WATER QUALITY SOLUTIONS

SWRO Pretreatment

by

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Global Product Manager, Desalination

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April, 2013

1924 - F.B. Leopold Establishes Company

1942 - F.O. Leopold Moves Company to Zelienople, PA

Company sold by Leopold family in 1972

2004 – Leopold celebrated 80th Anniversary

June 2006 – ITT Acquires Leopold

November 2011, ITT changes name to Xylem

Leopold Headquarters:	Zelienople, PA, USA
Manufacturing:	Zelienople, PA – Products
	Ontario, Canada - Products
	Watsontown, PA – Anthracite
Sales Offices:	Zelienople, PA – Americas
	United Kingdom – EU
	Dubai, UAE – Middle East
	Singapore – Asia Pacific

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Capabilities

- Extensive Experience
- Over 9,000 installations worldwide
- Full Engineering Design Services
- Computational Fluid Dynamics (CFD) Analysis
- Research & Development (PDC)
- Field Services
- Variety of Pilot Facilities
- DAF, Filtration, Denitrification, Desalination PT
- Gold Tag Service

The Desalination Process

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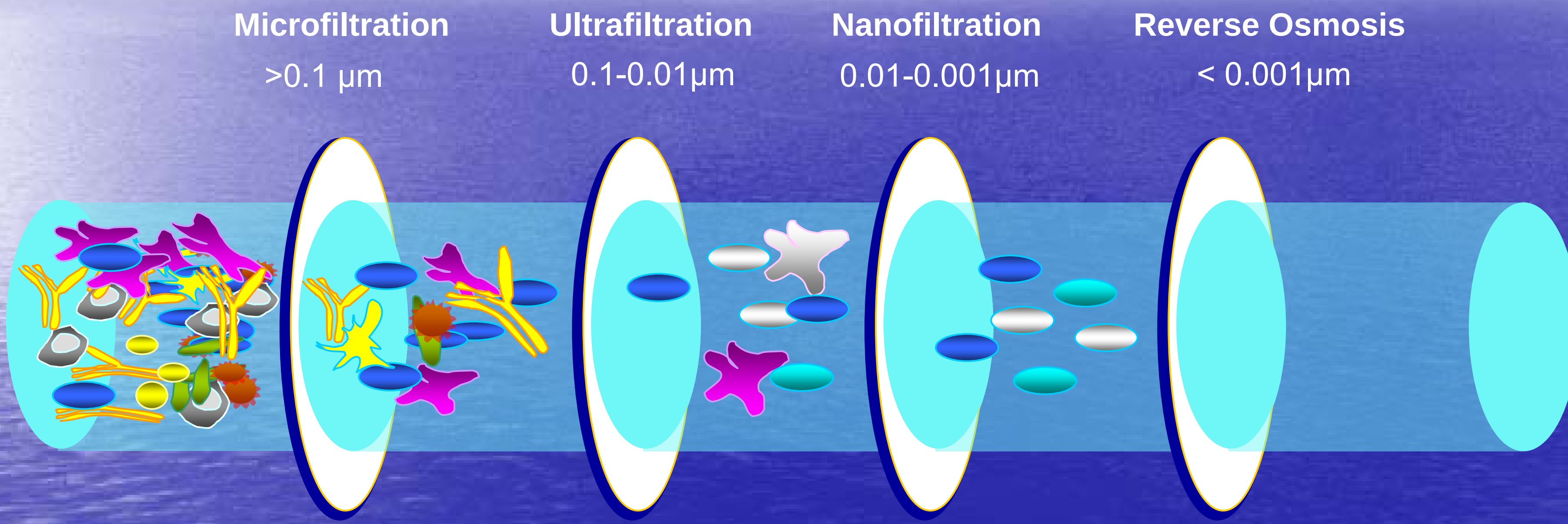

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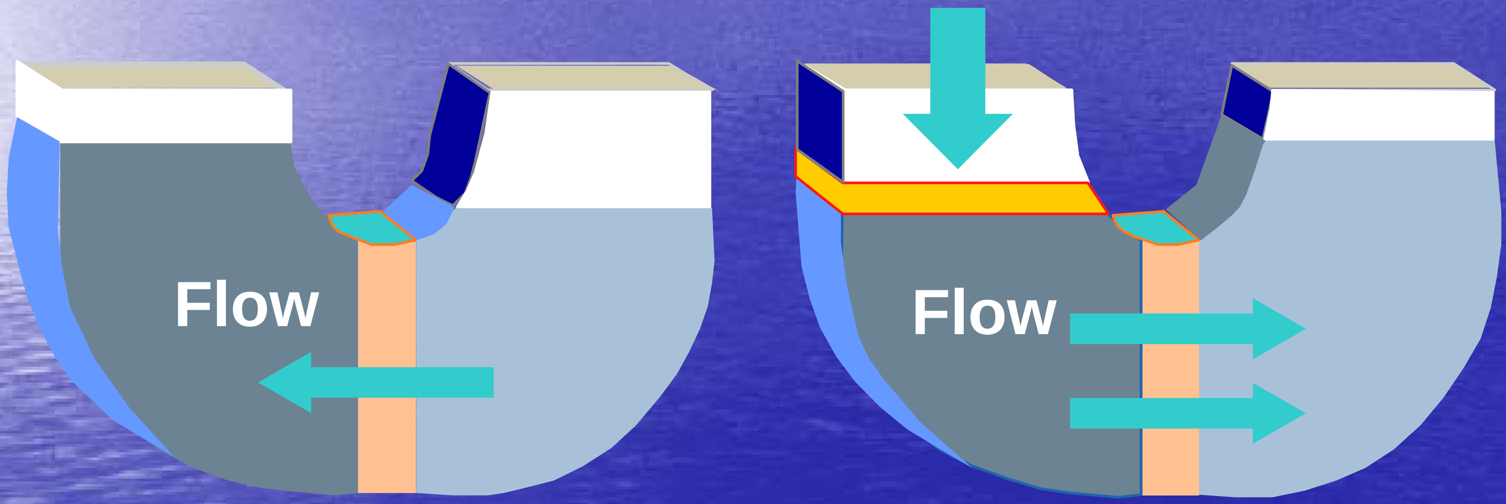
Reverse
Osmosis

Applied Pressure

Osmosis



Concentrated Solution

Membrane

Dilute Solution

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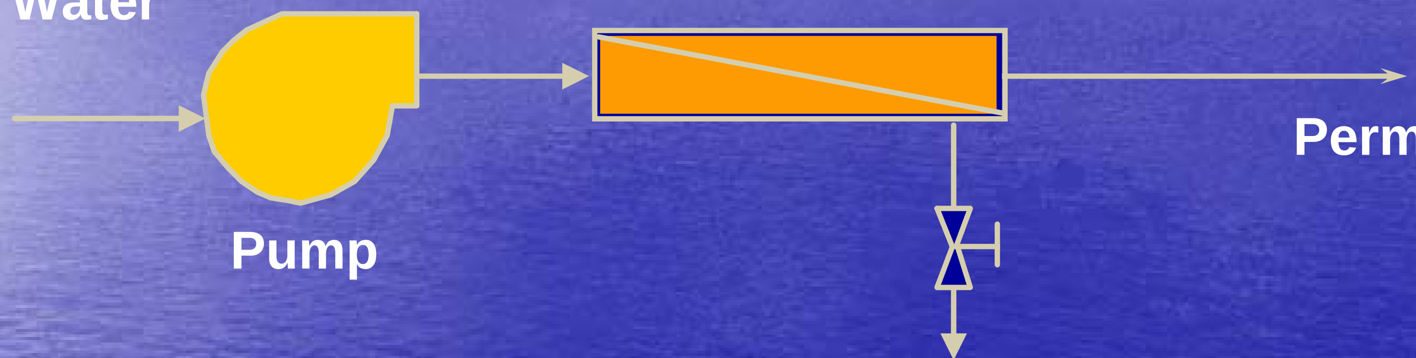
Simple RO System



Recovery Rate = P flow/F flow
Salt Rejection = 1-(P tds/F tds)
Pressure Drop = F pressure- C pressure

Facts: RO Membranes

- Pore Size of 0.0005 micron
- Removes *Salt & Soluble ions*
- Low Flux rate: 10-30 GFD
- Concentrate multiplies problem
- Permeate usually not degraded by poor feed water
- Low Recovery Rate: 30-40%
- High pressure: 55-76 bar
- Fails due to inadequate pretreatment

Membrane Fouling

Physical

- Deposits/entrapped particles on surface and into membrane pores

Biological

- Colonies which grow into slime deposits in feed spacer

Poor or no pre-treatment can result in

Lower Recovery Rates

Higher waste volumes to handle

Less finished water to provide customer

Lower Flux Rates

Higher capital costs for additional membranes

Larger foot print for treatment facility

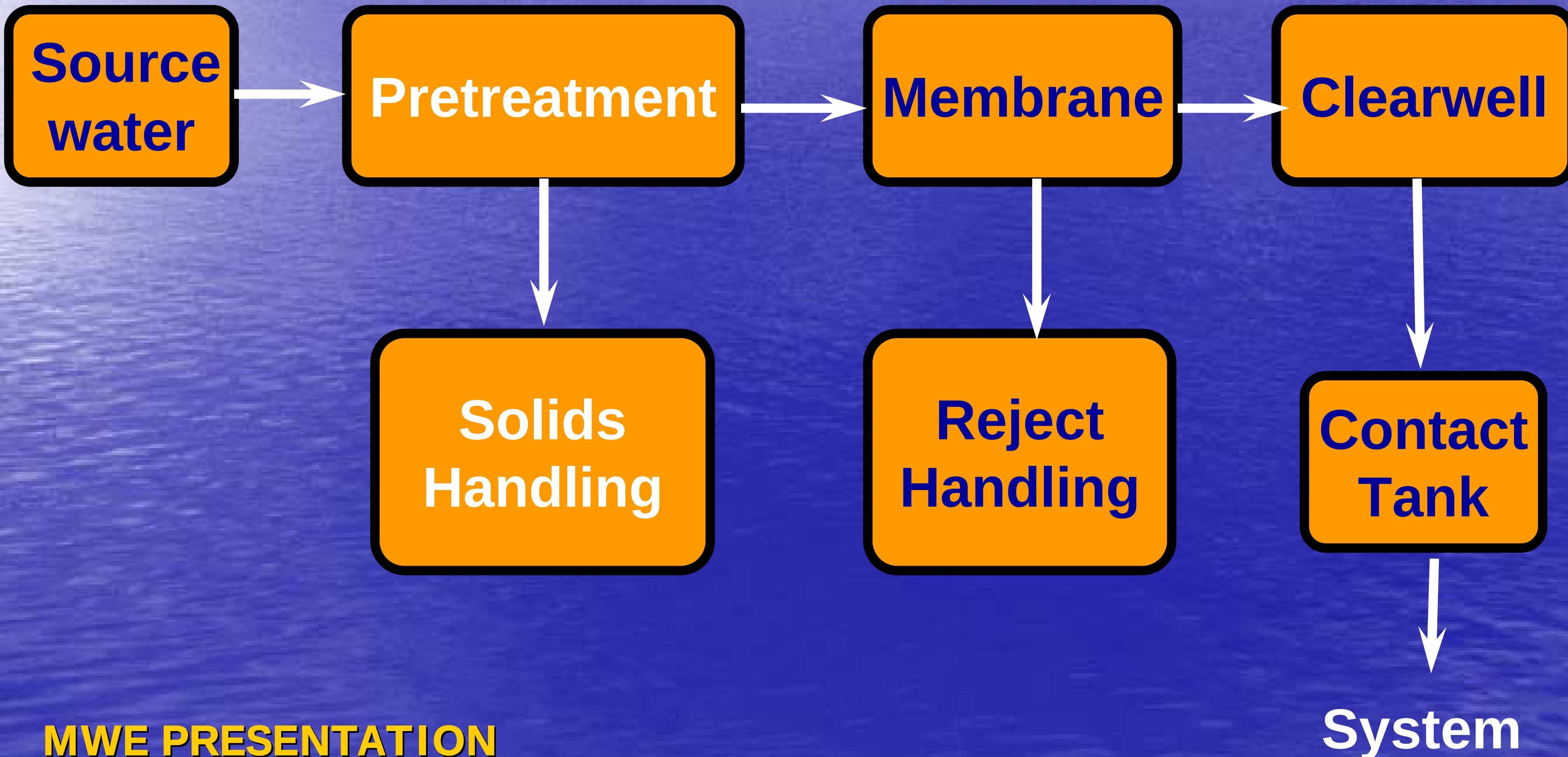
Increased Operational Cost

Increased pressure - higher energy cost

Requires more cleaning – more chemicals

Reduces membrane life – capital replacement

Ideal Membrane Water Treatment Scheme



Pretreatment Options

RO Membranes

Acid/scale inhibitor

Media filtration

Clarification/filtration

Cartridge filter

Membrane Pretreatment

- Every raw water is different
- Combination of factors can cause failures
- Must be reliable and consistent
- Need to solve problem early
- Multi-Barrier Approach
- Insurance Policy

