SolarBee® GridBee®

Energy Efficient Mixing

THMs: Source, Clearwell & Tank Controls

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TriState Seminar on the River 2013 Conference

Las Vegas, NV – September 24, 2013

Regulatory Driver

- **US EPA Stage 2 Disinfectants and Disinfection Byproducts Rule** requires that locational running annual averages for total trihalomethane (TTHM) concentration not exceed the maximum contaminant level (MCL) of 80 ppb anywhere within distribution systems, with phase-in beginning in 2012 (some utilities getting 2 year exemption).

  - Epidemiological data indicate that higher THM levels are a significant risk factor for developmental, reproductive, and carcinogenic health effects in humans. Primary exposure is often inhalation and skin absorption while showering.

Trihalomethanes are Volatile

- **THMs volatility**

Henry's Law Constants

NIST, 2011, median values
mol/kg-bar @ 25°C

Chloroform 0.25
Bromodichloromethane 0.45
Dibromochloromethane 0.97
Bromoform 1.80

Hypochlorous acid 298.00
Most chlorine in water is in the form of hypochlorous acid,

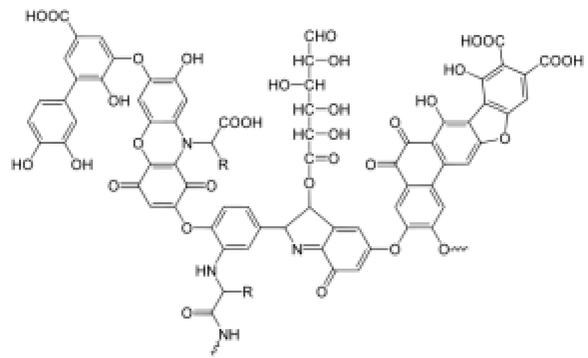
Several opportunities for reducing THMs

- At the treatment plant
  - **Reduce NOM** (Natural Organic Matter)
  - **Install a mixer in the CT basin.**
  - **Do air stripping of THMs at the clearwell.**

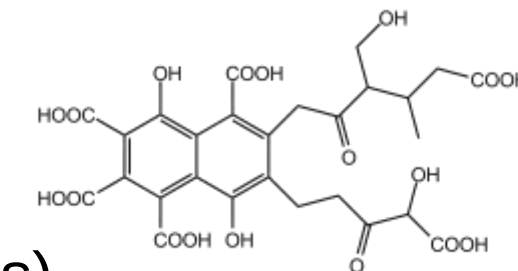
- In the distribution storage tanks
  - **Install a mixer in some or all tanks**.
  - **Do air stripping of THMs at one or more tanks.**

Trihalomethane Precursors

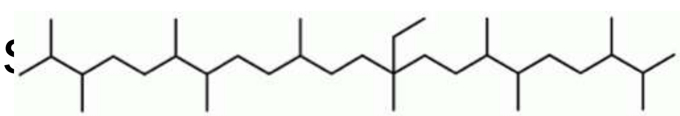
- Natural organic matter (NOM)
  - Humic acids – formed from microbial decay of plant matter such as lignin



  - Fulvic acids (lower molecular weight & more highly oxygenated humic acids)



- Algal organic matter (AOM)
  - More DBP/unit mass than humic acids
  - Carbonaceous and nitrogenous DBPs
  - Intercellular AOM forms more DBPs than extracellular AOM



Botrycoccane – only C & H

Principles for Trihalomethane Control: In the Source Water

- **Reduce NOM concentration**
  - AOM is highly reactive with chlorine and bromine in forming trihalomethanes and other DBPs
  - Cyanobacteria (aka blue-green algae) frequently “blooms” in nutrient rich and quiescent, stagnant waters. Harmful algal blooms (HABs) occur when cyanobacteria outcompete other forms of algae
  - HABs cause several problems for water utilities
    - Huge biomass provides AOM precursors to DBPs
    - Often taste and odor compounds
    - Often cyanotoxins
  - Other algae rarely “bloom”, diatoms may briefly in spring

USGS midwest survey found a 91% correlation

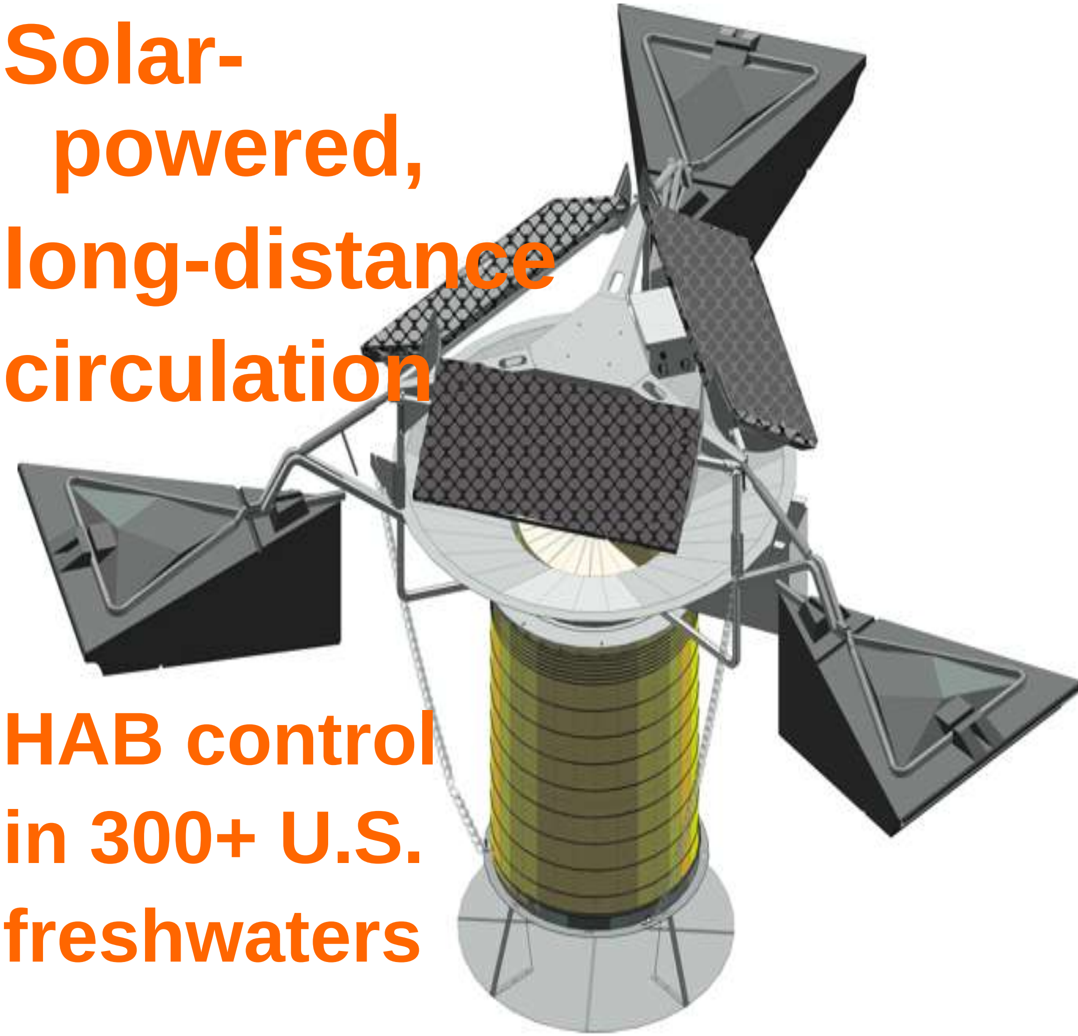
HAB Stimulatory Factors & Sustainable Treatments

