BUILDING A WORLD OF DIFFERENCE

June 24, 2015

Deammonification: Is it Right for You?

Ting Lu, PhD, PE
Jim Fitzpatrick, PE

100
1915 | 2015
BLACK & VEATCH
Building a world of difference.

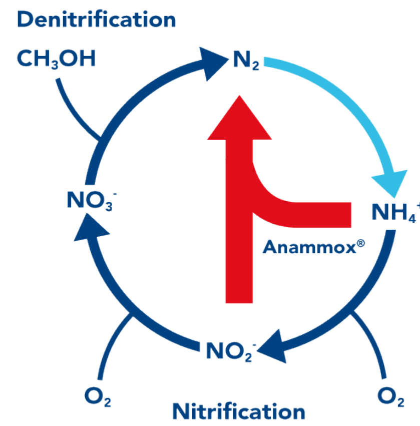
Ohio Water Environment Association
Preserving & Enhancing Ohio's Water Environment

OWEA 2015 Technical Conference and Exhibition
June 22-25, 2015
Kalahari Convention Center, Sandusky, Ohio

Outline

- Background and Overview
- Case Studies
- Conclusions

Nitrogen Cycle



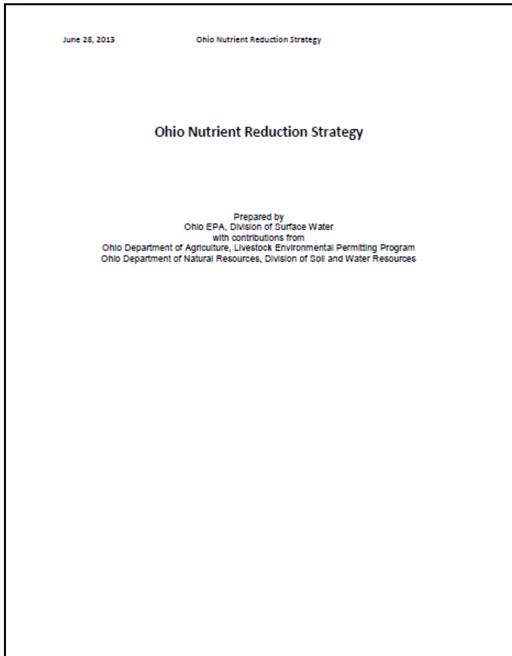
Courtesy Paques

METROPOLITAN SEWER DISTRICT of greater CINCINNATI

City of St. Joseph Missouri

dc water is life

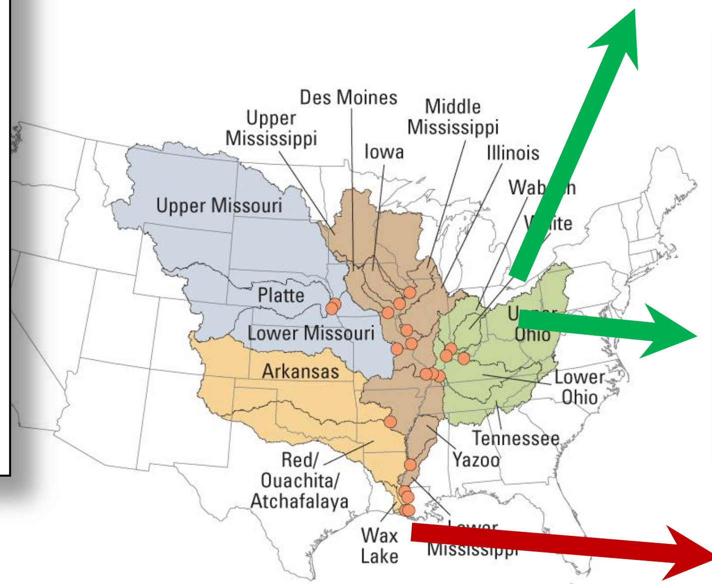
Drivers in Ohio


June 28, 2013 Ohio Nutrient Reduction Strategy

Ohio Nutrient Reduction Strategy

Prepared by
Ohio EPA, Division of Surface Water
with contributions from
Ohio Department of Agriculture, Livestock Environmental Permitting Program
Ohio Department of Natural Resources, Division of Soil and Water Resources

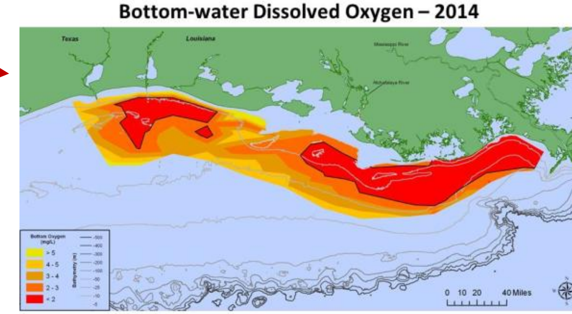
From http://ijc.org/en_/



From http://water.usgs.gov/nasqan/images/nasqan_ms_web.jpg

From http://wwwapp.epa.ohio.gov/gis/mapportal/hab.html

Bottom-water Dissolved Oxygen – 2014



Distribution of bottom-water dissolved oxygen July 27-August 1 (west of the Mississippi River delta), 2014. Black line indicates dissolved oxygen level of 2 mg/L.

Data source: Nancy N. Rabalais, LUMCON, and R. Eugene Turner, LSU
Funding sources: NOAA Center for Sponsored Coastal Ocean Research and U.S. EPA Gulf of Mexico Program

- Harmful algal bloom (HAB) in lakes → TP
- Gulf of Mexico hypoxia from Mississippi Atchafalaya River Basin (MARB) → TN