Membrane Pretreatment *Provides*

- Consistent water quality to the membranes
  - Removal of potential foulants
  - Solids that are easily processed

Would Like to have:

- Minimize footprint – high m/hr loading rate

Clari-DAF^{TM} System

- Produces Consistent Water Quality Effluent
- Produces Consistently High Sludge Solids
- High loading – m/hr

Impact of Clari-DAF System Pretreatment

Effluent Water Quality

- Higher Flux Rate
- Reduced Cleaning
- Higher Recovery Rate
- Protect Membrane
- Uses **NO POLYMER**

Solids Handling

- Less volume of sludge
- Less time to dewater
- Lower chemical cost
- Higher cake solids
- Lower disposal cost

Membrane Pretreatment Flotation Applications

-Algae laden waters -
-Red tide

- Organics
- Colloidal and Suspended Solids

-Soluble Metals – Fe, Mn, Al
-Free Oil & Grease
•Cold water

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Stoke's Law

$$V = \frac{G\,(P1 - P2)\,D^2}{18\,u}$$

- V = Velocity -Time to Settle/Float
- G = Gravity
- P1 = Particle Density
- P2 = Liquid Density
- D = Diameter of the Particle
- u = Viscosity of the Liquid

Coagulant/Polymer Addition

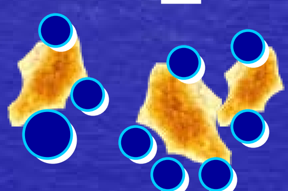
Gravity Settling

SIZE: <u>Hundreds</u> of Microns

SIZE: <u>Tens</u> of Microns

Buoyancy Flotation

Particle Size Difference



Bubble Addition

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- To develop solid process knowledge with regard to red tide / Harmful Algae Bloom removal, Leopold contracted an expert in red tide algae to grow Cochlodinium Polykrikoids, a prevalent red tide species, to concentrations of 0.5M, 1M, and 5M cells/L.
    - The Clari-DAF® process achieved excellent removal rates(>90%) at all feed concentrations.
    - Leopold developed a matrix of chemical dosing regimes that form the basis of sound process guarantees for our customers along with anticipated chemical consumption rates.
    - Based on these experiments, Leopold optimized the Clari-DAF mechanical design to minimize capital costs while maximizing algae removal efficiencies.

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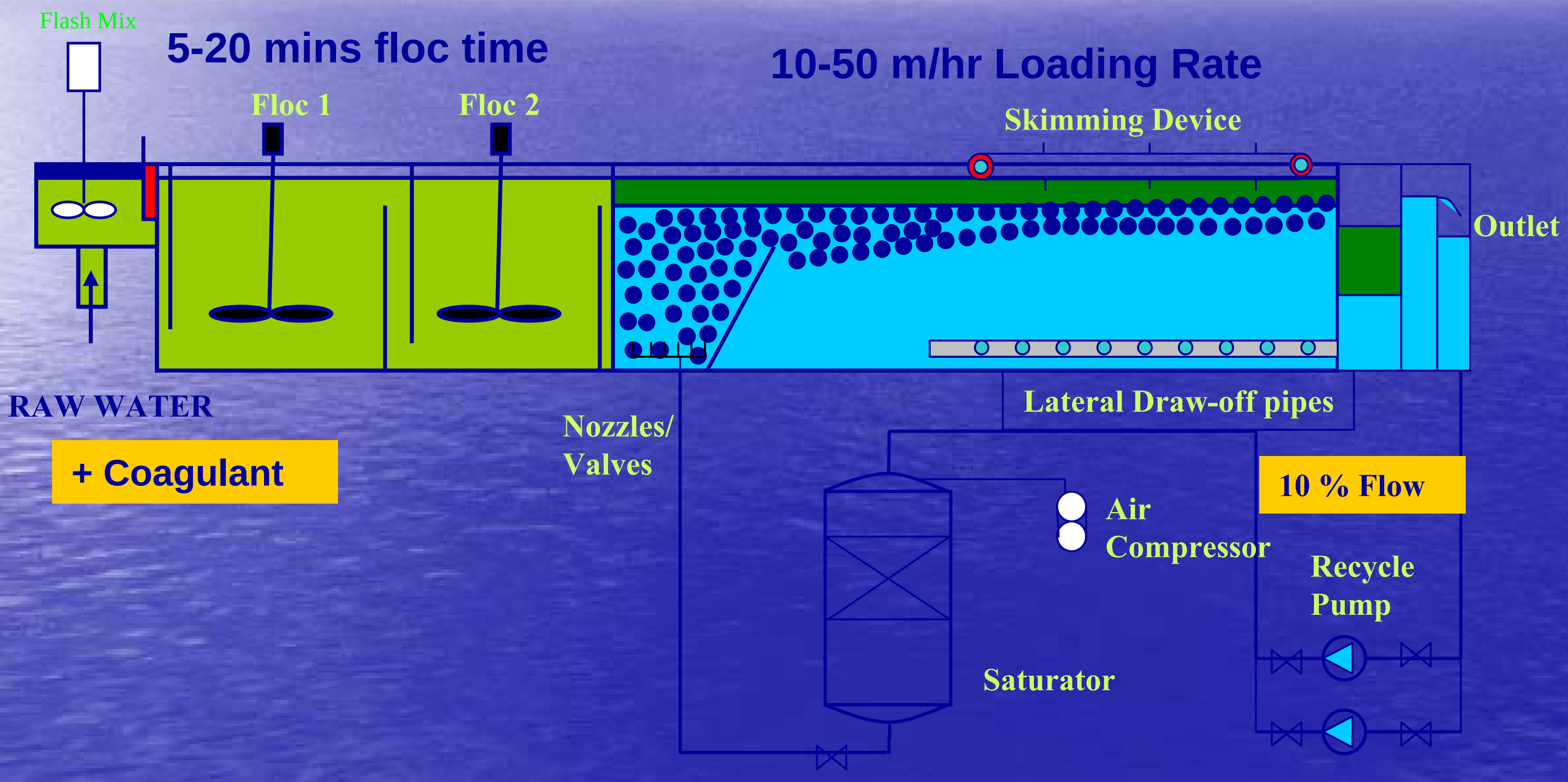
How does it Work ?



Compressed Air dissolved in water at 5.5 bar

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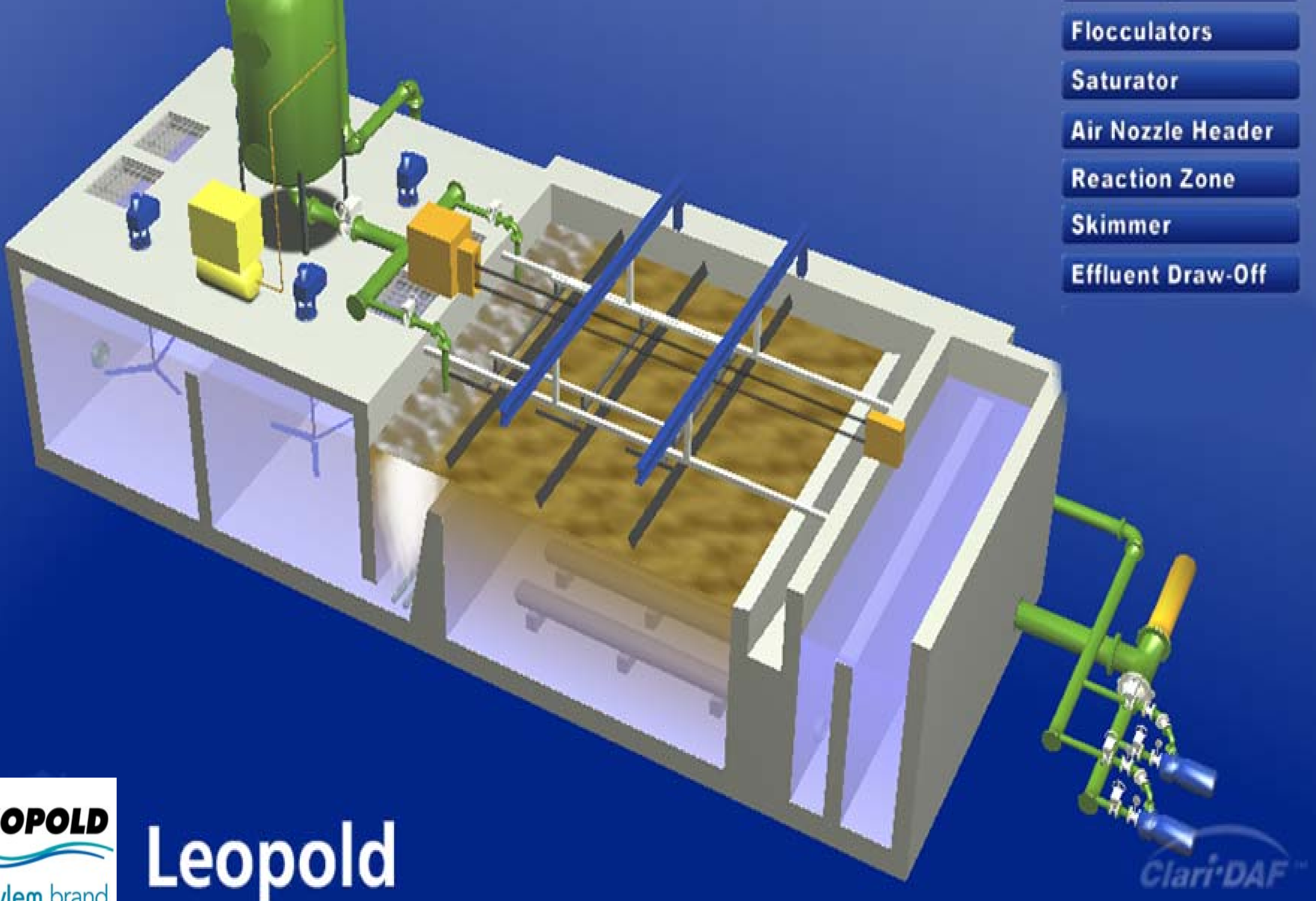