- **Sunlight for photosynthesis**
  - No sustainable, environmentally benign solution
- **Increasing temperatures**
  - No sustainable, environmentally benign solution
- **Excessive nutrient concentrations**
  - Watershed management
  - Waterbody management
- **Quiescent, stagnant water**
  - Waterbody management
    - Destratification, mixing water column
    - Solar-powered, long distance circulation

Hudnell (2013) An Alternative Approach to Regaining Designated Uses of Clean Water Act Section 303(d) Impaired Waters. Florida Water Resources Journal, 65/2:20-26.

HAB Control in Source Waters

Solar-powered, long-distance circulation

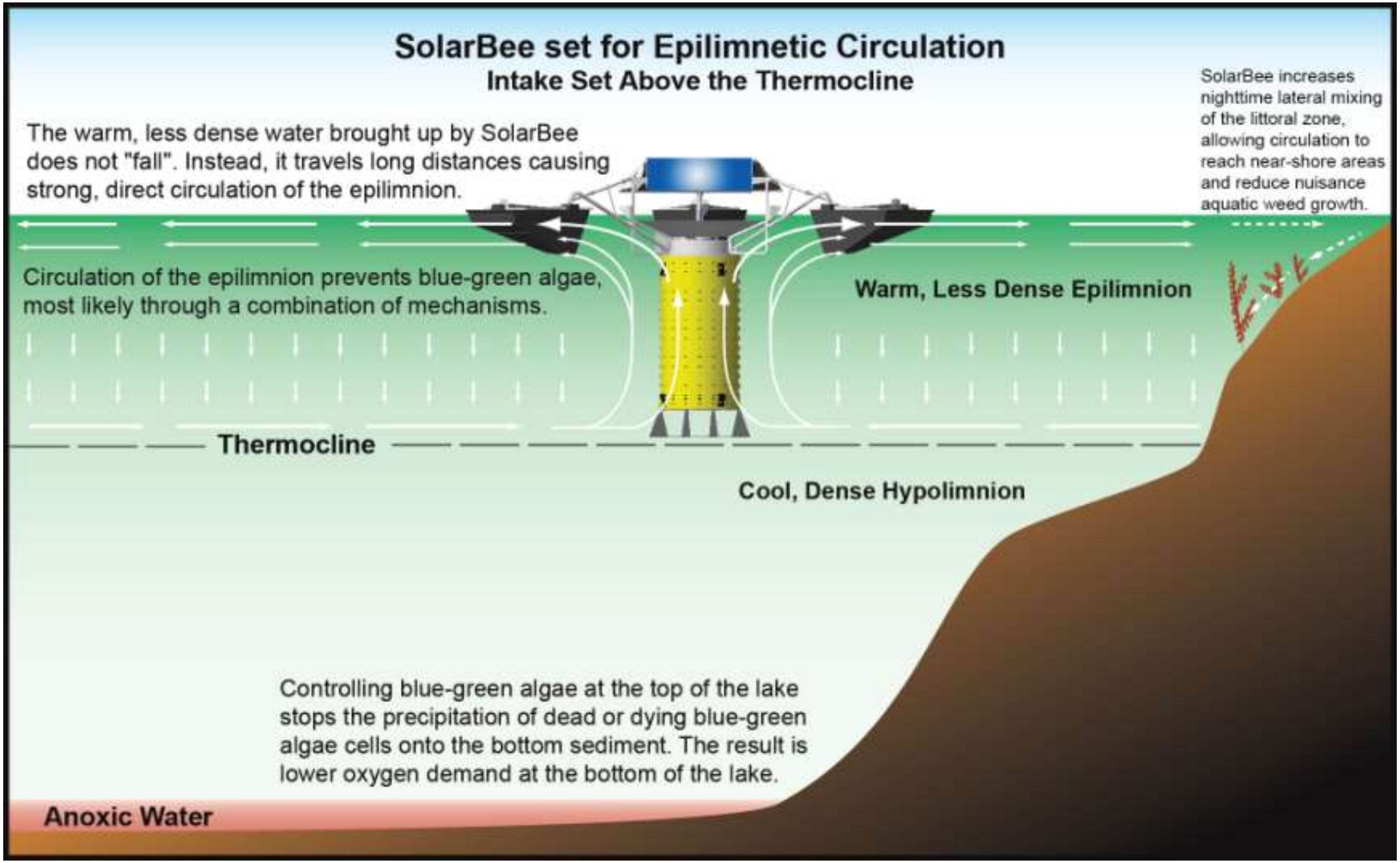


HAB control in 300+ U.S. freshwaters

Hudnell *et al.* (2010) Freshwater harmful algal bloom (HAB) suppression with solar-powered circulation (SPC). Harmful Algae, 9, 208-217

HAB Control in Source Waters

Solar-Powered Long-Distance Circulation



THMs: Where / how to address them?

