Welcome to our

THE ROLE OF SMART SERVICE RESERVOIRS IN DISTRIBUTION WATER QUALITY MANAGEMENT

With Special Guest Andy Seidel –
CEO and Chairman – UGSI Solutions Inc
Distribution Network Water Quality Management

May 27th 2020

UK Webinar with Panton McLeod
UGSI Solutions, Inc. is one of the fastest growing and innovative companies in the water industry.
For the last several decades, water utilities have focused on bringing state-of-the-art technologies to treatment plants in an effort to improve system water quality - the next several decades will focus on the distribution network itself

- Today, control of disinfectant residual and THM production in a drinking water plant is manageable
- Tank systems are designed for storage and system hydraulics – not water quality management
- Utilization of water storage tanks and reservoirs to improve delivered water quality starts with mixing
  - THM reduction
  - Residual control
Approximately 60% respondents claimed having difficulty meeting secondary disinfection target occasionally or greater (USA)

Frequency at which respondents report difficulty in meeting target chlorine residuals for secondary disinfection (n = 269)
Increased focus in US on reducing violations in distribution networks with state-by-state levels increasingly more stringent than federal (EPA) levels.

“Beginning April 29, 2019, a community water system using a chemical disinfectant or that delivers water that has been treated with a chemical disinfectant shall maintain a minimum residual disinfectant concentration throughout the distribution system sufficient to assure compliance with the microbiological MCLs and the treatment technique requirements specified in § 109.202. The minimum residual disinfectant concentration is 0.2 mg/L.”

* TX and LA have 0.5mg/l mandatory residuals
For example, for 2014-2016 total coliform violations were roughly twice that of any other category of MCL violation in CA.

Table 5: Number and Population of PWSs with Violations of Maximum Contaminant Levels (MCLs), Maximum Residual Disinfectant Levels (MRDLs), and/or Treatment Techniques (TT)

<table>
<thead>
<tr>
<th>No</th>
<th>Category</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of PWSs</td>
<td>Population</td>
<td>No. of PWSs</td>
</tr>
<tr>
<td>1</td>
<td>Inorganic Contaminants</td>
<td>296</td>
<td>206,654</td>
<td>232</td>
</tr>
<tr>
<td>2</td>
<td>Synthetic Organic Contaminants (SOCs)</td>
<td>6</td>
<td>15,802</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Volatile Organic Contaminants (VOCs)</td>
<td>2</td>
<td>250</td>
<td>0</td>
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<tr>
<td>4</td>
<td>Radionuclide Rule</td>
<td>28</td>
<td>23,865</td>
<td>26</td>
</tr>
<tr>
<td>5</td>
<td>Total Coliform Rule (TCR)</td>
<td>442</td>
<td>620,245</td>
<td>419</td>
</tr>
<tr>
<td>6</td>
<td>Disinfectants And Disinfection Byproducts Rule (DBPR)</td>
<td>62</td>
<td>214,665</td>
<td>74</td>
</tr>
<tr>
<td>7</td>
<td>Surface Water Treatment Rules (SWTR, IESWTR, LT2SWTR)</td>
<td>31</td>
<td>20,766</td>
<td>42</td>
</tr>
<tr>
<td>8</td>
<td>Groundwater Rule</td>
<td>2</td>
<td>27,360</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Lead And Copper Rule (LCR)</td>
<td>1</td>
<td>3,441</td>
<td>11</td>
</tr>
</tbody>
</table>

Under the TCR, results are reported on a presence/absence basis. CWSs are required to routinely sample between one sample per month and 120 samples per week, depending on the size of the system. NTNC and TNC systems are generally on a monthly or quarterly sampling frequency. A public water system is in violation of the total coliform MCL when any of the following occurs:

- For a public water system which collects at least 40 samples per month, more than 5.0 percent of the samples collected during any month are total coliform-positive; or
- For a public water system which collects fewer than 40 samples per month, more than one sample collected during any month is total coliform-positive; or
- Any repeat sample is fecal coliform-positive or E. coli-positive; or
- Any repeat sample following a fecal coliform-positive or E. coli-positive routine sample is total coliform-positive.
Water storage assets are the increasingly preferred as intervention points for water quality improvement in a distribution network

Reservoir water quality management requires:

- Energetic mixing to de-stratify aging water and ensure tank homogeneity
- Effective monitoring to ensure real-time water quality understanding
- Accurate dosing of chemicals at the right time in the right amount
- Strong process control with feedback for optimization of consumable use
Un-mixed tanks suffer from temperature and chemical stratification which creates a cascade of issues

Effective tank mixing:

- Better distribution of disinfectant throughout the tank that can reduce biofilm risk and ensure consistent effluent residual
- Lower overall water temperature that is favorable for residual longevity
- Decreased sediment accumulation in tank
- Prevention of destructive ice formation
Passive mixing systems are not effective - field research and modeling demonstrates very short-lived mixing results – density differences are powerful.