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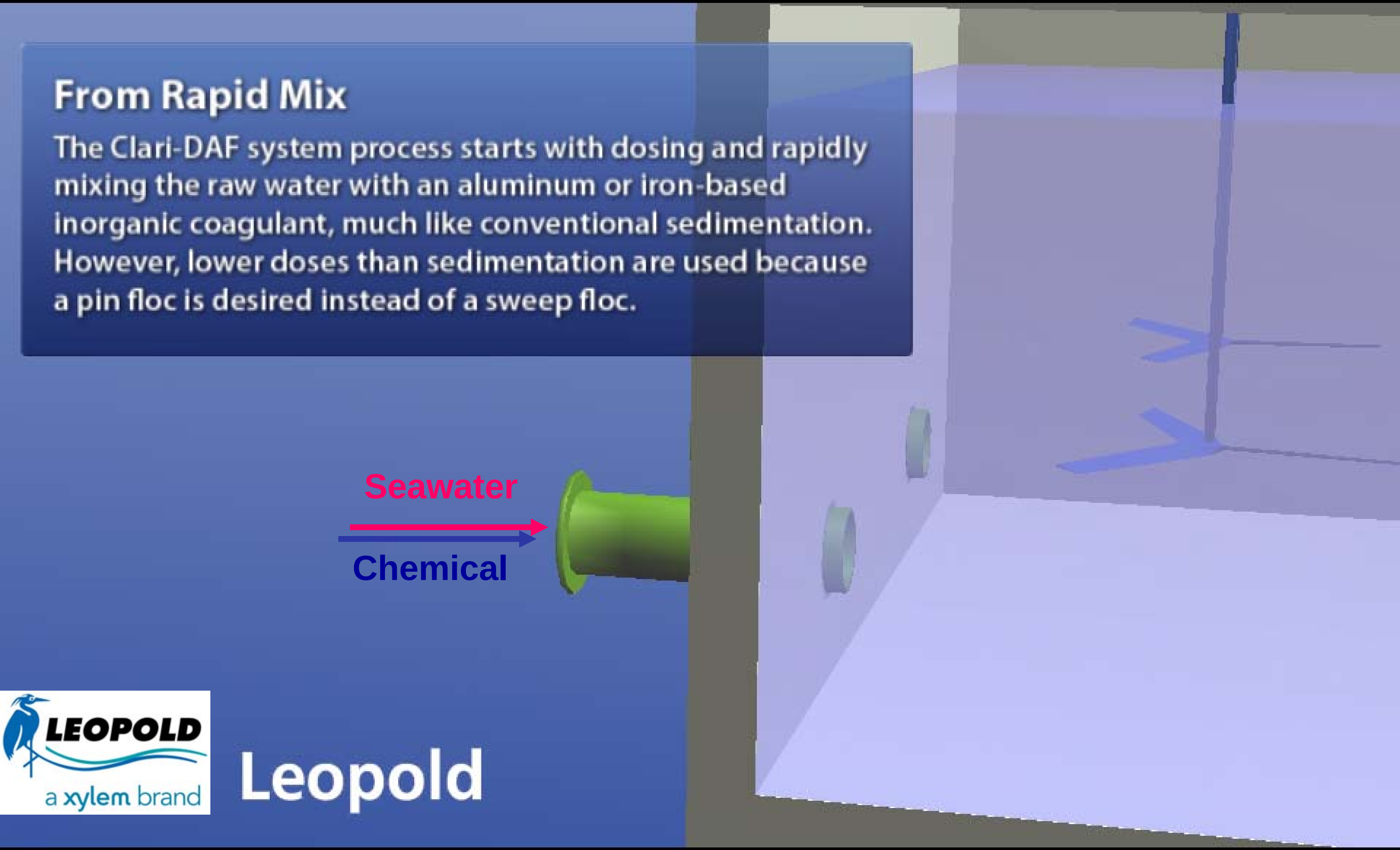
Rapid Mix


From Rapid Mix
The Clari-DAF system process starts with dosing and rapidly mixing the raw water with an aluminum or iron-based inorganic coagulant, much like conventional sedimentation. However, lower doses than sedimentation are used because a pin floc is desired instead of a sweep floc.
Seawater
Chemical
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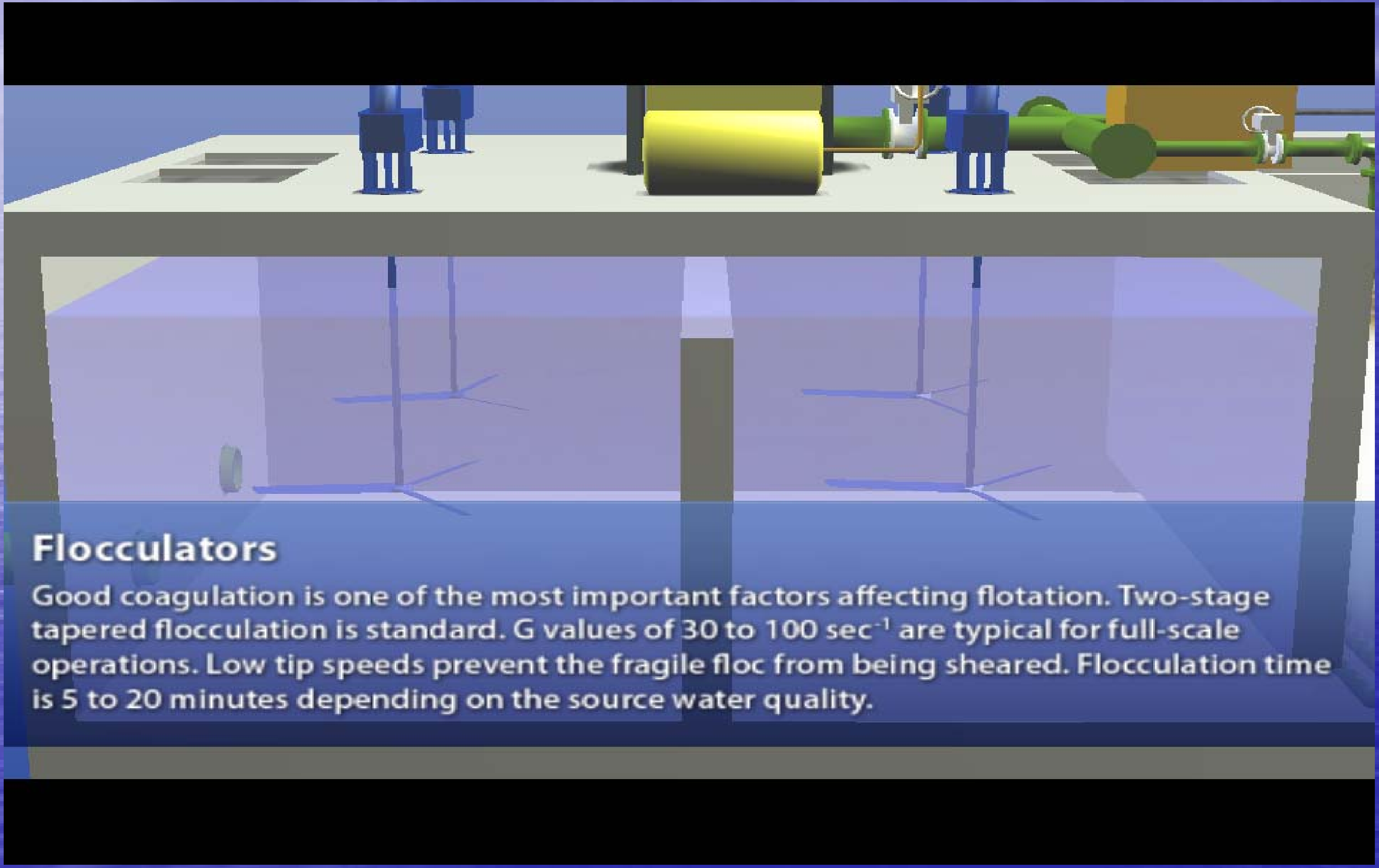
Flocculators



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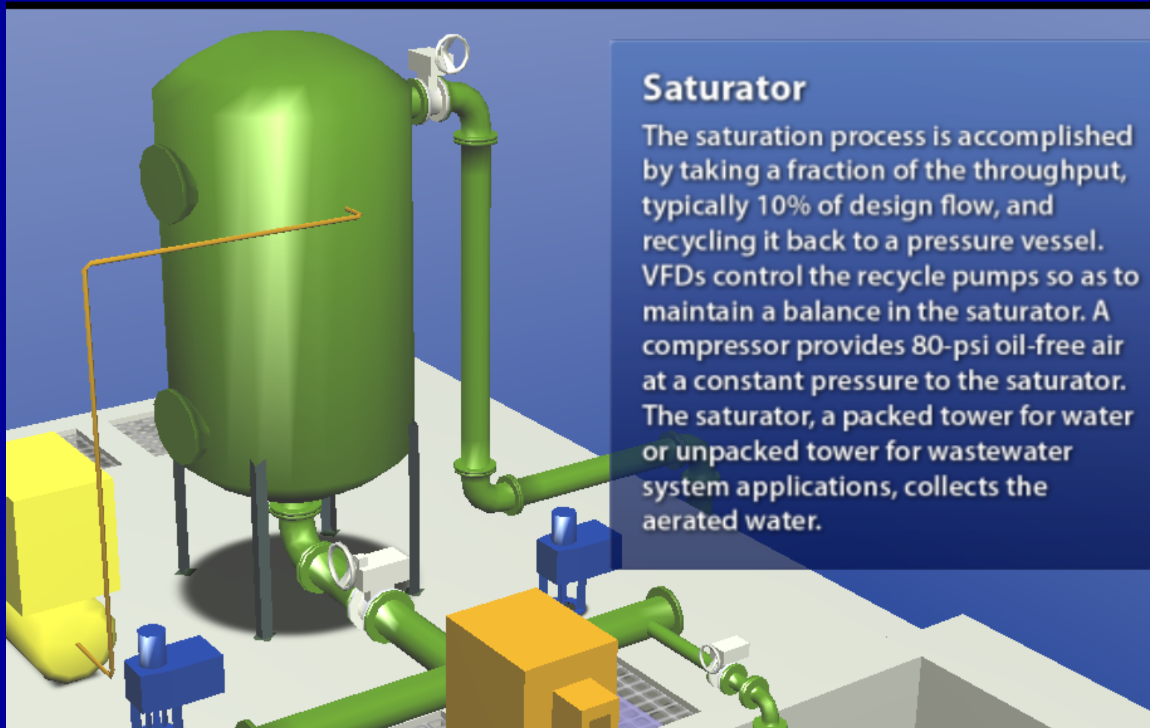
Saturator