DEAMMONIFICATION

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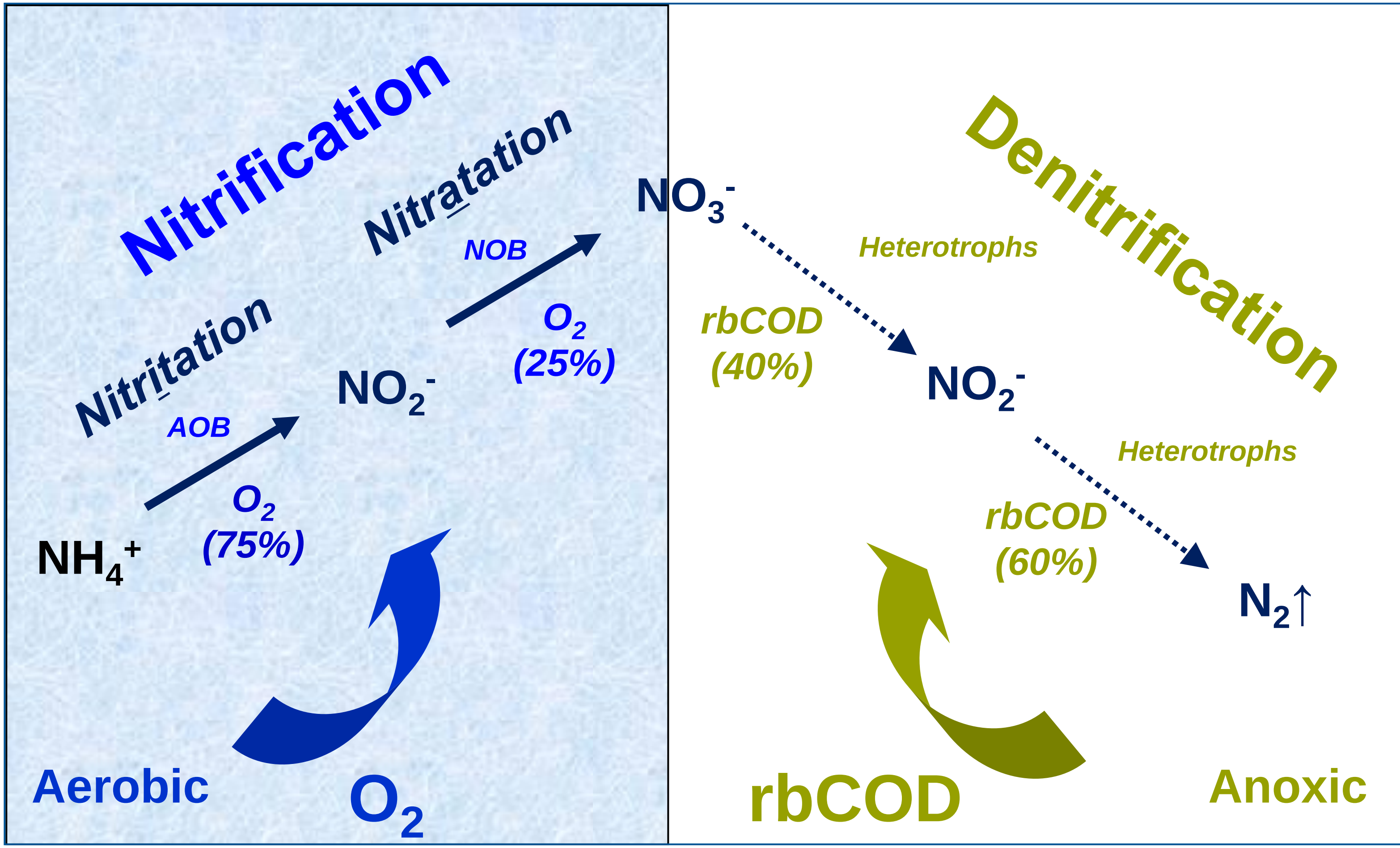
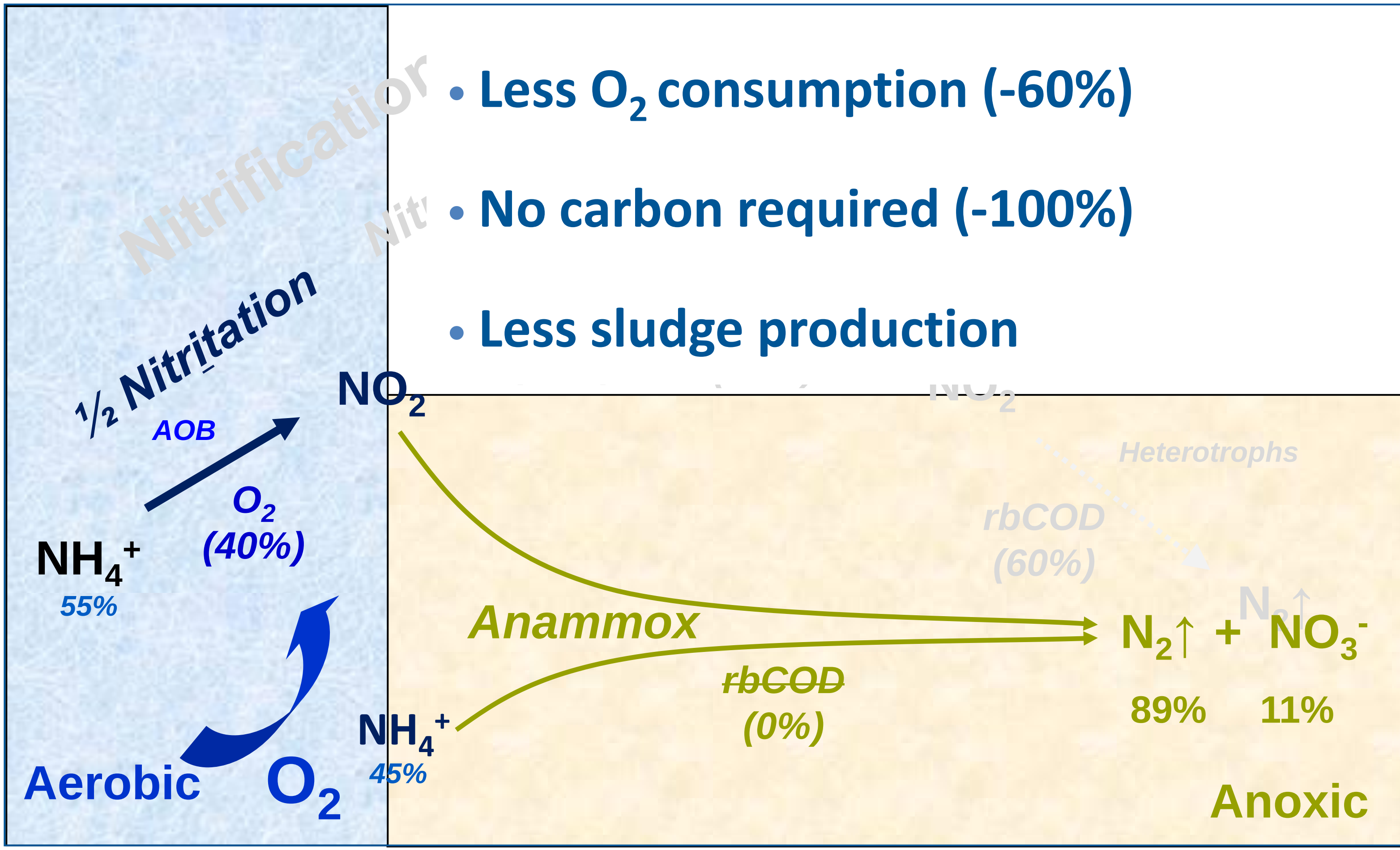
Conventional Nitrogen Removal



Consumes a lot of oxygen and chemicals. Energy intensive.

Deammonification

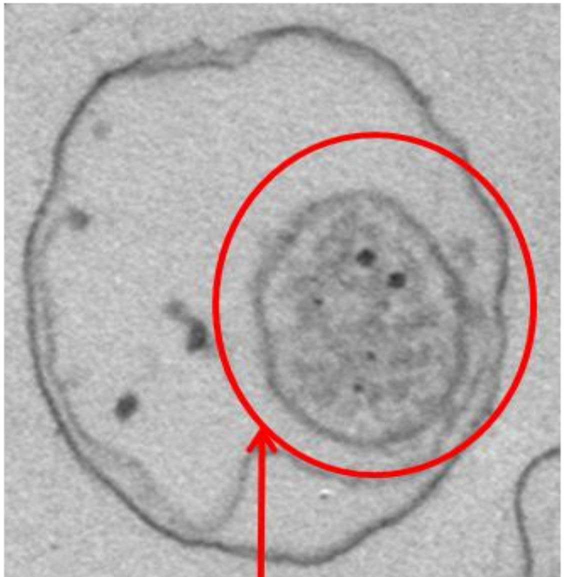
- Less O_2 consumption (-60%)
- No carbon required (-100%)
- Less sludge production



A two step process but occurring in one stage

Anammox Overview

Order: Planctomycetales[2]



Micrograph by Helen Markewich

Unique internal cell organelle: the anammoxosome

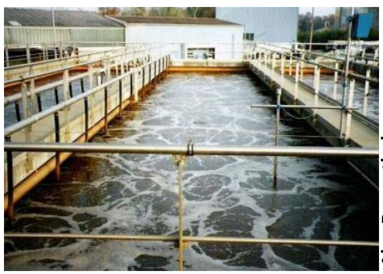
- **Extremely slow cell growth rate (~10 day doubling time)**
  - Biomass retention is critical
  - Optimal temperature = 25 – 35 °C
- **Various control complexity**
  - Timed intermittent aeration
  - DO and pH feedback control
  - NO_2^-, NO_3^-, and NH_3 feedback control
  - Control competing NOBs

Exponential growth in sidestream installations since discovery (1990s) and commercialization (2000s)

Side Stream Treatment with Anammox


Alex Rosenthal

Primary Sludge


Alex Rosenthal

Waste Activated Sludge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Anaerobic Digestion


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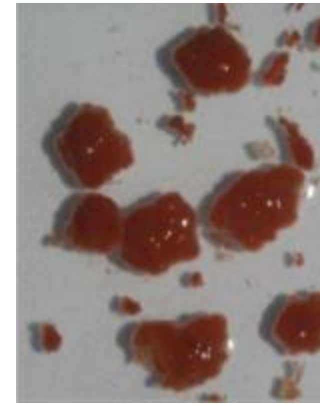
Dewatering


Alex Rosenthal


Alex Rosenthal

NH_3-N = 500-2000 mg/L

NH_3-N = 50-200 mg/L , NO_X-N = 5-20 mg/L

Anammox grows well in digestate liquors

Startup range: 1-2 months (w/ seed) ↔ >6 months (w/o seed)

Digestate Sidestream Application

Total WWTP Energy Use

60 % Used For Aeration

50 % For Nitrification

10-20 % N Load From Sidestream

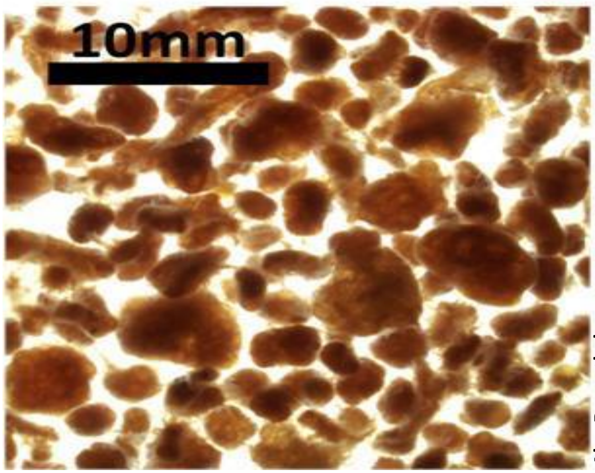
60 % More Efficient Than Conventional

Total WWTP Energy savings of 2-4 %

Biggest Drivers

1. **Reduce or eliminate carbon supplementation**
2. **N removal in a small footprint**

Reactor Types and Technologies



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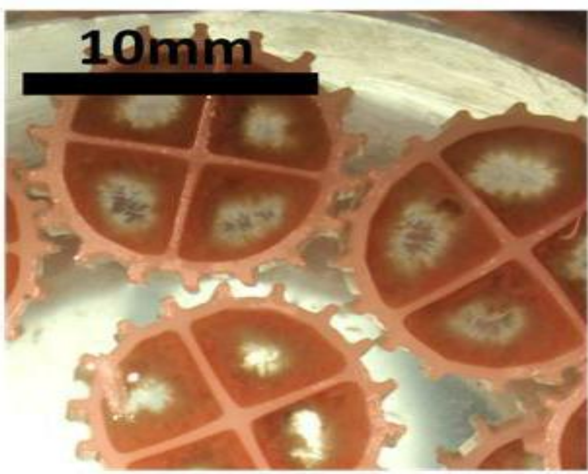
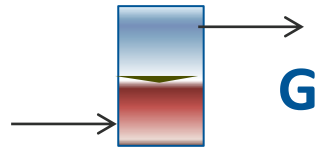
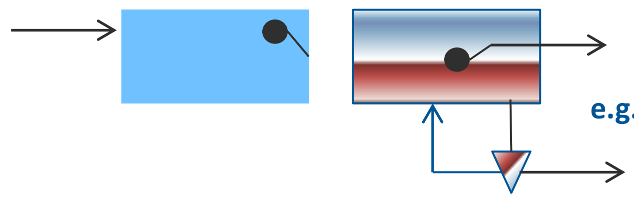