**Scaled model of passive mixing**

*Georgia Institute of Technology*

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**Cold Water**

Introduction

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**Courtesy of Prof. Phillip Roberts**

*Georgia Institute of Technology*
Properly sized active tank mixing eliminates tank stratification

Payson AZ 0.5MG Rim View Tank (1.9 ML)

Fill Cycles

Mixer off

Mixer On

Company Confidential
Central Highlands Water: 4 ML reservoir with low chlorine residual
Chlorine residuals show significant improvement after mixing with no additional chemical addition.
Effective mixing can come in a variety of configurations depending upon process objective and site constraints.

Tank Shark® Eductor Mixer
PAX Jet Mixer
PAX Impeller Mixer
Southlake, TX: Mixers add stability to disinfectant residuals system wide

System of seven tanks had seasonal issues with residual stability.
After adding mixers to each tank, residual was more uniform throughout the system.
Northglenn, CO: Mixers add stability to disinfectant residuals and allowed for lower plant chlorine dosing

- In summer months, Northglenn increased residual (free-chlorine) plant exit values to 1.4ppm to offset loss in the network
- Increased free chlorine levels resulted in higher rates of THM formation
- By adding mixers, the utility observed higher and more uniform network residuals and no longer needed to increase plant exit residuals – thereby lowering THM formation risk
Punta Gorda, FL: Mixers add stability to disinfectant residuals and allowed for lower plant chlorine dosing

- Located in a warm climate, Punta Gorda employed many operational strategies such as operating at lower tank levels, flushing and manual boosting to maintain chlorine residuals in their network.

- After installing the Tank Shark® eductor style mixer, the utility experienced consistent residual residuals and was able to reduce flushing by 75%.

Adding appropriate mixing energy to tank ensure tank is de-stratified and exhibits consistent residual.

2MG Punta Gorda Isles Tank
Old Town, ME: De-icing – mixers can prevent ice formation in some tanks

**Case Study**

**Side-by-side standpipes in winter**

**Tank #1 – Mixed by PAX**

**Tank #2 – Not mixed**

- De-icing application – mixer distributes warmer incoming water to top of tank to inhibit ice formation
- Prevents tank damage
Wet Installation of PAX Mixers is Common

PAX Tank Mixers: Robotic Installation of Jet Mixer
Mixer choice depends on process objective with consideration of available power, turnover, geometry, climate and dosing needs.

**For Example:**

- Mixer must achieve mixed tank within cycle-time of tank (mixing has to be faster than rate water enters and leaves the tank)
- De-stratification, ice-prevention, chemical dosing, THM aeration all require different mixer capacity and power
Ultimately, powerful and effective tank mixing is the *gateway* decision for improving distribution network water quality.
Chloramine & Free Chlorine Residual Optimization and Management in the Distribution Network
Utilities have no “free lunch” as the choice of secondary disinfectant will determine the problems they will contend with:

**Secondary Disinfectant Choice**

- **Free Chlorine**
  - Boosting to offset degradation
  - DBP (THM and HAA5 issues) formation

- **Chloramines**
  - Chloramine degradation (ammonia formation)
  - Nitrification (nitrite and nitrate MCLs)
Chloramines, used in about a third of municipal water systems, provide longer protection in distribution systems and are less prone to encourage DBP formation

\[
\text{NH}_3 + \text{OCl}^- \leftrightarrow \text{NH}_2\text{Cl} + \text{HO}^-
\]

Monochloramine is formed by the reaction of chlorine and ammonia with a chlorine atom substituting for one of the three ammonia hydrogen atoms

1:1 Molar Ratio Equates to a 5:1 Weight Ratio (Chlorine to Ammonia)
Chloramine Breakpoint Curve: Knowing where you are on the curve allows for precise dosing action.
Chloramine decay rate triples from 50°F to 77°F - seasonal issues
Chemical usage increase significantly with water temperature increases: examples of six active Monoclor® RCS sites

Chemical usage can quadruple during warm months

Monthly average (2017-2018)

Chemical feed rates need to be adjusted (winter/summer)
Proper sizing of chemical feed system and storage is required
Boosting in distribution allow to raise residual above the maximum dose allowed at the treatment and use also less chemical to achieve it.
Four criteria must be met for proper chloramine control in reservoirs:

1. Proper mixing to ensure a homogenous water body that will not stratify
2. Accurate dosing of ammonia and chlorine to ensure proper ratio given the position on the breakpoint curve
3. High energy mixing that ensures instantaneous reaction of introduced chemicals
4. Real-time monitoring and control logic to maintain or achieve equilibrium by responding to dynamic reservoir conditions
Effective mixing can come in a variety of configurations depending upon process objective and site constraints – for example – RCS applications require higher mixing energy and must accommodate chemical injection.
A residual control system automatically adjusts disinfectant residual to a pre-determined set-point and maintains that set-point with beneficial water quality impact to the zones it serves.

