Piloting the Cleargreen Deammonification Process at the Tri-City WRRF

by
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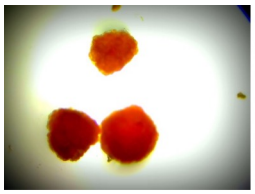
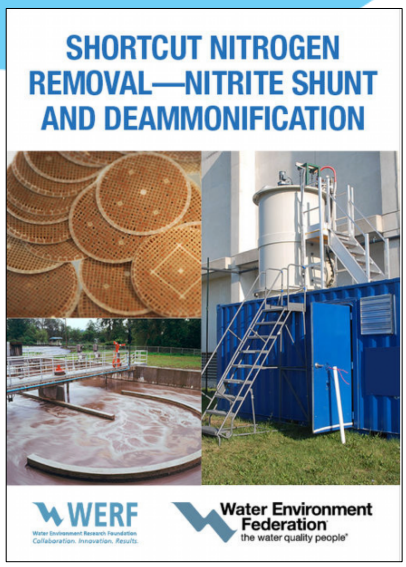
Christophe Desmottes – Suez - DENARD

Acknowledgements

Session Overview

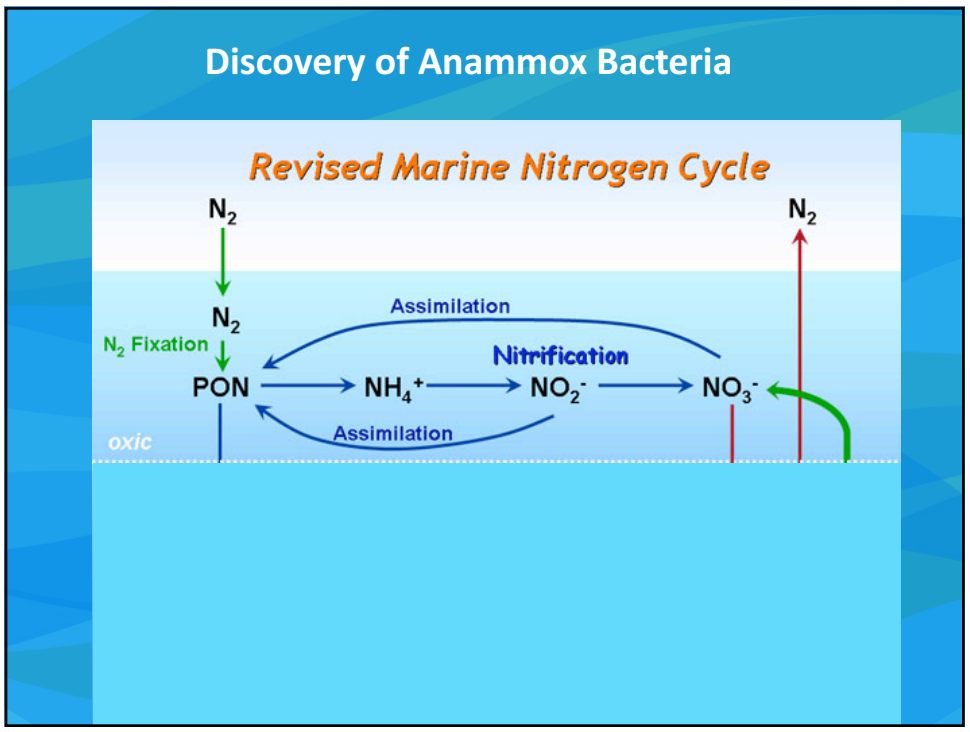
- Anammox Background
- Overview of Pilot Plant
- Pilot Operations
- Findings/Dale's Opinions
- Sidestream Application

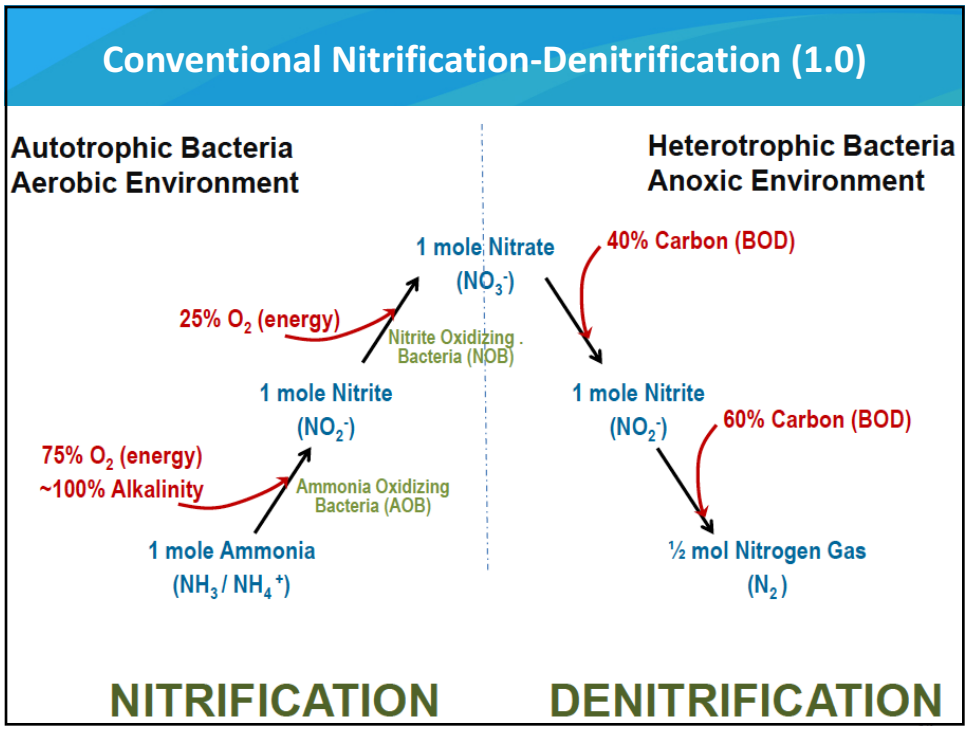




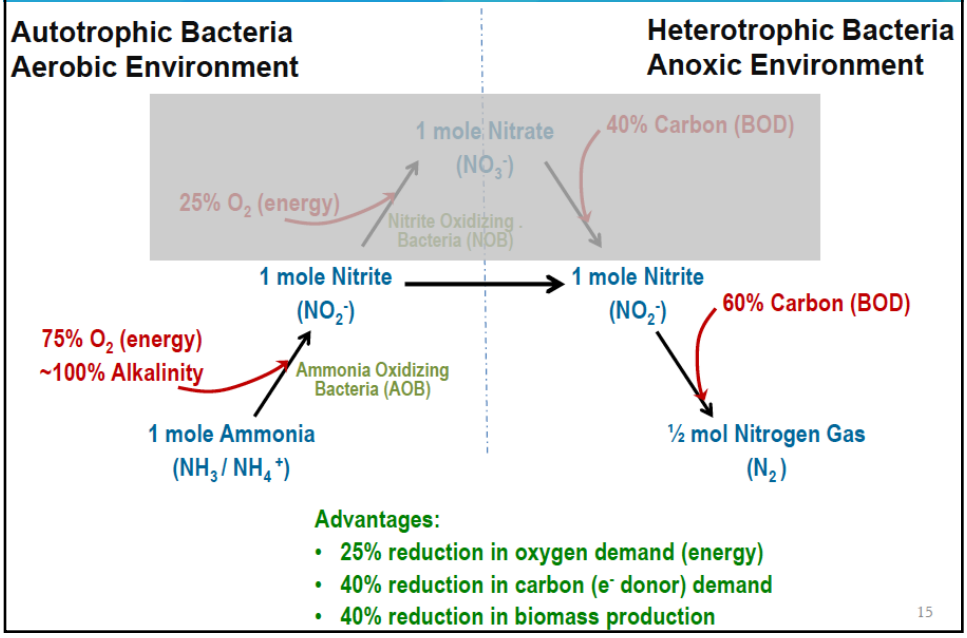
richwine environmental

Anammox Background


Discovery of Anammox Bacteria
Revised Marine Nitrogen Cycle
N2
N2
N2 Fixation
Assimilation
Nitrification
PON
NH4+
NO2-
NO3-
Assimilation
oxic
N2