- **1:** Front end of the plant
- Try to prevent THM formation at the front end of the plant, before residual disinfectant is added.
- Reduce NOM (Natural Organic Matter)
- Reduce Chlorine Dose used for the CT calculation?
    - To lower "C", you have to increase "T"
    - "T" is calculated in one basin or in several, depending on the plant design.
    - If there is a significantly sized reservoir in the CT calc, consider intense mixing to increase "T" and prove an improved baffle factor with a tracer study.

Bend, Oregon: Clear Well Contact Time

Case Study on Outback Reservoir #2

Function: Clear Well

Capacity: 2.23 MG tank above ground steel tank

Flow Rate: **7,000 gallons** per minute at peak

Inlet Outlet Structure: Separate 180 Degrees Apart

Before mixer: 30 minutes "T" detention time, baffle factor 0.1

With mixer: 80 minutes "T" detention time, baffle factor 0.25

This was achieved with (1) 3,000 gpm direct flow mixer. Customer had expected to need 2 or 3 units to achieve goal.

Principles for Trihalomethane Control: In the Field

- **Minimize chlorine usage -** Boost early, as needed to maintain residual
- **Minimize water age -** Cycle tanks as much as possible
- **Circulate water & ventilate tank -** Mixing volatizes some THMs, reduces Cl usage, evens water age top to bottom

Mixing the water:

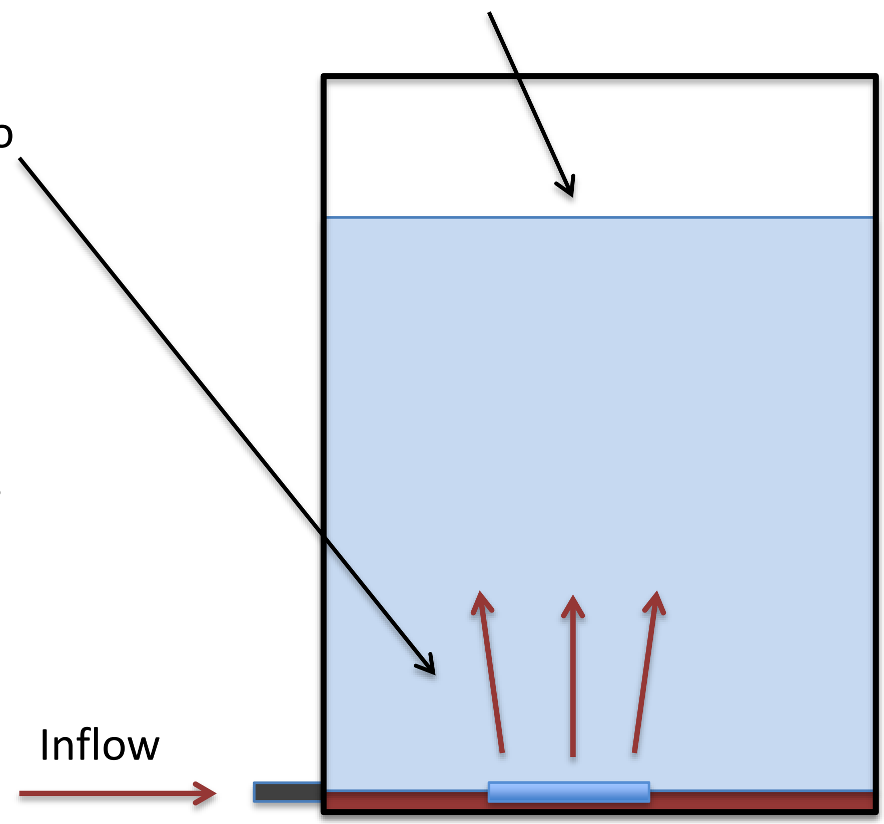
- Increases THM formation rate
- Increases THM volatilization rate
- Reduces TMH formation potential

2a: Mixing distribution storage tanks

1. "**<u>Solution by dilution</u>**". If a mixer is picking up the untreated inflow water (a) as fast as it is coming in, and (b) all the way to the bottom of the tank, like the GS-12 does, then high THM water is mixed into low THM water before it can go back into system.

2. **<u>Volatization at the surface</u>.** Constant surface renewal exposes THM to the air in the headspace

3. <u>**Less stagnation** in the tank will cause better residual</u>, both in the tank and downstream. So **<u>less downstream boosting</u>** will be needed, resulting in less system THM problems.

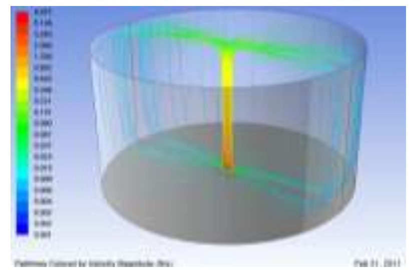


BUT, *not all distribution water goes into a tank before it gets to the customer, so the effectiveness will vary based on exact flow path.*

Mixing Technology

Solar-Powered Mixing

SB500-10,000

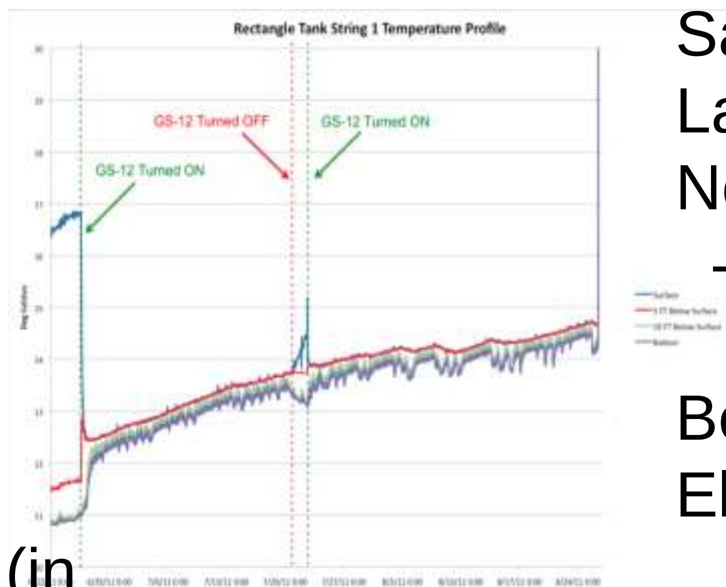


Grid-Powered Mixing

GS-12
45,000
GPM

Mixing Prevents

- Temperature stratification
- Stagnation
- Dead zones
- Short-circuiting
- Biofilm build up
- Loss of residual
- Nitrification events
- Risk of ice damage (in northern states)