LAS
Aqueous Ammonia

Gas Chlorine
Bulk Hypo
On-Site Hypo

Company Confidential
San Jose, CA – Monoclor® RCS trailer at San Jose Water Company: 1 MG reservoir

Case Study

Tank Size: 1 MG (3.8 ML)
Turnover: 4 days
Problem: Chronically low residual (<0.2 mg/l)
Solution: Monoclor® RCS System
Chloramine residual control systems can take on a number of different configurations depending on tank particulars and client preferences.
Site conditions in San Jose: Tank Shark® mixing and injection hardware
Tank Shark® mixer and injection device was installed while the tank was in service.

TANK & HATCH PENETRATIONS
Monoclor® RCS Chloramine Management System Results

Introduction of “challenge water” volumes

Imported water introduced in high quantities throughout the trial caused momentary and intermittent concentration changes followed by quick recovery.

60 Days
Installing a Boosting System in Miguelito Reservoirs Results in Achieving Target Residual Levels in Downstream Alum Rock and Crothers Tanks.
In utility with 13 tanks, residual can be observed to improve system wide over three years (6 RCS and 13 mixers).

Low residual during warm months
Ultimately, optimal disinfectant residual control involves a number of mitigation steps throughout a distribution network – analysis, mixing and controlled boosting.
Thousand Oaks, CA – experienced chronic chloramine residual variability

**Disinfection**

**Fine-tune Chloramine Disinfectant Residual Levels in Distribution Networks**

Water utilities can mitigate disinfectant-residual degradation by using automated chloramine management systems in water storage assets.

BY ANDY SEIDEL, MATT MILLER, AND PAUL JORGENSEN

**CHLORAMINATION AS a disinfectant strategy in potable water systems provides many benefits, including a lower potential for disinfection byproduct formation, such as trihalomethanes (THMs), and improved disinfectant persistence.**

However, a significant challenge for water treatment plant operators relates to the shifting chemical equilibrium among ammonia, chlorine, and chloramines in water distribution systems. Premature decay of chloramine compounds can release free ammonia into distribution systems and lead to nitrification, taste-and-odor issues, and other complications as ammonia is consumed by various species of bacteria, ultimately causing unwanted nitrification. On the other hand, over-chlorination results in undesirable chloramine species such as dichloramines and trichloramines that engender taste-and-odor issues as well as provide additional potential for disinfection byproduct production.

Operational activities such as tank dumping, frequent tank cycling, chlorine “burns” in distribution systems, and inefficient chlorine “boosting” in tanks and reservoirs increase utility expenses because of unpredictable manpower scheduling, overtime, and additional lab work as operators struggle to meet water quality levels, particularly in warmer months. Most chloramine decay occurs post-treatment plant as water ages in pipes, reservoirs, and tanks. Therefore, arresting chloramine degradation in distribution system storage assets is the most efficient way to maintain water quality and manage operating costs.

An automated residual control system (ARCS) deftly manages the shifting chemical equilibrium along a reservoir’s disinfectant breakpoint curve (Figure 1) to ensure all free ammonia is reacted.

**Scope of Utility**
- 51,000 Customers
- 17,000 Service Connections
- 230 miles of distribution lines
- 16 Water Storage Tanks

**Warm climate and periodic drought conditions wreak havoc on water age and water quality**
- Nitrification risk

Featured in AWWA OpFlow 2018
Despite having 10 PAX mixers, chloramine residual remained difficult to control, so the utility rented residual control trailers for two tanks for one season of residual boosting.

Figure 3. Thousand Oaks’ Pederson and Willow Tanks
As water temperature increased, disinfectant residual decreased and nitrite formation increased as ammonia-oxidizing bacteria became more active.

Large swings in Total Chlorine eliminated with RCS trailers

“Canary in Coalmine” nitrite levels were kept low
The rental trailers were so successful that Thousand Oaks purchased two permanent systems which control system residual today.

