Trends in Wastewater Disinfection Peracetic Acid (PAA)

County Sanitary Engineers Association of Ohio
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Lewis Center, OH
Ed Pelton – Pelton Environmental
EPelton@PeltonEnv.com

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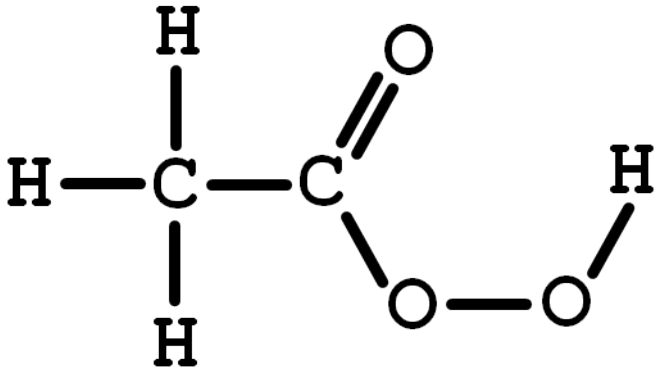
PART 1

Peracetic Acid

- Definition
- Disinfection
- Oxidation



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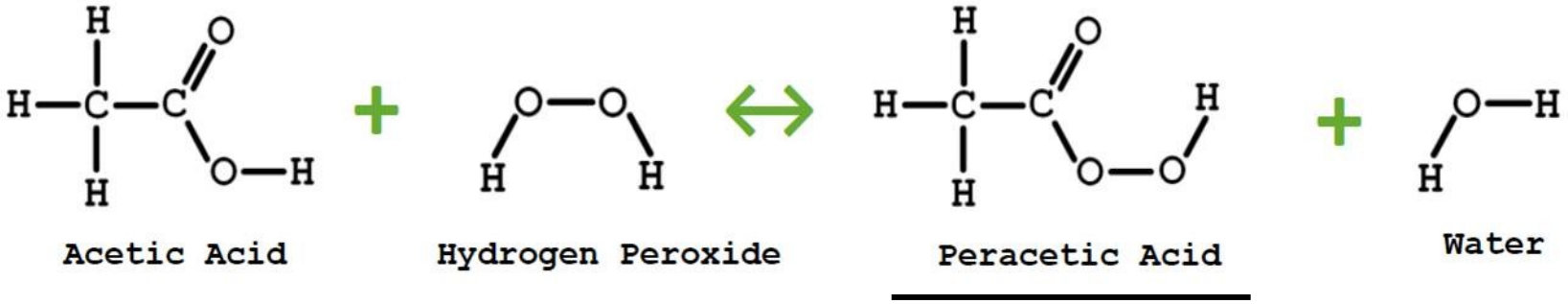
Definition

An **organic peroxide** that results from the reaction between Acetic Acid, Hydrogen Peroxide and Water.



PAA exists only in **equilibrium** with the other components in aqueous solution.

PAA is a strong **disinfectant** and a strong **oxidant**.

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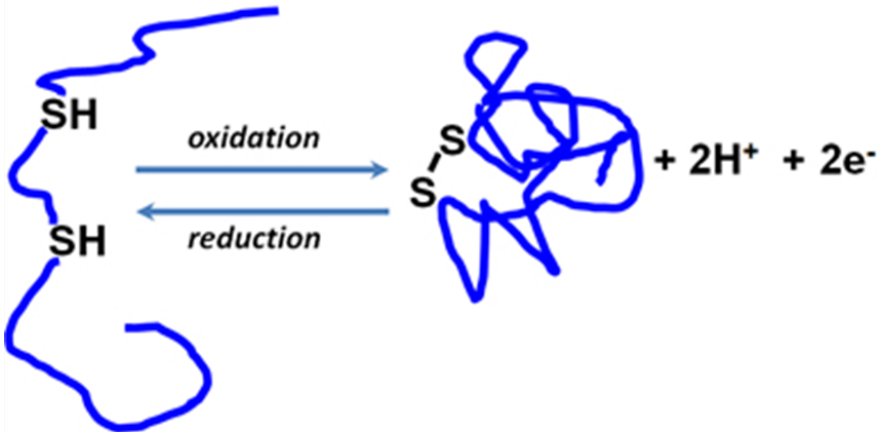
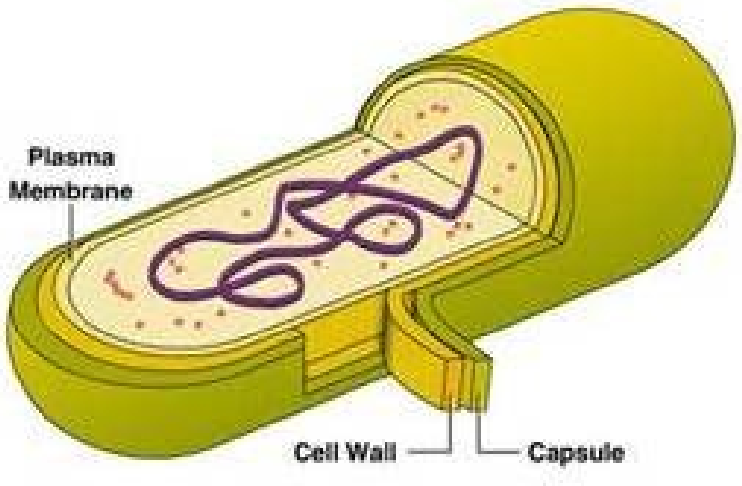
Strong Disinfectant

PAA oxidizes **enzymes** (proteins) and **nutrients** inside bacteria cells, rendering them unviable.





These mechanisms enable PAA to disrupt bacteria effectively and efficiently (**low doses, short contact times**)

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Strong Oxidant

The standard oxidation potential (at pH 7) of PAA is higher than most common oxidants.

