lowering THM levels in finished water
  - But NOT a silver bullet!!!
- Different aeration technologies vary in their effectiveness and energy usage
  - Calculate energy consumption per MGD treated
- The PAX Mixer + active ventilation alone can significantly reduce THM levels

Some final thoughts:

- Stage 2 D/DBP Rule is a burden ***and*** an opportunity
  - Opportunity to look holistically at your distribution system
  - Opportunity to fix some things for the LONG TERM
- Everything matters
  - Quality of your source water
  - Condition of your pipes
  - Condition of your tanks
  - Mixing, water age, etc. etc.
  - Optimization is the key
- Use Stage 2 Rule compliance as an opportunity to step up your game in overall water quality and water consistency

Questions? Want to learn more?

- Visit us at AWWA Annual Conference – Boston, June 9-12
- Upcoming PAX webinars: Mixing, Aeration, Active Residual Control in the Distribution System
- Questions/comments - contact one of us:
  - Peter Fiske: pfiske@paxwater.com or
  - Liz Hirschhorn: lhirschhorn@paxwater.com or
  - Randy Moore: rmoore@utilityservice.com
- Interest in examining whether TRS is suitable for your system?
  - contact Ethan Brooke: ebrooke@paxwater.com
- Review our case studies and articles and other references at:

www.paxwater.com or www.utilityservice.com

Thank You!