2019 Willow Tank Residual Plot Depicting 2.2 ppm Setpoint Being Maintained
System wide annual average: water quality has improved significantly since 2015

![Graph showing improvement in water quality since 2015 with RCS Systems Installed.]
Distribution Map (2015): Purchased 5 PAX mixers and *rented* 2 Monoclor® RCS trailers
Distribution Map (2017): System wide water quality improved after purchase of additional 5 PAX mixers and 2 Monoclor® RCS systems

- <0.5 ppm
- >0.5 ppm
By examining multiple years of compliance data, we were able to observe that a 2.2 ppm residual would remove system nitrification risk.

**Figure 4. Chlorine vs. Nitrite**

By plotting the aggregated sample data for all tanks, Thousand Oaks can forecast a system average residual that can eliminate any nitrification risk.
Coppell, TX: chloraminated consecutive system with chronically low residual

- Low residual (0.42 mg/l – regulatory minimum is 0.5 mg/l)
- Nitrification risk
- Periodic flushing; 66 MG (250 ML) in 2015
- Periodic breakpoint chlorination (creating THM risk)

1.5 MG (5.7 ML) Elevated Storage Tank
Chloramine residual control systems can take on a number of different configurations depending on tank particulars and client preferences
Controlling chloramine residual levels in-tank reduces nitrification risk

**Before**

Low residual with incipient nitrification

**After**

Residual in control
With no nitrification
2018 residual data at Southwestern Tank #1 illustrates ability to boost setpoint during difficult summer months.
Chemical usage shows seasonality: Peak during the summer months – high chlorine use indicates more free ammonia from wholesaler in warmer months.
Coppell, TX: Monoclor® RCS hardware included structures, analytics, controller, mixer and chemical feed

1.5 MG elevated tank

Water Quality Station (WQS)

PWM 500 Mixer

CL feed skid (Bulk Hypochlorite)

Smart Controller

NH₃ feed skid (LAS – liquid ammonium sulfate)
Utilizing water storage tanks as chlorine residual intervention points is a best practice; more effective than “in-line” boosting

- Tanks are a source of chlorine demand (sediment, bio-film etc.) – solve issue at source
- Tank volume provides a convenient “buffer” allowing a safe place to add chlorine and monitor before subsequent network experiences chlorine dose
  - Allows option to valve-off
  - Allows holding for adjustment
- Mixing of entire volume is ensured versus dosing into a pipe
A “Smart Tank” with residual control automatically adjusts disinfectant residual to a pre-determined set-point and maintains that set-point with beneficial water quality impact to the zones it serves.
Halifax, Canada – 9 MG ground storage tank with consistent chlorine residual issues (influent was 0.7ppm with decay to 0.3ppm in warmer months)
Demonstration **SmartBoost™** trailer in summer of 2018 managed residual to desired 0.7 ppm immediately

- 100 gpm Tank Shark® mixer
- Microclor® 60 PPD OSHG as free chlorine source
THM Removal Systems

Removing THMs by Storage Tank Aeration and Mixing
Utilities have no “free lunch” as the choice of secondary disinfectant will determine the problems they will contend with:

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  - Boosting to offset degradation
  - DBP (THM and HAA5 issues) formation

- **Chloramines**
  - Chloramine degradation (ammonia formation)
  - Nitrification (nitrite and nitrate MCLs)
Trihalomethanes (THMs) – Long history of contaminant regulation

“The Total Trihalomethane Rule was the first modern drinking water regulation (USEPA, 1979). It established the precedent for a new regulatory methodology that is now standard procedure” Victor J. Kimm, USEPA Head of Drinking Water Program 1975-1985

- 3 of 18 US Drinking Water Rules are on THMs
- US EPA Stage 2 DBP Rule mandates an **80 ppb** MCL based on a sample location running average (LRAA)
- THMs are second leading cause of MCL violations after BAC-T

* 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.

**PAX TRS™ removes THMs by tank aeration after they form**

\[
\text{Free Chlorine (Cl)} + \text{Natural Organic Matter (NOM)} = \text{Disinfection Byproducts (DBP)}
\]
THMs form faster at higher temperatures
THMs are volatile ... just like CO₂

• THMs would rather be in gas phase than liquid phase
• The **driving force** for mass transfer from liquid phase to gas phase is based on a difference in concentration between THMs in the water and THMs in the air
• THMs can build up in the headspace of a tank if its not actively ventilated, stopping THM volatilization (Henry’s Law)
• Optimizing a tank to volatilize THMs can be simple or complex, depending on the tank conditions, the amount of treatment needed and energy constraints/cost
Henry’s Law constants dictate the percentage of THM’s that can saturate the tank head-space – *in equilibrium*