Conventional Nitrification-Denitrification (1.0)
Autotrophic Bacteria
Aerobic Environment
Heterotrophic Bacteria
Anoxic Environment
1 mole Nitrate
(NO3-)
40% Carbon (BOD)
25% O2 (energy)
Nitrite Oxidizing
Bacteria (NOB)
1 mole Nitrite
(NO2-)
1 mole Nitrite
(NO2-)
60% Carbon (BOD)
75% O2 (energy)
~100% Alkalinity
Ammonia Oxidizing
Bacteria (AOB)
1 mole Ammonia
(NH3 / NH4+)
½ mol Nitrogen Gas
(N2)
NITRIFICATION
DENITRIFICATION

Nitritation-Denitritation (Nitrite Shunt) (2.0)



Advantages:

- 25% reduction in oxygen demand (energy)
- 40% reduction in carbon (e^- donor) demand
- 40% reduction in biomass production

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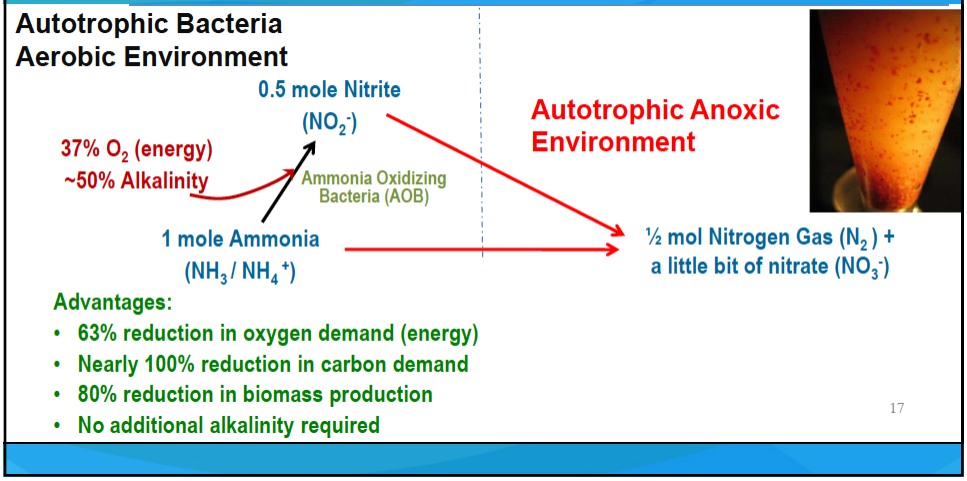
Partial Nitritation–Annamox "Deammonification" (3.0)



Advantages:

- 63% reduction in oxygen demand (energy)
- Nearly 100% reduction in carbon demand
- 80% reduction in biomass production
- No additional alkalinity required

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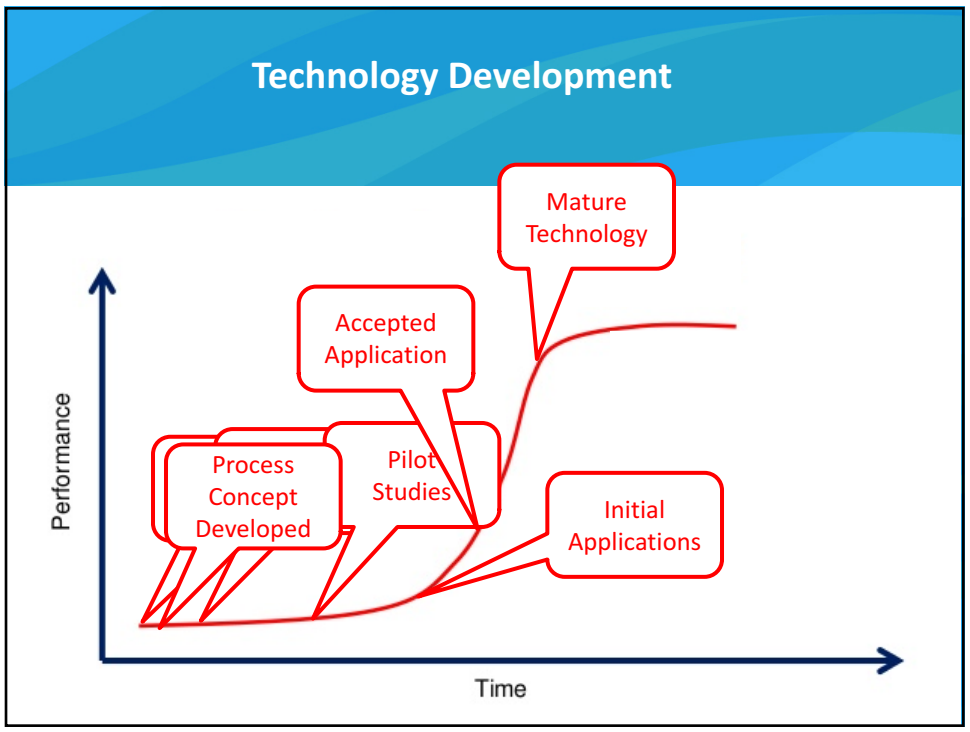
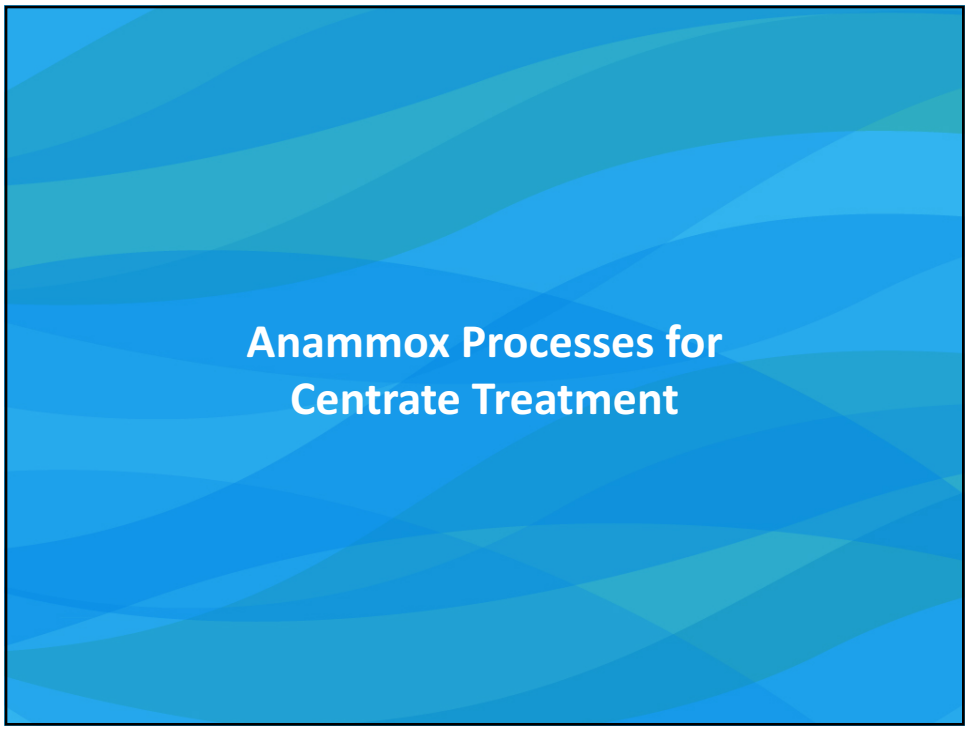
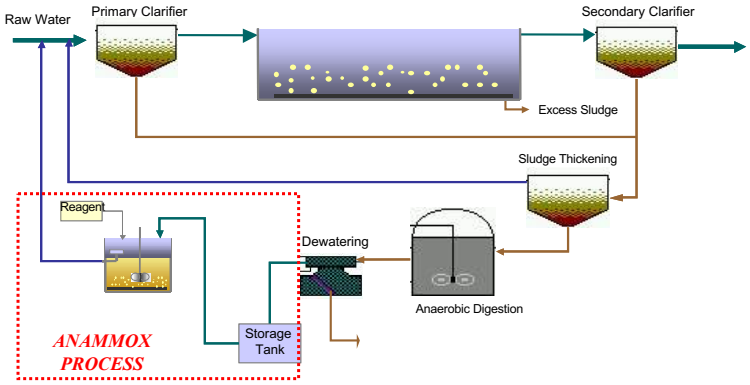
Anammox Granules

