AQUA-AEROBIC SYSTEMS, INC.
A Metawater Company

AquaNereda®

Aerobic Granular Sludge Technology

Tatiana Mazzei
Project Applications Engineer

Overview

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- History of Aerobic Granular Sludge
- What is Aerobic Granular Sludge?
  - Attributes
  - Granule Formation
- AquaNereda Process & Operation
- Comparison of AquaNereda vs. Other Processes
- Demonstration Facility and Pilot Units
- Installations Worldwide and in the U.S.
- Summary

History of Aerobic Granules

From The Netherlands to the United States

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1995 — Aerobic Granule Research Begins

1996 — First Granules in Laboratory

2005 — First Industrial AGS Plant (Netherlands)

2009 — First Municipal AGS Plant (South Africa)

2016 — AASI North America Licensee

2017 — First AquaNereda Pilot in North America

2018 — Construction of Demo Facility Begins (Rockford, IL)

2020 — First North American AGS Plant Start-up (Foley, AL)

Demo Facility Operation Begins

78 Nereda® Plants Worldwide

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Nereda® Plants Worldwide

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AquaNereda® in the U.S.

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Rock River Water Reclamation District

Rockford, IL
Capacity (Ave) 0.2 MGD
Capacity (Max) 0.4 MGD

RIVIERA UTILITIES
Serving South Baldwin County

Wolf Creek, AL
Capacity (Ave) 3.5 MGD
Capacity (Max) 6.0 MGD

Kahului Airport

Maui, HI
Capacity (Ave) 0.08 MGD
Capacity (Max) 0.08 MGD

City of Whitefish

Whitefish, MT
Capacity (Ave) 2.0 MGD
Capacity (Max) 6.0 MGD

IDAHO SPRINGS
CLEAR CREEK COUNTY COLO.

Idaho Springs, CO
Capacity (Ave) 1.0 MGD
Capacity (Max) 2.0 MGD

UNIFIED GOVERNMENT
Wyandotte County • Kansas City, Kansas

Wolcott, KS
Capacity (Ave) 2.0 MGD
Capacity (Max) 6.0 MGD

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Aerobic Granular Sludge Technology

Technical Overview

Aerobic Granular Sludge

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Definition

"Granules making up aerobic granular activated sludge are to be understood as aggregates of microbial origin, which do not coagulate under reduced hydrodynamic shear, and which subsequently settle significantly faster than activated sludge flocs."

- True microbial biomass
- Aerobic granular sludge's SVI5 comparable to SVI30 of conventional activated sludge
- Minimum particle diameter of 200 μm

Aerobic Granular Sludge

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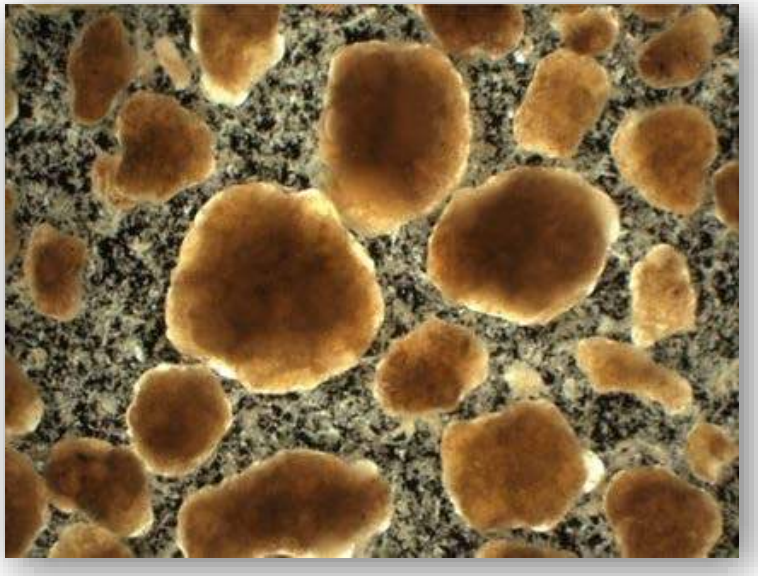
Conventional Activated Sludge vs. Granule Structure

Conventional Activated Sludge



Aerobic Granular Sludge

Aerobic Granular Sludge

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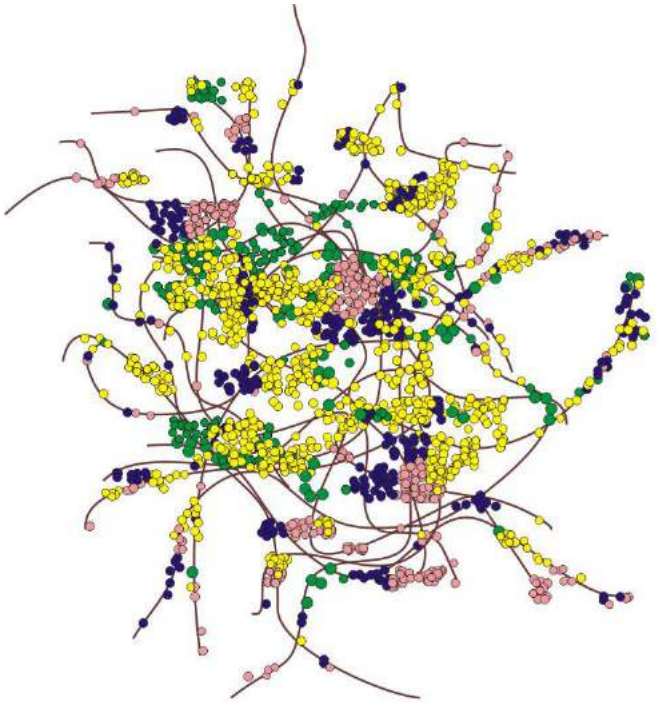
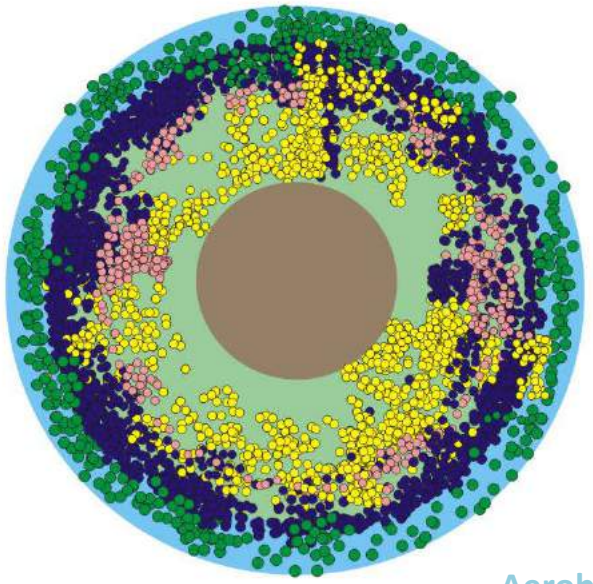
Conventional Activated Sludge vs. Granule Structure





Conventional Activated Sludge
Mixed Microbial Community

Aerobic Granular Sludge
Layered Microbial Community

Source: engineersjournal.com

FISH Analysis

(Fluorescence In Situ Hybridization)