Independent Studie

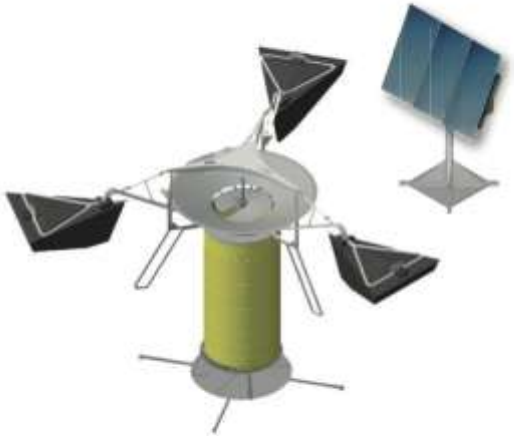
San Francisco PUC
Santa Clarita WD
Las Vegas VWD
Normal, IL
- Tracer or Temp.

Bend, OR, Clear Wel
Elizabeth, IL, Ice

Potable Water Mixers

Passive Mixer

Solar-powered Mixer (Small / Medium Tanks)



Solar-powered Mixer (Large Tanks)

Elevated Impeller Mixer

Elevated Nozzle Mixer

Submersible (floor) Sheet-flow Mixer

ANSI/NSF 61 ANNEX G

The Standard:

ANSI/NSF Standard 61: ANSI/NSF Standard 61 was published in 1988 to establish minimum requirements for the control of potential adverse human health effects from products that contact drinking water.

Annex G: ANSI/NSF Standard 61 was revised in December 2008 to establish requirements for use when a 0.25% lead content requirement needs to be met in addition to current chemical extraction requirements of the standard. These requirements were placed in Annex G.

In 2010 the lead content evaluation procedures were moved to ANSI/NSF 372, and Annex G updated to reference it. Annex G will be retired in October 2013, in favor of ANSI/NSF 372.

Certifying Agencies:

Various agencies are approved to test and certify products to the ANSI/NSF Standard 61 and Annex G certifications. These include NSF, CSA, UL, and others.

Medora Corporation Potable Mixers:

Medora Corporation’s potable mixers, including the GS-12 and GS-14 in all available motor voltage configurations, and its THM Removal Systems, are certified to ANSI/NSF Standard 61.

Mixing & Ventilation to Control THMs in the Field

Yuma, AZ, 3, 3MG tanks

Mean TTHM reduction 71 to 46 ppb during 2 years of treatment

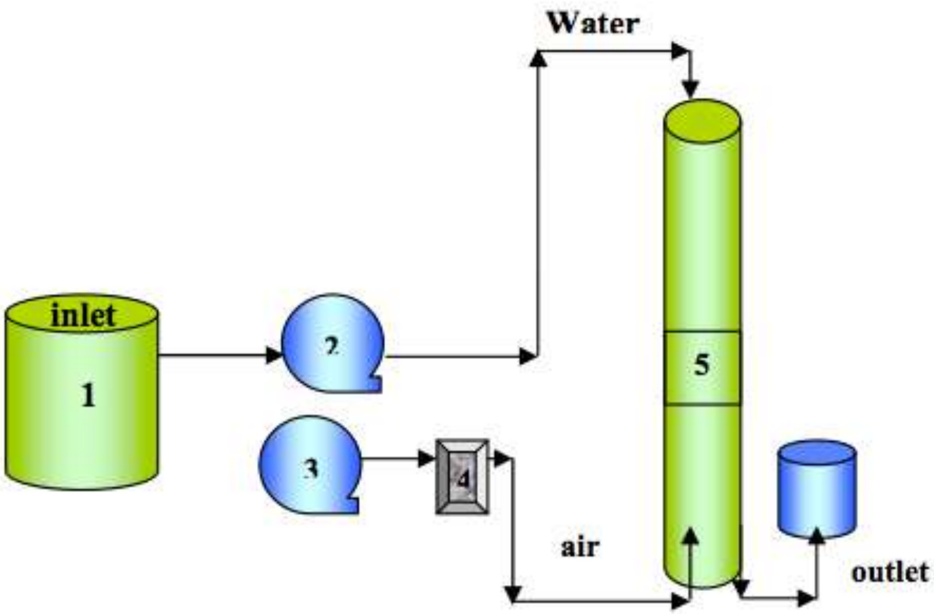
Bayfield, CO, 0.84MG tank

Initial results show TTHM reduction = 40-50%,

Cl use reduction = 30%

Mixing does not provide enough reduction at all sites

Traditional Air-Stripping Technology



1. Feed tank
2. Feed pump
3. Air compressor
4. Flow meter
5. Air stripping column

- Air strippers remove volatile contaminants from water by contacting air and water to optimize transfer kinetics.
- Common types of air strippers include packed towers, multi-staged bubble systems, venturi eductors, and spray nozzles.
- Removal effectiveness is related to the air:water ratio.