Oxidant	Standard Potential (V)
Hydroxyl Radical	2.80
Ozone	2.07
Peracetic Acid	1.81
Hydrogen Peroxide	1.78
Potassium Permanganate	1.68
Chlorine Dioxide	1.57
Chlorine	1.36

PAA is a strong and effective oxidant - readily attacks bacteria as well as organic pollutants

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Uses in Microbial Control

PAA 35
Medical Device Sterilization

VigorOx® Citrus XA
Citrus Canker Control

VigorOx® WWT II
Wastewater Disinfection

1980 1990 2000 2010

VigorOx® LS&D
Surface Sanitization

Spectrum®
Poultry Processing

VigorOx® O&G
Oil Field Biocide

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PART 2

Wastewater Disinfection

- Formulation
- EPA Label
- Efficiency
- Kinetics in Wastewater
- Properties
- Drivers for Conversion
- Conversion Steps

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Formulation

Manufacturers are developing peracetic acid solutions that are specifically formulated for wastewater disinfection. POTW's should opt for these blends to reduce dosage requirements and operating costs. PeroxyChem's peracetic acid formulation for wastewater disinfection is registered and labeled as VigorOx® WWT II

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Formulation

Equilibrium can be achieved at different *PAA:H_2O_2:AA* ratios

- Increasing H_2O_2
  - Helps reduce PAA demand, reduces overall usage
  - Increases Dissolved Oxygen (DO)
- Increasing Acetic Acid
  - Increases BOD

	VigorOx®	Other A	Other B
Peracetic Acid	15%	12%	22%
Hydrogen Peroxide	23%	18%	5%
Acetic Acid	16%	20%	45%
BOD (mg/L)	1.98	2.62	3.02
DO (mg/L)	0.93	0.94	0.32
Net BOD (mg/L)	**1.05**	**1.68**	**2.70**

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Properties

Formulation	**15% / 23%**
Normal State	Liquid
Odor	Pungent “vinegar” smell
Density	1.16 g/mL (9.67 lb/gal)
Freezing point	-56 ˚F
pH	< 1
Solubility	Completely soluble
Stability	1 year at T < 84 ˚F
NFPA	

- Flammability: flashpoint above 200 ˚F
- Health: short exposure cause injury
- Reactivity: decomposition at high temperature
- Oxidizer

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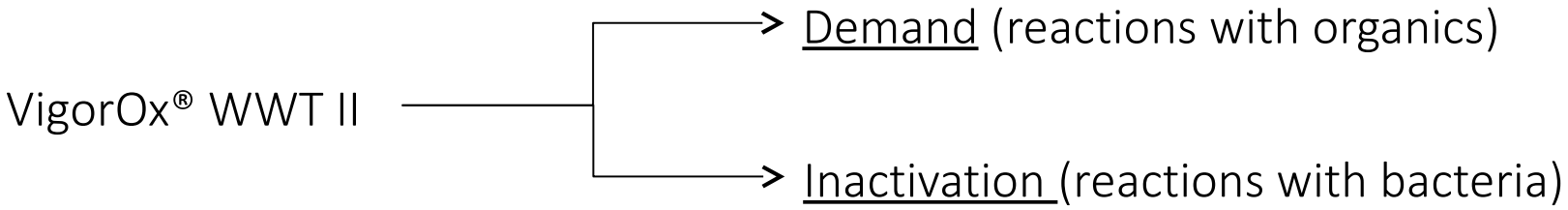
Reactions in Wastewater

When **VigorOx WWT II** is added to **wastewater**, multiple reactions take place:



The inactivation and demand kinetics impacts the overall **efficiency** of PAA Disinfection (dose & contact time).

- Hydrogen Peroxide helps satisfy demand, improving efficiency
- TSS has little impact on efficiency
- Ammonia, nitrates and nitrites do not impact PAA performance or demand

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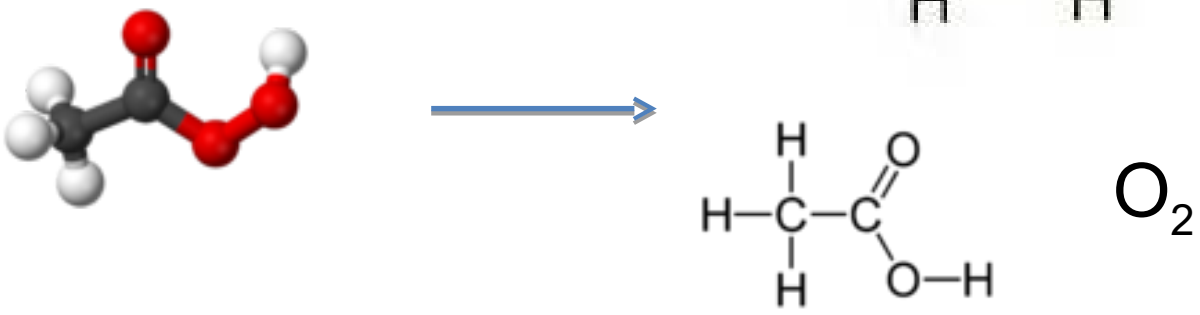
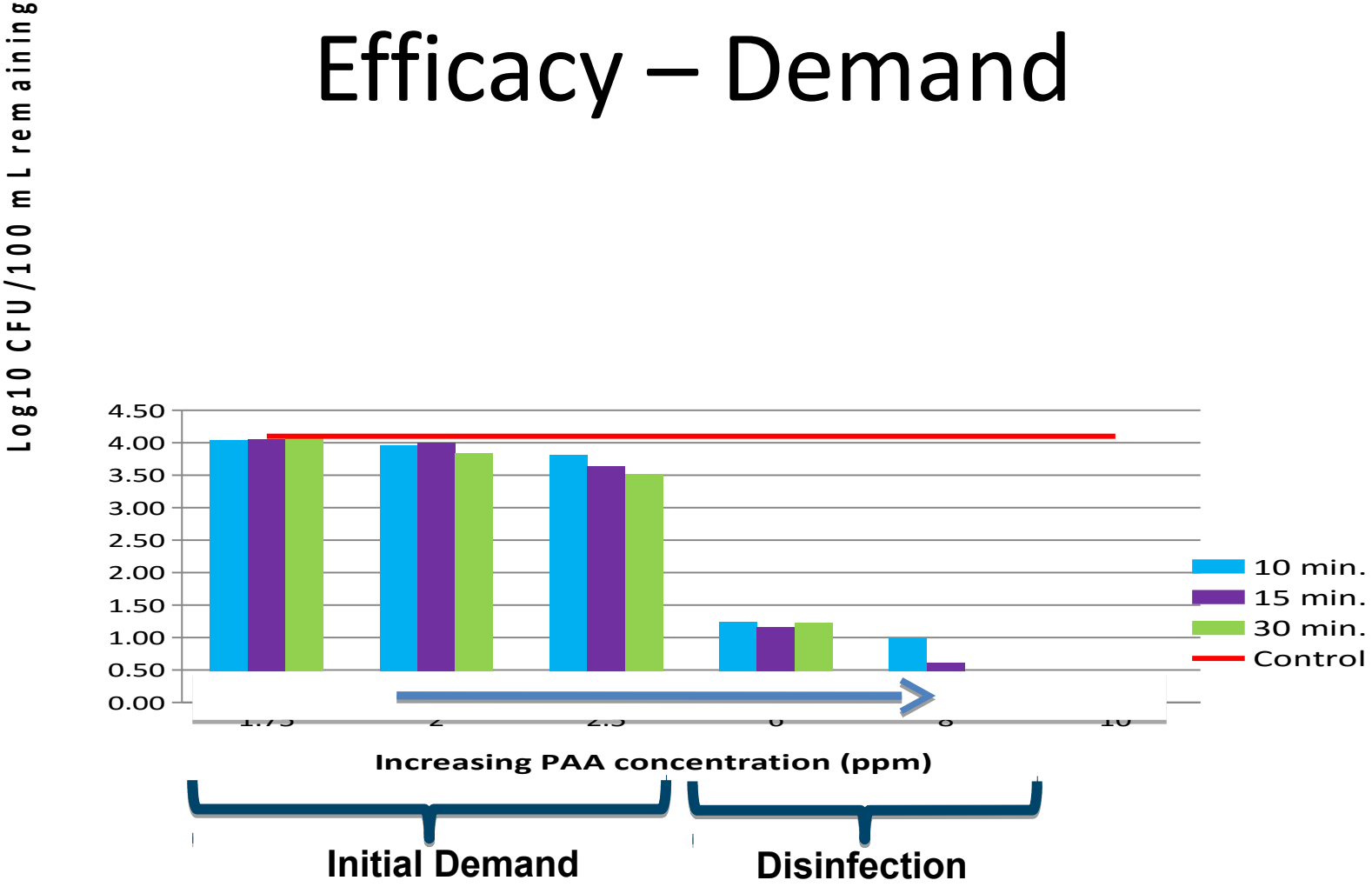
Peracetic Acid in Wastewater