Technology Development S-Curve


Technology Development
Mature Technology
Accepted Application
Process Concept Developed
Pilot Studies
Initial Applications
Performance
Time

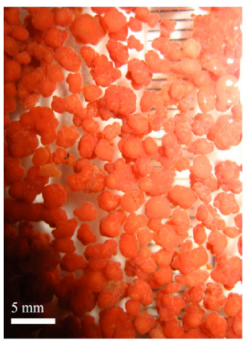

Anammox Processes for Centrate Treatment

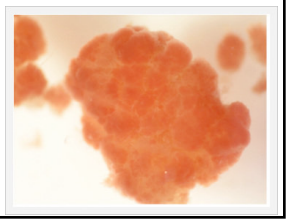
Where does process fit?



Background on Anammox Bacteria

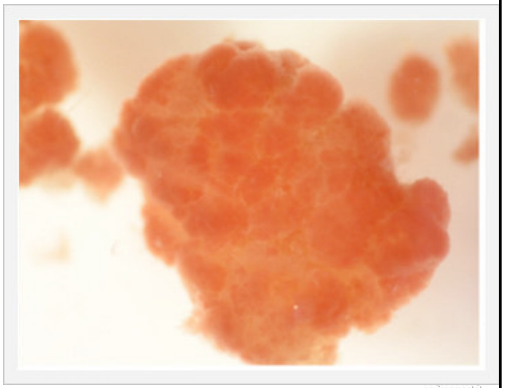
- Extremely slow cell growth rate (doubling time of 10 days)
  - Biomass retention is critical
  - Optimal temp. = 25 – 35 ° C
- Great for sidestream treatment
  - High ammonia concentrations
  - High temperatures
- Control Complexity
  - Timed intermittent aeration
  - DO and pH feedback control
  - NO_2^-, NO_3^-, and NH_4 feedback control





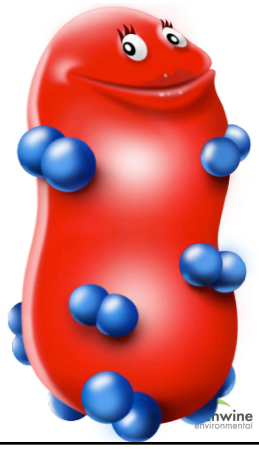
Anammox Centrate Treatment Processes

- SBRs
  - DEMON
  - Cleargreen
- Continuous Flow
  - Paques (ANNAMOX®)
- Attached Growth
  - DeAmmon®
  - ANITA™ Mox



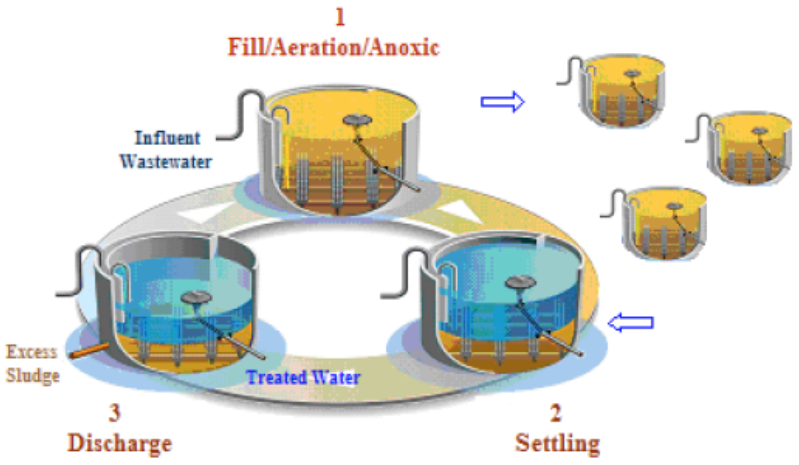
Control Strategies

- Dissolved Oxygen Control
- Ammonia-Based Aeration Control
- Ammonia vs. Nitrate Aeration Control
- pH Control



Cleargreen™ Anammox Centrate Treatment Process

Cleargreen™ Sidestream Treatment Process



What is Cleargreen™ ?

Cyclic

Low

Energy

Ammonia

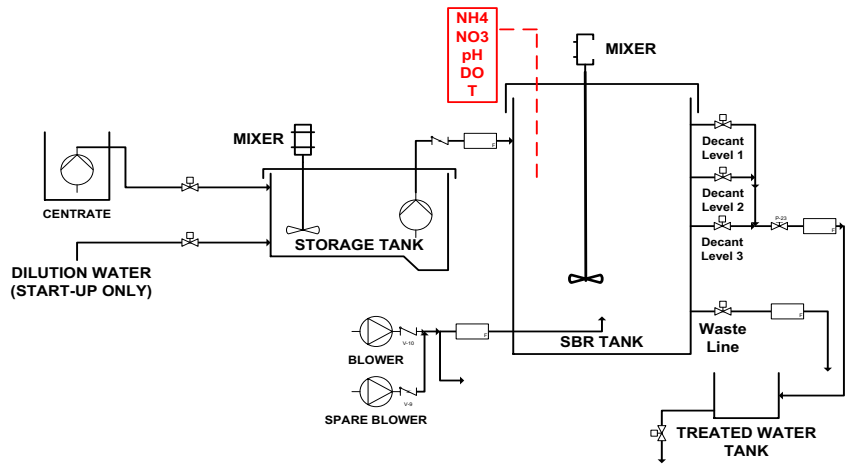
Removal

What is Cleargreen™ ?