<table>
<thead>
<tr>
<th>THM species</th>
<th>Henry’s law constant @ 20 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroform</td>
<td>0.13 (87% in water)</td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td>0.08</td>
</tr>
<tr>
<td>Chlorodibromomethane</td>
<td>0.04</td>
</tr>
<tr>
<td>Bromoform</td>
<td>0.02 (98% in water)</td>
</tr>
</tbody>
</table>

Chloroform is the most “volatile” (easiest to remove)

Bromoform is the least “volatile” (hardest to remove)
Henry’s Law limits passive THM removal, but active mixing allows THM’s to bridge the diffusional barrier. But you need **STRONG** mixing.
Adding active ventilation breaks Henry’s Law
Equilibrium in tank head-space
THM removal systems need three equipment components to effect removal:

**Mixer**: Continually introduces THM laden water to the air-water interface

**PowerVent™**: Blows fresh air into the tank, exhausting THM laden air and providing the driving force for mass transfer

**Air-water interface**: Surface or spray aeration equipment increases available water surface area for additional mass transfer
There are three common in-tank aeration configurations for THM removal:

- Mixer + PowerVent™
- Surface Aeration
- Spray Aeration
Multiple hardware options are available based on process objectives and site-specific issues

<table>
<thead>
<tr>
<th>Tank Mixers</th>
<th>Active Tank Ventilation</th>
<th>Aeration Equipment</th>
<th>THM Analyzers</th>
<th>Controls</th>
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</thead>
<tbody>
<tr>
<td><img src="image1" alt="Tank Mixer" /></td>
<td><img src="image2" alt="Active Tank Ventilation" /></td>
<td><img src="image3" alt="Aeration Equipment" /></td>
<td><img src="image4" alt="THM Analyzers" /></td>
<td><img src="image5" alt="Controls" /></td>
</tr>
</tbody>
</table>
PAX TRS™ aerator installations are straightforward and do not require extensive tank modifications (crane is required)

Western Water (10 ML tank) near Melbourne, Australia ~ 35% TTHM removal (ADWG limits are 250 ppb)
Achieving THM reduction across a system requires treatment at different points with treatment at the clearwell or at tanks.
Oban, Scotland
## Principal Design Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Clearwell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank Volume</td>
<td>2.25M liters</td>
</tr>
<tr>
<td>Tank Dimensions (L X W)</td>
<td>19 m x 24.8 m</td>
</tr>
<tr>
<td>Tank Height (TH)</td>
<td>14.6 m</td>
</tr>
<tr>
<td>High Water Level</td>
<td>14.0 m</td>
</tr>
<tr>
<td>Low Water Level</td>
<td>1.0 m</td>
</tr>
<tr>
<td>Turnover</td>
<td>9.6M liters</td>
</tr>
<tr>
<td>Target for THM removal [%]</td>
<td>50%</td>
</tr>
</tbody>
</table>
Site Layout
• Two Cells
• Two AMS THM Analyzers
1. 24/8 aeration turned on. Both CWT running into supply
2. 24/08 to 13/09 Optimise aeration whilst throttling back CWT2 and increase flow to CWT1. Found that treated water hydraulically preferred CWT1
3. 13/09 to 15/09 Running on CWT1 only – effectively an initial test period
4. 15/09 to 21/09 Switched CWT2 back into supply over perceived Chlorine loss due to aeration
5. 21/09 Running on CWT2 only
6. 29/09 to 30/09 Power outages at site caused wq issues.
Colorado Springs Utilities

- 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.
Manitoba Canada – Plumas Clearwell

- Canada has 100 ppb TTHM limits
- RFP issued June 2016
- 70% TTHM removal target
- Year-round treatment
- System startup November 2016
- Clearwell under building install location

Winter temperatures of -40° C
Below grade clearwell – installation of one surface aerator (guides) + mixer
PAX PowerVent® with in-line duct heater
TRS on-off validation results = 70% removal
San Jose, CA: 12 MG More Avenue Reservoir

- SJWC (investor owned utility) purchased water from Santa Clara Valley (wholesaler)
- Rising organics and bromide due to drought conditions
THM removal is influenced by tank turnover; the PAX TRS™ at More Avenue was delivering high rate of removal during periods of low demand (on/off validation)
PAX TRS™ active feedback control using THM sensors yield ~50% operating cost savings

Integration of on-line THM analyzers provide an opportunity to save on energy
Chlorine is not lost during the aeration process

\[ \text{HOCl} \leftrightarrow \text{H}^+ + \text{OCl}^- \]

- 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
Distribution Network Water Quality Management

May 27th 2020

UK Webinar with Panton McLeod