- PAA breaks down to water, oxygen and acetic acid (vinegar) upon reaction with microbes, organics, TSS and auto-decomposition



Efficacy – Demand



Significant disinfection is not observed until demand is satisfied

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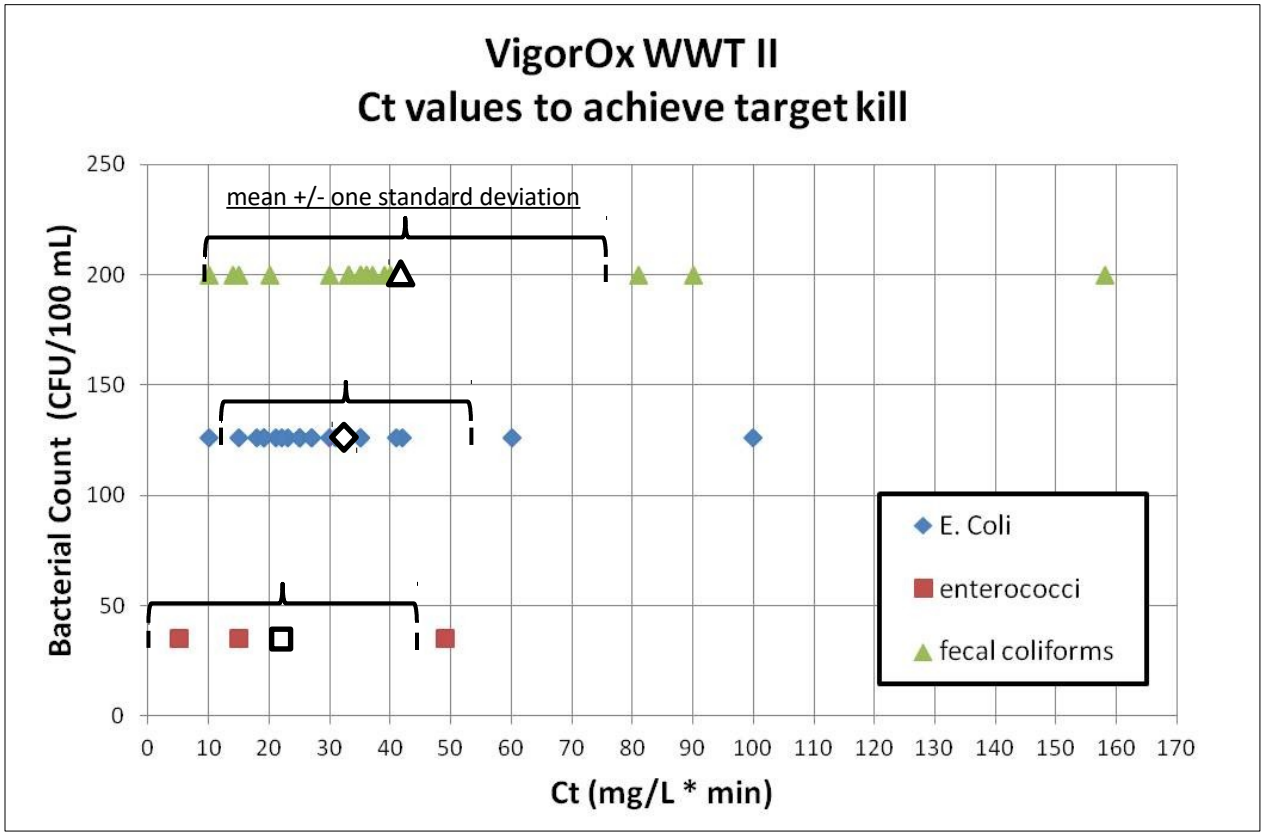
VigorOx® WWT II
Wastewater Disinfection Technology

Disinfection Efficiency



Data from VigorOx WWT II on 57 secondary effluents.
Range of Ct values reflects **site-specific PAA kinetics**.