Cyclic
Low
Energy
Ammonia
Removal

- 60% less oxygen demand (aeration energy savings)
- 0% external carbon demand (chemicals cost savings)
- 25 to 30% less sludge production
- 20 to 40% reduction in biological treatment volumes

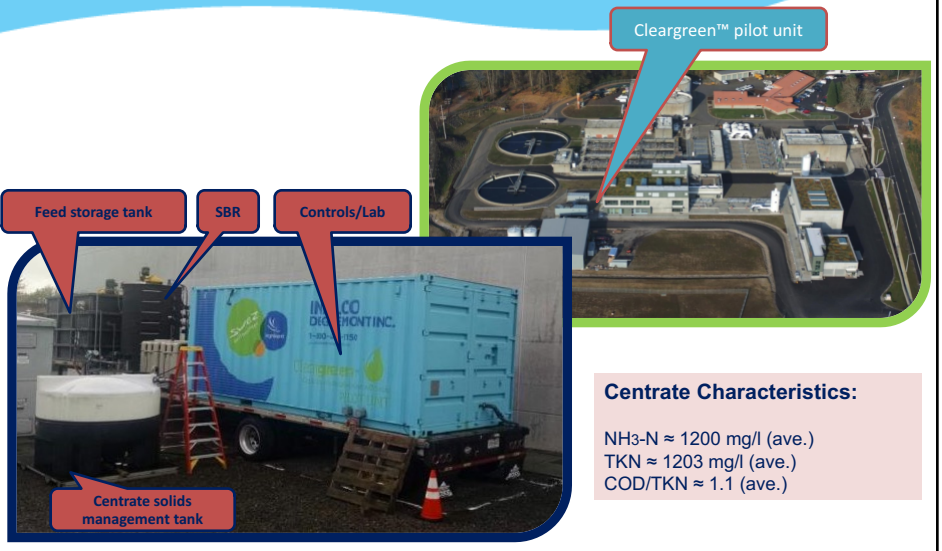
Cleargreen™ PFD



Tri-City WRRF
Cleargreen™
Centrate Treatment Pilot Project

Cleargreen™ Pilot Trailer

Tri-City WRRF Centrate Treatment Pilot



Centrate Characteristics:

NH_3-N ≈ 1200 mg/l (ave.)
TKN ≈ 1203 mg/l (ave.)
COD/TKN ≈ 1.1 (ave.)