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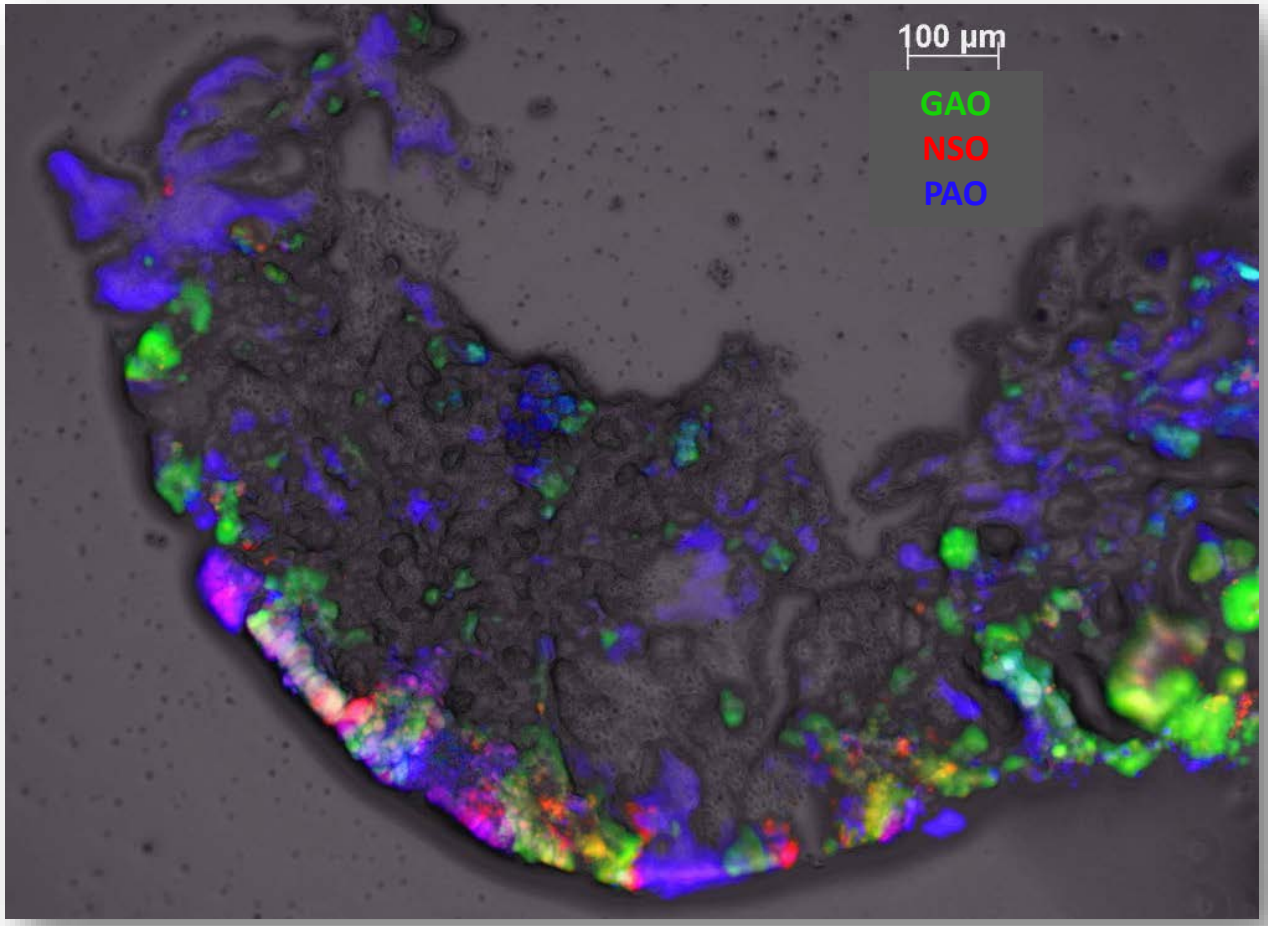

GAO: Glycogen Accumulating Organism
NSO: Nitrifying Organisms
PAO: Phosphate Accumulating Organisms

Aerobic Granular Sludge

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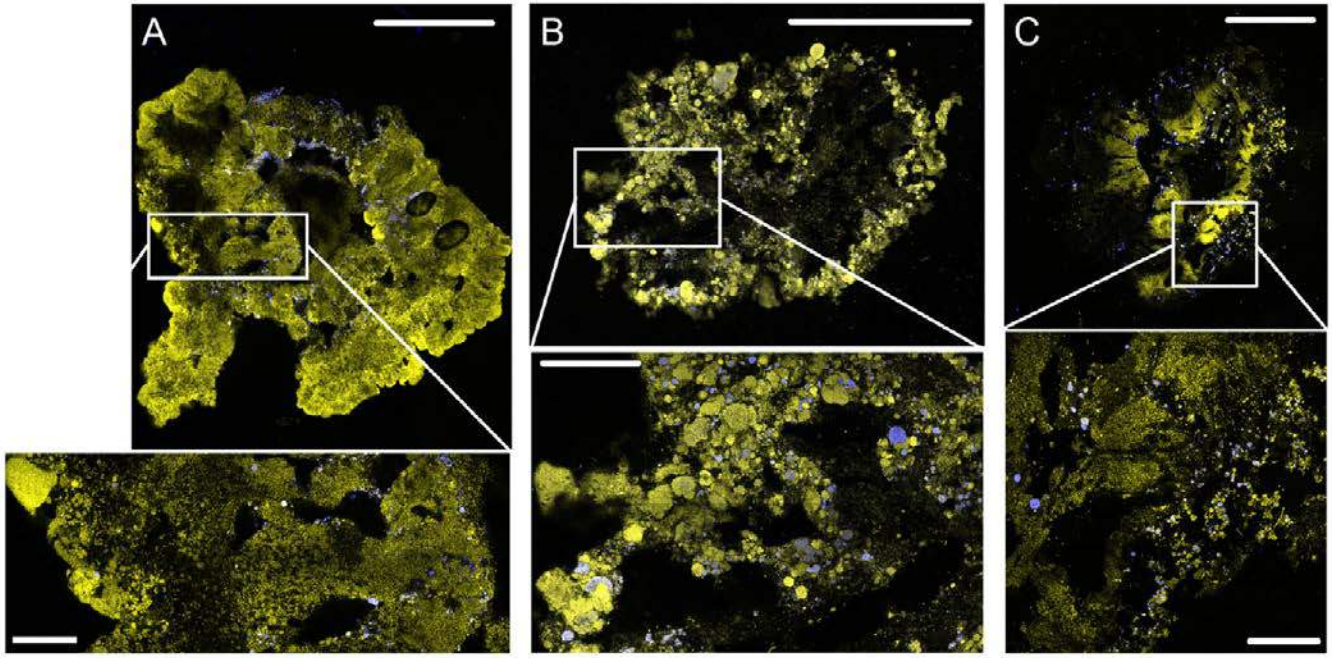
Granular Structure

- Granules are not perfectly spherical
  - Complex structures with voids and channels
  - Allows penetration of nutrients into larger particles



Szabo, E., Liebana, R., Hermansson, M., Modin, O., Persson, F., Wilen, B. M., . . . Department of Chemistry and Molecular Biology. (2017). Microbial population dynamics and ecosystem functions of Anoxic/Aerobic granular sludge in sequencing batch reactors operated at different organic loading rates. *Frontiers in Microbiology*, *8* doi:10.3389/fmicb.2017.00770