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Efficacy – Indicator Organism

Matrix	Organism	Inactivation (log)	Dose (mg/L)	Time (minutes)	Reference
Secondary effluent	Total coliform	2	1.5	20	Zanetti et al., 2007
Secondary effluent	Total coliform	2	2	16	Stampi et al. 2002
Secondary effluent	Total coliform	3	2	27	Koivunen et al,. 2005
Secondary effluent	Total coliform	4	1.5	20	Stampi et al., 2001
Secondary effluent	Total coliform	4	3	15	Madoni et al., 1998
Secondary effluent	Fecal coliform	3	2	16	Stampi et al. 2002
Secondary effluent	*E. coli*	2	1.5	20	Zanetti et al., 2007
Secondary effluent	*E. coli*	3	2	16	Stampi et al. 2002
Secondary effluent	*E. coli*	4	1.5	20	Stampi et al., 2001
Secondary effluent	*E. coli*	3	4	10	Dell'Erba et al., 2004
Secondary effluent	Enterococci	4	3	15	Madoni et al., 1998
Secondary effluent	Enterococci	2	2	16	Stampi et al. 2002
Secondary effluent	Enterococci	4	1.5	20	Stampi et al., 2001

PAA's efficacy against bacteria has been well documented

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Wastewater Disinfection Technology

Drivers for Conversion

Cl_2 / NaOCl Toxicity	Peracetic Acid does not require quenching
Cl_2 / NaOCl DBPs	Peracetic Acid does not produce disinfection byproducts
Cl_2 Safety	Peracetic Acid does not require a Risk Management Plan
UV Performance	Peracetic Acid effective in low UVT and peak flows
UV Capital Cost	Peracetic Acid is a no-capital cost full service solution

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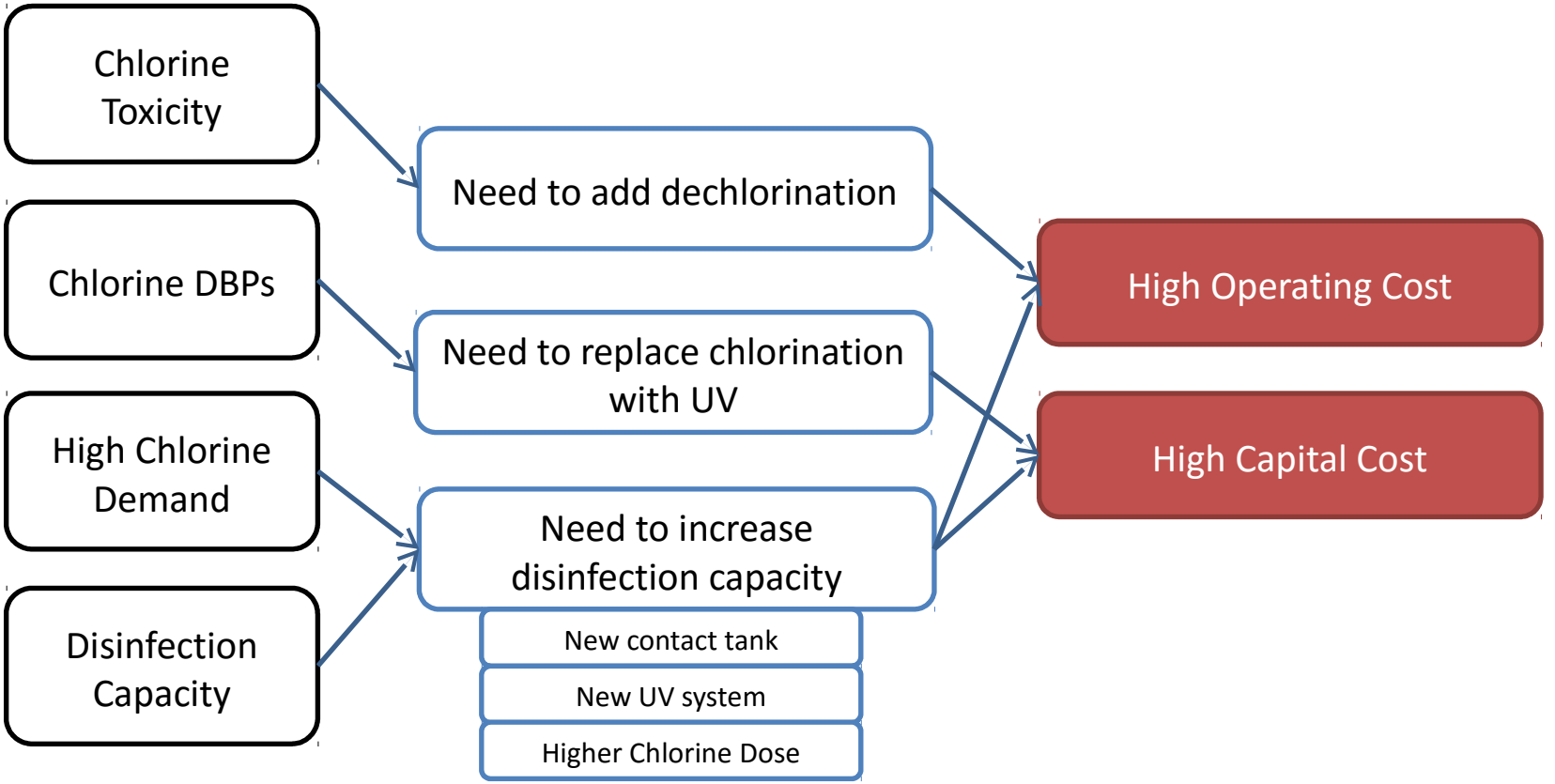
Drivers for Conversion to PAA



PAA can be the most economical disinfection alternative

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Wastewater Disinfection Technology

Drivers – Chlorine Toxicity

Issue	Trigger	Examples
Chlorine present in effluent is toxic to aquatic life in receiving water	New Residual limit: • Chlorine: 0.01 mg/L	• ON1 (1.5ppm PAA) • CA2 (1.0ppm PAA) • IL1 (1.0ppm PAA) • FL1 (1.5ppm PAA)

Assessment of Alternatives

	Cl2 + SBS	UV	VigorOx (PAA)
Operating Cost	2 Chemicals $$	Power, Lamp/Ballast $$	1 Chemical $$
Capital Cost	Tank, Pump, Controller $$	System, Concrete $$$$	Tank, Pump, Controller *N/A*

PAA does not require quenching due to its low toxicity

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Drivers – Chlorine DBPs

Issue	Trigger	Examples
Chlorine reacts with organics in effluent and produces toxic and carcinogenic compounds	New DBP limit: • TTHM: <60 ppb (CA) • NDMA: 0.1 ppb (CA)	• CA1 (8.0ppm PAA) • FL2 (1.0ppm PAA)