Cleargreen™ Pilot Storage Tank

Storage Tank

- 3100 gal
- Plastic, steel cage

Cleargreen™ Pilot SBR

Cleargreen™ Sampling

Composite Samplers

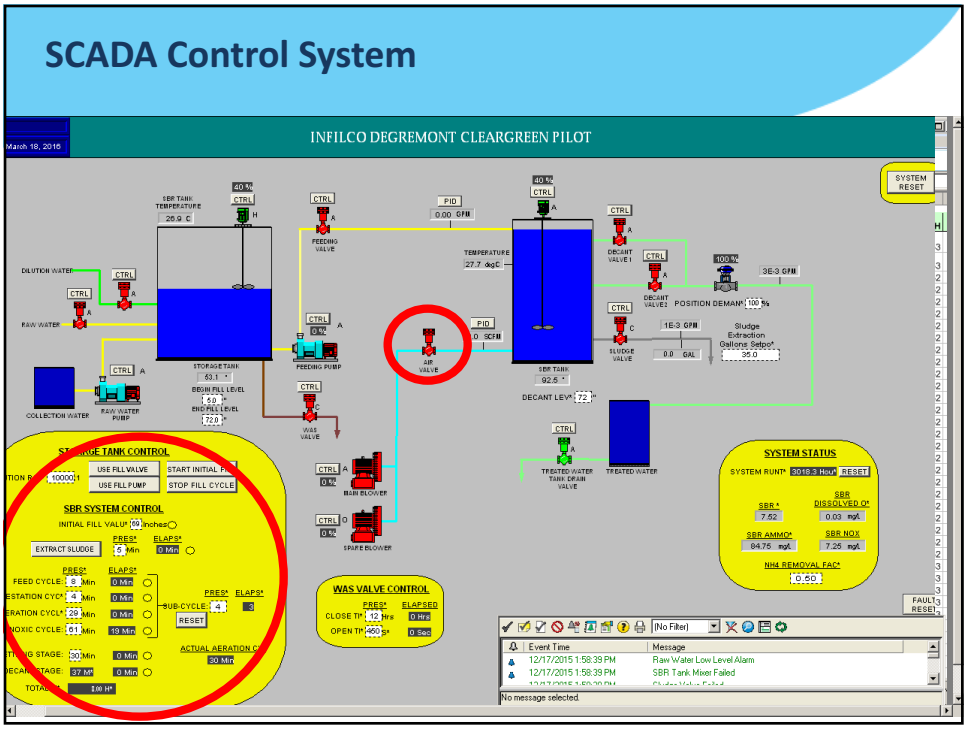
Influent | Effluent

Grab Samples for onsite analysis

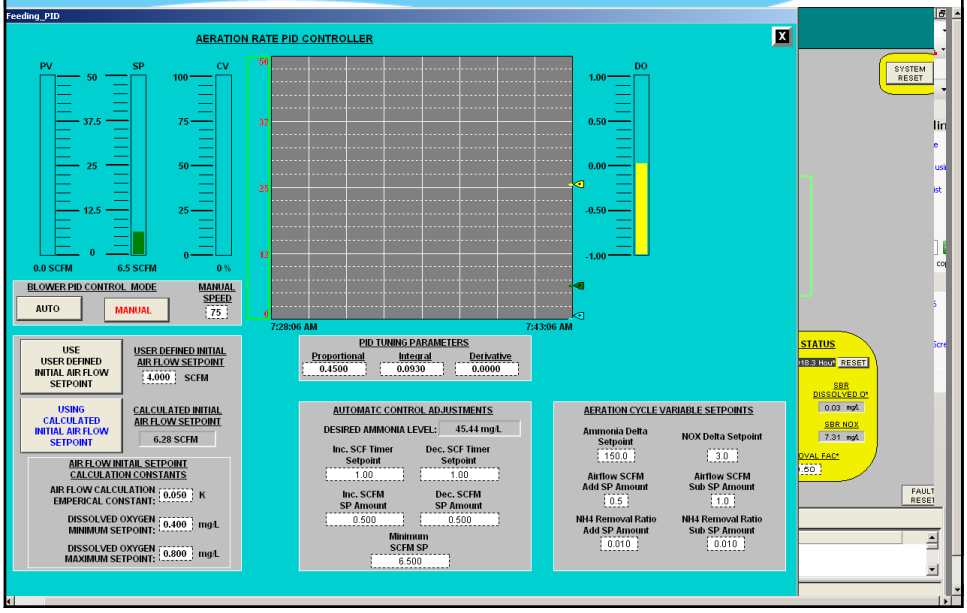
- From SBR tank fourth sampling valve

Pilot Lab

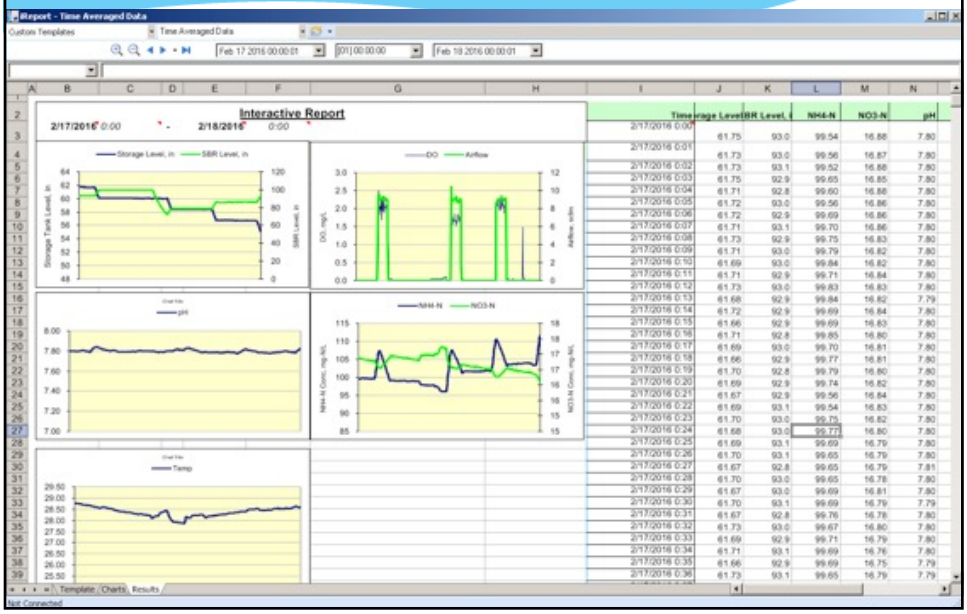
SCADA Control System



System Aeration Control



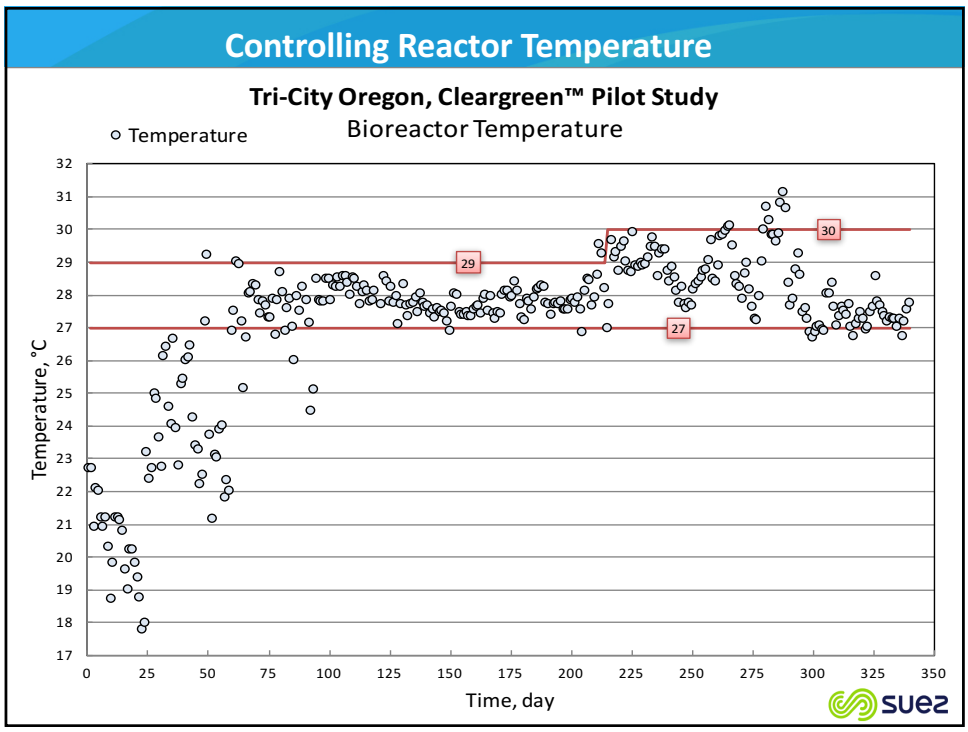
Data Logging at 1-Minute Intervals

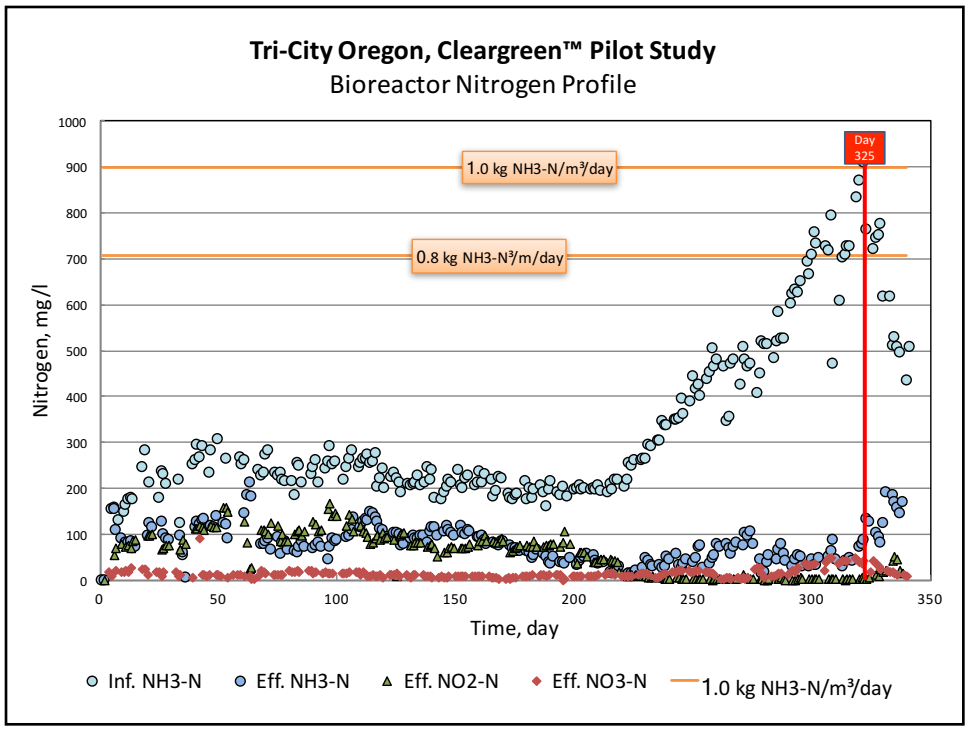


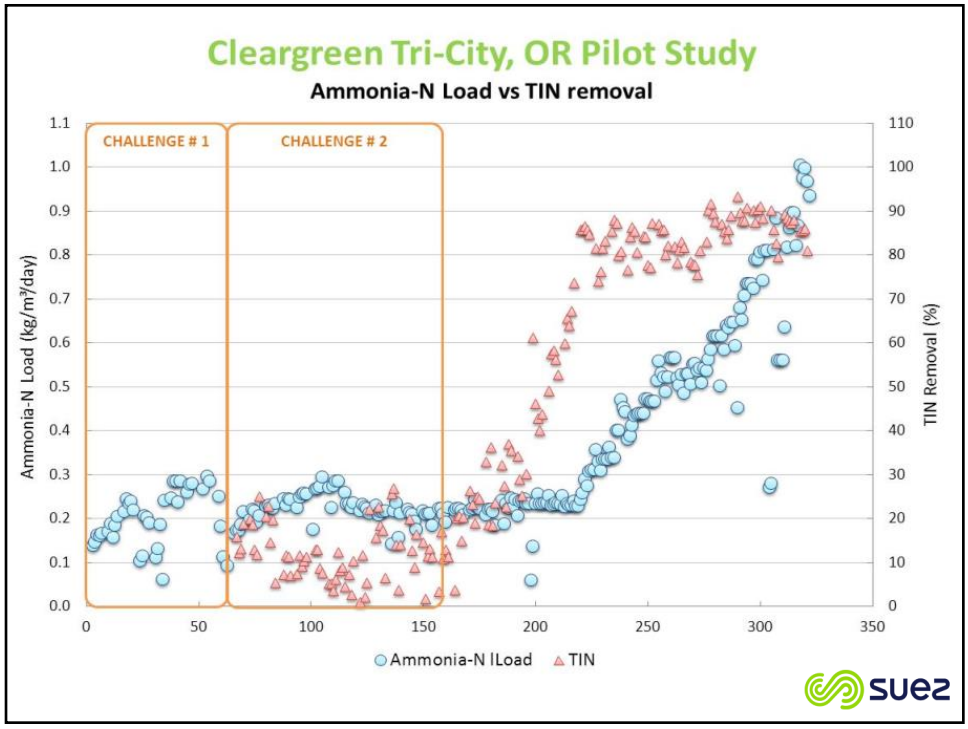
YSI Ammonia and Nitrate Probes

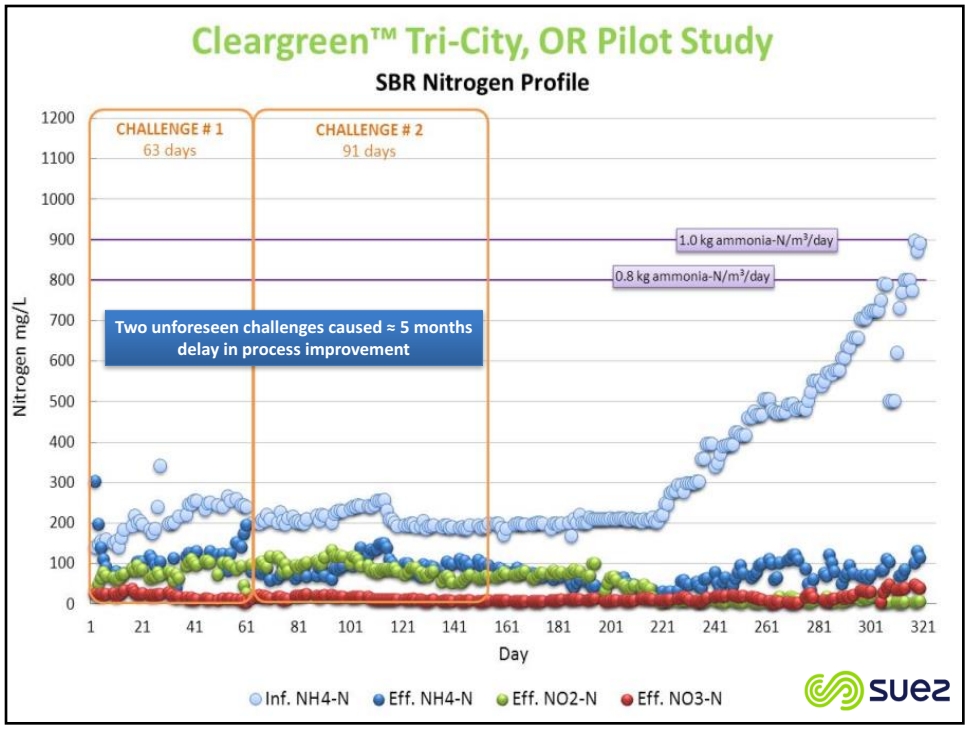
Cleargreen™ Pilot Findings

Controlling Reactor Temperature





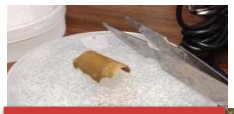

Cleargreen Tri-City, OR Pilot Study
Ammonia-N Load vs TIN removal
CHALLENGE # 1
CHALLENGE # 2
Ammonia-N Load (kg/m³/day)
TIN Removal (%)
Ammonia-N lLoad
TIN
suez


Cleargreen™ Tri-City, OR Pilot Study
SBR Nitrogen Profile
CHALLENGE # 1
63 days
CHALLENGE # 2
91 days
1.0 kg ammonia-N/m³/day
0.8 kg ammonia-N/m³/day
Two unforeseen challenges caused ≈ 5 months delay in process improvement
Nitrogen mg/L
Day
Inf. NH4-N
Eff. NH4-N
Eff. NO2-N
Eff. NO3-N
suez

Challenges & Solutions

- **Challenge # 1 (Day 1 to Day 63)**