Alex Rosenthal



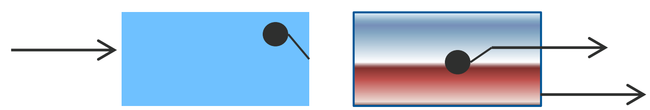
Granular Upflow

e.g. Anammox® (Paques)



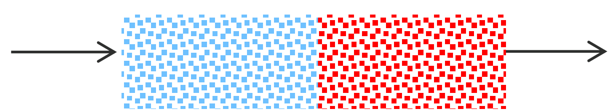
SBR + Cyclone

e.g. DEMON® (World Water Works)



SBR

e.g. Cleargreen™ (IDI)



Media (MBBR or IFAS)

e.g. ANITA™ Mox (Veolia/AnoxKaldnes)

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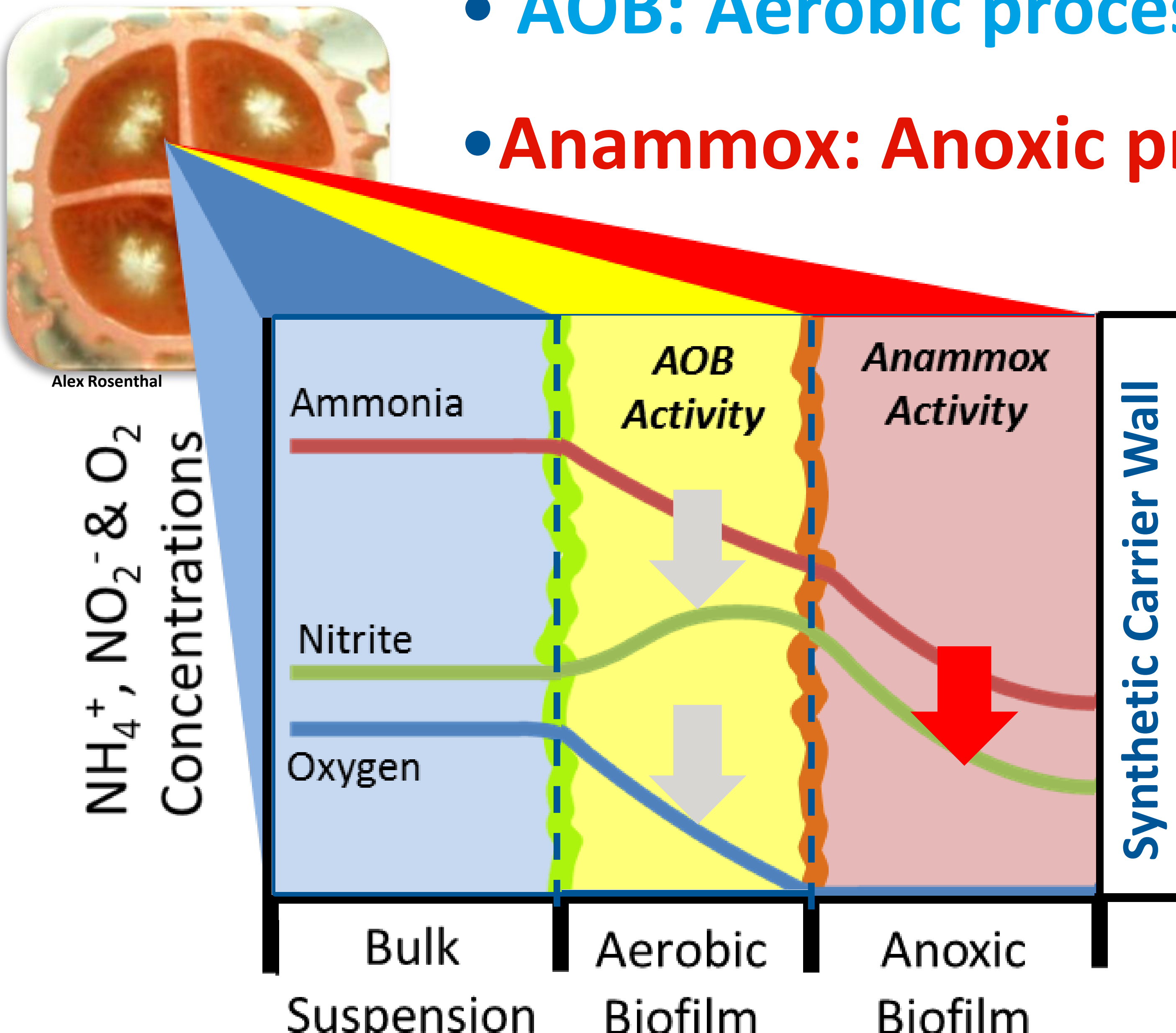
- **AOB: Aerobic process**
- **Anammox: Anoxic process**



Design Components

Physical layout

Anammox sludge
(granule startup)

Carrier media

Screens (media)

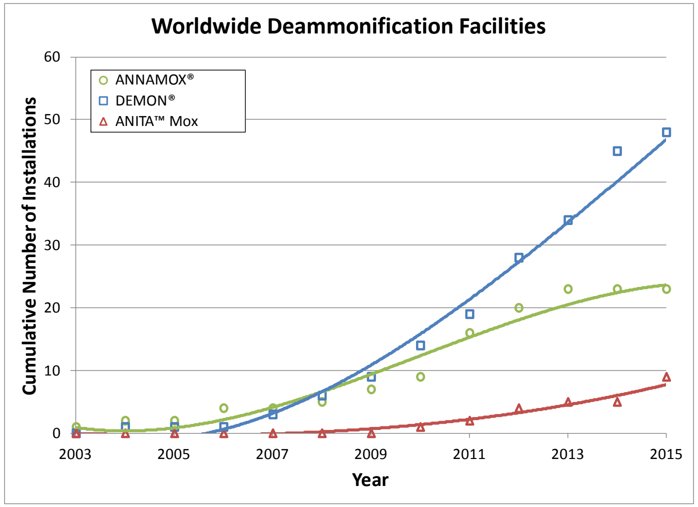
Mixing

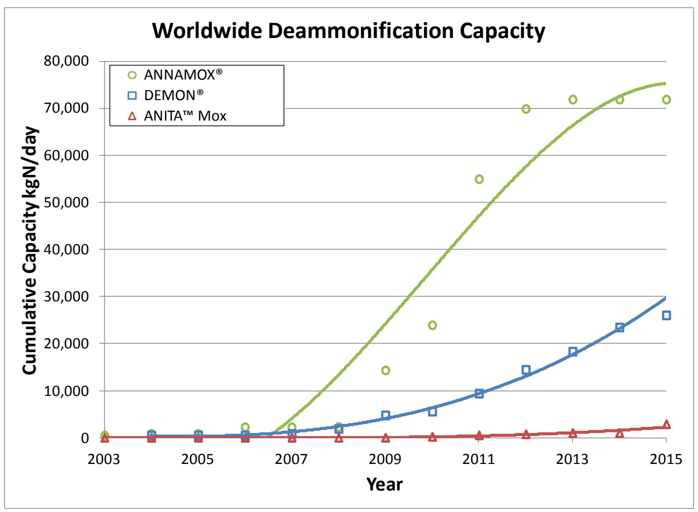
Aeration
•Blowers
•Coarse bubble diffusers

Cyclone
(Demon®)

Decanter
(SBR)

Gaining Traction in North America





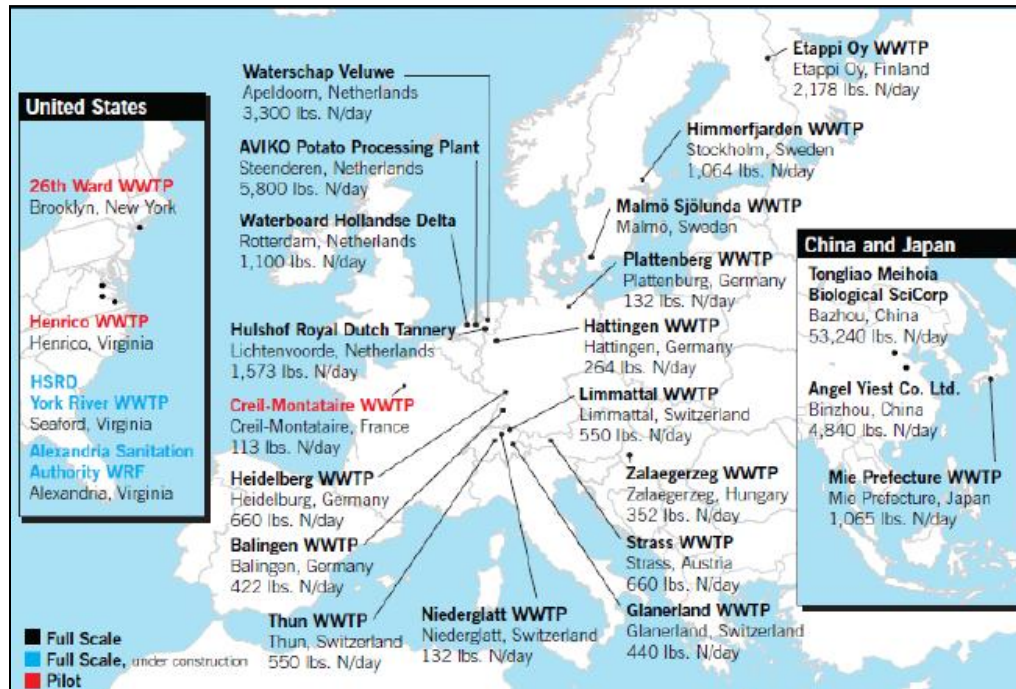
New Since 2012

Full-Scale

- Greeley, CO
- Guelph, Ontario, CAN
- Durham, NC
- Washington, DC
- Pierce County, WA