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Dispersion Header Pipe

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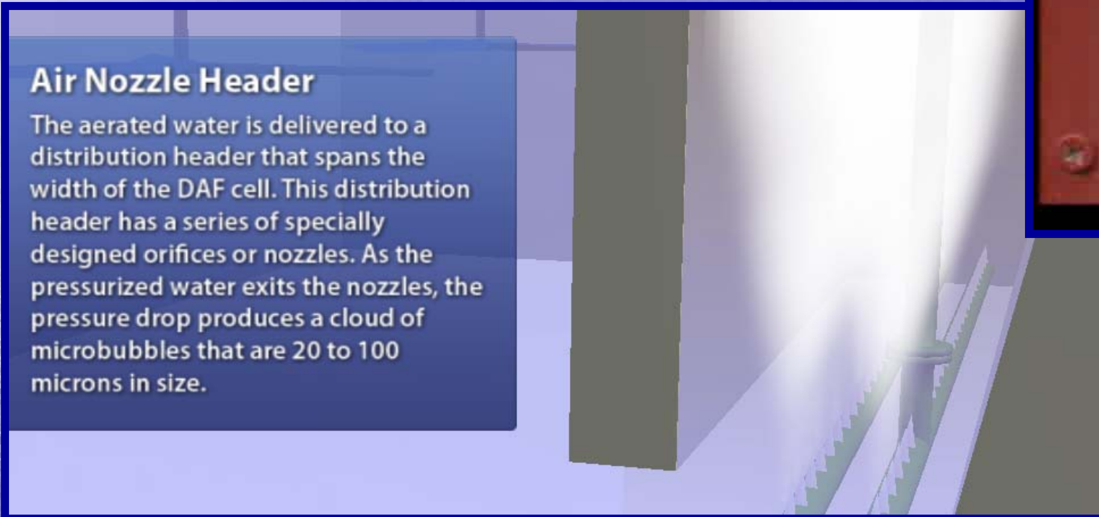
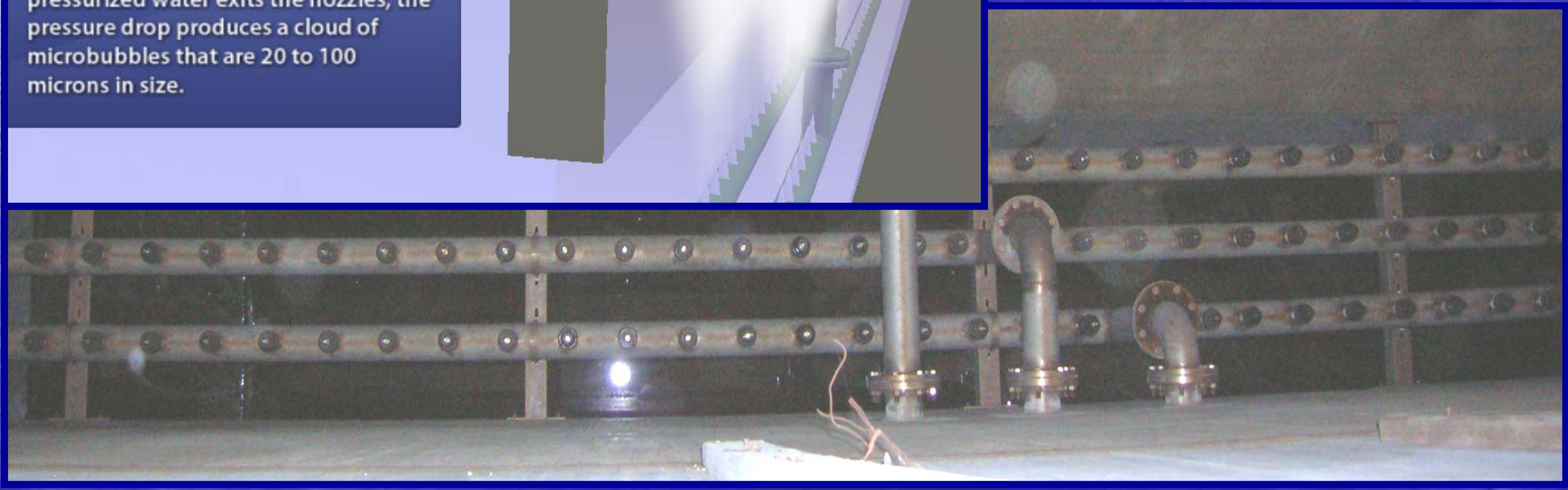
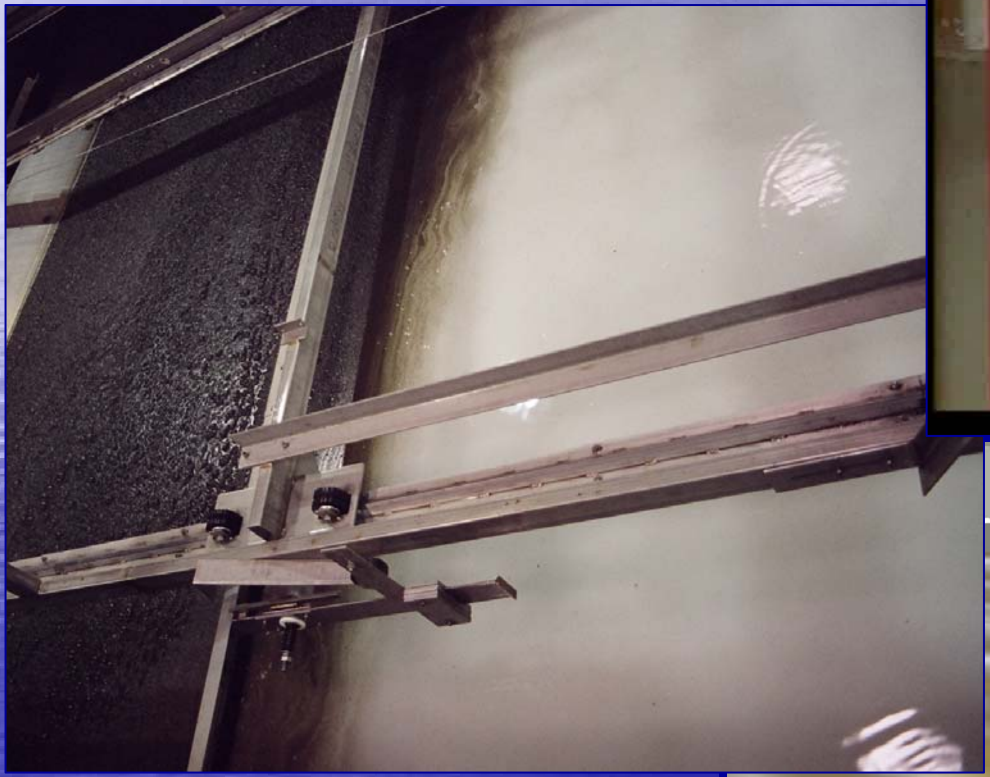
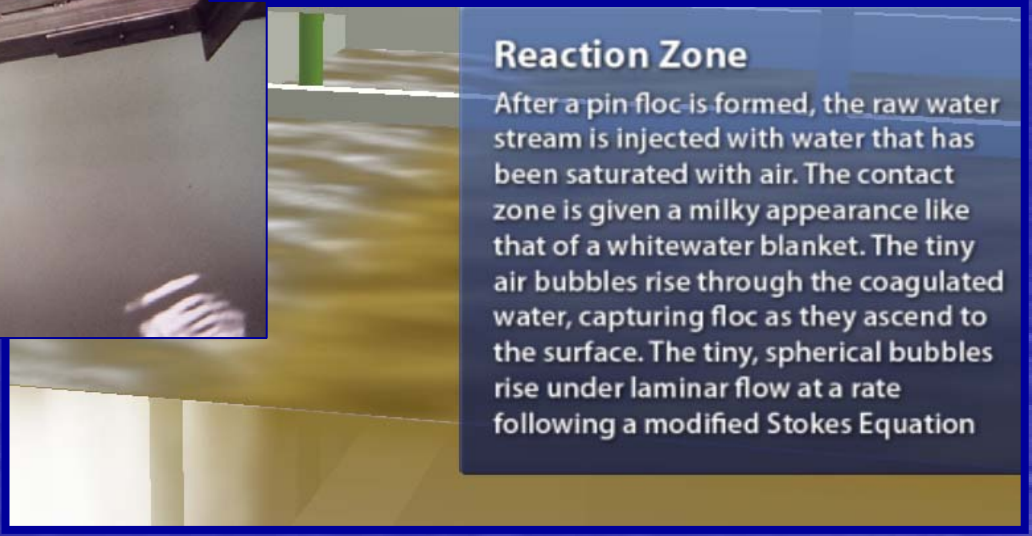
Nozzles


Air Nozzle Header
The aerated water is delivered to a distribution header that spans the width of the DAF cell. This distribution header has a series of specially designed orifices or nozzles. As the pressurized water exits the nozzles, the pressure drop produces a cloud of microbubbles that are 20 to 100 microns in size.



Reaction Zone





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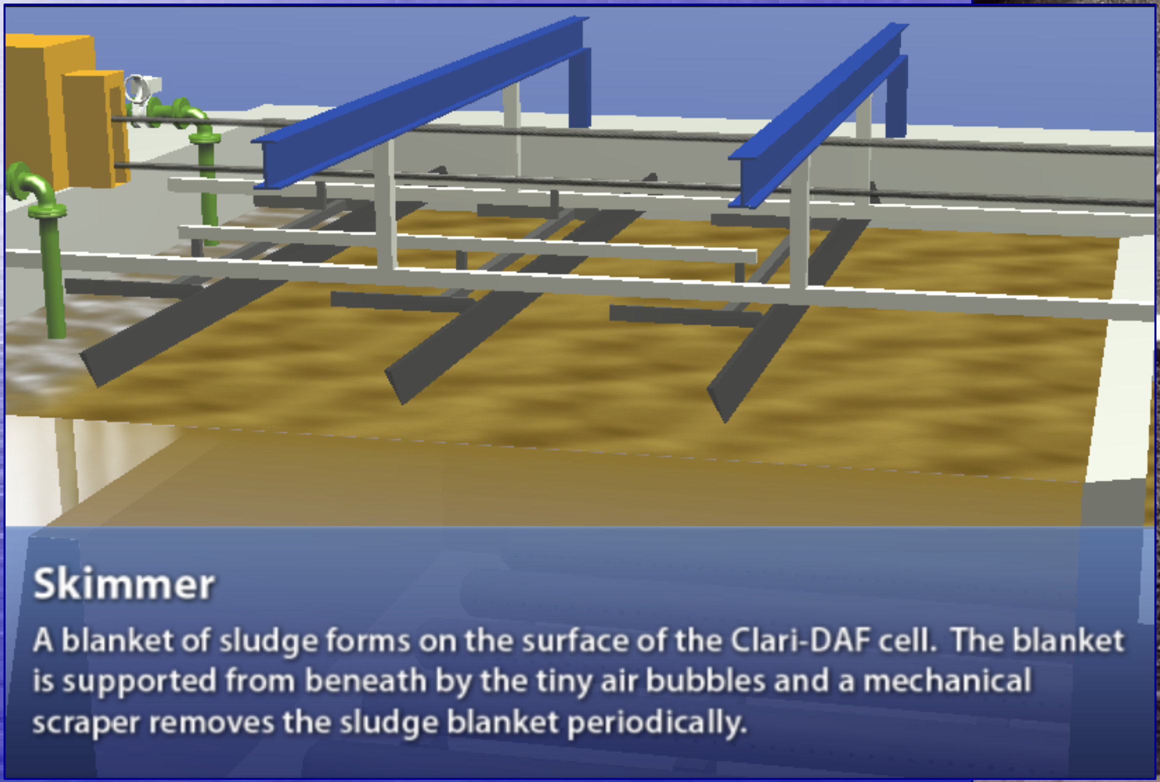
Sludge Skimmer