Assessment of Alternatives

	~~Cl2 (FL)~~	UV	VigorOx (PAA)
Operating Cost		Power, Lamp/Ballast $$	Chemical $$
Capital Cost		System, Concrete $$$$	Tank, Pump, Controller *N/A*

PAA does not produce TTHMs, Cyanide or NDMA

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Drivers – Chlorine Demand

Issue	Trigger	Examples
Low effluent quality results in extremely high chlorine doses (>40ppm) or low UV transmittance	• High Operating Cost • Risk of non-compliance on: Residual, DBP, Bacterial Count.	• TN2 (12ppm PAA) • WA1 (10ppm PAA) • CA3 (8ppm PAA)

Assessment of Alternatives

	Cl2	UV	VigorOx (PAA)
Operating Cost	Chemical $$$	Power, Lamp/Ballast $$$*	Chemical $$
Capital Cost	Existing	System, Concrete $$$$	Tank, Pump, Controller *N/A*

PAA requires lower doses and shorter contact times than chlorine

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Drivers – Capacity

Issue	Trigger	Examples
Current system (UV or Chlorination) does not have the capacity to meet Bacterial limit	New Bacterial limit: • from 200 to 23 cfu / 100ml	• TN1 (12ppm PAA) • TX1 (3.5ppm PAA) • CA2 (1ppm PAA)

Assessment of Alternatives

	Cl2	UV	VigorOx (PAA)
Operating Cost	Chemical $$	Power, Lamp/Ballast $$	Chemical $$
Capital Cost	New Contact Channel $$$$	System Expansion $$	Tank, Pump, Controller *N/A*

PAA can improve existing UV or work with existing contact tank

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PART 3

Case Studies

- Florida
- New Jersey
- Tennessee
- Texas
- Illinois
- Oregon
- Kentucky

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St Augustine, FL

Plant Information	
Effluent Source	Municipal
Average Flow	3.5 MGD
Peak Flow	5.0 MGD
Previous Disinfection	Chlor/Dechlor

Conversion to VigorOx WWT II	
Conversion Driver	DBP, Toxicity
Conversion Date	Sep 2011
VigorOx System	Bulk

Disinfection Performance	
Average Dose	1.5 ppm
Average Contact Time	30min
Indicator	F.C. /Entero
Limit	200/35cfu/100ml

Toxicity	
Receiving water body	Matanzas River
Maximum Residual:	1.0 ppm

4 years of continuous use!

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Hoboken, NJ

Plant Information	
Effluent Source	Municipal
Average Flow	10 MGD
Peak Flow	20 MGD
Previous Disinfection	UV

Conversion to VigorOx WWT II	
Conversion Driver	UV Performance
Conversion Date	Nov 2015
VigorOx System	Tote

Disinfection Performance	
Average Dose	2.5 ppm
Average Contact Time	2 min
Indicator	Fecal Coliform
Limit	200 cfu/100ml

Toxicity	
Receiving water body	Hudson River
Maximum Residual:	N/A

Achieved compliance after peracetic acid injected upstream aging UV

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Memphis, TN

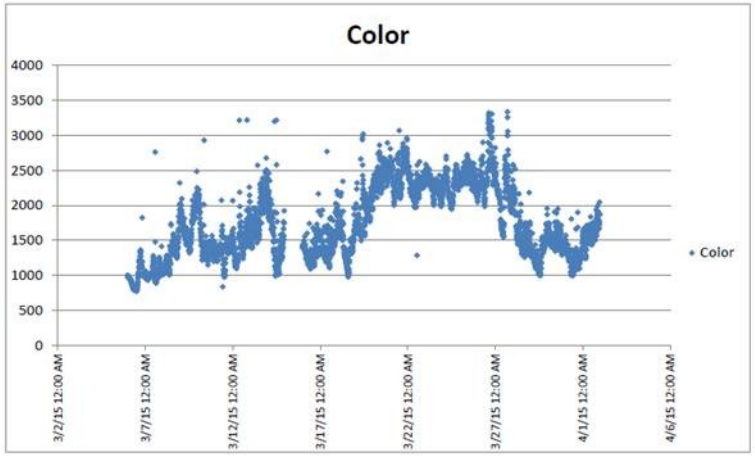
Plant Information	
Effluent Source	Muni + Industrial
Average Flow	90 MGD
Peak Flow	200 MGD
Previous Disinfection	-

Conversion to VigorOx WWT II	
Conversion Driver	Cost
Conversion Date	2017
VigorOx System	Bulk

Disinfection Performance	
Average Dose	12 ppm
Average Contact Time	45 min
Indicator	E. coli
Limit	126 cfu/100ml

Toxicity	
Receiving water body	Mississippi River
Maximum Residual:	2.0 ppm

Automated Demand Control



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Tullahoma, TN

Plant Information	
Effluent Source	Municipal
Average Flow	3 MGD
Peak Flow	7 MGD
Previous Disinfection	Cl2 / SO2

Conversion to VigorOx WWT II	
Conversion Driver	Toxicity / Safety
Conversion Date	2016 (trial in 2014)
VigorOx System	Tote

Disinfection Performance	
Average Dose	0.75 ppm
Average Contact Time	45 min
Indicator	E. coli
Limit	126 cfu/100ml

Toxicity	
Receiving water body	Rock Creek (DF=1)
Maximum Residual	TBD

Low Toxicity in Small Stream

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Pasadena, TX

Plant Information	
Effluent Source	Industrial
Average Flow	15 MGD
Peak Flow	45 MGD
Previous Disinfection	Chlor / Dechlor

Conversion to VigorOx WWT II	
Conversion Driver	Contact Tank Cost
Conversion Date	2014
VigorOx System	Bulk

Disinfection Performance	
Average Dose	3.5 ppm
Average Contact Time	15 min
Indicator	E. coli
Limit	126 cfu/100ml

Toxicity	
Receiving water body	Bayou Channel
Maximum Residual	N/A

Shorter Contact Time

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Mundelein, IL

Plant Information	
Effluent Source	Municipal
Average Flow	1.0 MGD
Peak Flow	5.0 MGD
Previous Disinfection	Chlorination

Conversion to VigorOx WWT II	
Conversion Driver	Dechlor Cost
Conversion Date	2015
VigorOx System	Tote

Disinfection Performance	
Average Dose	0.5 ppm
Average Contact Time	120 min
Indicator	F. Coliforms
Limit	200 cfu/100ml