Principles for Trihalomethane Control: In the Field

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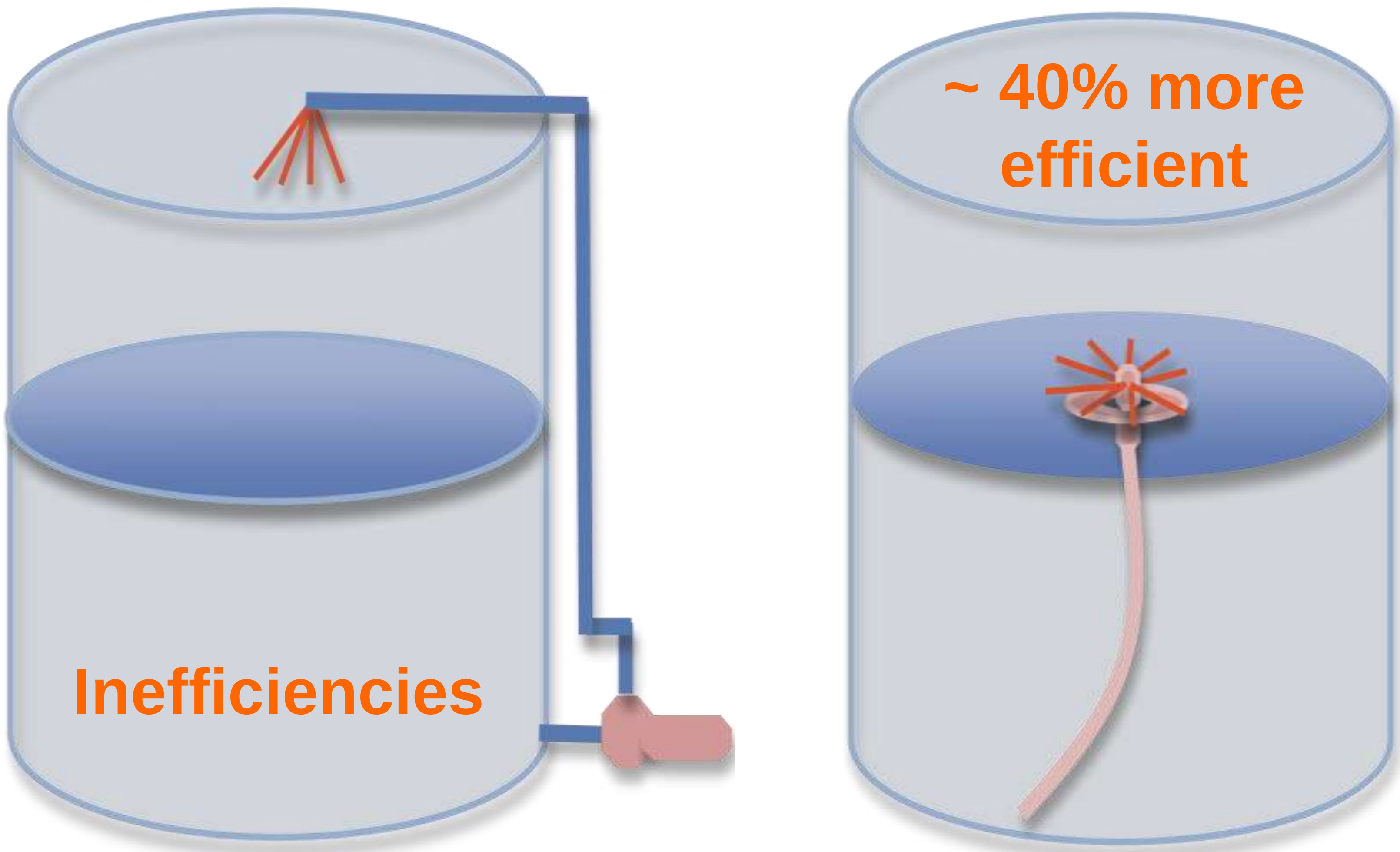
- **Minimize water age** - Cycle tanks as much as possible
- **Circulate water & ventilate tank** - Mixing volatizes some THMs, reduces Cl usage, evens water age top to bottom
- **Air strip THMs** - Best done in field where levels highest, but clearwell may be last tank for some users
  - **When air stripping THMs, keep upflow rate $\geq$ fill rate** - Otherwise, new, cooler, higher THM & Cl

Air Stripping R&D Goal and Objectives

- **Goal -** efficient THM reduction for all tank types, sizes, situations
  - **Maximize processing efficiency**
    - THM removed/hp x volume of water processed/min
    - High 1st pass removal rate
    - **Exhaust formation potential -** Circulate water to react NOM & Cl, remove THMs, minimize downstream levels
  - **Minimize costs -** Must be affordable. Treatment may be need at multiple locations
    - Capital outlay - Rent for trial period
    - Operating costs - Reduced energy use & associated green-house gas emissions
    - Maintenance cost - Few moving parts, durable, NSF approved
  - **Easy to install -** No emptying tank, divers, new hatches