Pilot

- John E. Egan WRP, Chicago, IL
- Robert W. Hite WRF, Denver, CO
- Joint WPCP, Los Angeles County, CA
- Mill Creek WWTP, Cincinnati, OH
- St. Joseph, MO
- Tomahawk WWTF, Johnson County, KS



Source: T. Farina (2012) An Overview of Sidestream Treatment Alternatives Used to Increase Nutrient Removal, OWEA Annual Conference, Aurora, Ohio

Rapidly becoming established for sidestream applications

CASE STUDIES

- Cincinnati, OH
- St. Joseph, MO
- Washington, DC

Background

METROPOLITAN SEWER DISTRICT of greater CINCINNATI

MSDGC

- 230,000 residential and commercial users
- 250 industrial users

Mill Creek WWTP

- Up to 430 mgd primary and disinfection
- Up to 240 mgd activated sludge treatment
- Fluid bed incineration: ~100 dry ton per day

Major Industrial Waste: Landfill Leachate

Landfill Leachates		Flow	TCOD	SCOD	NH_4-N	pH	Ca	Temp
		MGD	(mg/L)	(mg/L)	(mg/L)		(mg/L)	(˚C)
Regular Strength	Avg.	0.1	4,226	1,988	650	8.5	100	25
	Min		1,290	1,110	140	7.6	85	15
	Max		20,600	4,900	1,460	10.6	140	29
High Strength	Avg.	0.2	65,000	60,000	1,932	6.9	3,200	30
	Min		49,000	35,500	1,434	5.4	2,667	28
	Max		105,000	95,000	3,500	7.1	3,570	38

High organic and ammonia concentrations.
Significant variability.

Leachate Treatment Challenges

Industrial Load	POTW
• Highly variable • High strength • Very odorous • Discharge to big interceptor	• Process instability • Consumes energy • Odor control • CSO events • New WWTP?

Increasing importance of treatment alternatives for leachate

Pilot Project Objectives

Treatability	• How feasible is deammonification for leachate treatment?
Inhibition	• Does leachate pose inhibition risks to the deammonification process?
Stability/Reliability	• How stable/reliable is the deammonification process for this application?

Processes Piloted

Regular leachate:

- ANITA™ Mox
  - Moving Bed Biofilm Reactor (MBBR)
  - Integrated Fixed Film Activated Sludge (IFAS)
- Nitrite shunt

High strength leachate:

- Anaerobic Member Bioreactor (AnMBR)
- Upflow anaerobic sludge blanket (UASB) + ANITA™ Mox

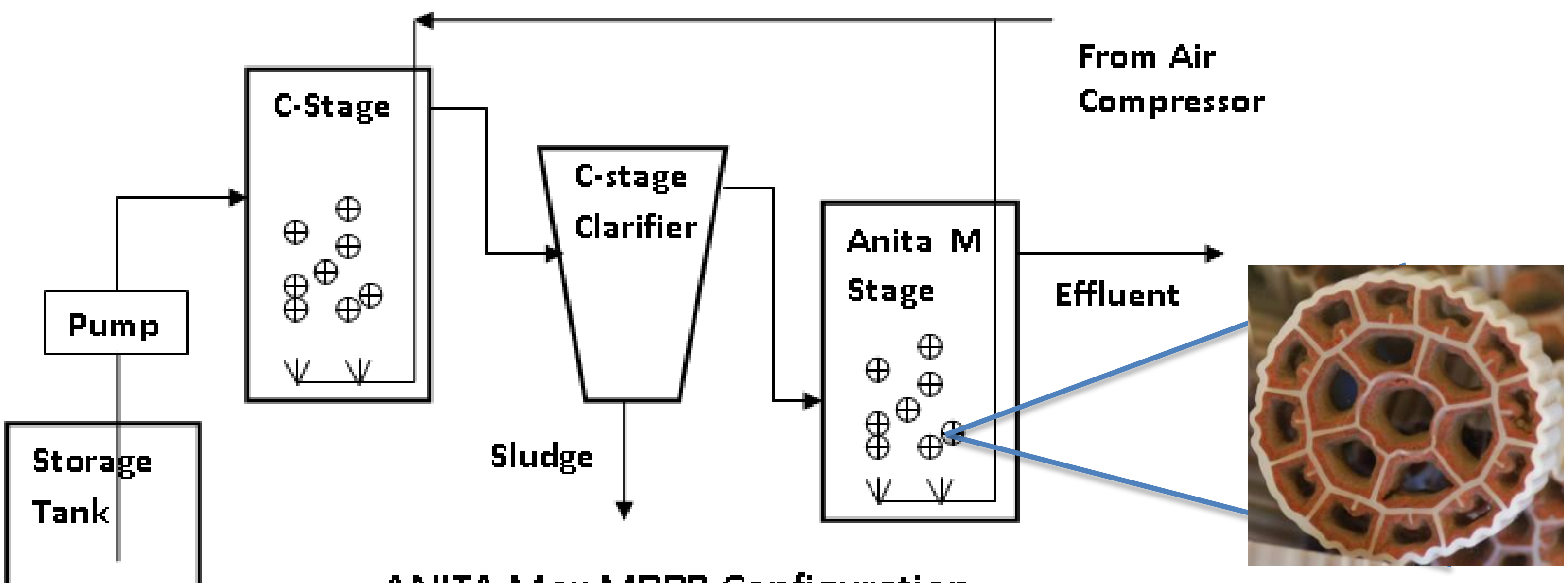
Pilot MBBR Flow Schematic

C-stage

- Heterotrophic bacteria
- Carbon removal

A-stage (ANITA™ Mox)

- AOB & Anammox
- Nitrogen removal



ANITA Mox MBBR Configuration

Maintain the right microbial structure!