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Mechanical Desludging

Reciprocating Skimmer

Low Maintenance
0.25 hp Motor
Gentle on sludge

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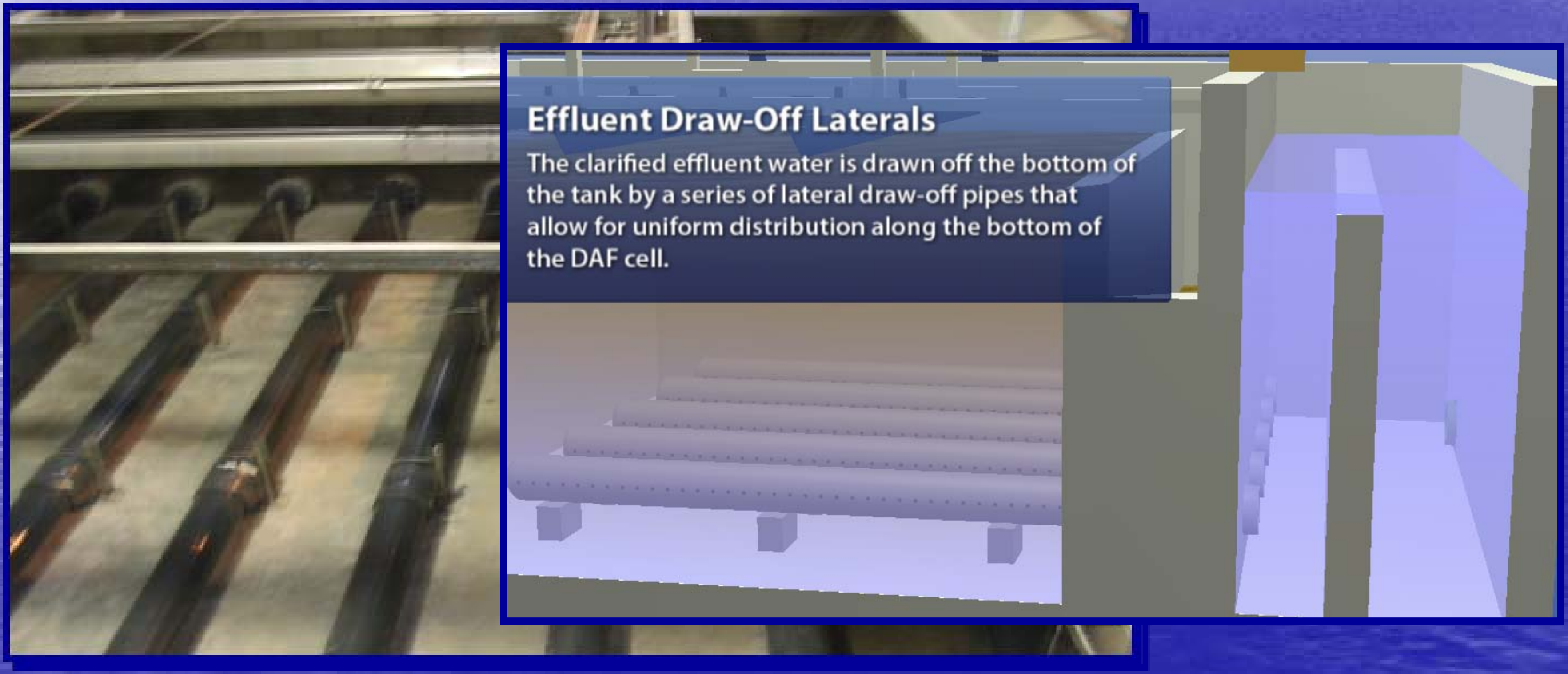
3% - 5% sludge solids

Hydraulic De-sludging

Procedure

- Effluent gate closed
- Water level rises
- Spray water starts
- Sludge flows to collection trough
- .5 - 1% sludge solids

Laterals



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Plant	City	State	# Trains	Capacity
Fern Hill	West Chester	PA	2	3 MGD
Table Rock	Greenville	SC	12	75 MGD
Fresh Pond	Cambridge	MA	6	24 MGD
Mulgrave	Mulgrave	NS	1	0.5 MGD
Spring Canyon	Fort Collins	CO	1	0.5 MGD
Evitts Creek	Bedford	PA	3	15 MGD
Hornbine	Swansea	MA	2	0.5 MGD

Systems Operating

Plant	City	State	# Trains	Capacity
Florence	Florence	CO	2	6 MGD
Mostiste	Sobeslav	Czech Rep	2	4.6 MGD
Winnipeg	Winnipeg	Manitoba	8	105 MGD
Waco	Waco	TX	8	135 MGD
San Luis Obispo	San Luis Obispo	CA	1	7 MGD
Del Valle	Livermore	CA	1	7 MGD
Middletown	Middletown	NY	3	6 MGD

Leopold Clari-DAF System™

Shuwaikh SWRO, Kuwait

Commissioned in April of 2011
In Commercial Operation since October 2011

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Design Parameters

- Plant Design Flow 105 MGD (16,900 m3/hr)
- 8 DAF Basins
- Basin Loading Rate 9gpm/sf (22m/hr) (collector area rate)
- Total Flocculation time of 13 Minutes
- 10% Recycle Flow

Plant Intake/Screening Structure in Foreground, Clari-DAF Building in Background

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Process Notes

- Moderate influent turbidities averaging ~ 5 NTU since startup
  excursions as high 40 NTU experienced

- Red-Tide event Occurred in May 2012.

- Clari-DAF System is currently being utilized for preconditioning of
  UF membrane influent.

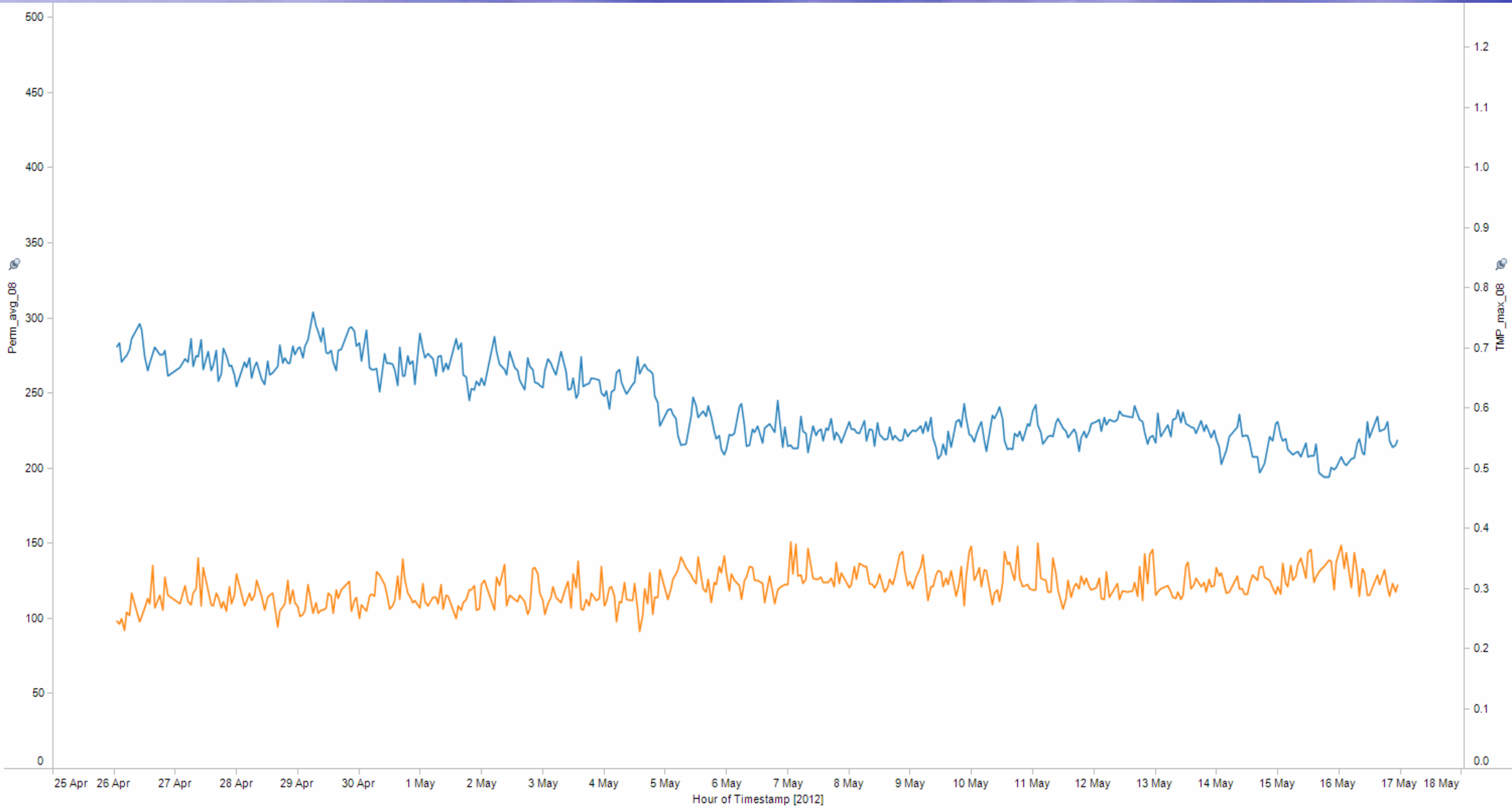
-Typical Chemical Dose to Clari-DAF System:

  2-ppm of Ferric Chloride

  30-ppm of Sulfuric Acid for RO Scale Prevention

- Excellent UF Permeability and Recovery to Date

UF PERFORMANCE



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Measure Names
Perm_avg_08
TMP_max_08

• Xylem, Leopold recently completed extensive pilot testing in Oman using our state-of-the-art desalination pretreatment pilot units, which include:

- •Clari-DAF® system
- •FilterWorx™ system – single stage or 2-stage gravity media filtration.

•The source water was pulled from an existing open intake structure and was pre-chlorinated before the pilot units.

•Influent turbidities ranging from 1-3 NTU and TSS <20mg/L.

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Desalination Pretreatment Pilot Interior Photos

Clari-DAF® Container

FilterWorx® Container

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Filter Columns

Flocculation
Clari-DAF Tank

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Desalination Pretreatment – Algae Removal

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Oman Pilot Study

with Leopold® Desalination Pretreatment Systems (Apr. to Oct. 2010)

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Oman Pilot Study April-October 2010

Oman Raw Water Quality

Parameter	Average	Min	Max
Turbidity (NTU)	1.40	0.28	6.93
pH	8.11	7.69	8.37
Temperature (°C)	31.4	28.4	33.8
Salinity (‰)	36.85	35.46	39.83
TSS (mg/L)	UDL	UDL	15

Scenarios Tested and Results

Parameter	Avg. SDI
1 Stage DMF (Direct Filtration)	<4
DAF + 1 Stage DMF	<3.5
DAF + 2 Stage DMF	<2.5

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Algae Removal Study

with Leopold® Desalination Pretreatment Systems

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Pretreatment Technologies Jar Testing for Algae Removal

- **The catastrophic 2008–2009 red tide in the Arabian gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate Cochlodinium polykrikoides**

Mindy L. Richlen [a,*] , Steve L. Morton [b], Ebrahim A. Jamali [c], Anbiah Rajan [d], *Donald M. Anderson* [a]

[a] Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA
[b] NOAA/NOS Marine Biotoxin Program, 331 Ft. Johnson, Charleston, SC 29415, USA
[c] Marine Resources Research Centre, Ministry of Environment and Water, P.O. Box-21, Umm Al Quwain, United Arab Emirates
[d] Biodiversity Management Marine Sector, Environment Agency Abu Dhabi, P.O. Box-45553, Abu Dhabi, United Arab Emirates

- ***"A pattern of subsequent recurrence of C. polykrikoides blooms following an initial outbreak has been observed in other parts of the world, suggesting that this species may become a persistent HAB problem in this region. As Arabian Gulf countries rely on desalination plants as the primary source of freshwater, the disruption of plant operations by recurring Cochlodinium blooms poses a serious threat to the drinking water supply in the region, and represents an unprecedented HAB impact."***