Toxicity	
Receiving water body	Des Plaines River
Maximum Residual	1.0 ppm

Avoid Cost and Complexity of De-chlorination

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Clackamas, OR

Plant Information	
Effluent Source	Municipal
Average Flow	7 MGD
Peak Flow	12 MGD
Previous Disinfection	Chlor/Dechlor

Conversion to VigorOx WWT II	
Conversion Driver	Safety & Cost
Conversion Date	2014
VigorOx System	Tote to Bulk

Disinfection Performance	
Average Dose	1.5 ppm
Average Contact Time	60 min
Indicator	E. coli
Limit	126 cfu/100ml

Toxicity	
Receiving water body	Willamette River
Maximum Residual:	1.0 ppm

Chlorine Safety Concerns
Elimination of RMP

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Mayport Naval Station, FL

Plant Information	
Effluent Source	Ships & Vessels
Average Flow	2 MGD
Peak Flow	4 MGD
Previous Disinfection	Chlor/Dechlor

Conversion to VigorOx WWT II	
Conversion Driver	DBPs
Conversion Date	2015
VigorOx System	Tote to Bulk

Disinfection Performance	
Average Dose	2.5 ppm
Average Contact Time	60 min
Indicator	F.C./Enterococci
Limit	200/35 cfu/100ml

Toxicity	
Receiving water body	St, John's River
Maximum Residual:	1.0 ppm

Elimination of DBPs

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Bowling Green, KY

Plant Information	
Effluent Source	Municipal
Average Flow	7 MGD
Peak Flow	15 MGD
Previous Disinfection	UV

Conversion to VigorOx WWT II	
Conversion Driver	UV Operating Cost
Conversion Date	2015
VigorOx System	Tote

Disinfection Performance	
Average Dose	1.3 ppm
Average Contact Time	20 min
Indicator	E. coli
Limit	126 cfu/100ml

Toxicity	
Receiving water body	Barren River
Maximum Residual	1.0 ppm

Replaced UV System – O&M

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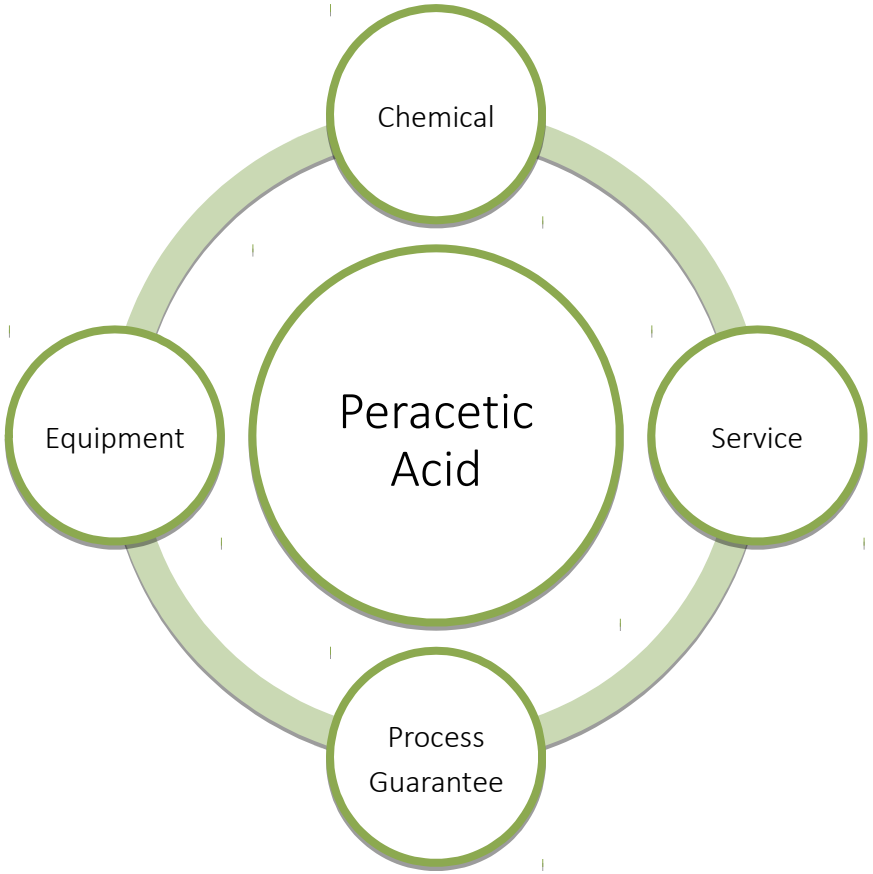
PART 4

Conversion Path

- Testing, Piloting and Trialing
- Process Modeling
- Compliance



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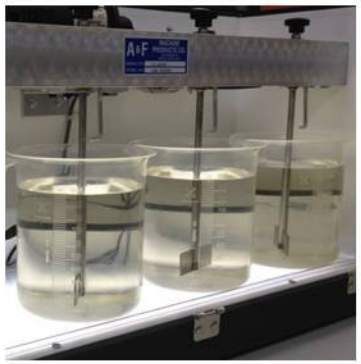
Conversion Steps



FINAL EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

Bench Test → Pilot → Full Scale Trial → Permit Change → Installation & Startup

Regulator

Regulator

Regulator

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Pilot Reactor Trialing

PeroxyChem's Disinfection Pilot Reactor (DPR) enables side-stream testing to measure effectiveness at different dose rates under varying effluent quality conditions.

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On-line Residual Analyzer

Amperometric,

Membrane-electrode

Submersible Probe enables automatic PAA dose control.

Third-party validated.