Pilot Plant Layout

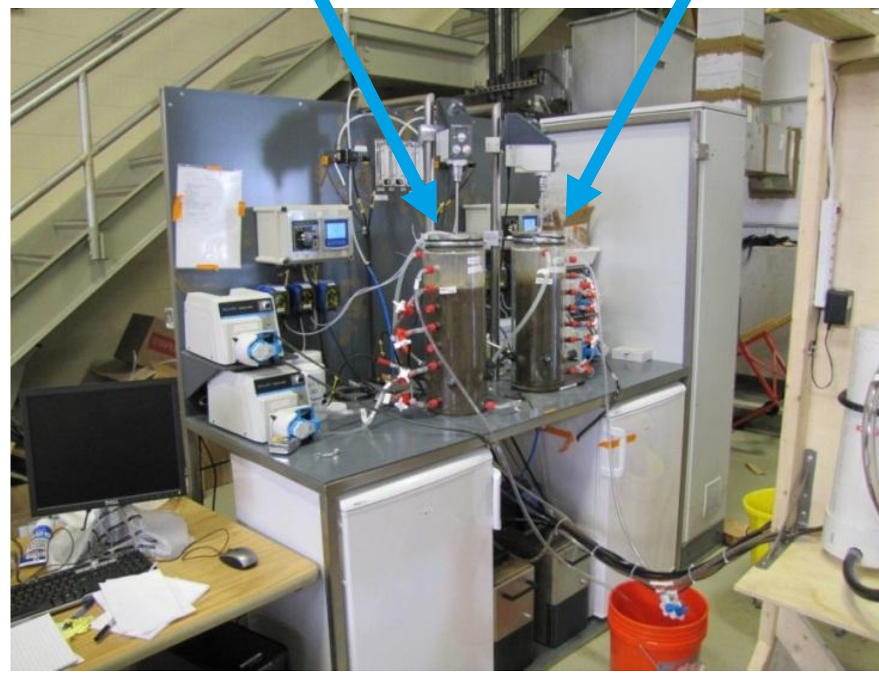
A-Clarifier

C-Clarifier

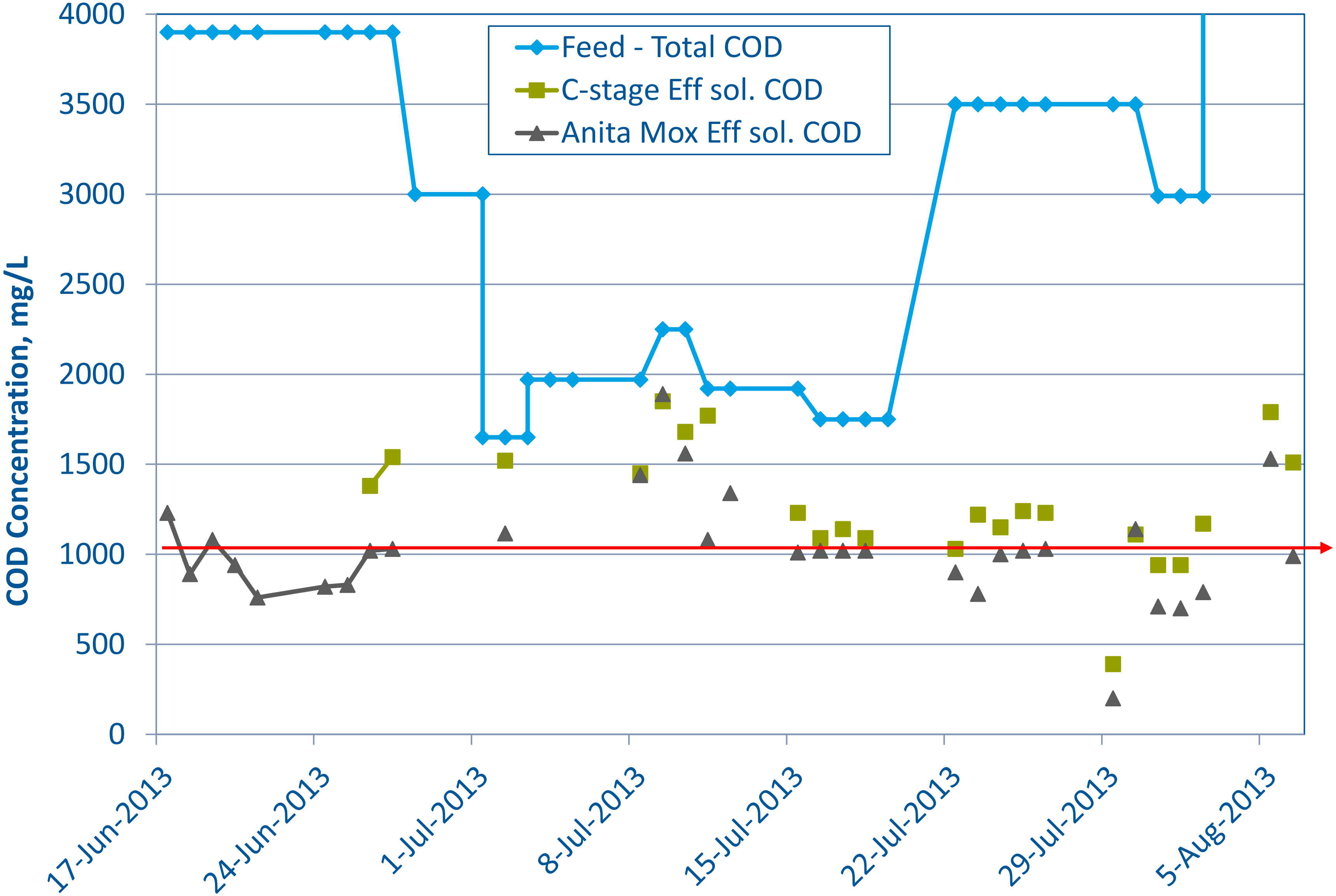
C-Stage Reactor

Train 1 A-Stage Reactor

Train 2 A-Stage Reactor

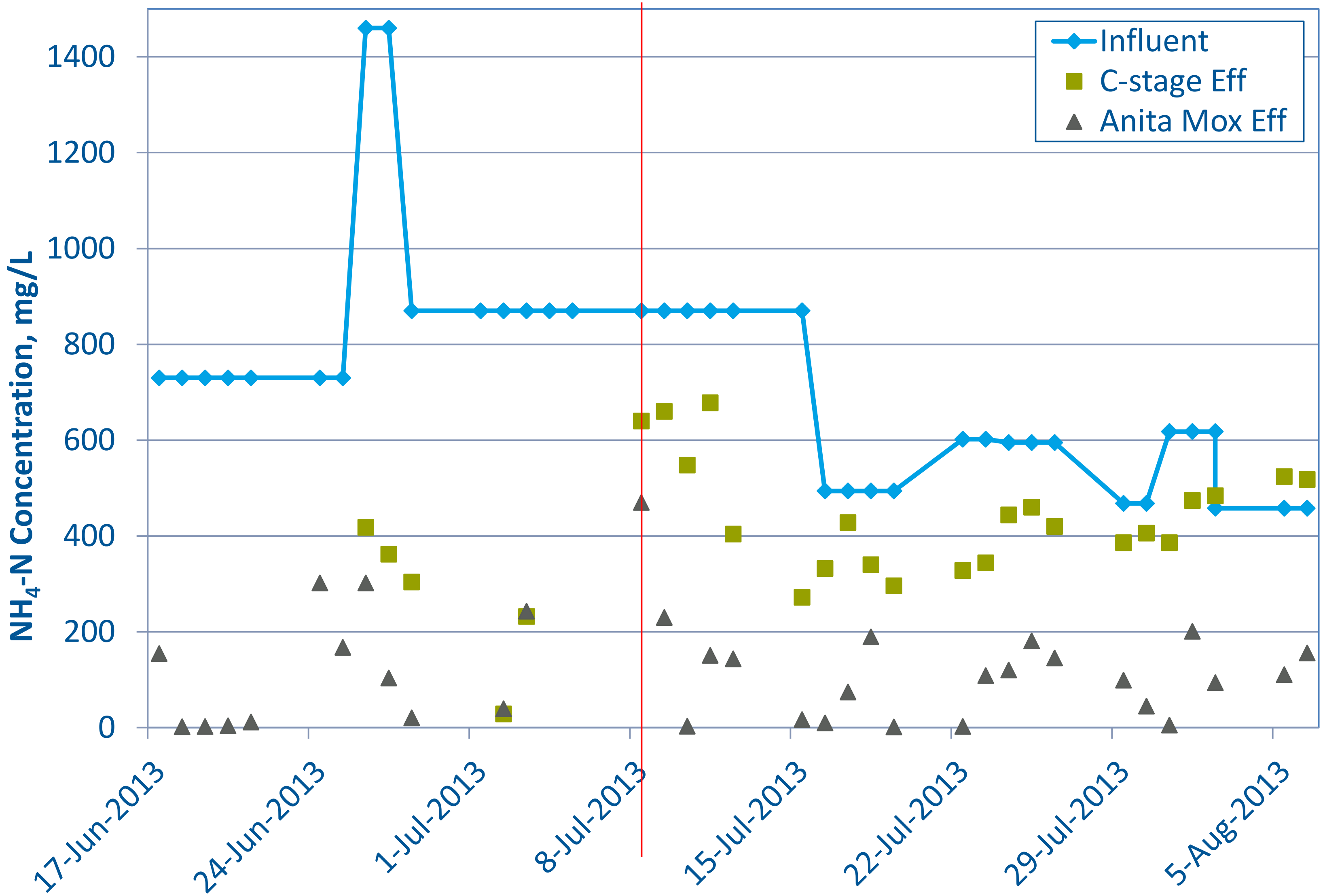


MBBR – COD Profiles

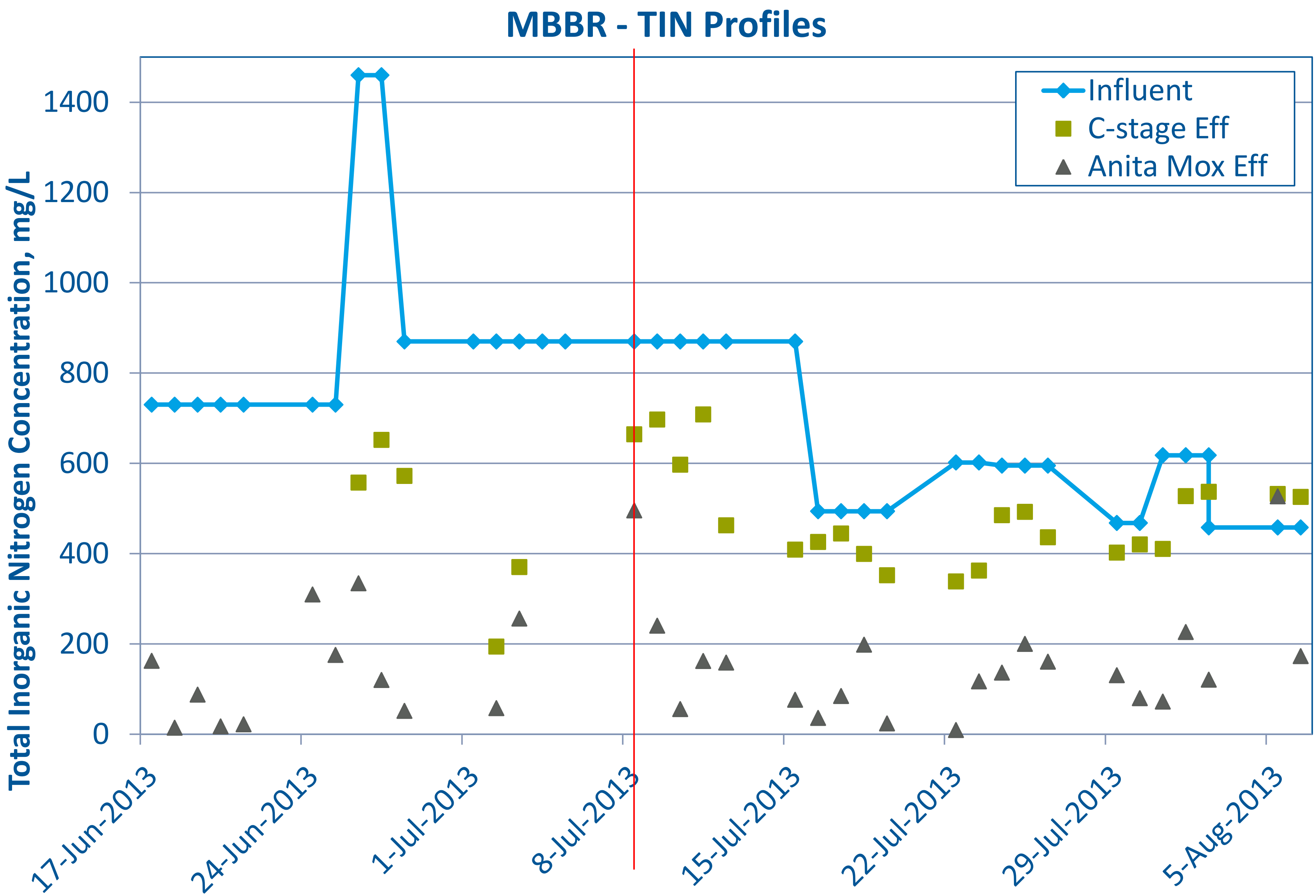


Majority of COD was removed by C-stage.