- *Source:* *http://uaeagricent.moew.gov.ae/redtide/Richlen_et_al_Cochlodinium_in_the_Arabian_Gulf_09%5B1%5D.pdf*

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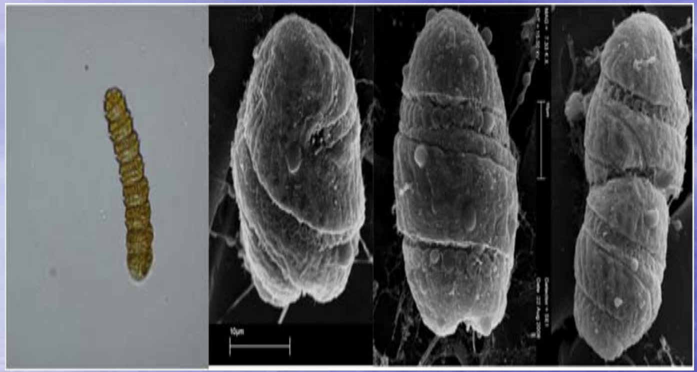
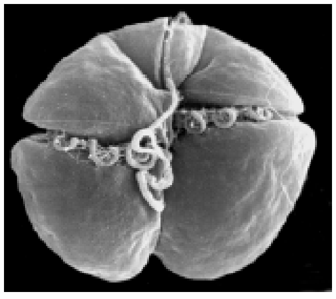
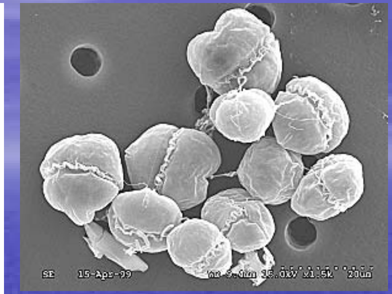
Four Species of Algae Which Leopold has Extensively Studied in Combination with the Clari-DAF System

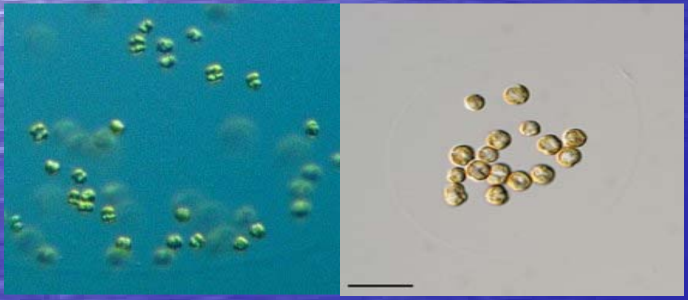


- *Cochlodinium polykrikoides (20-30 μm x 30-40 μm)* **(Globally)**

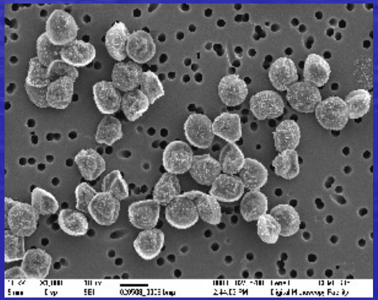


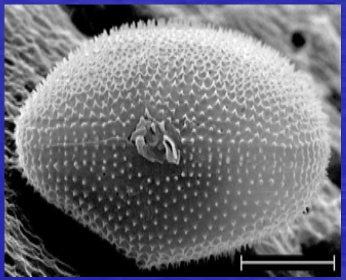


- *Karenia brevis (18-45 μm)*
- ***(Gulf of Mexico)***



- *Phaeocystis globosa* (4-6 μm)
- ***(Polar Oceans)***





- *Prorocentrum minimum (18-20 μ m)*
- ***(Europe)***

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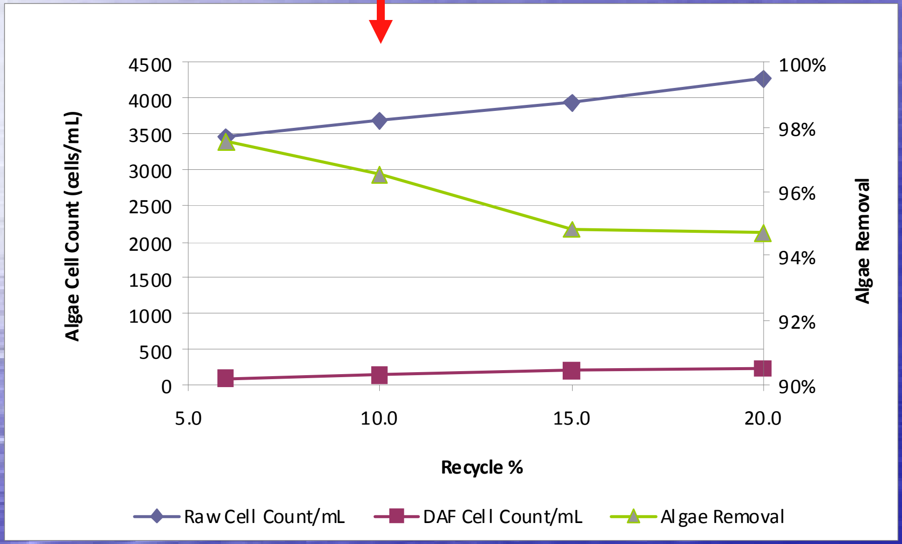
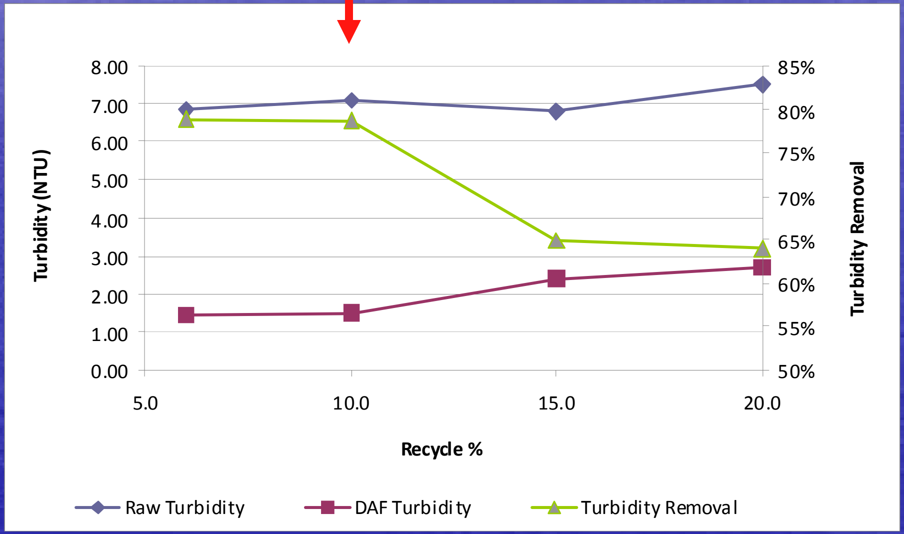
Effect of Recycle Rate

10% recycle





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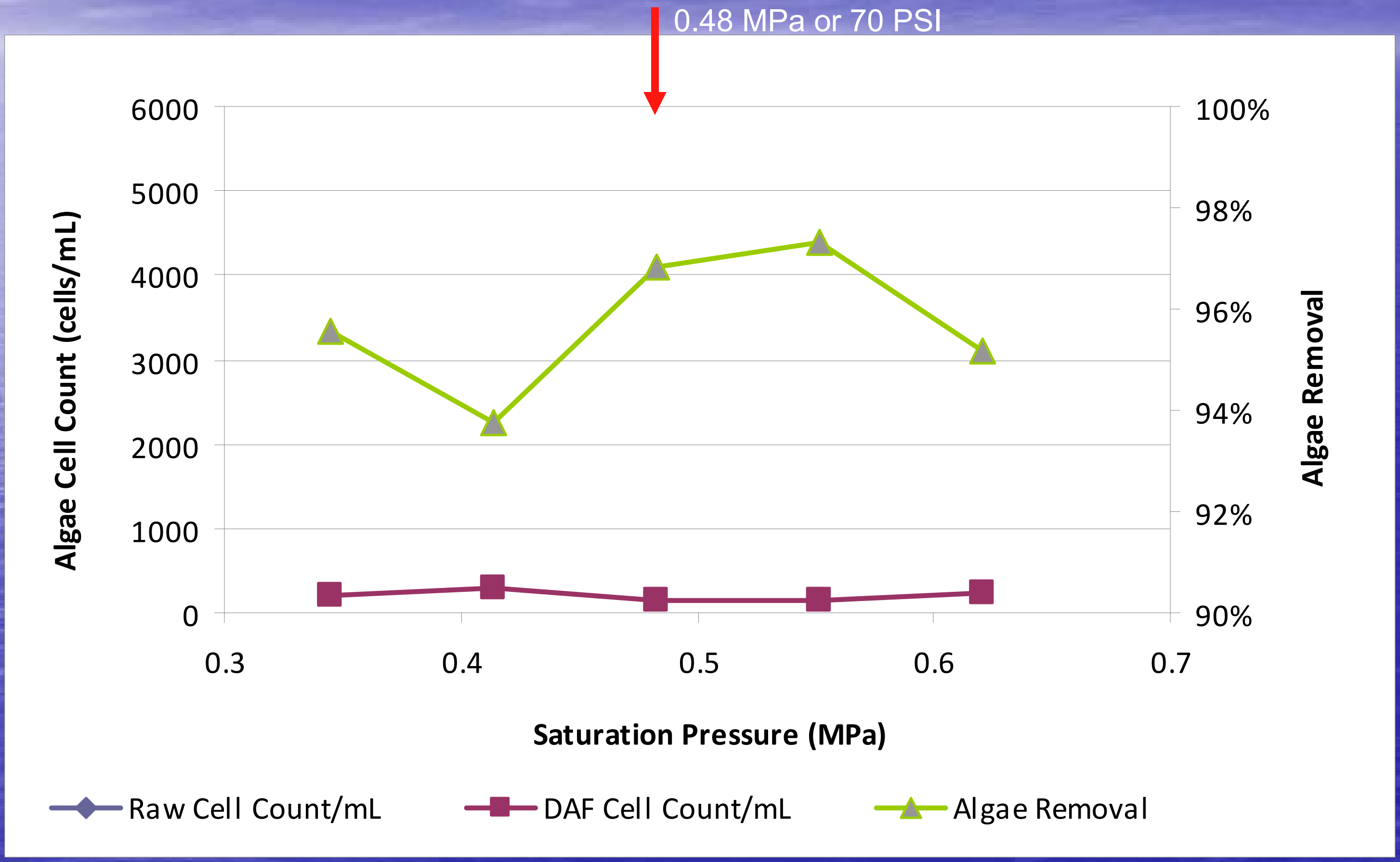
Effect of Saturation Pressure