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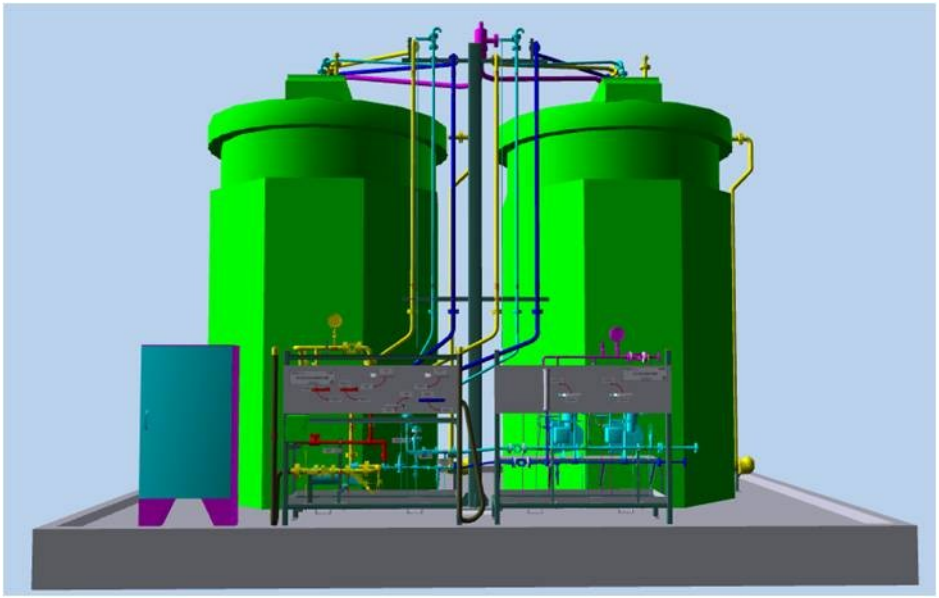
PART 5

Equipment & Implementation

- Bulk Systems
- Tote Systems



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Implementation – Storage

Bulk Storage Considerations

- Acceptable materials include:
  - HDPE Linear (5yr max)
  - Passivated SS-304L
- Containment required (double wall acceptable)
- Product shelf life (C >15%)
    - 1 year, T < 86 ˚F
    - 4 months, T < 100 ˚F
    - 1 month, T < 110 ˚F
- Free-lift emergency relief manway and conservation vent
- Avoid overflow lines
- Unique quick connect for fill line (avoid contamination)
- Consider all local codes and regulations

Safety Considerations: containment, materials, venting, connections

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Wastewater Disinfection Technology

Implementation – Storage

Tote Storage Considerations

- Containment required
- Never store on wooden pallets
- Do not store near reducing agents or combustibles (20 ft minimum distance)
- Do not block vents
- Indoor Storage
  - Ventilation of 1 $ft^3/min/ft^2$
- NFPA classification
  - Class IV Organic Peroxide
  - Does not support a flame
- Electrical
  - Intrinsically safe recommended for areas that are not well ventilated

Safety Considerations: containment, materials, venting

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Implementation – Pumps

Pump Skid Considerations

- Duty and Redundant
- Peristaltic, Diaphragm or Solenoid acceptable
- Off-gas valve required at pump head for diaphragm and solenoid pumps
- Wetted Materials
  - Passivated 304L SS
  - Teflon
  - Santoprene™ (peristaltic pumps)
- Controller
  - Flow-paced
  - Compound loop
- Containment Required

Safety considerations: redundancy, venting, containment, materials

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Implementation – Piping

Piping Considerations

- Compatible wetted materials of construction (Teflon / 304SS)
- Vented ball valves
- Pressure relief valves to prevent PAA entrapment
- Dilution water / Flush line
- Flex Connections for Tanks / Totes / Pumps
- Gaskets
  - GORE-TEX®
  - Teflon
  - Garlock Gylon® Style 3504
- Thread sealant
  - White Teflon Tape (Do not use anti-galling tape)
  - Fluorolube®

Safety considerations: venting, materials, flushing, flex connections

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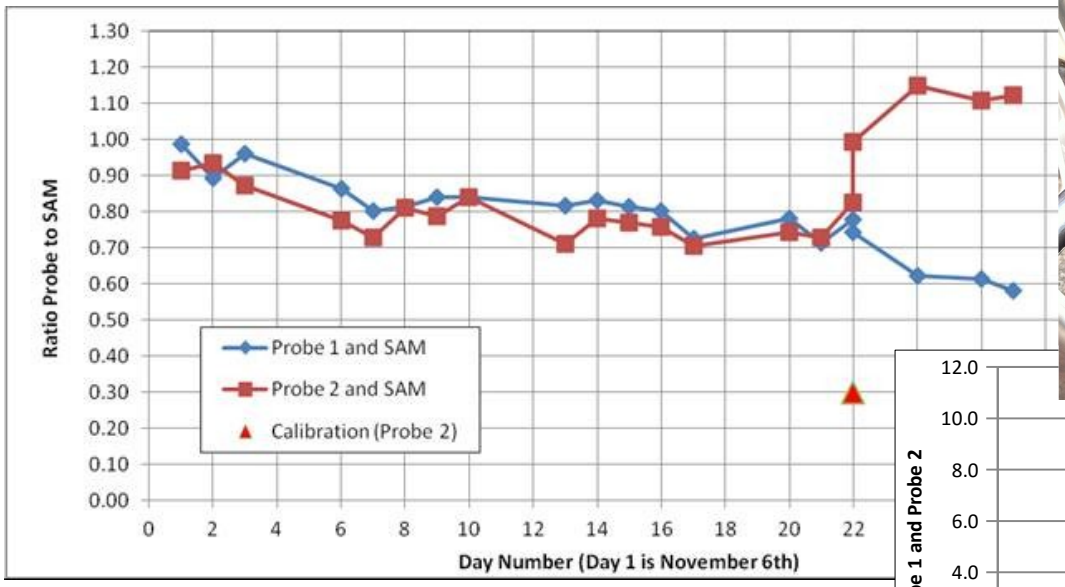
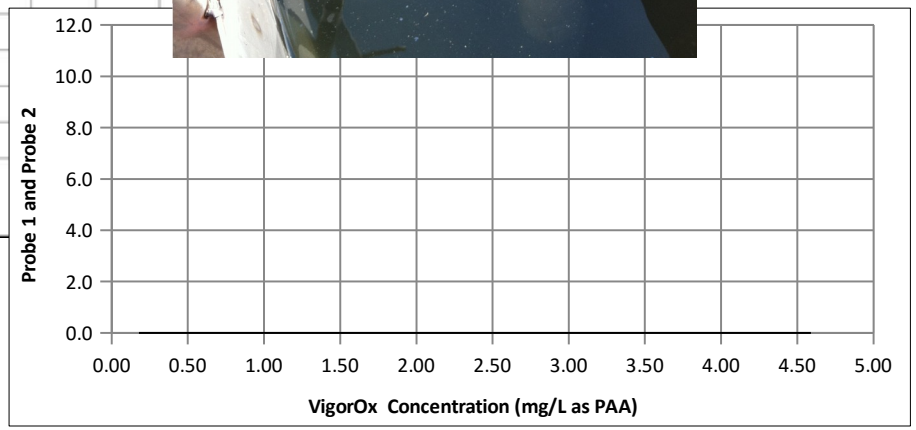
Implementation – Control





On-line residual measurement makes compound loop control possible for PAA

New generation submersible probes validated for VigorOx

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Wastewater Disinfection Technology

Implementation – Low Temp

Freezing Point:

- VigorOx WWT II -56˚F
- Sodium Hypochlorite -20˚F
- Sodium Bisulfate 43˚F

No heat-tracing required with PAA

Low freezing point makes PAA ideal for cold weather applications

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Methods of Chemical Supply

- Bulk deliveries of 4,000 gallons
- 300 gallon IBC totes
- 55 gallon drums.