Aerobic Granular Sludge

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Settleability

- Excellent settling properties
- Increased MLSS

Granule Formation

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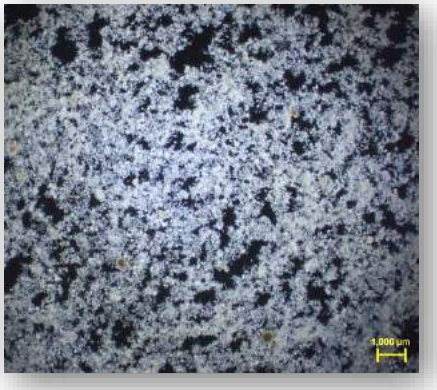
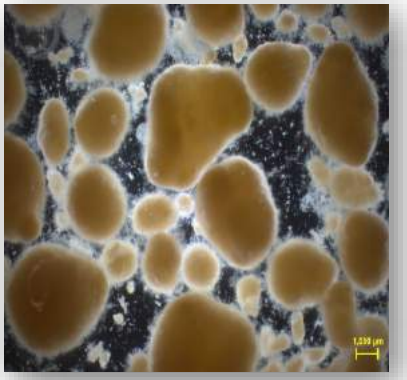
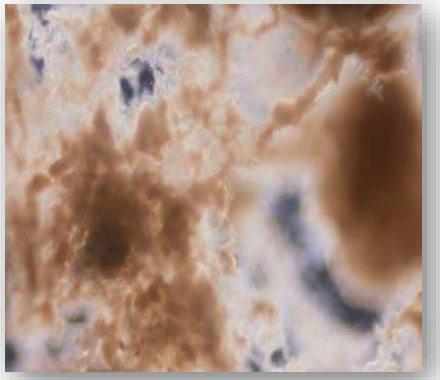
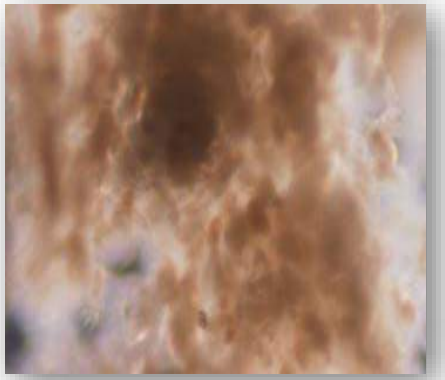
Selection Mechanisms

1. Hydraulic selection for fast-settling particles
2. Biologic selection of EPS-forming microorganisms

Granule Formation

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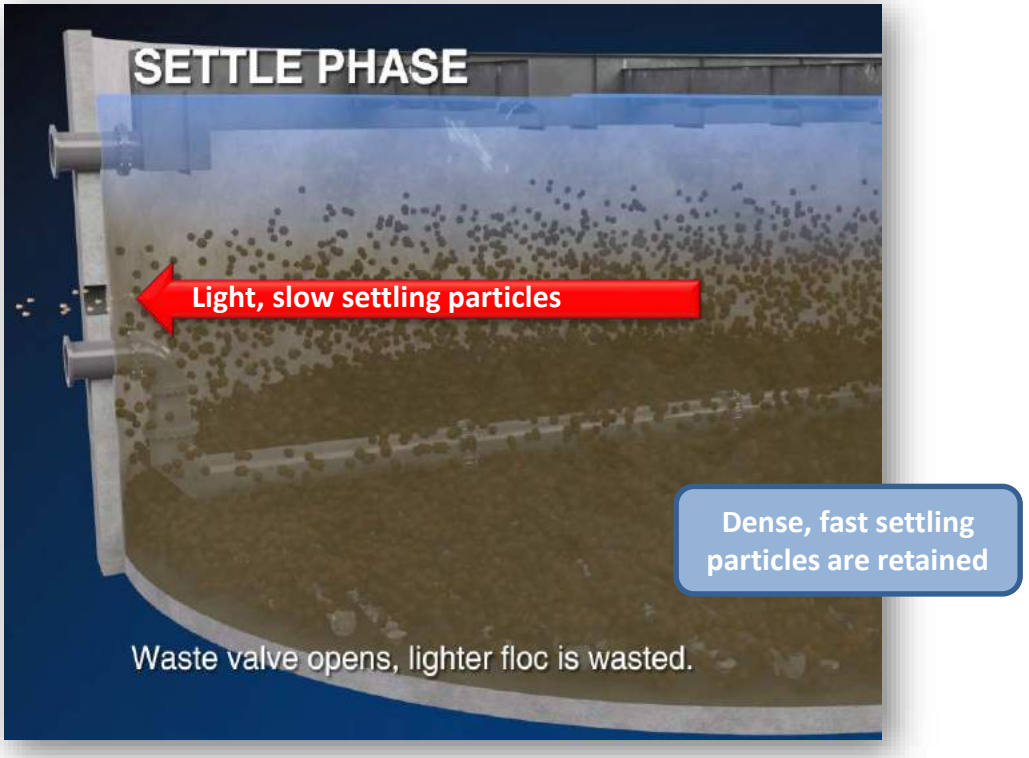
Hydraulic Selection

- Selective wasting
- Wash out smaller particles
- Dense granules settle faster than CAS
- Decreased settling time



Granule Formation

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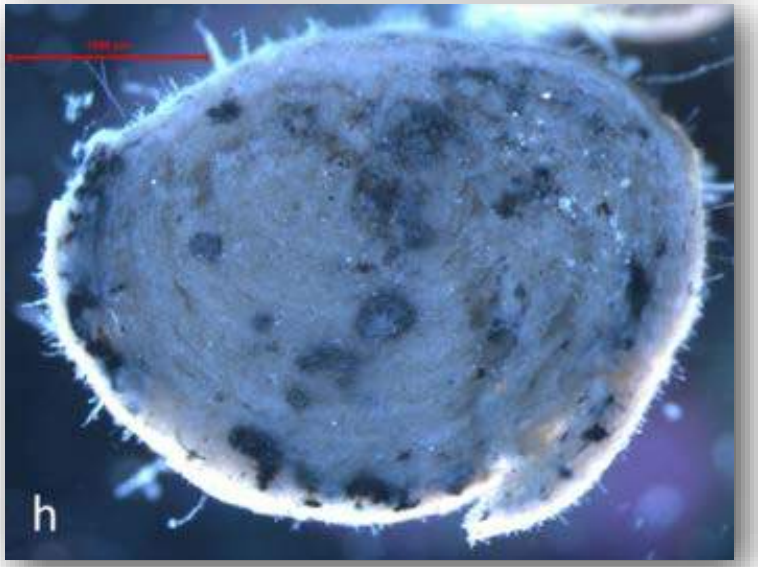
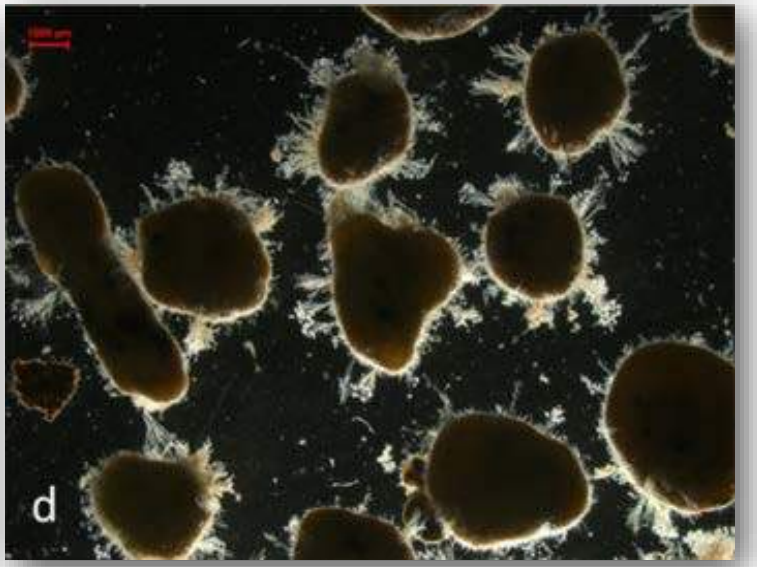
Biologic Selection