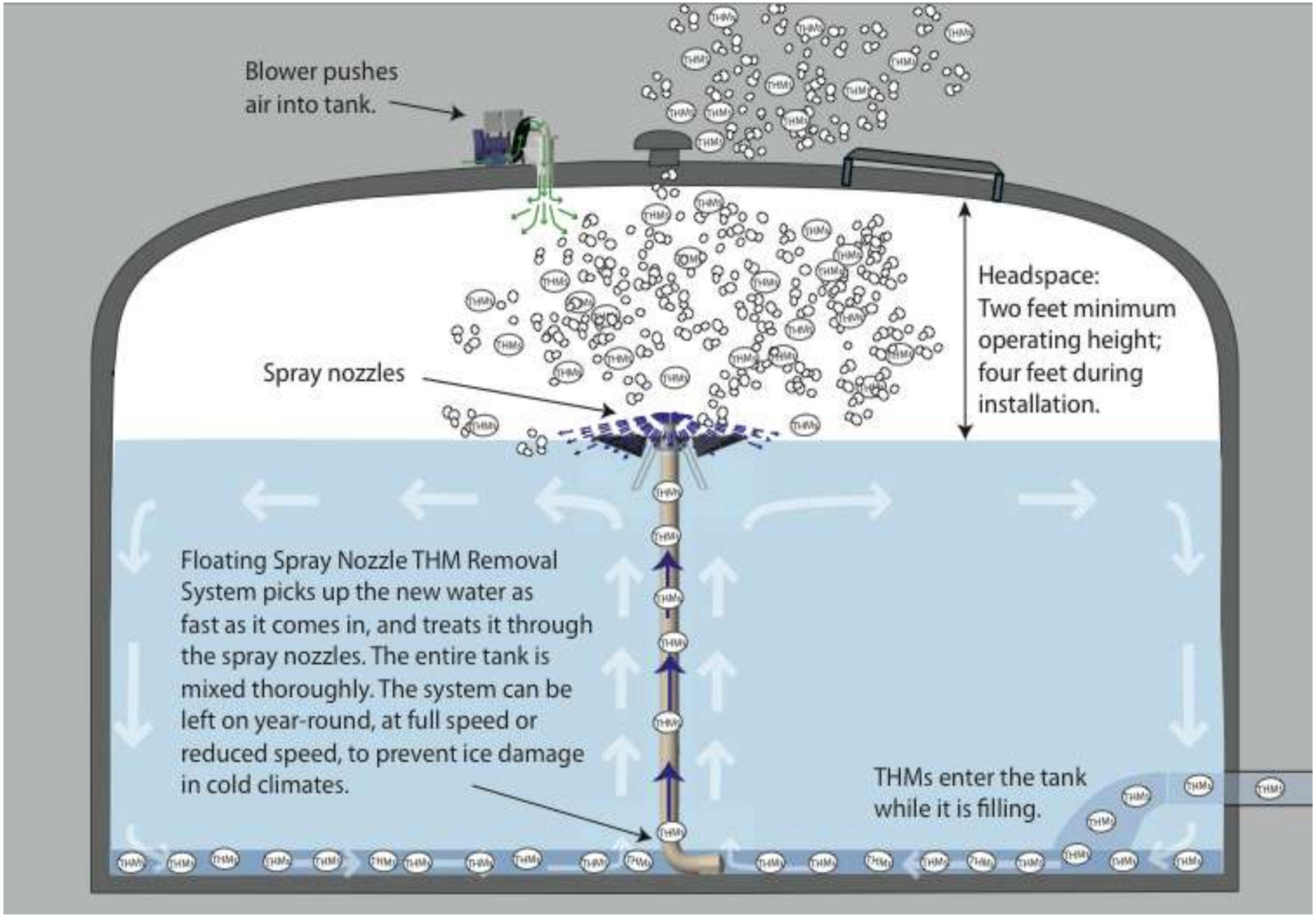
Air Stripping Technology R&D

Design Considerations



Air Stripping Technology R&D

Floating Spray-Nozzle System



Air Stripping Technology R&D

Floating Spray-Nozzle System

12,000 G test tank

Air Stripping Technology R&D

Floating Spray-Nozzle System

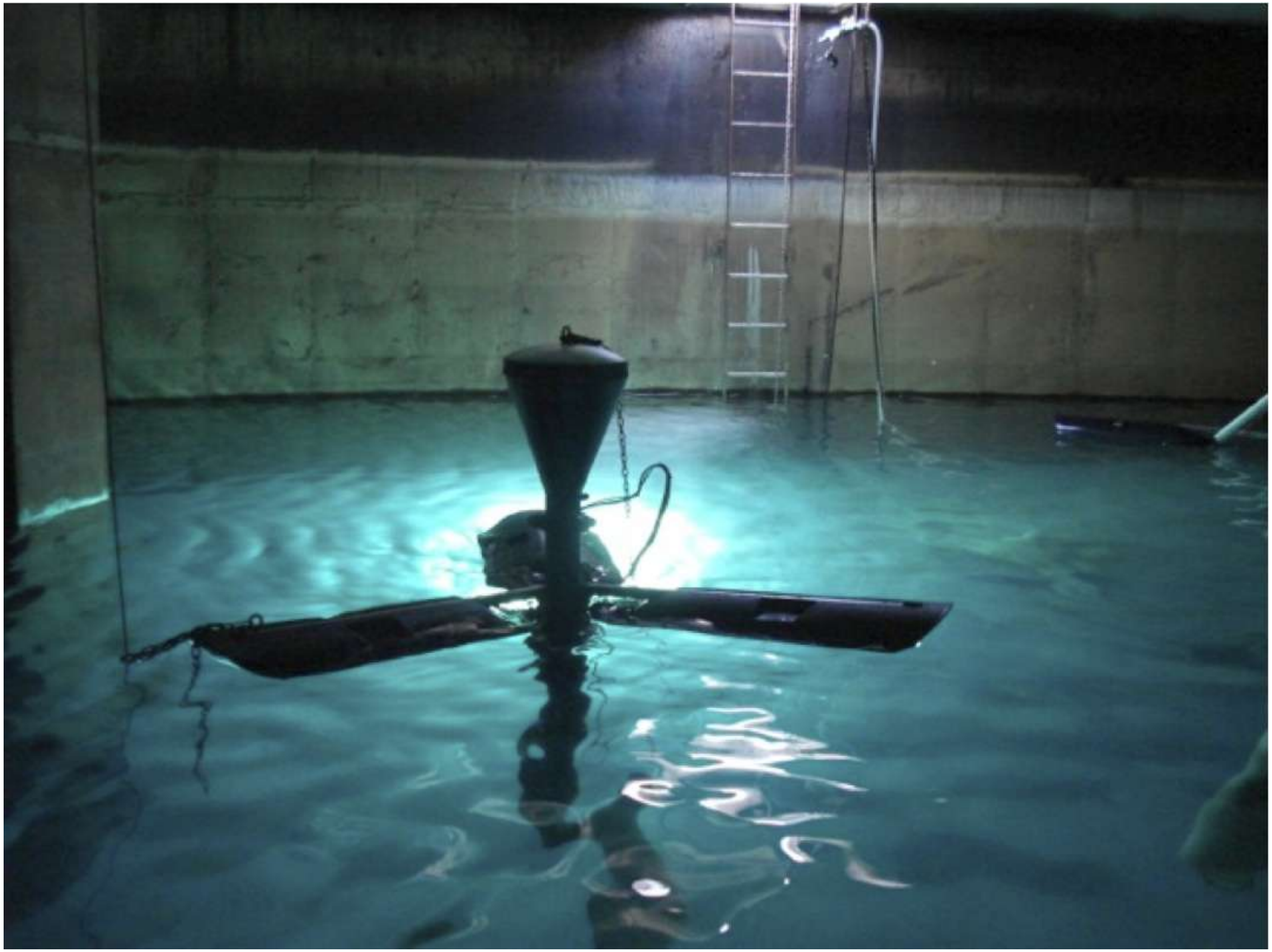
Air Stripping Technology R&D
Floating Spray-Nozzle System