MBBR - Ammonia Profiles



A-stage removed majority of ammonia instead of C-stage after ~July 9th



A-stage removed majority of influent TIN after ~July 9th

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ANITA™ Mox Design Criteria

	CINCINNATI		DENVER*	LA**
Feed	Regular Leachate		Centrate	Centrate
Media	Originated from Denver			
	REMOVAL (%)	SRR*** ($g/m^2/day$)	SRR ($g/m^2/day$)	SRR ($g/m^2/day$)
COD	80	15	N/A	N/A
TIN	82	1.1	2.5	2

*Hollowed et al (2013) Evaluation of the Anita-Mox Moving Bed Biofilm Reactor Process for Sidestream Deammonification at the Robert W. Hite Treatment Facility, Denver Colorado, WEF Nutrient Removal & Removery Conference, Vancouver, Canada.

**Nicholas Smal, Michael Liu, Robert Morton (2014) Pilot-scale Evaluation of Anita Mox for Centrate Nitrogen Removal at the JWPC, California Water Environment Association Annual Conference, Santa Clara, California.

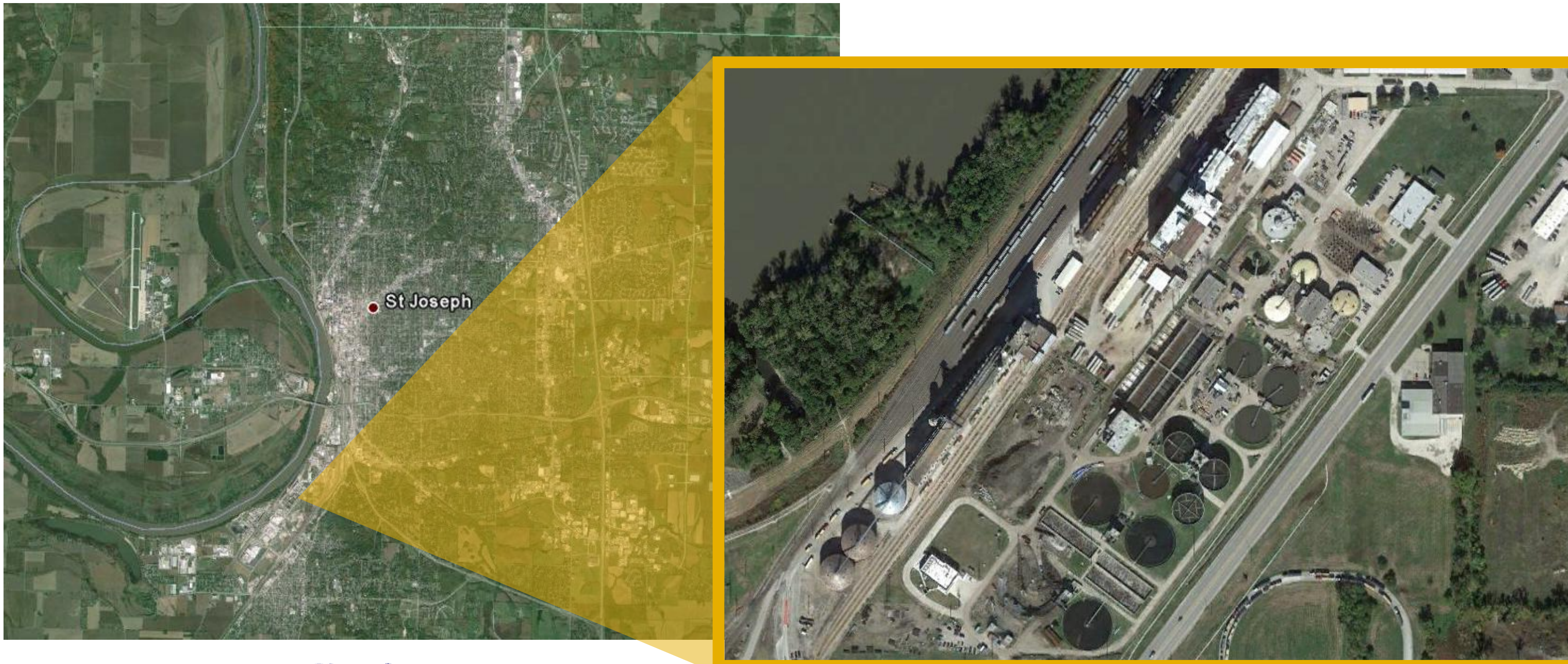
***Surface Removal Rate

MSDGC Pilot Conclusions

Treatability	• ANITA™ Mox capable of treating regular landfill leachate • Seeded media from centrate was able to adapt to leachate
Inhibition	• Apparent inhibition from leachate attributed to a lower surface removal rate (SRR)
Stability/Reliability	• Biofilm medium is very reliable and robust to respond to toxic conditions (i.e. nitrite build up)

ST. JOSEPH, MISSOURI

Background



City of St. Joseph Missouri

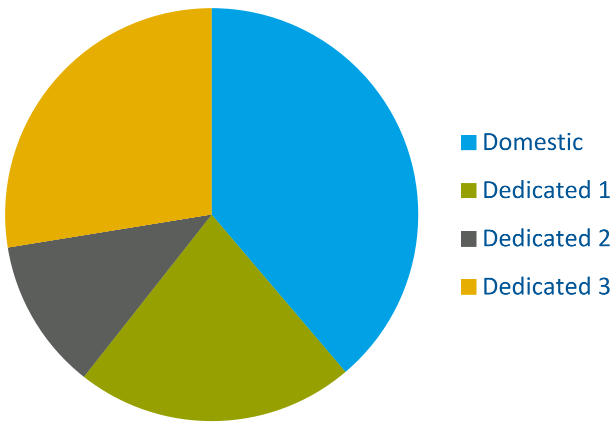
- 77,000 residents
- 30 industrial users

Water Protection Facility

- 20-mgd annual average
- New permit limits for ammonia
- Two SIUs = 15% influent flow and 50% TN load

Industrial community is essential to the City

Goals and Objectives



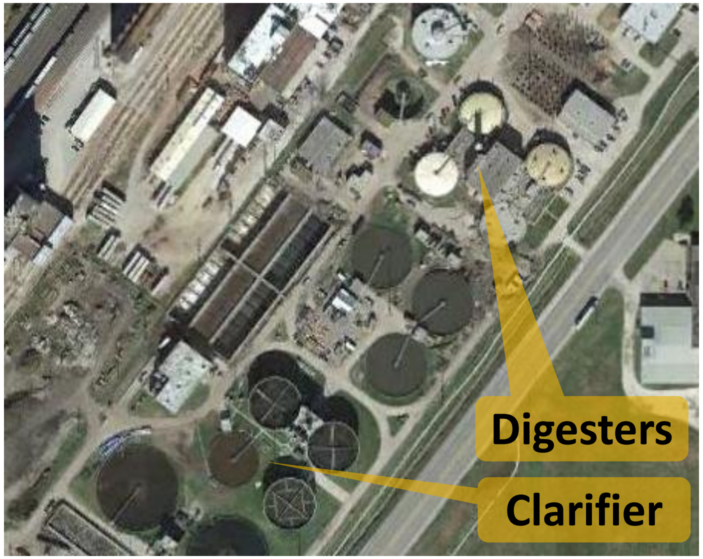
8000 ppd Influent NH_3-N
– 4200 ppd Permitted
3800 ppd NH_3-N to remove

Technical Assistance Program

- **Public/private partnership**
  - City
  - Industrial users
  - Consultants
- **Innovative approaches to allow increased industrial production as well as meet new NPDES permit limits**
- **Pilot new nitrogen removal technologies**

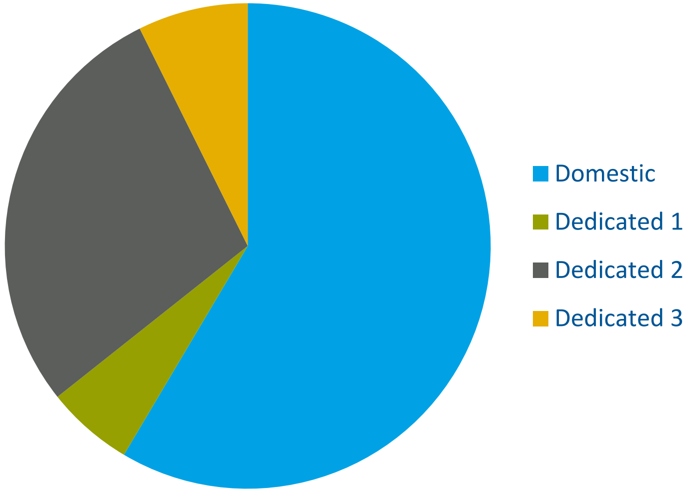
New approaches to reduce costs to both City rate payers and industrial users