- Select for PAOs which secrete EPS
- EPS is the chemical backbone of the granule
- Dense bacterial gathering allow rapid settling





Source: Pronk M., Water Research 2015

Granule Formation

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Biologic Selection

- Granules are settled at the bottom of the reactor
- Influent is introduced into the granule bed
  - High F/M ratio
- Anaerobic conditions

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AquaNereda®

Operational Description

AQUA-AEROBIC SYSTEMS, INC.
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Agricultural

Industrial and Residential Reuse

Influent

Biological Processes

Filtration

Membranes

Screening and
grit for disposal

Solids
Handling

Disinfection

Direct
Discharge

PRIMARY

SECONDARY

TERTIARY

AquaNereda® Technology

AQUA-AEROBIC SYSTEMS, INC.
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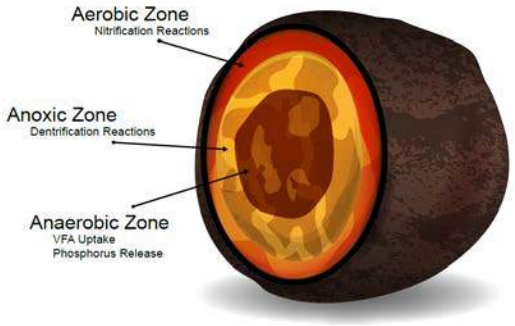
Process Overview

- Simple, one-tank reactor concept
- No secondary clarifiers
- Enhanced biological nutrient removal
- Timed cycle flexibility
- No sludge recirculation



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Simplified Flow Diagram

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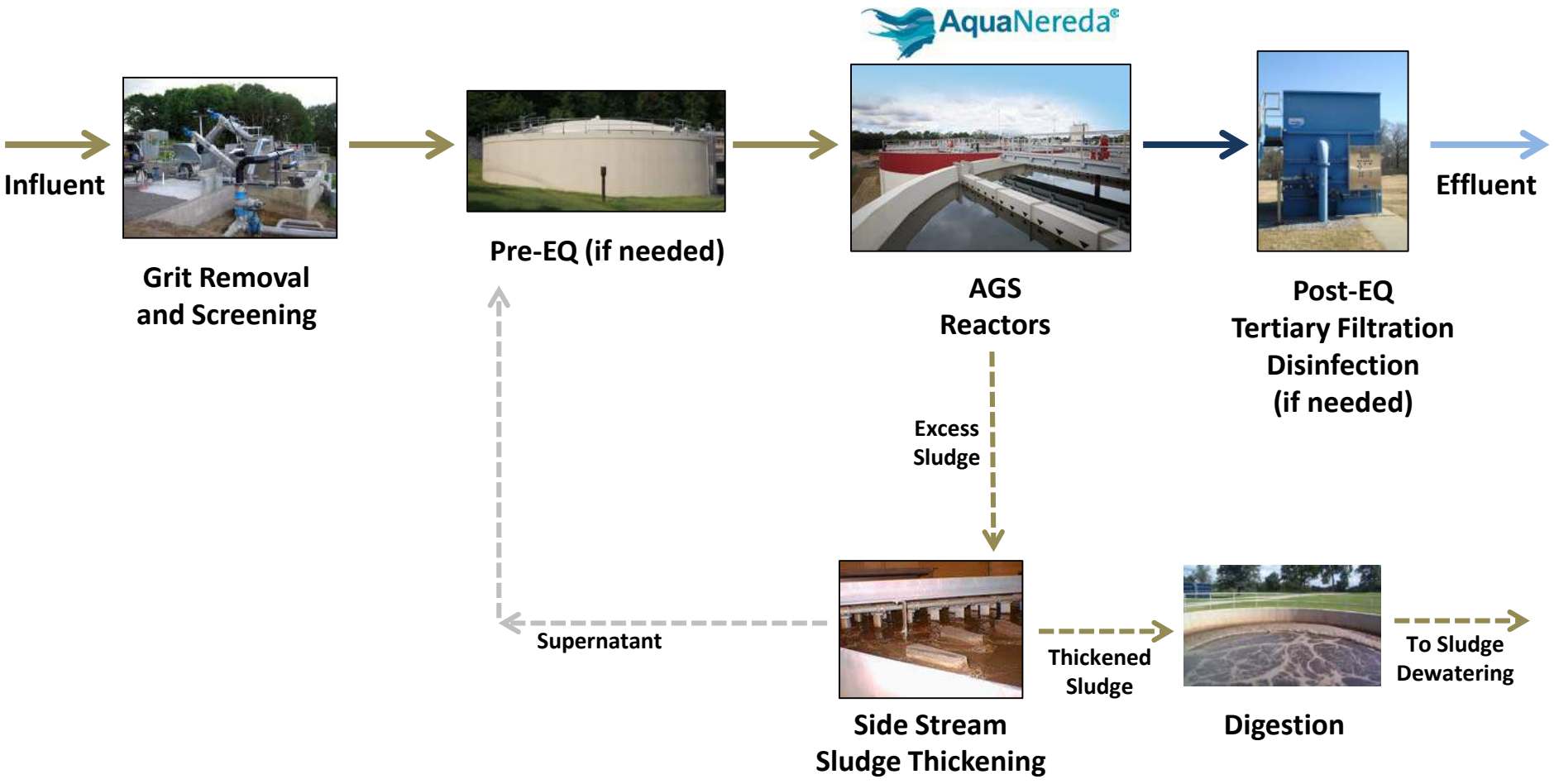