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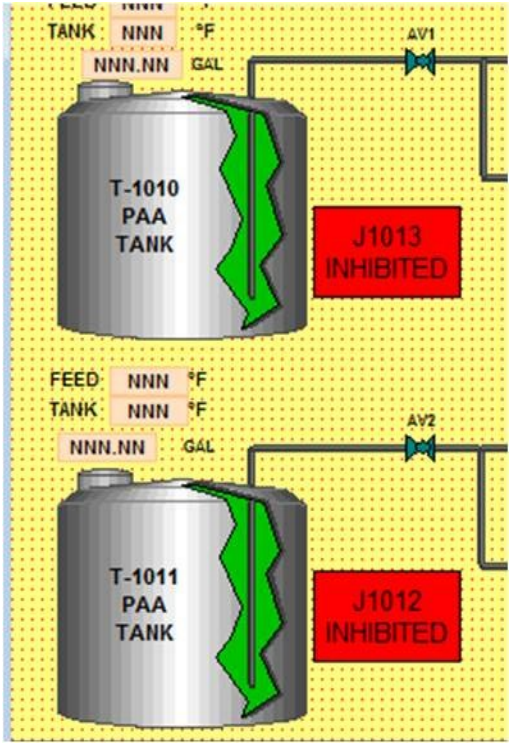
Methods of Supply



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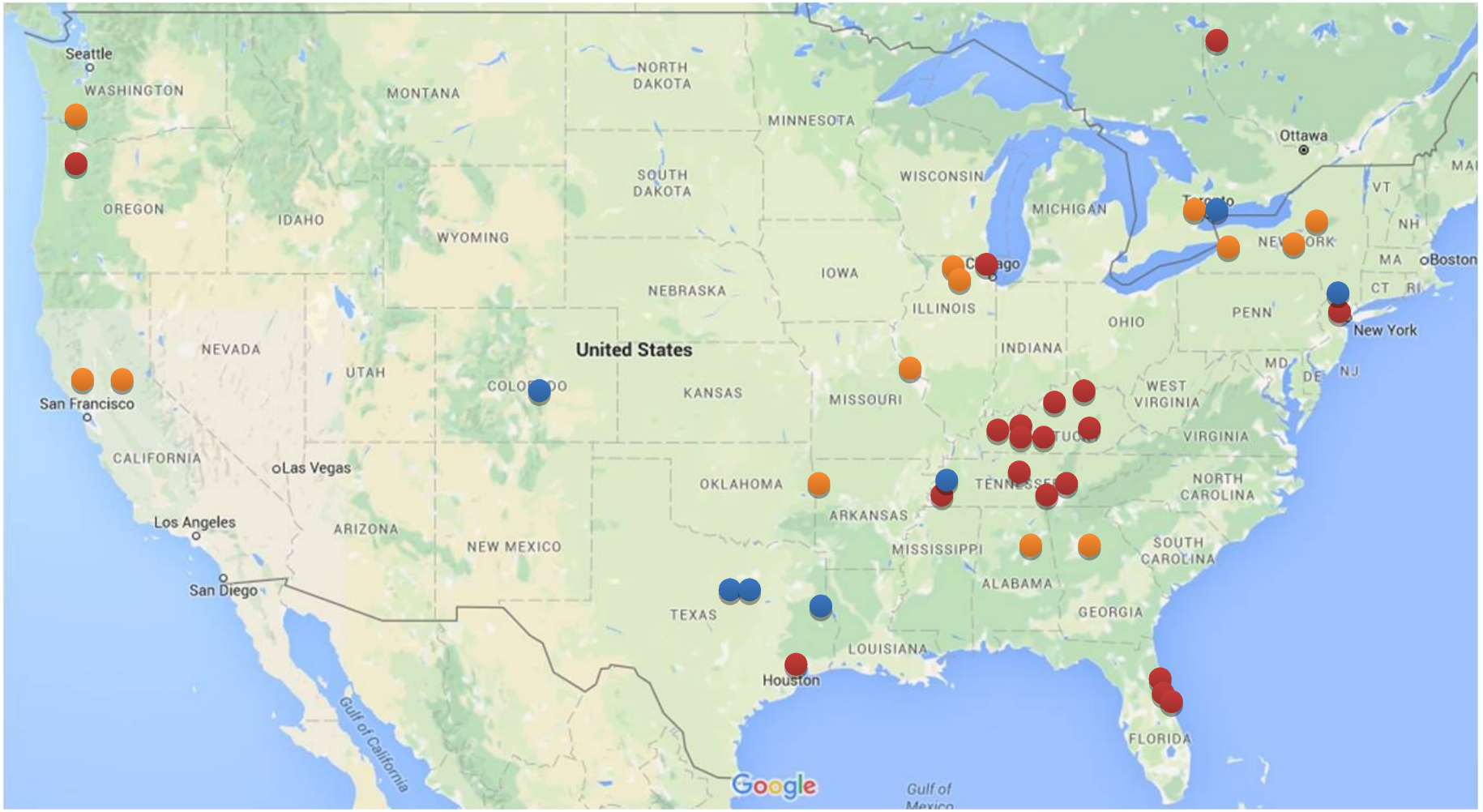
Experience



CONVERSION FULL SCALE TRIAL PILOT TRIAL

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Experience in OH.

- One replacement of Sodium Hypo, Steubenville, OH
- Ohio EPA position: currently the same as Chlorine low residual and ergo quenching required
- Pilot Testing in Cincinnati, OH
  - Acute toxicity testing
  - E Coli disinfection
  - CT evaluation

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Questions? Comments?

Pelton Environmental Products
Email: EPelton@PeltonEnv.com
Phone: 440-838-1221

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