Concept for Future Nitrogen Removal



- **Deammonification conversion**
  - Two unused secondary digesters
  - Existing mixing and heating
  - Potential alkalinity addition
- **Re-route SIUs from clarifier**

3800 ppd Removal Required
– 3200 ppd Deammonification by SIU
600 ppd Nitrification by POTW



- **Feasible compliance scenario**
- **Pilot studies to evaluate treatment technologies**

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Nitrogen Removal Technology Evaluations

Preliminary Alternatives Screening

- Integrated Fixed Film Activated Sludge (IFAS)
- ANITA™ Mox Moving Bed Biofilm Reactor (MBBR)
- DEMON® Sequencing Batch Reactor (SBR)
- Granular Activated Sludge
- 2-stage Membrane Bioreactor (MBR)
- Nitrite Shunt

Bench-Scale Pilot Testing

- ANITA™ Mox MBBR (by B&V)
- ANITA™ Mox MBBR (by AnoxKaldnes)

Demonstration-Scale Pilot Testing

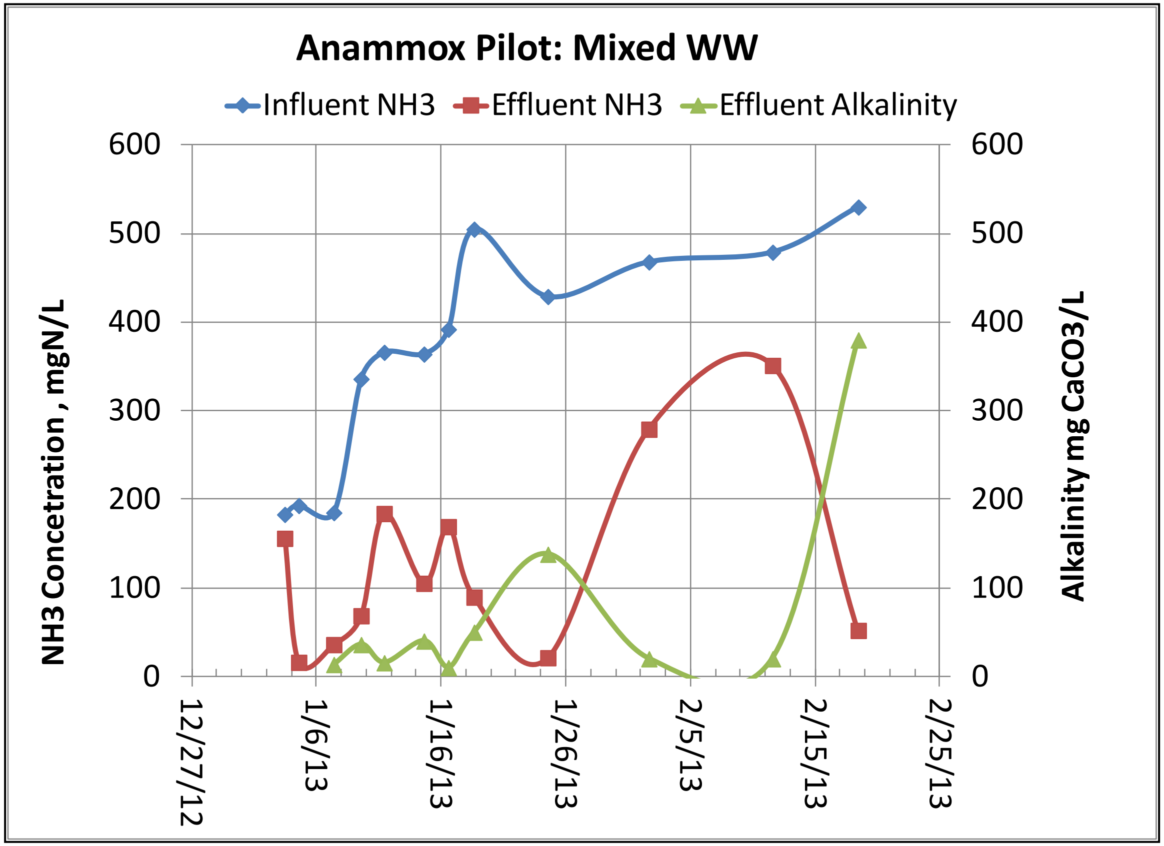
- DEMON® SBR(at WPF by World Water Works)
- DEMON® SBR (at SIU by World Water Works)

Initial Bench-Scale Piloting

Influent Conditions	Reactor Conditions
Reactor #1: 45% SIU#1, 45% SIU#2, 10% WPF digester sludge supernatant	0.25 m^2 pre-colonized media from NYC pilot
Reactor #2: SIU#1 – Slaughter house wastewater	1 to 2 day hydraulic retention
Reactor #3: SIU#2– tannery wastewater	Single-stage intermittent aeration
	30 to 35 °C

NH_3 and alkalinity monitored to track performance

Anammox MBBR Pilot - Mixed Influent



- **At 30ºC (±0.8) average temperature:**
  - Average ammonia removal efficiency = **70% (± 23)**
  - Average removal rate = **1.5 g/m²-d (± 0.7)**

Alkalinity limiting episodes

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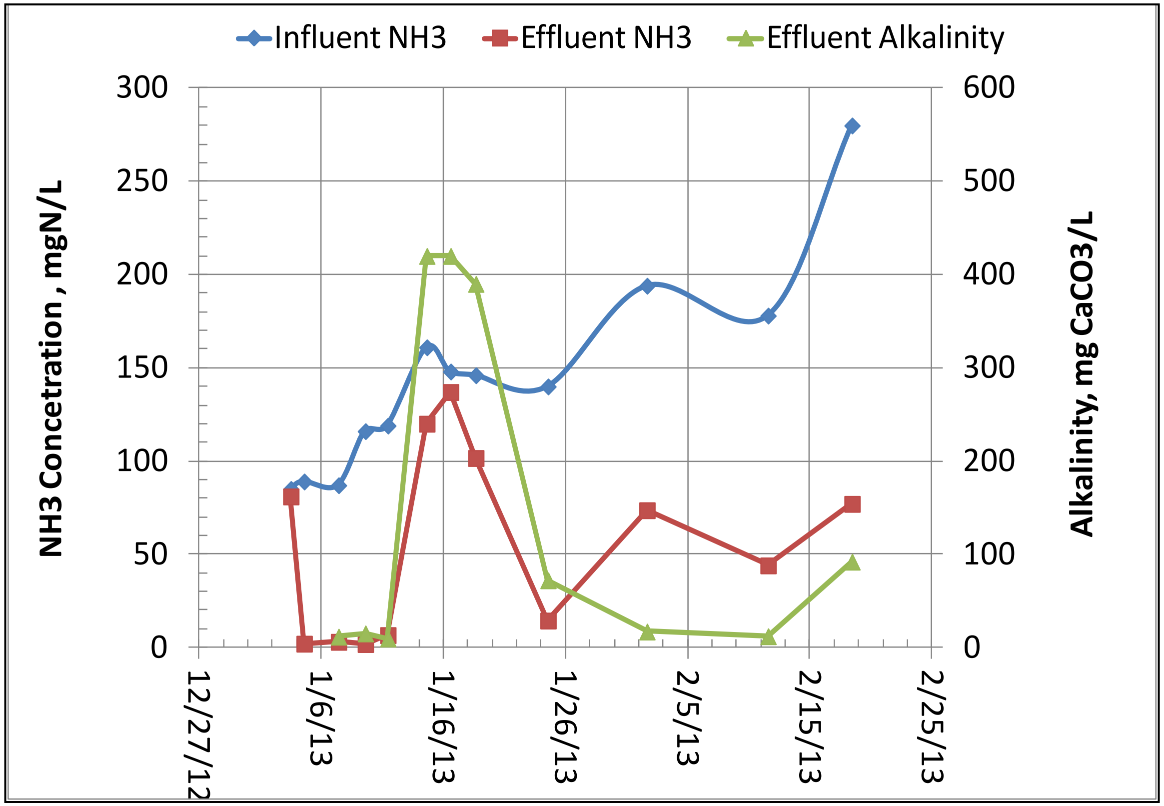
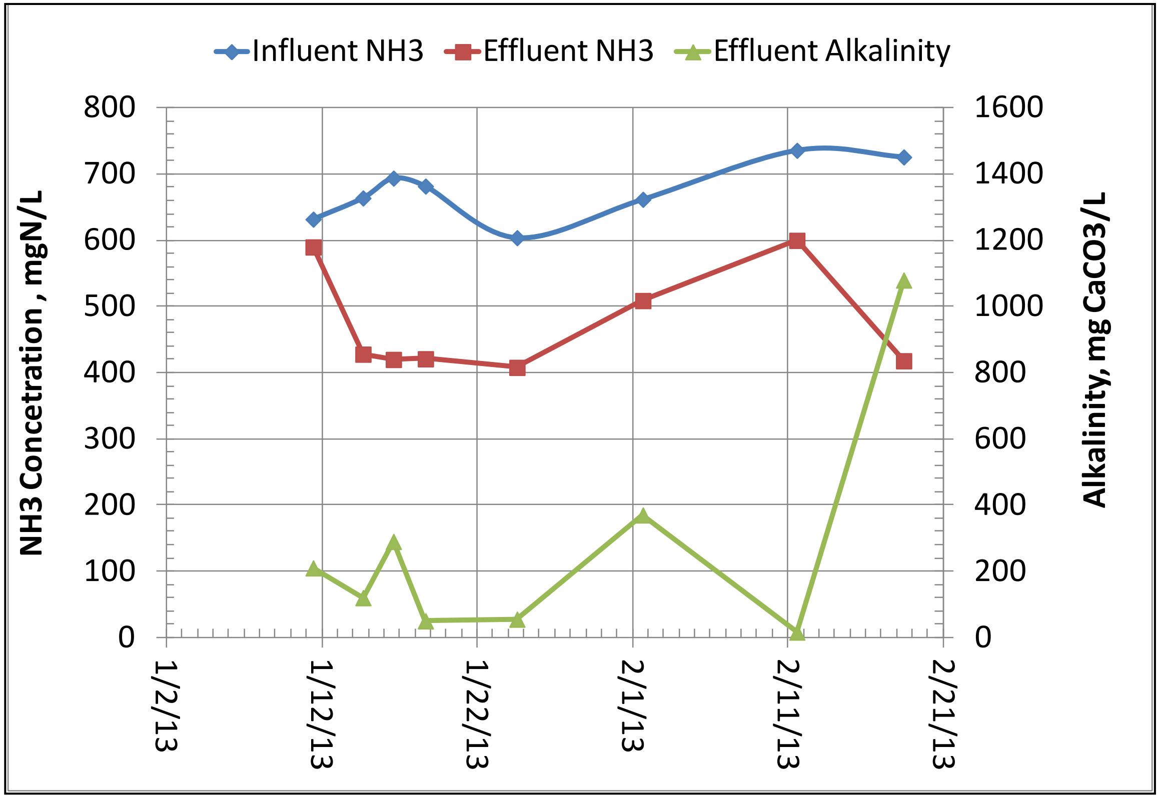
Anammox MBBR pilot - SIU #1 Influent