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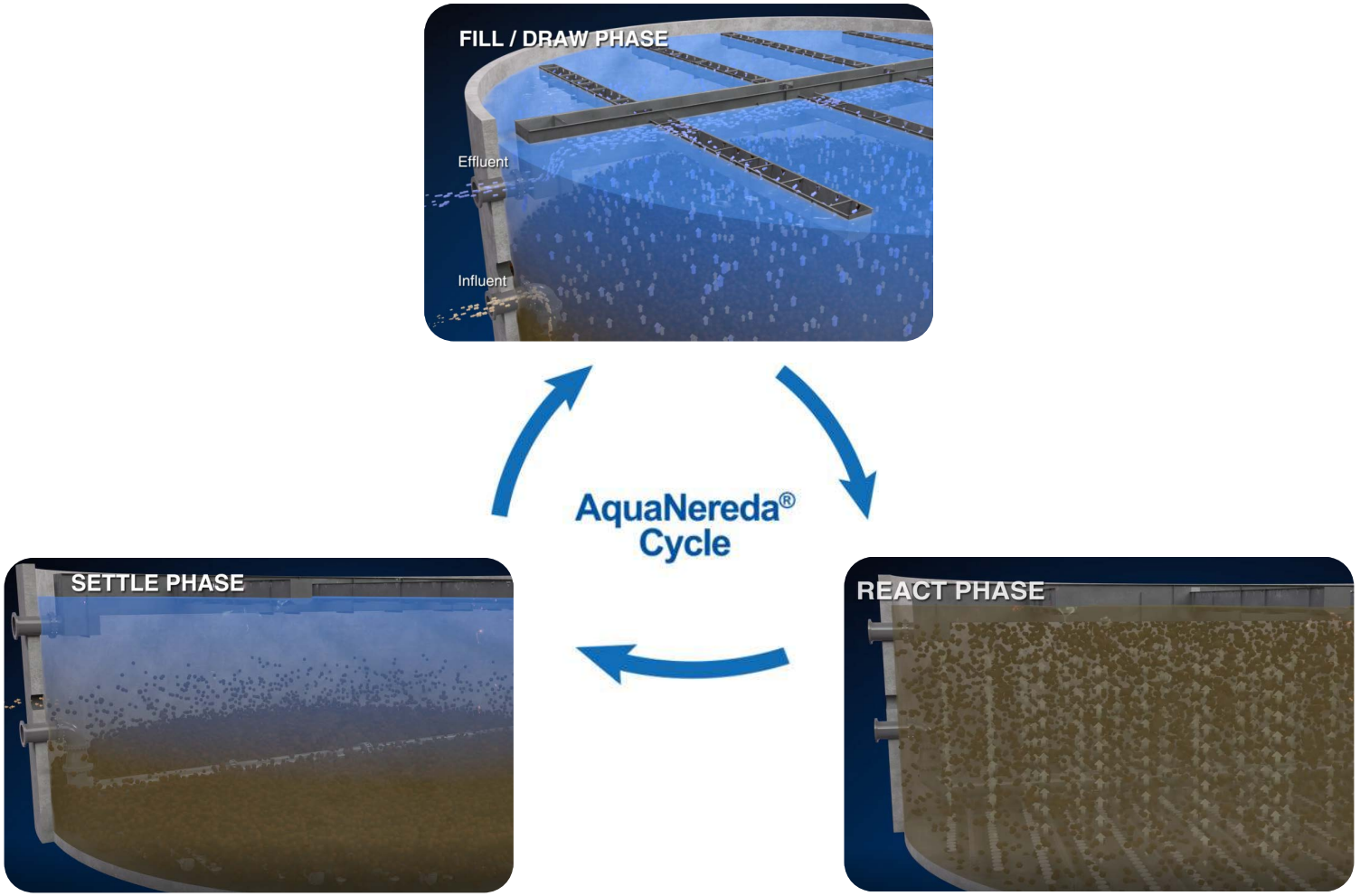
Process Cycle



AquaNereda® Characteristics

AQUA-AEROBIC SYSTEMS, INC.
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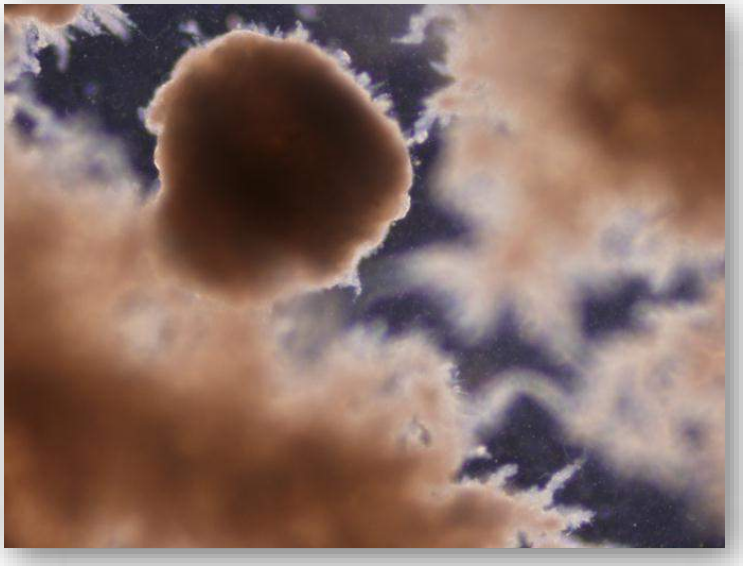
- Excellent settling properties
- Up to 75% smaller footprint
- Up to 50% energy savings
- Increased capacity
- Sustainable, robust technology
- No support media
- No bulking sludge
- Chemical savings



Source: T.R. Devlin Aerobic Granular Sludge Presentation

AquaNereda® Characteristics

AQUA-AEROBIC SYSTEMS, INC.
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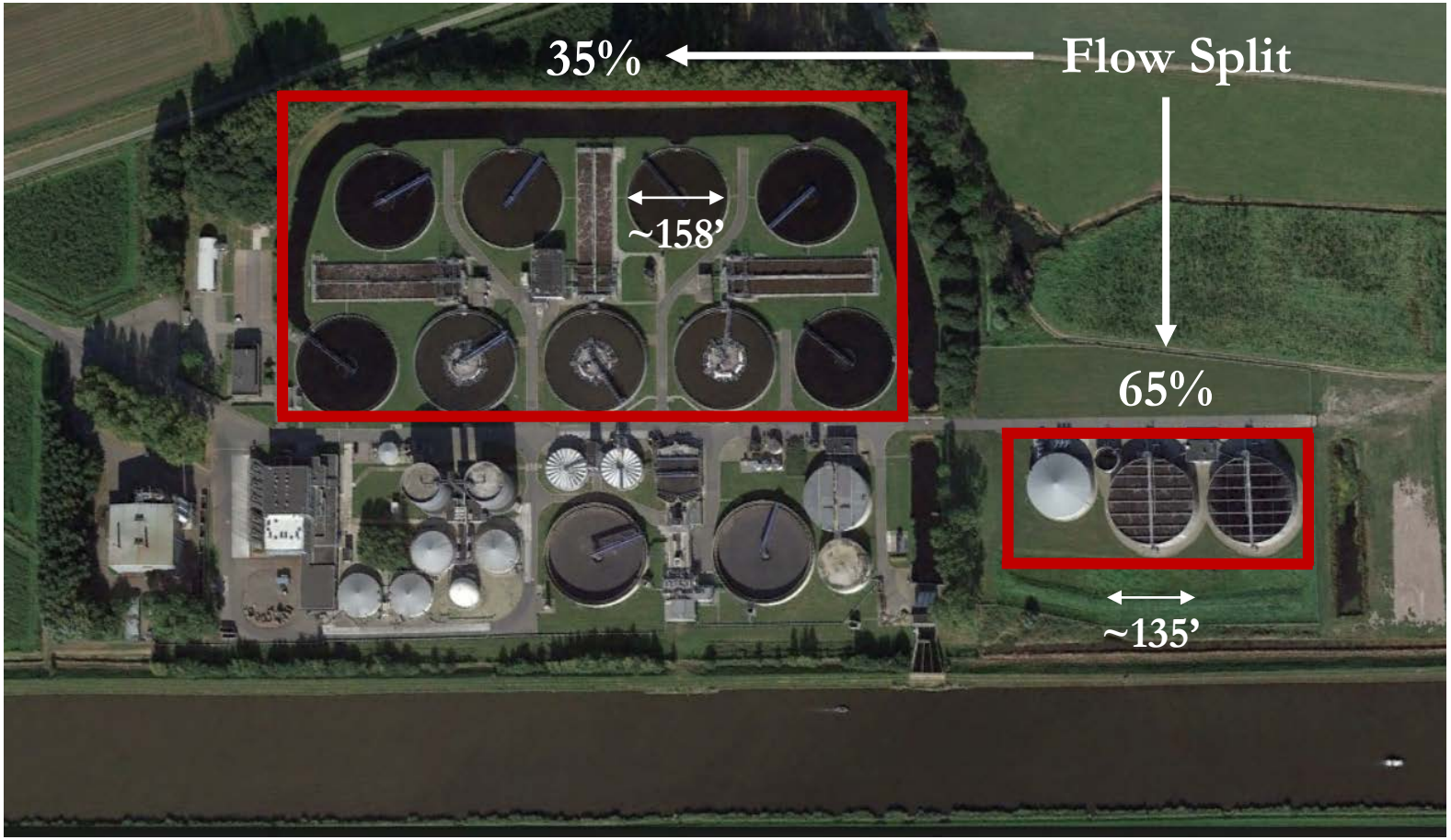
Up to 75% Footprint Reduction