Thousands of small nozzle-outlet holes

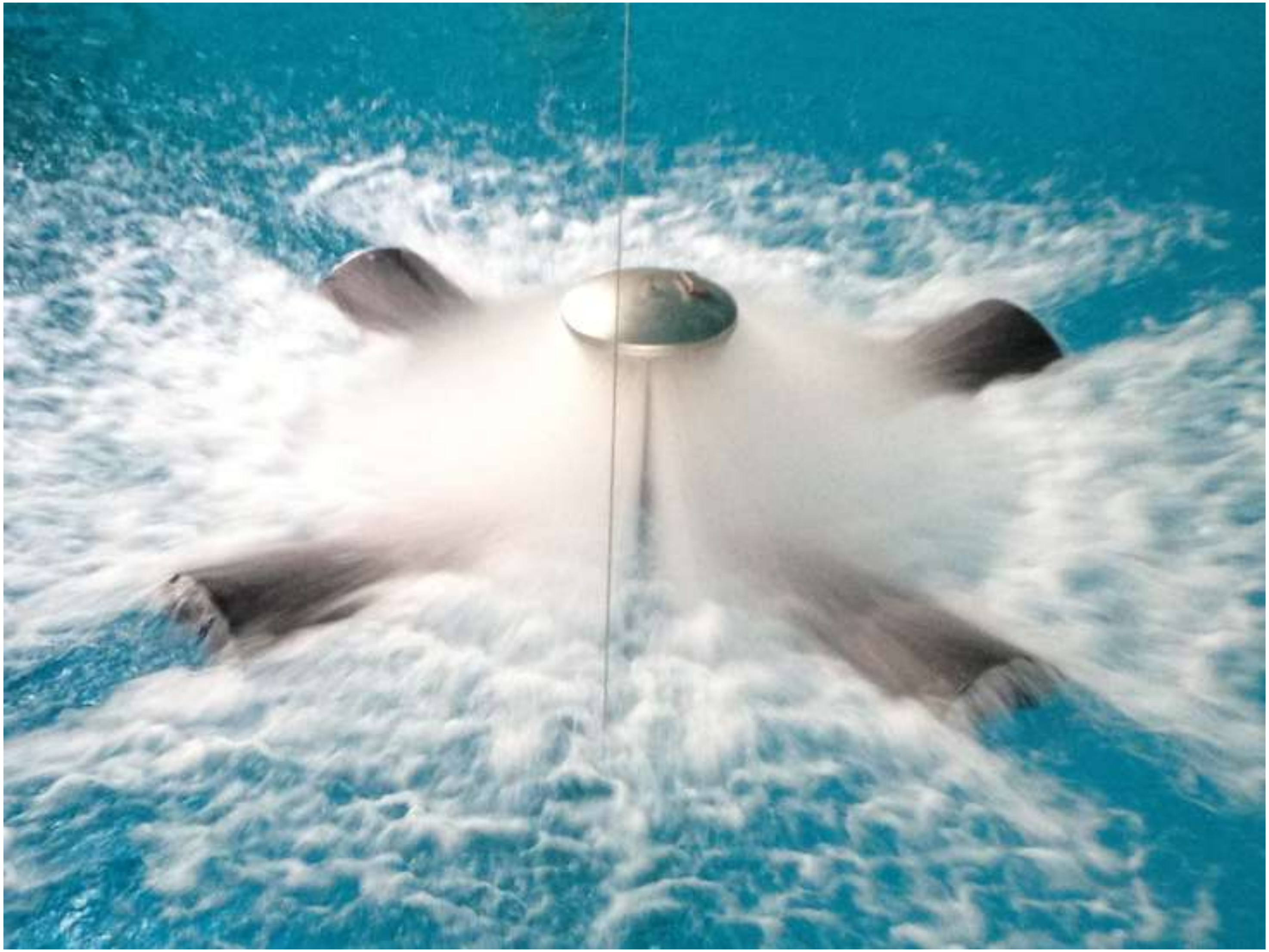
Air Stripping Technology R&D

Floating Spray-Nozzle System

Air Stripping Technology R&D
Floating Spray-Nozzle System



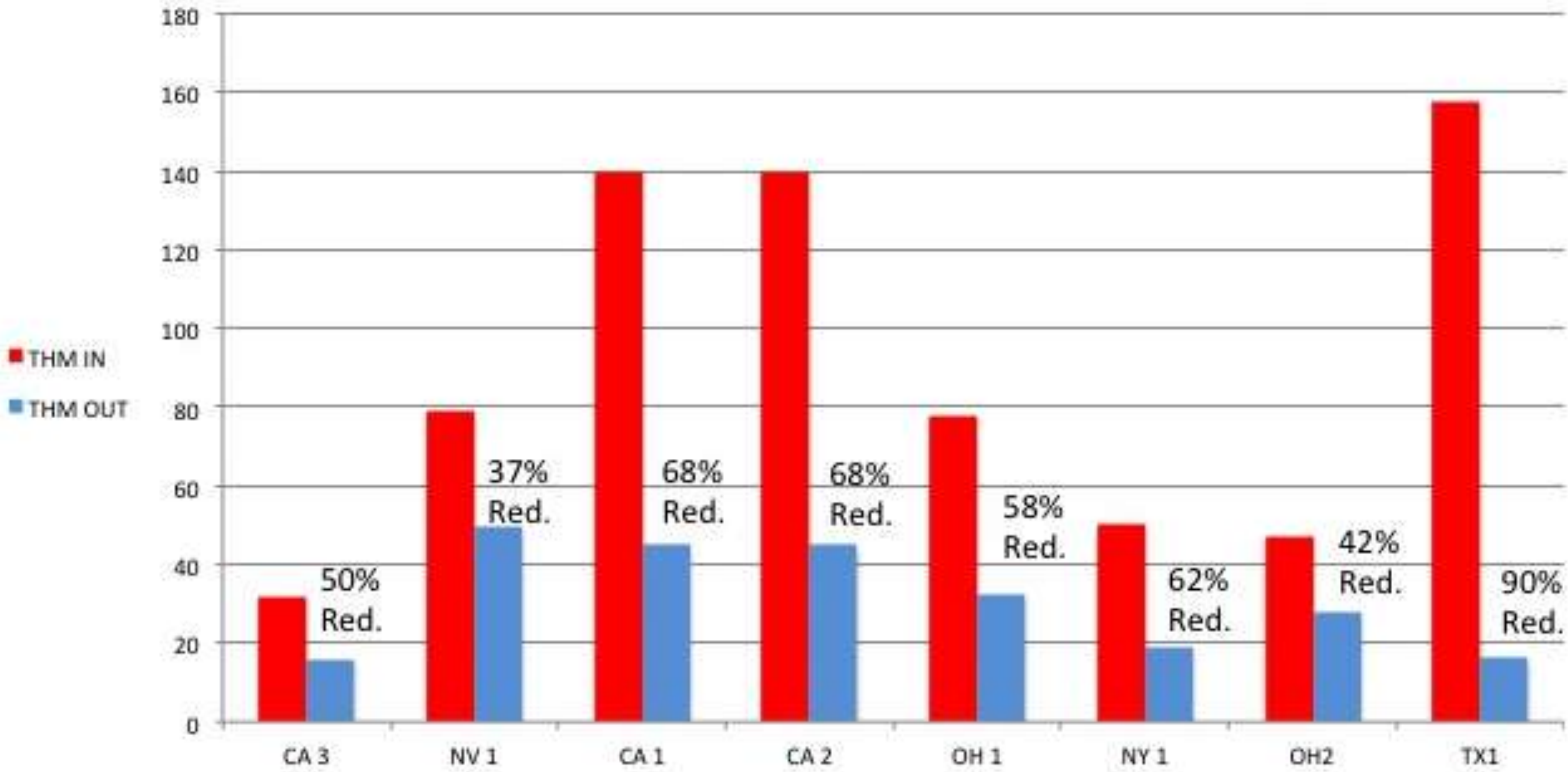
Air Stripping Technology R&D
Floating Spray-Nozzle System