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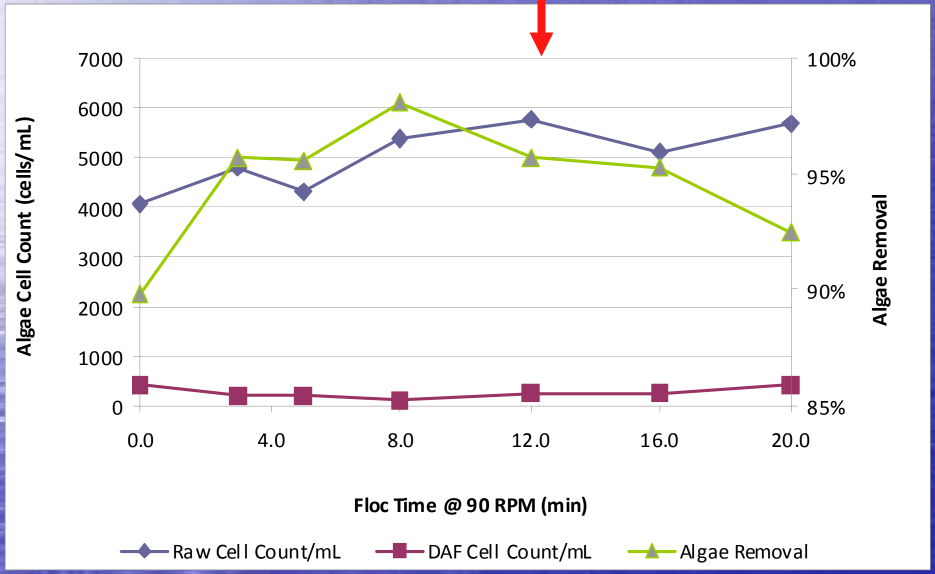
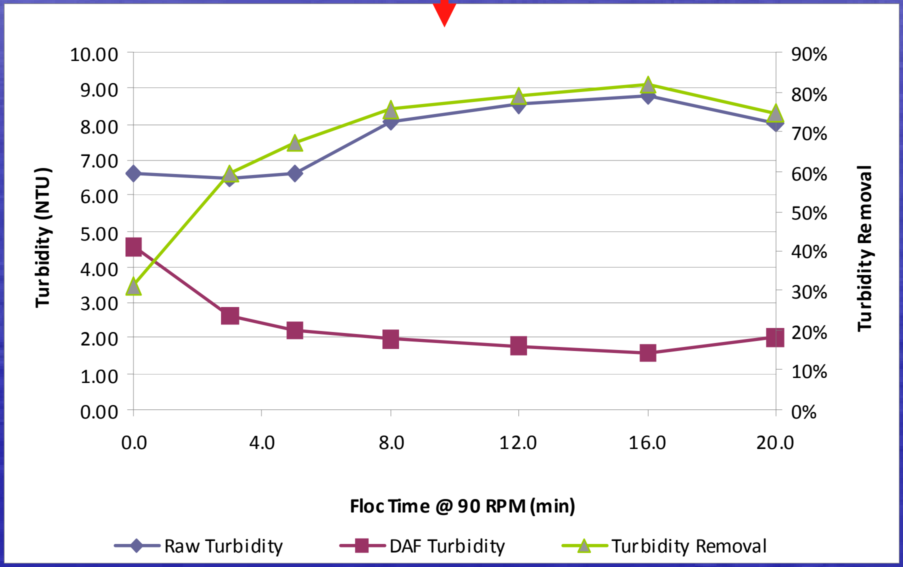
Effect of Flocculation Time

12-13 minutes





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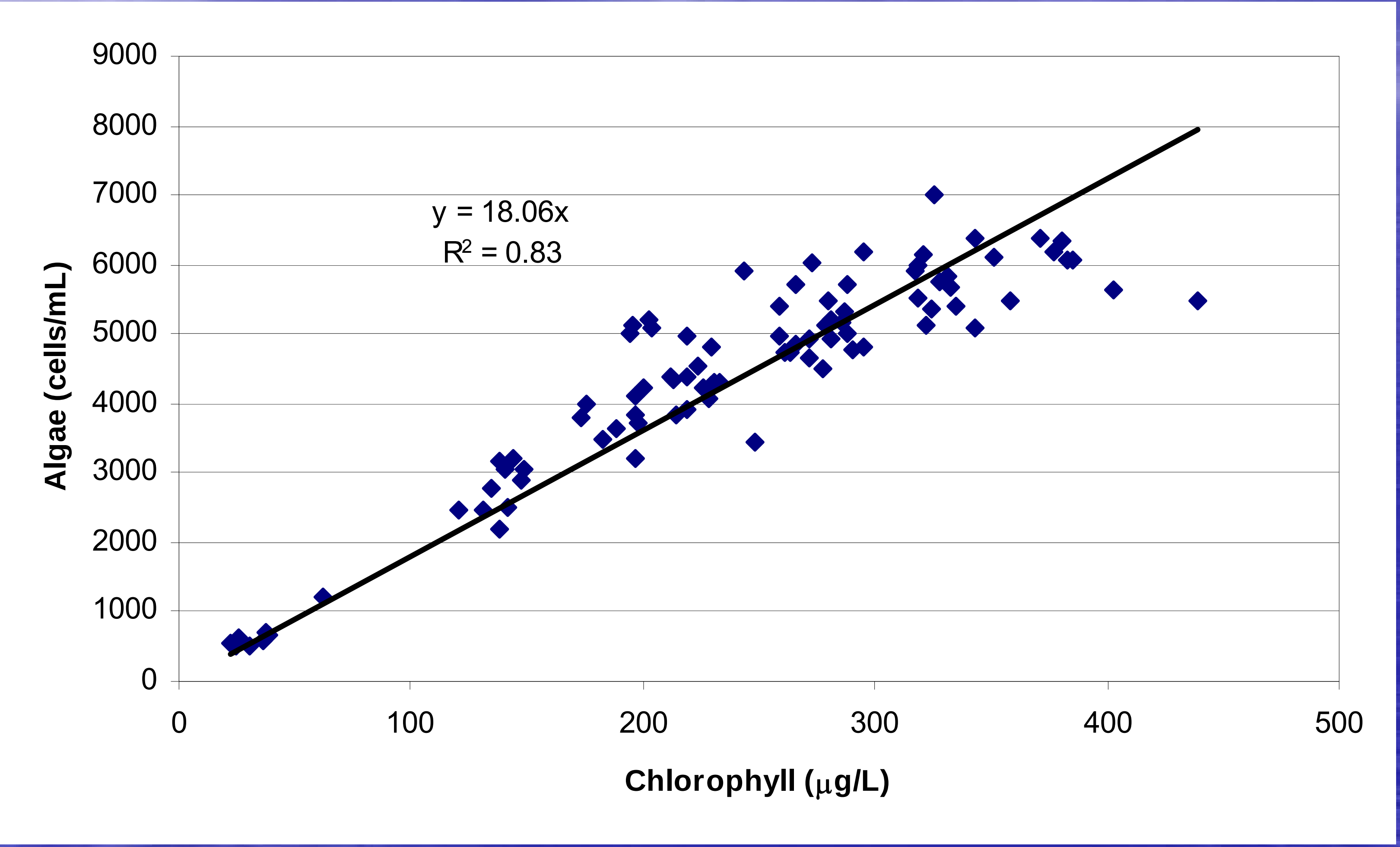
Correlation Between Algae Counts and Chlorophyll Concentrations



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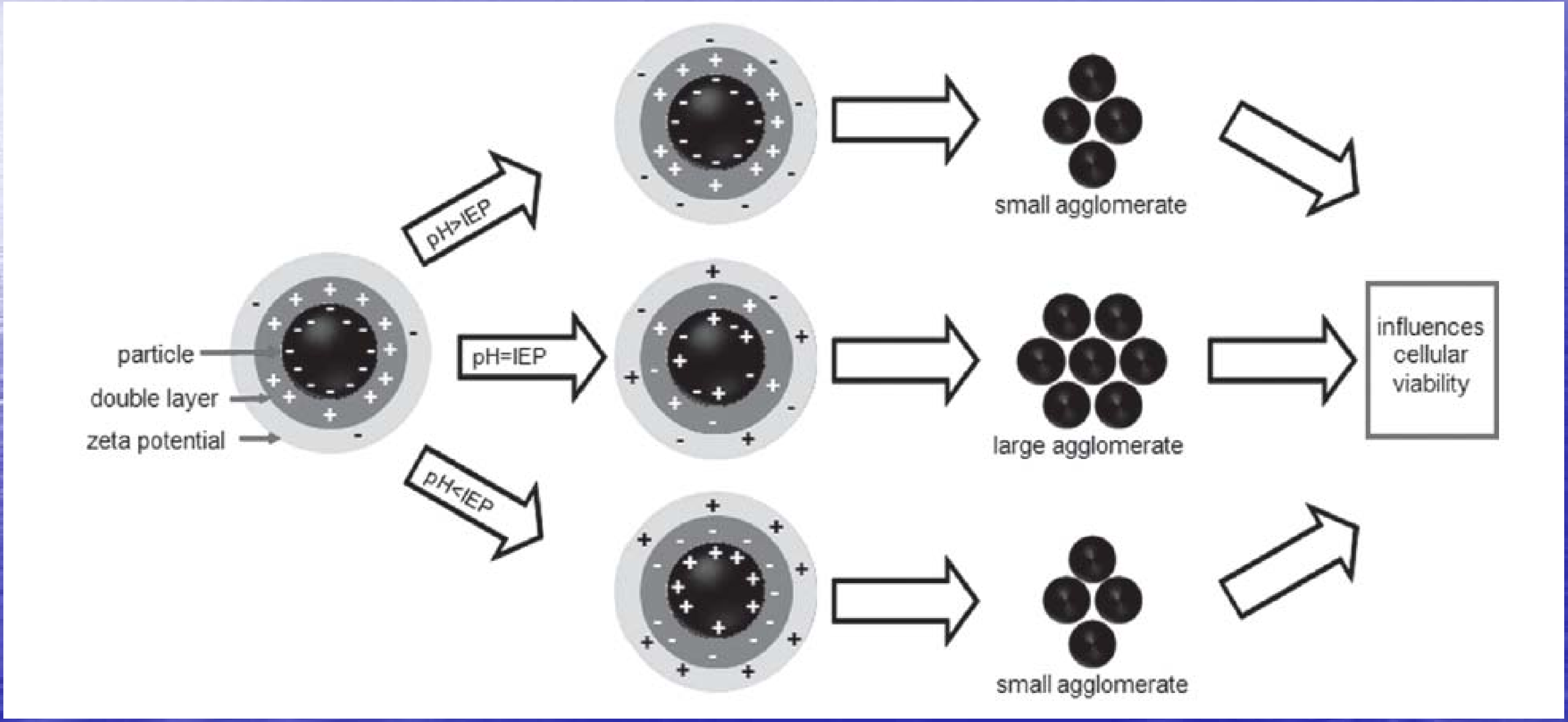
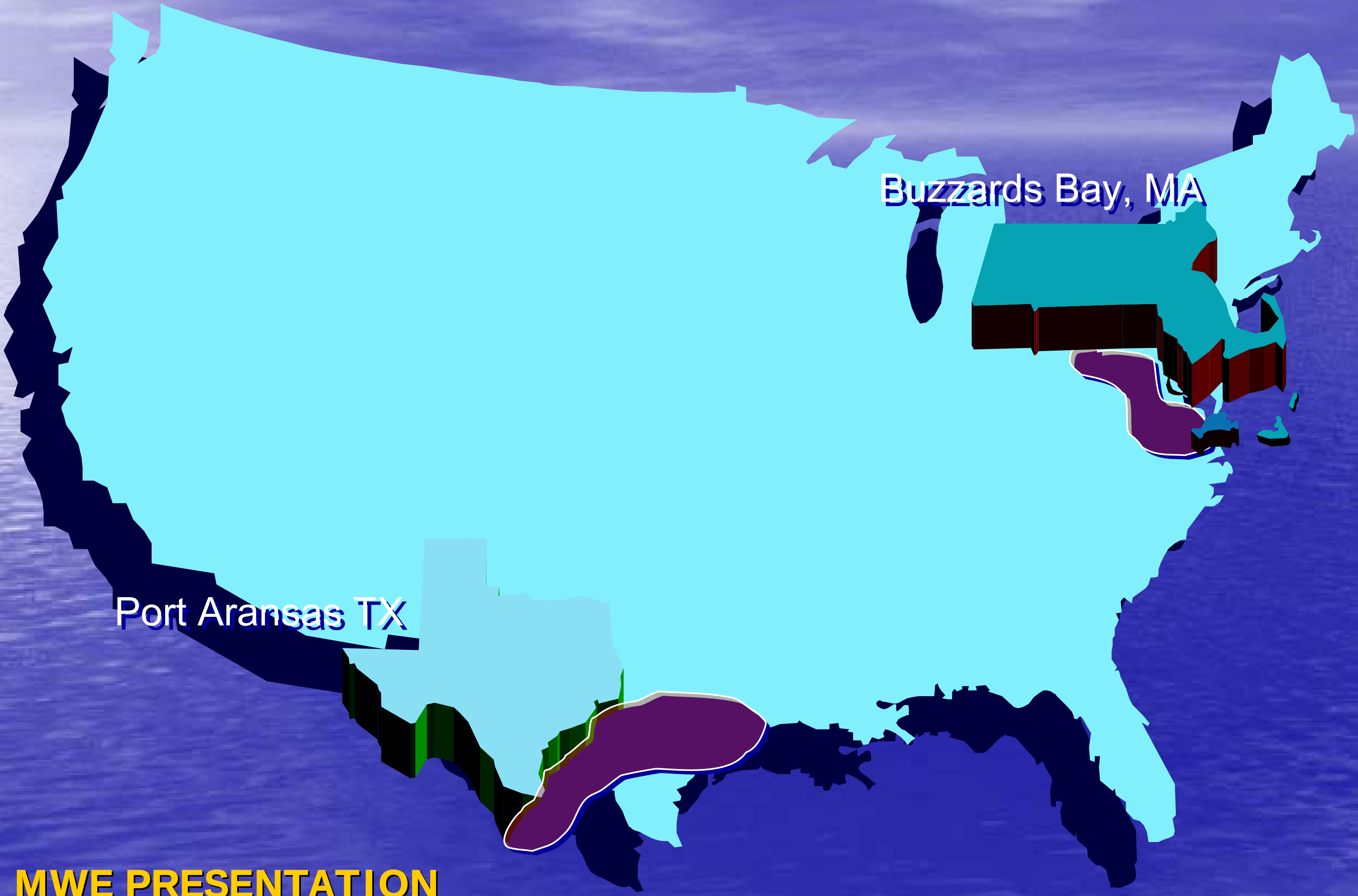
Conceptual Model for Effect of pH on Coagulation Applying Iso-electric Point