Garmerwolde WWTP, NL

AquaNereda® Characteristics

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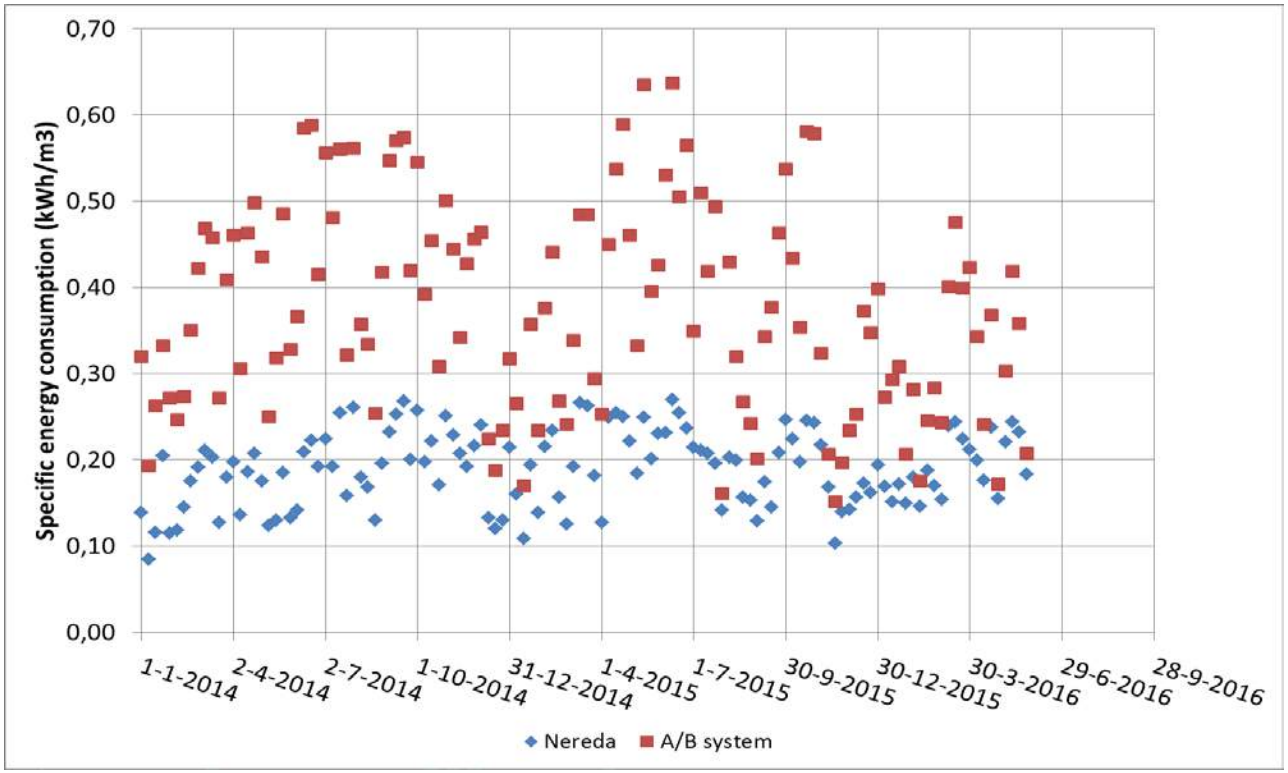
Up to 50% Energy Savings



Garmerwolde WWTP, NL

AquaNereda® Characteristics

Significant Chemical Savings

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Chemical	Unit	A/B system		Nereda		
		2014	2015	2014	2015	2016
Fe	ton	119	130	25	8	0
Coagulant	ton PEactive	39	30	-	-	-
Flocculant	ton PEactive	8.4	7	-	-	-
PAC	kgal	38	37	-	-	-
C-source	kgal	189	159	-	-	-

In 2015, 8 ton of Fe was used during storm events.

In 2016, the operator better managed the system and used no Fe

Data from Garmerwolde WWTP, NL

AquaNereda® Technology

AQUA-AEROBIC SYSTEMS, INC.
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Process Robustness

- Displays robustness during less-favorable conditions:
  - Salinity fluctuations
  - Toxic shock
  - Chemical spikes
  - pH fluctuations
  - Load variations

Conventional activated sludge and aerobic granular sludge with shock addition of 5,000 ppm NaCl after 5 min of settling.

CAS **AGS**

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AquaNereda®

Process Comparison

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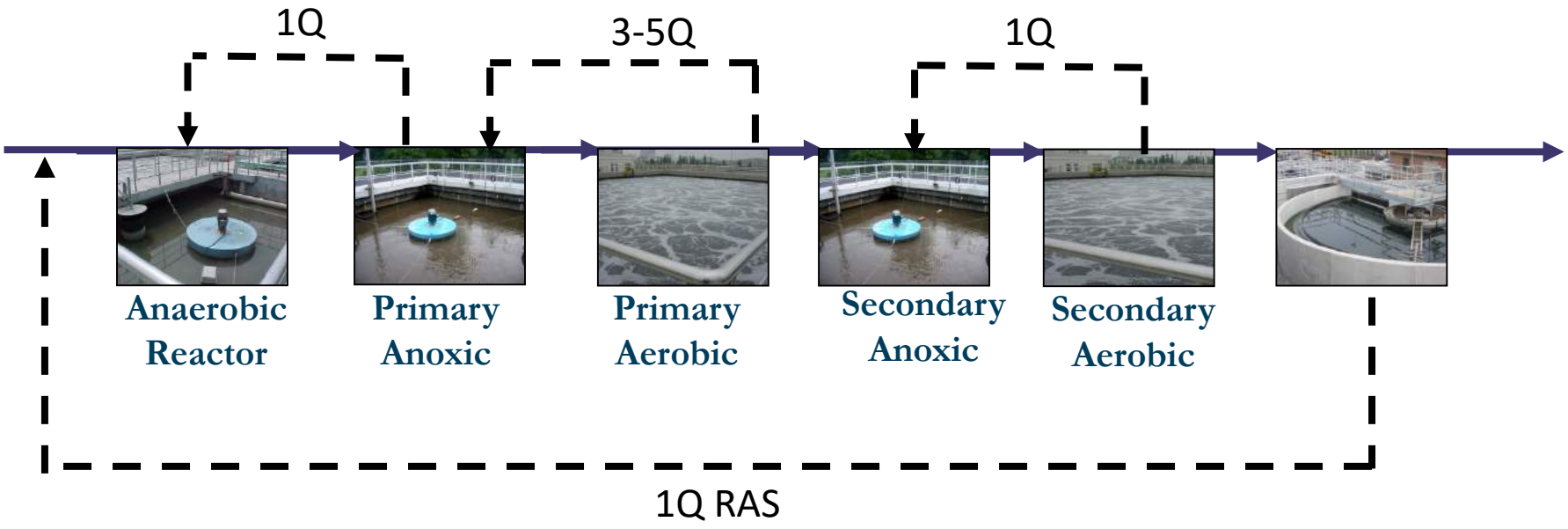
Comparison