2hp turbine blower on skid, on top of tank

FSN: Initial THM Reduction Results

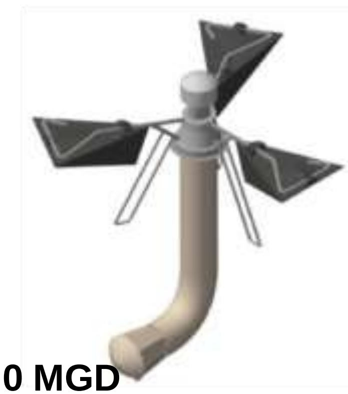
Design goal 40-50% TTHM reduction
Mean reduction across eight systems = 59%



Medora lab results except for utility contract lab results at CA1, 2, 3

Floating Spray-Nozzle Systems

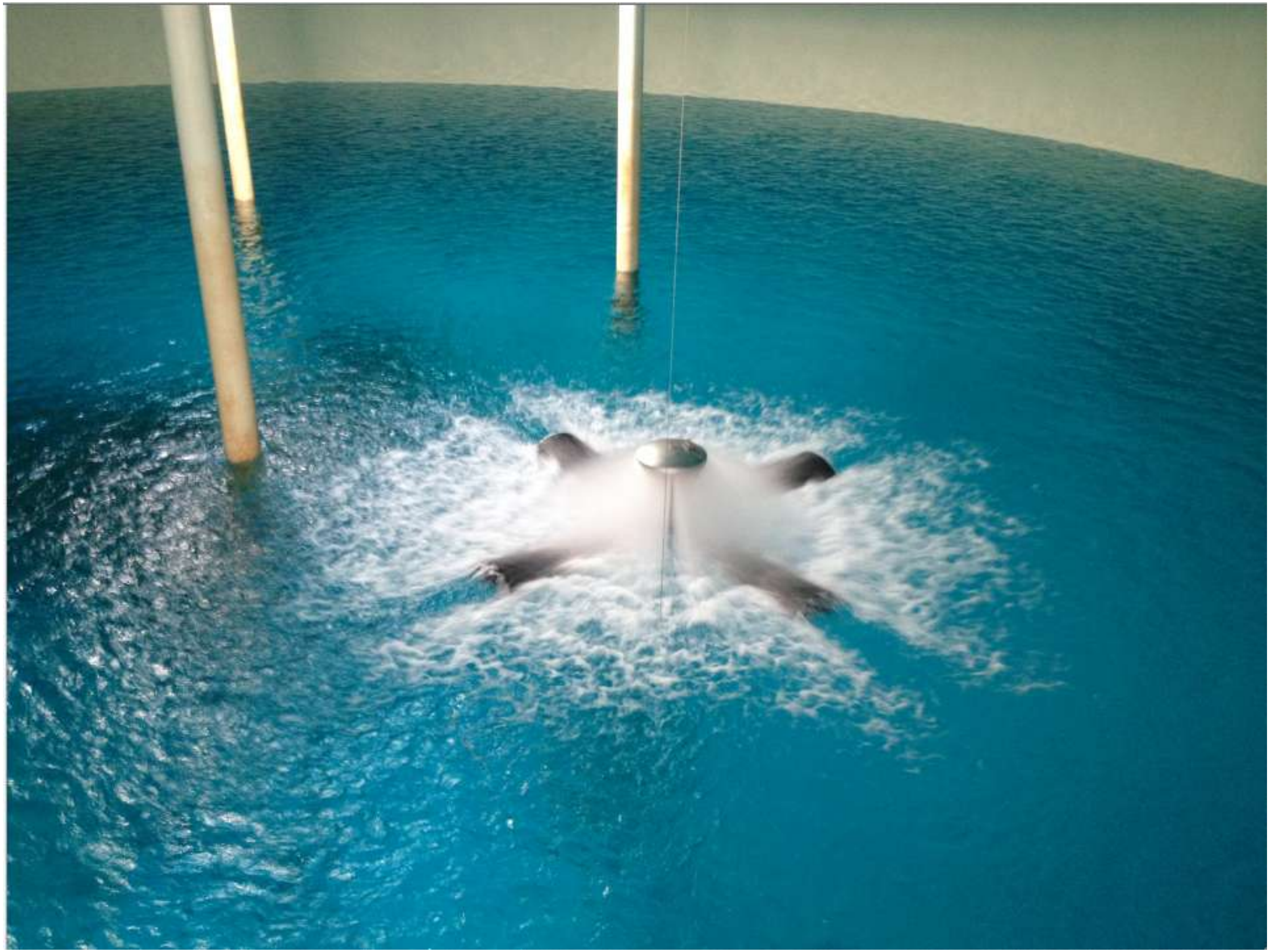
3, 5, 10 & 15 HP

Model SN3	Model SN5	Model SN10	Model SN15
			
0.25 MGD	0.33 MGD	0.66 MGD	1.0 MGD

System design is based on: Tank size, shape, configuration, mean and peak water-fill rates and daily flo-through rates, max and min THM levels, THM species, amount of reduction desired, THM off-peak needs, other.

Systems include: FSN unit(s), blower(s), and often a GS-12 or -24 mixer for mixing when the FSN(s) is not needed

FSN-15 floating spray nozzle in operation



Thank You ! – *Questions ?*

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Literature, videos, case studies and more information