  - ❑ The centrate temperature is 16°C - 60°F instead of originally mentioned 30°C - 86°F by Tri-city.
  - ❑ Pilot SBR integrated temperature control system undersize.
  - ❑ SBR temperature fluctuated between 18°C to 26°C for the first 63 days of the trial.

Solution:
- Installed water heater in pilot storage tank to maintain feed at 28° C



Calcium carbonate solid formation in the shape of the water heater coil

Inorganic solids accumulation in SBR biomass

Challenge # 2 (Day 64 to Day 154)

- ❑ Process performances were not improving.

DENARD Investigated

- ❑ Centrate micronutrient analyses.
- ❑ Treatability study to assess centrate toxicity for Anammox with three 600ml reactors using Bio-farmed Anammox biomass.
- ❑ Detected and analyzed accumulation of inorganic matter in SBR

Cause

- ❑ Try-City plant uses lime for alkalinity control in the MBR
- ❑ MBR effluent was used to dilute the centrate and sodium bicarbonate was added for alkalinity control in pilot
- ❑ High temperature near water heater precipitated Calcium carbonate in storage tank, inorganic accumulation limited Anammox.

Solutions:
- Minimize inorganic solids introduction into the SBR by stopping storage tank mixing
- Additional cleaning of storage tank

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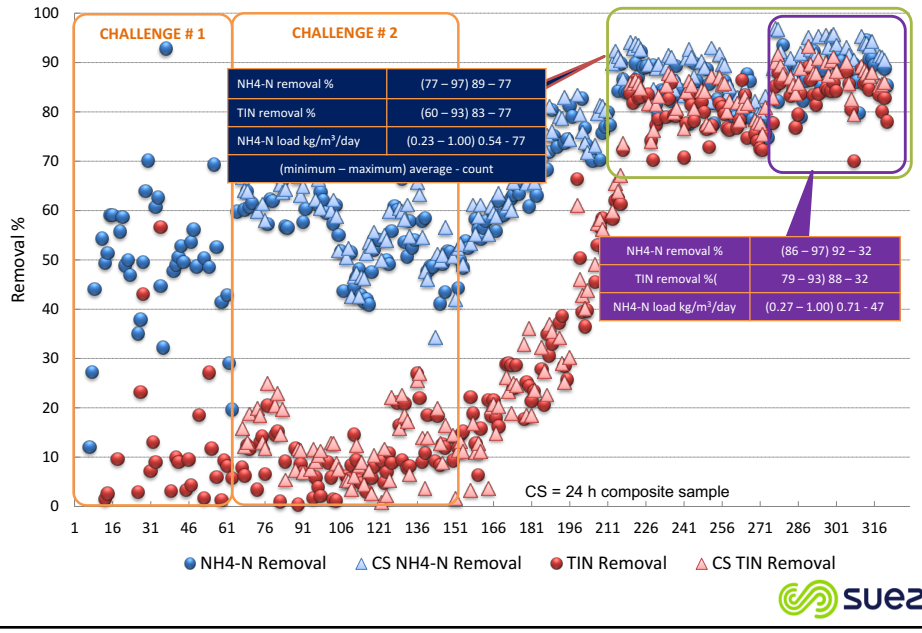
Cleargreen Tri-City, OR Pilot Study