5-Stage BNR System

Comparison to Typical Multi-Stage BNR System



Process Comparison

Footprint

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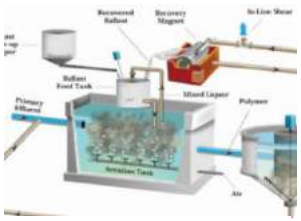
BNR


SBR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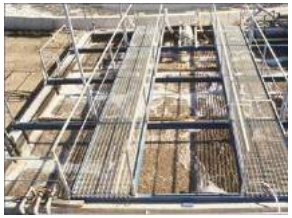
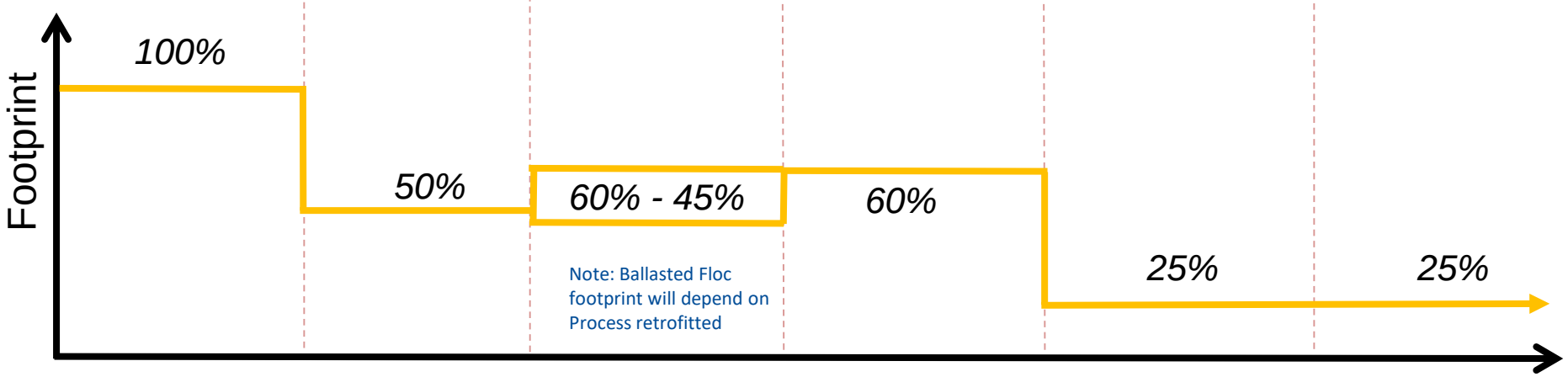

IFAS


MBR


AquaNereda®



Process Comparison

Energy

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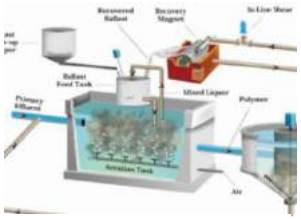
BNR


SBR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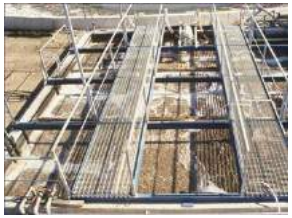
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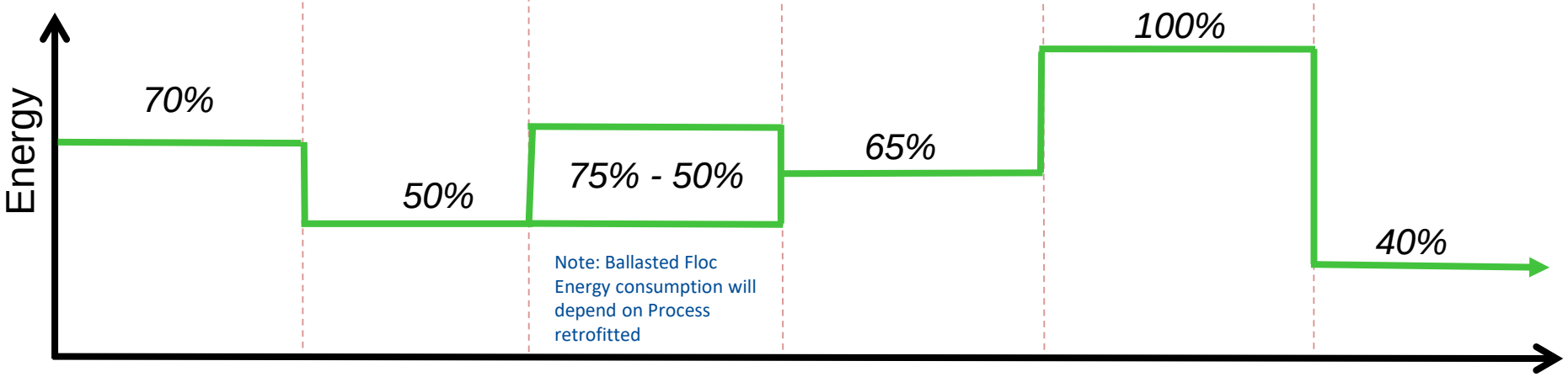

Process Comparison

20-Year Life Cycle Cost

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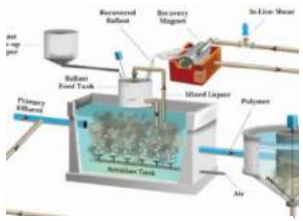
BNR