Harmful Algae Blooms (HAB) in US



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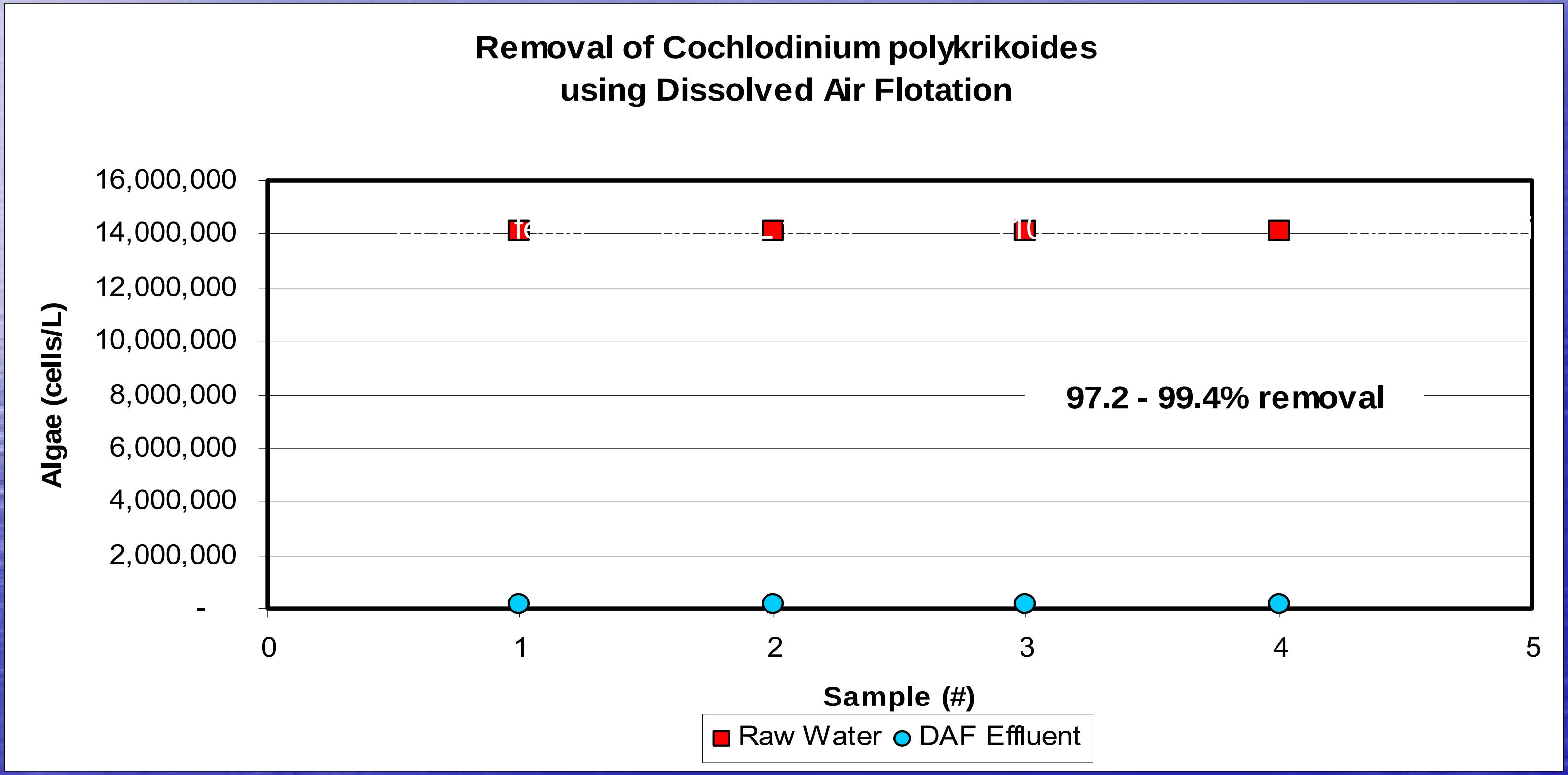
Jar Test on a HAB in Buzzards Bay, MA in the USA (Aug, 2011)



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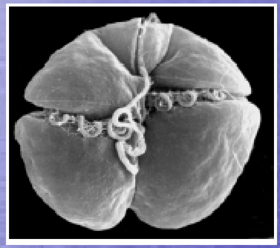
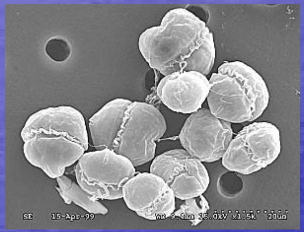
Study on a HAB at Port Aransas TX (Nov, 2011)

Species: *Karenia brevis*

0.1-0.4 Million cells/L

Diameter 18-45 μm





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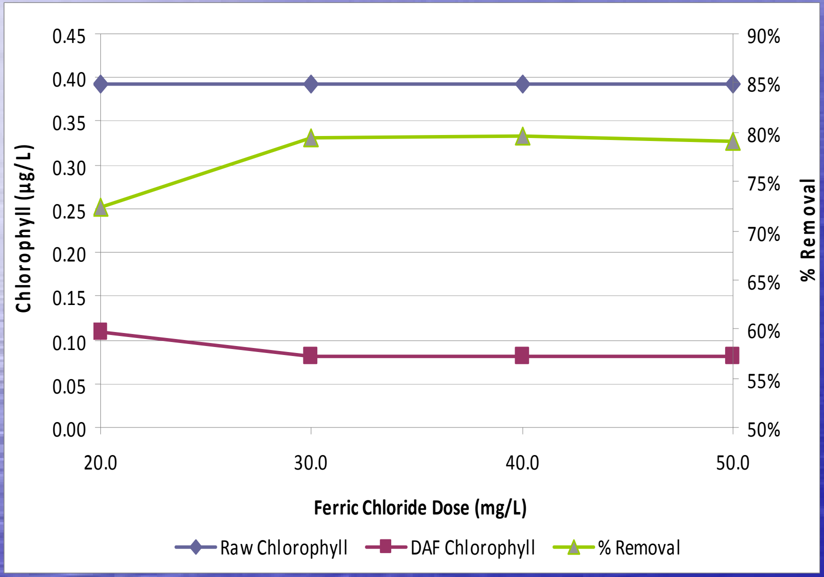
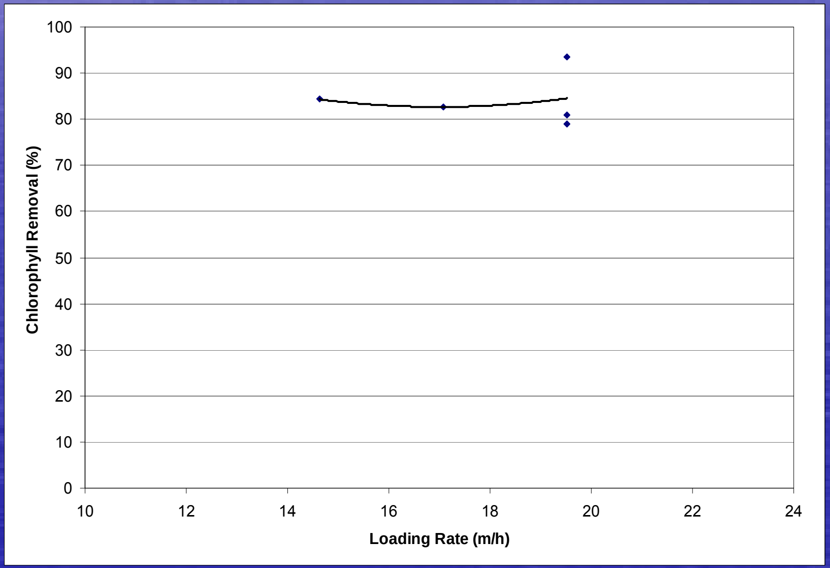
Study at Port Aransas TX (Nov, 2011)





Bench Scale Test (Gt 80160)

Pilot Scale Test (Gt 80160) (loading based on total flotation basin)

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Pretreatment Technologies Oil Removal

- To further Leopold's process knowledge base, oil removal studies have also been performed.
  - ≥99% removal of free oil was obtained at concentrations of 100 mg/L
  - Further testing has shown >95% removal is also achievable with emulsified oil.

Testing indicated that mechanical design parameter for optimum algae removal are also ideal oil removal.

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Study on a HAB at Port Aransas TX (Nov, 2011)

Species: *Karenia brevis*

- Bench scale DAF and pilot scale DAF achieved comparable removal efficiency indicating process scaling up was feasible

- With pH adjustment the coagulant dosage was reduced by half while achieving the same removal efficiency.

- Even though the depth of the flotation cell was only 5 feet deep (1.5 m), a hydraulic loading rate as high as 24 m/h (based on Collector Area) was proved feasible for algae removal.