- **At 34 ºC (± 1.7) average temperature:**
  - Average ammonia removal efficiency = **86% (±0.14)**
  - Average removal rate = **0.71g/m² –d (±0.24)**

1/11 to 1/24/13 - temperature dropped to 22ºC

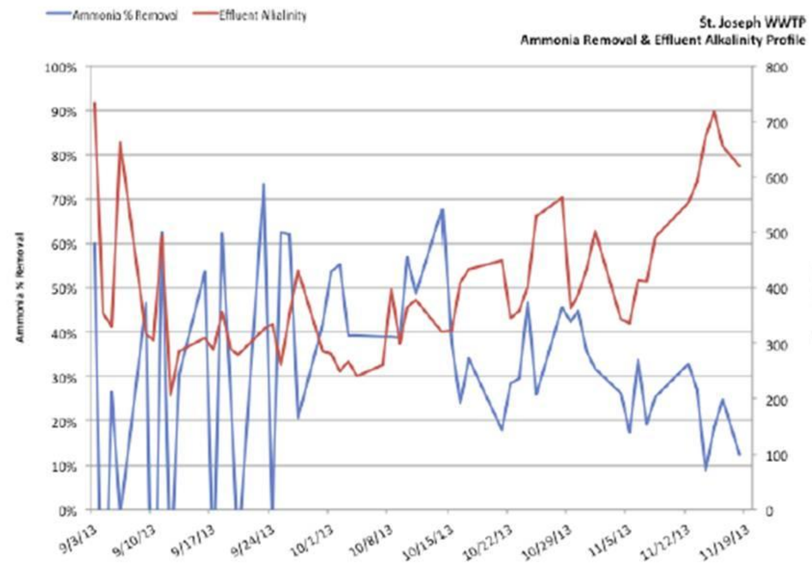
Anammox MBBR pilot - SIU #2 Influent



- **At 33 °C (± 0.7) average temperature:**
  - Average ammonia removal efficiency = **30% (±12)**
  - Average removal rate = **1.1 g/m² –d (±0.22)**

Inhibition suspected from micronutrient deficiencies and/or biocide

DEMON® Full Scale Demonstration



- WPF and SIU locations
- Average ammonia removal = 70%

Variability of wastewater characteristics hindered performance

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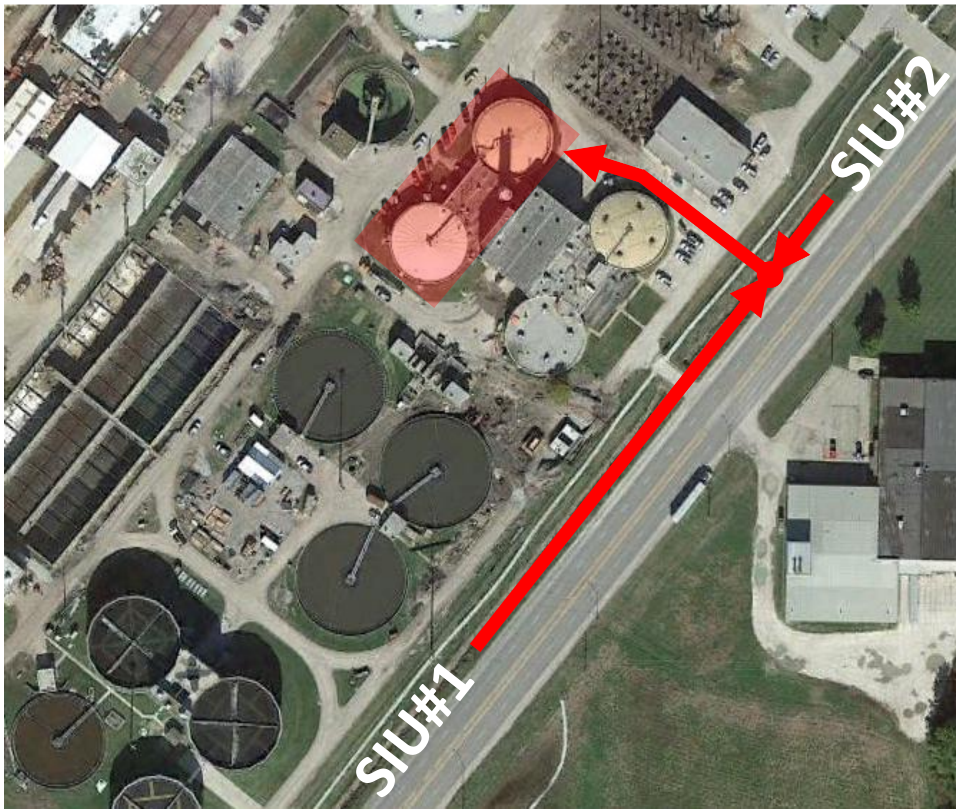
Conceptual Design



Project Estimate = $20-29 million
•Yard piping
•Equalization basin
•Influent pump station
•Digester conversion
•Blower modifications

Approximately 30% lower capital costs than conventional MLE alternative

WASHINGTON, DC

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Deammonification for DC Water

FTF design based on DEMON® process

Blue Plains AWTP Filtrate Treatment Facility

- **Design Features**
  - BFP filtrate from thermal hydrolysis → anaerobic digestion
  - DEMON® process, largest of its kind, first multi-tank system
  - Treat 1.1 mgd with NH_3-N up to 3,000 mg/L
  - Remove ~27,340 lb-N/day
- **Schedule**
  - 2013 - design completed
  - March 2014 - construction NTP
  - Dec 2016 - substantial completion
- **Probable Construction Cost**
  - $ 47-53 Million

CONCLUSIONS

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Is Deammonification Right for You?

Considerations:

- Effluent nitrogen limits
- Wastestream characteristics - C:N ratio
- Anaerobic digestion
- Space constraints
- Potential toxicity or inhibition - pilot testing
- Temperature
- Chemical and energy costs
- Existing facilities and operations

Deammonification is generally lowest cost alternative on $/lb N removed basis

For Further Details:

T. Lu, B. George, D. Metz, D. Linn, A. Bahar, H. Zhao (2014) How Does Deammonification Technology Work in Industrial Waste: A Case Study of Using Anita Mox Process to Treat Landfill Leachate, *WEFTEC Proceedings*, New Orleans, Louisiana.

G. Hunter, R. Jezek, A. Clements, D. Gilpin, A. Nifong, C. Johnson, M. Ekenberg (2014) Communication and Technology: Winning Formula for Treatment of Industrial Waste, *WEFTEC Proceedings*, New Orleans, Louisiana.

P. Thomson, B. Blair, S. Kharkar, N. Passarelli, C. deBarbadillo, R. DerMinassian, B. Woods, J. Doane, J. Tattersall (2014) Deammonification Treatment of Filtrate Sidestream at Blue Plains AWTP: Project Challenges and Updates, *WEFTEC Proceedings*, New Orleans, Louisiana.

Building a **world** of difference.®

Together

Ohio Water Environment Association

Preserving & Enhancing Ohio's Water Environment

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METROPOLITAN SEWER DISTRICT of greater CINCINNATI

SEAL OF THE CITY OF ST. JOSEPH MO

City of St. Joseph Missouri

dc water is life

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