SBR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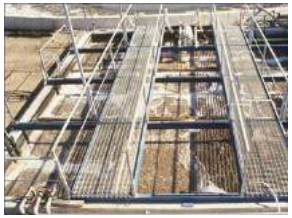
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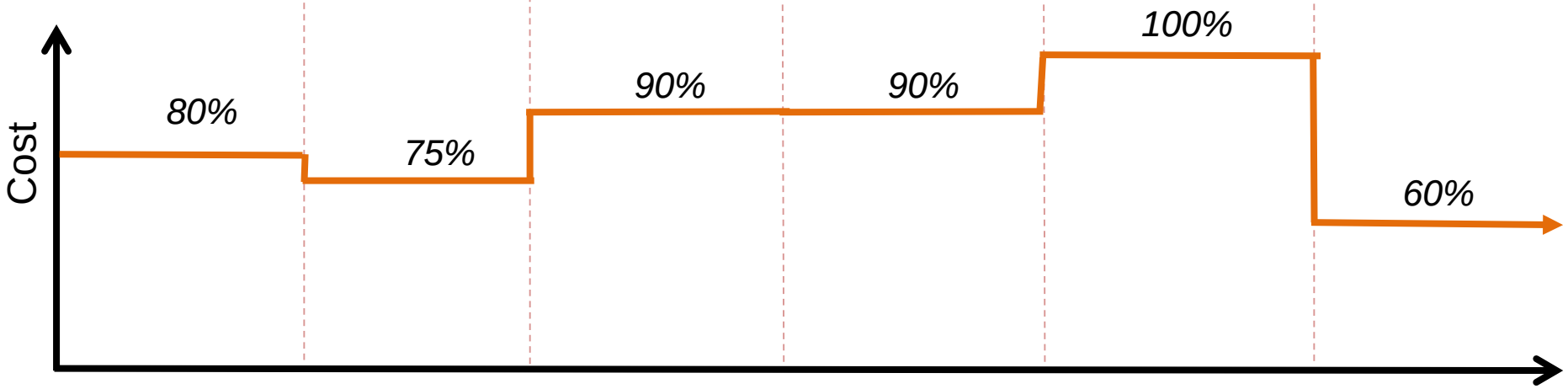

*R. Reardon, et. al., "Can Innovative Technologies Provide Benefits to Municipal Water Resource Recovery Facilities." 2016

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AquaNereda®

Operations

AquaNereda® Operations

Typical System Components

- Aeration system
- Pumps
- Valves
- Internal process piping
- Wier assembly
- Instrumentation
- Controls

AquaNereda® Operations

Mechanical/Maintenance

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Inside the Tank:

- Fine air bubble diffusers

Outside the Tank:

- Pumps
- Valves
- Blowers
- Instrumentation
  - Probes (pH, DO, ORP, TSS)
  - Analyzers (Phosphorus, Ammonia)

AquaNereda® Operations

Process/Laboratory

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Operations:

- SVI
- MLSS
- Sieve analysis (bi-weekly)

Laboratory:

- BOD/COD
- Ammonia
- Phosphorus
- TSS

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AquaNereda® Demonstration Facility

Rockford, IL USA

AquaNereda® Demo Facility

Rockford, IL

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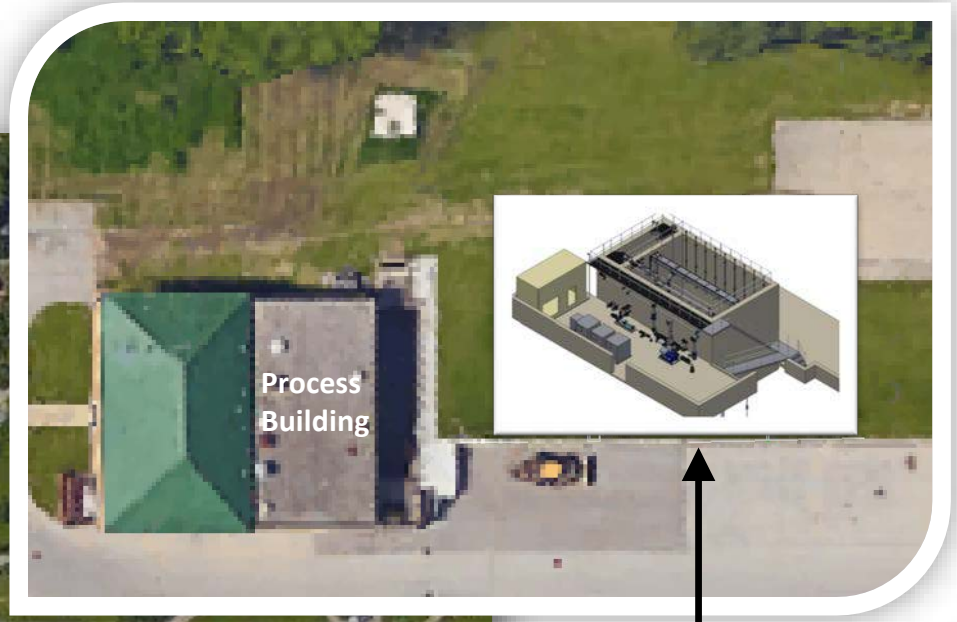

**AquaNereda®
Reactor**

AquaNereda® Demo Facility

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Reactor

- Capacity: 200,000 gal/day
- Volume: 94,250 gallons
- Dimensions: 30 ft (L) x 20 ft (W)
- Depth: 21.0 ft
- Sludge Holding Tank: 15,000 gallons

AquaNereda® Demo Facility

Average Performance Since Start-up

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Parameter	Influent (mg/L)	Effluent (mg/L)
COD	223	23
sCOD	88	14
BOD_5	150	5
TSS	144	9
Total N	26	4.9
NH_4-N	14	0.6
Total P	2.55	0.5
UVT	36%	76%

AquaNereda® Demo Facility

High Load Operation

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Parameter	Influent (mg/L)	Effluent (mg/L)
COD	628	41
TSS	210	10
TN	58.8	6.0
Total P	3.4	0.44

Flow: 0.3 - 0.35 MGD

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AquaNereda®

US Installations

AquaNereda® Projects

U.S. Installations

- Wolf Creek, Alabama
  - Start-up: Jan. 2020
- Whitefish, Montana
  - Detailed Design
- Maui Airport
  - Detailed Design
- Idaho Springs, Colorado
  - Detailed Design

Wolf Creek - September 2018

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Summary

AquaNereda® Summary

AQUA-AEROBIC SYSTEMS, INC.
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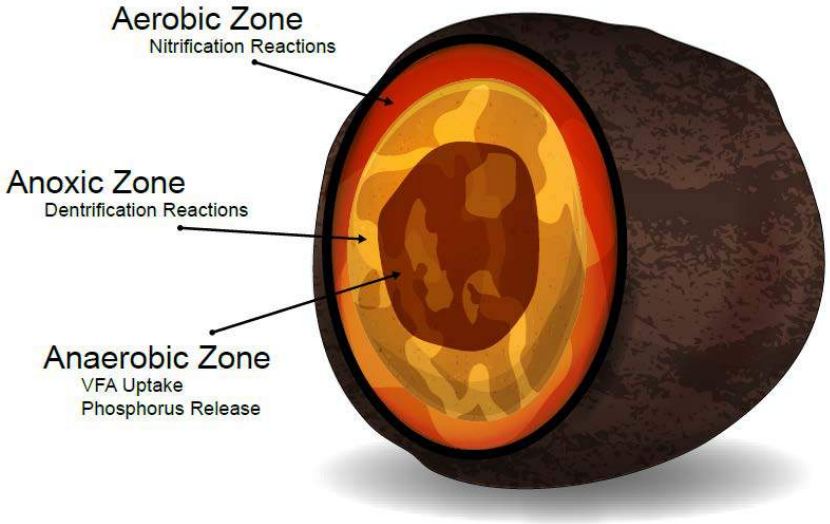
- AGS reduces footprint, increases capacity and reduces energy
- Achieves BNR and Bio-P removal
- Easy to operate
- Full-scale plants, demo facility and pilots to assist in design validation and regulatory approval
- Installations around the world, with many coming soon to the U.S.



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Questions?