SBR Nitrogen Removals



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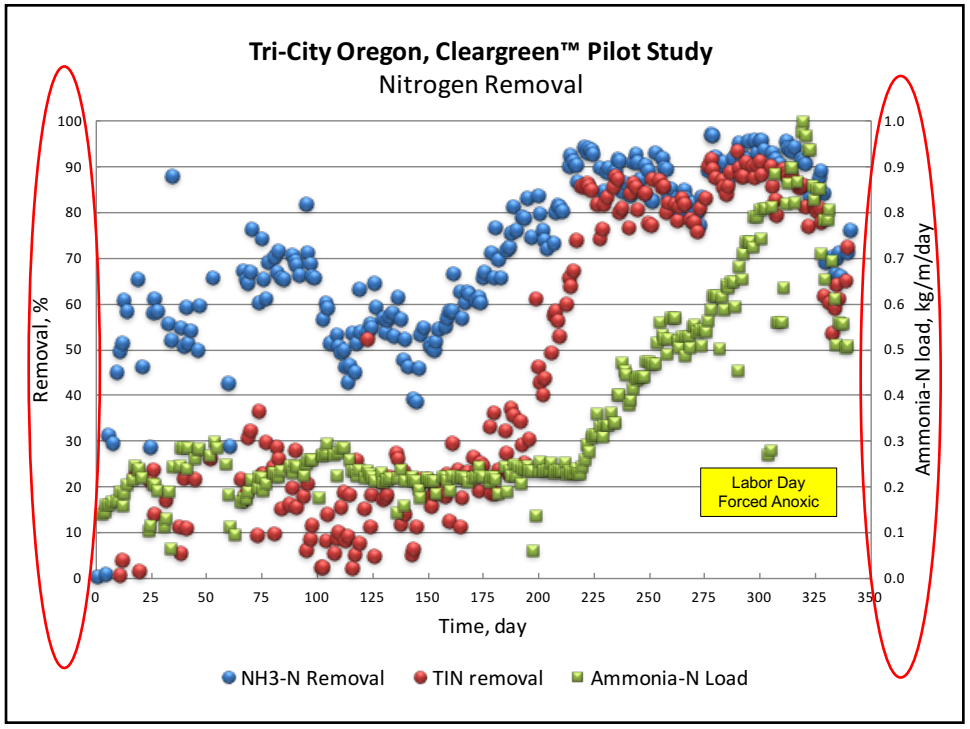
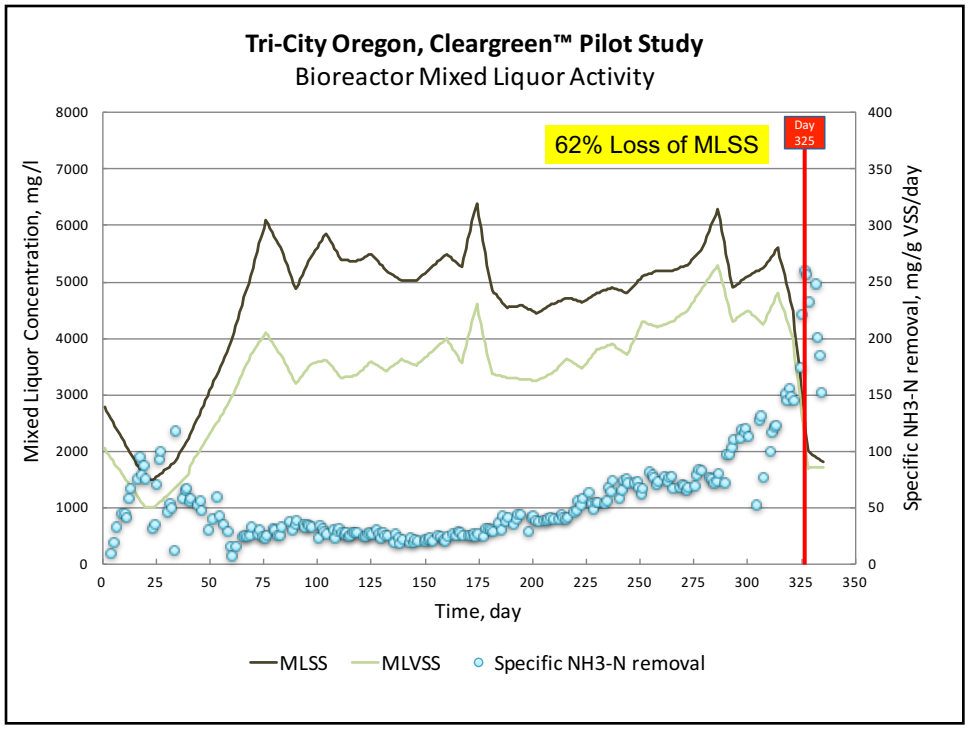
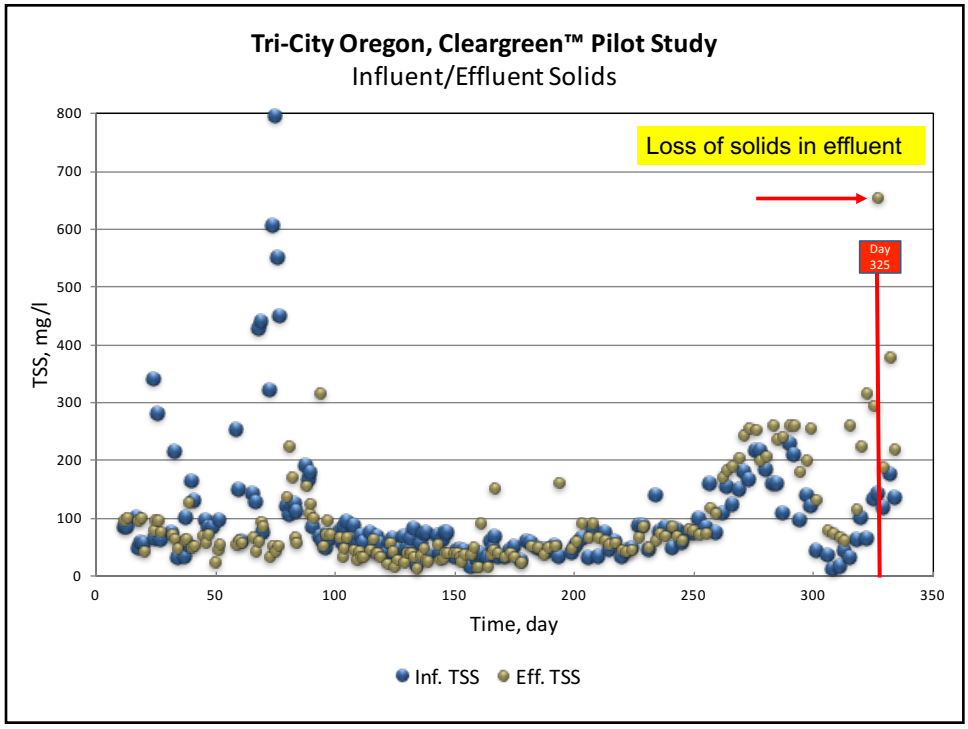
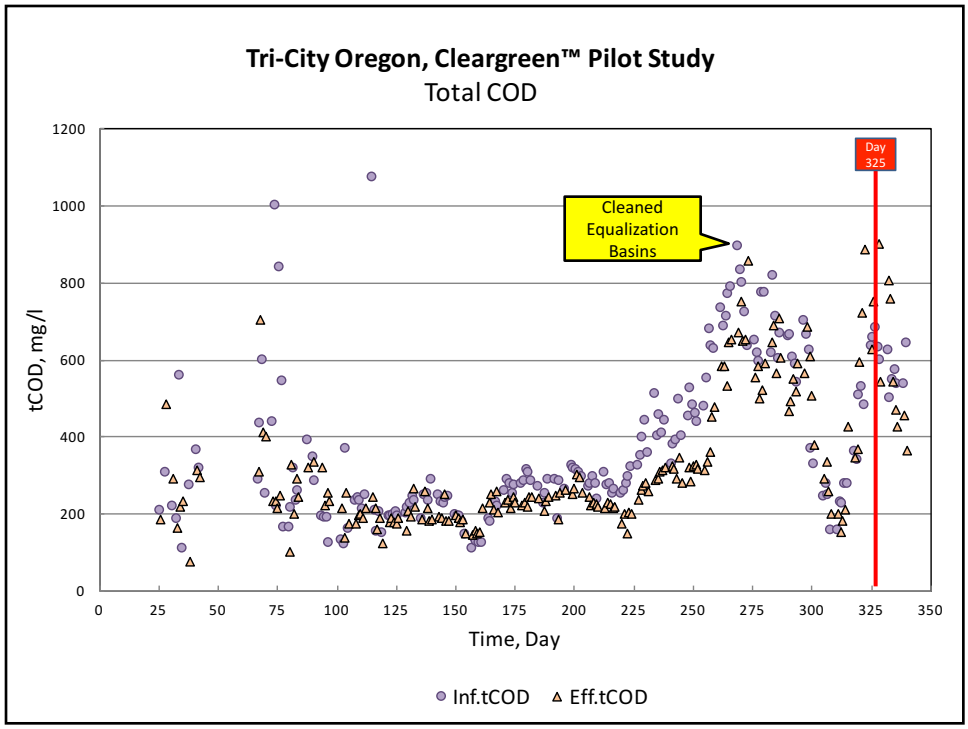
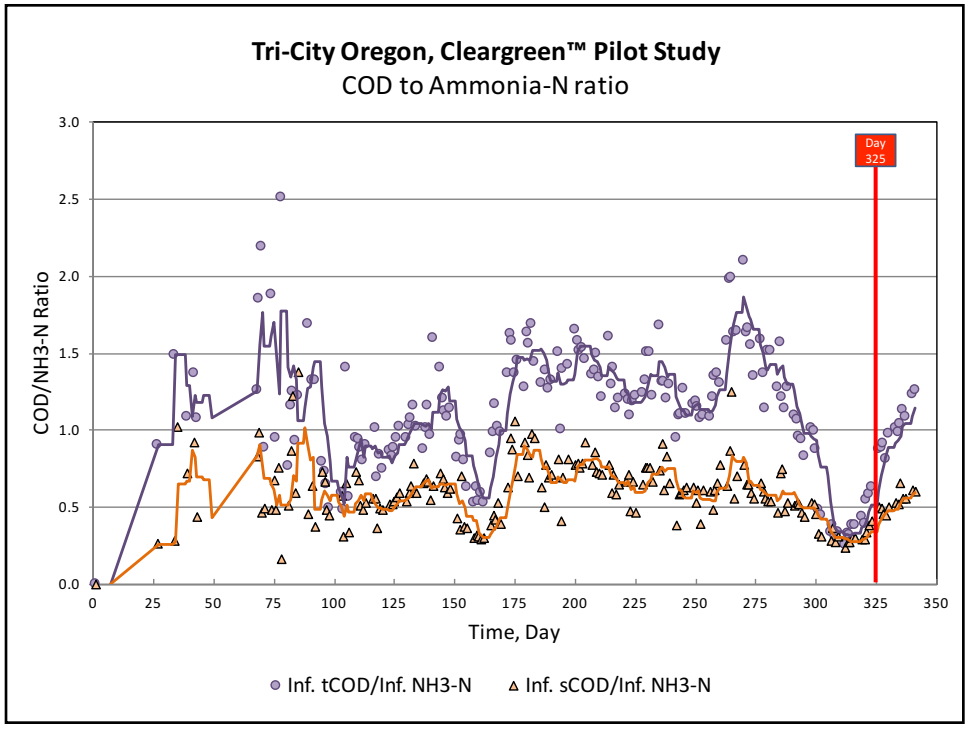

Tri-City Oregon, Cleargreen™ Pilot Study
Nitrogen Removal
Removal, %
Ammonia-N load, kg/m/day
Time, day
Labor Day
Forced Anoxic
NH3-N Removal
TIN removal
Ammonia-N Load


Tri-City Oregon, Cleargreen™ Pilot Study
Bioreactor Mixed Liquor Activity
62% Loss of MLSS
Day 325
Mixed Liquor Concentration, mg/l
Specific NH3-N removal, mg/g VSS/day
Time, day
MLSS
MLVSS
Specific NH3-N removal


Tri-City Oregon, Cleargreen™ Pilot Study
Influent/Effluent Solids
Loss of solids in effluent
Day 325
TSS, mg/l
Time, day
Inf. TSS
Eff. TSS


Tri-City Oregon, Cleargreen™ Pilot Study
Total COD
Day 325
Cleaned Equalization Basins
tCOD, mg/l
Time, Day
Inf.tCOD
Eff.tCOD


Tri-City Oregon, Cleargreen™ Pilot Study
COD to Ammonia-N ratio
COD/NH3-N Ratio
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Day 325
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Time, Day
Inf. tCOD/Inf. NH3-N
Inf. sCOD/Inf. NH3-N

Final Steps

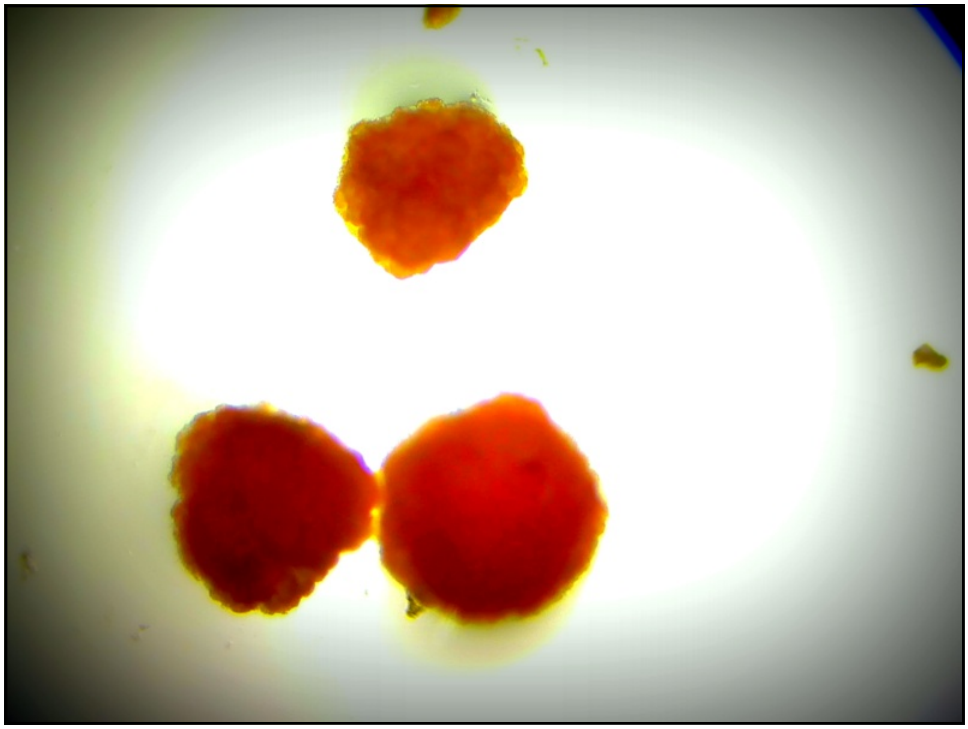
- Process Performances Demonstration

  One month (September 12th to October 12th) demonstration of process performances at Ammonia-N load between 0.8 kg/m³/day and 1.0 kg/m³/day.

- Increase Nitrogen Load to Process Failure

  Based on Tri-City's centrate's ammonia-N concentration of 1100 mg/l, the NH3-N loading potential are:

  - 1.1 kg/m³/day to 1.3 kg/m³/day with 8 hour cycle
  - 1.5 kg/m³/day to 1.8 kg/m³/day with 6 hour cycle



Dale's Opinions

- Centrate quality critical to system design
- Centrate alkalinity is adequate for process
- High polymer dose in dewatering centrifuge will affect anammox growth
- COD/Solids Load critical to successful operation
  - Design centrate equalization with solids removal
  - Centrifuge startup (slop) and clean should not go to centrate equalization
- Must operate and control with same intensity as activated sludge system
- Decanter design must allow for variable reactor depth/volume operation
- Full scale system startup

Acceptable Applications

- Permits with low TN limits
- Improve stability of nitrification for low NH3-N limits
- Lower operating costs
  - Lower power use
  - Lower requirement of alkalinity addition
  - Lower requirement for supplemental BOD, if required
  - Lower WAS production

The Real Question Is ……

- "Is centrate treatment cost effective?
- ANSWER is…..

Depends

Questions?