ANAEROBIC MEMBRANE BIOREACTOR (AnMBR) FOR SUSTAINABLE RECOVERY OF WATER & NUTRIENTS

ER-201434

Kahao Lim[1], Tyler Penfield[1], Chad Olney[1], Patrick J Evans[2], Prathap Parameswaran[1]

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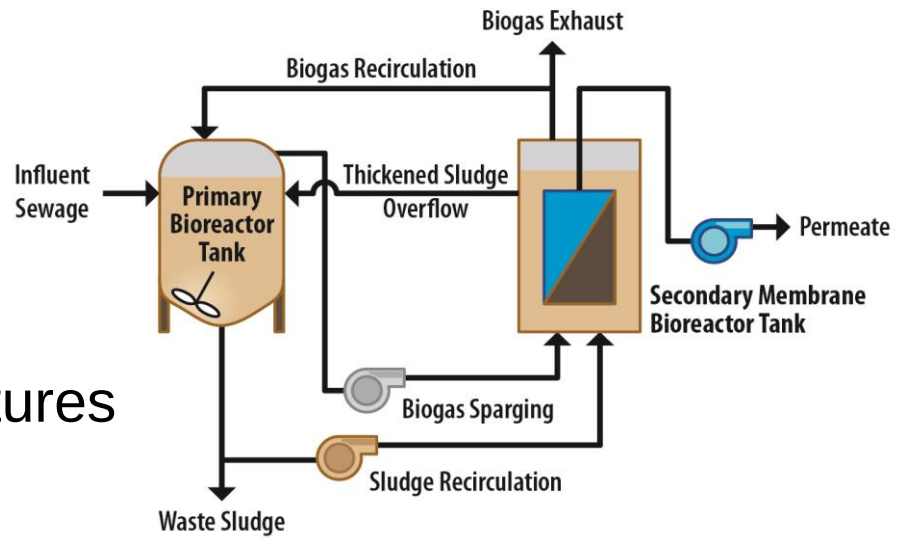
Project Team

Performer	Organization	Responsibilities
Pat Evans, Ph.D.	CDM Smith	PI
Prathap Parameswaran, Ph.D. Stacy Hutchinson, Ph.D.	Kansas State University	Co-PIs, Ft. Riley Demonstration
Perry McCarty, Sc.D.	Professor Emeritus	Co-PI, Technical Advisor
Jaeho Bae, Ph.D.	Inha University	Co-PI, S. Korea demo
Wayne Parker, Ph.D.	University of Waterloo	Technical Advisor
Bruce Rittmann, Ph.D., Rosa Krajmalnik-Brown, Ph.D.	ASU	Biofouling and microbial characterization
Matt Higgins, Ph.D.	Bucknell University	Dewatering
Tom Speth, Ph.D.	US EPA	Tech Advisor/Transfer
Martin Page, Ph.D., Kathryn Guy, Ph.D.	ERDC/CERL	Army SMEs, Tech Transfer, NH_3 removal
Sonny Maga, P.E.	NAVFAC EXWC	Navy SME, Tech Transfer

Technical Objectives

- Determine and compare the cost and performance of gas-sparged and GAC-fluidized AnMBRs for treating domestic wastewater

- Remove BOD_5 and TSS
- Remove nutrients
- Recover dissolved methane
- Produce re-usable water
- Treatment at varying temperatures
- Energy-neutral operation
- Minimize sludge production
- Compare 2 AnMBR configurations
- Compare to conventional aerobic wastewater treatment



Quantitative Performance Objectives

Performance Objective	Data Requirements	Success Criteria
Effectiveness	• COD • BOD_5 • Ammonia • Total phosphorus • Total sulfide • Total suspended solids • Turbidity • pH • Dissolved methane	• ≤ 60 mg/L • ≤ 10 to 30 mg/L • ≥ 90% removal • ≥ 90% removal • ≤ 0.1 mg/L • ≤ 10 to 30 mg/L • ≤ 2 NTU • 6 - 9 • ≥ 90% removal
Energy Footprint	• Various	• Energy neutrality
Implementability	• Organic loading rate • Hydraulic residence time • Biosolids production • Membrane flux (net) • Maintenance clean frequency • Recovery clean frequency • Wastewater temperature • Dissolved methane removal rate • Clinoptilolite robustness • Phosphorus removal rate • Ammonia removal rate • Electrolysis	• ≥ 0.6 kg COD m^{-3} d^{-1} • ≤ 20 h • ≤ 0.2 g TSS/g COD • ≥ 6 LMH • ≤ 3 times per week • ≤ 2 times per year • Achieves effectiveness at ≥ 10 °C • ≥ 0.5 g m^{-2} d^{-1} (based on 20 mg/L) • NH_3 loading decrease ≤ 10% • ≥ 60 mg L^{-1} d^{-1} (based on 4 mg-P/L) • ≥ 2 g L^{-1} d^{-1} (based on 29 mg-N/L) • ≥ 90% ammonia removal

Approach

Task 1 - Site Visit

Completed
April 21, 2015

Task 2 - Technology Demonstration Plan
- Engineering Design
- Demo Plan Preparation

Accepted August 24, 2016

Task 3 - Field Demonstration
- Installation
- Startup
- Continuous Optimization

S. Korea system started up
October 30, 2015

Ft. Riley system started up
July 15, 2016

Task 4 - Reporting
- Final Report
- Cost & Performance Report

Site Descriptions

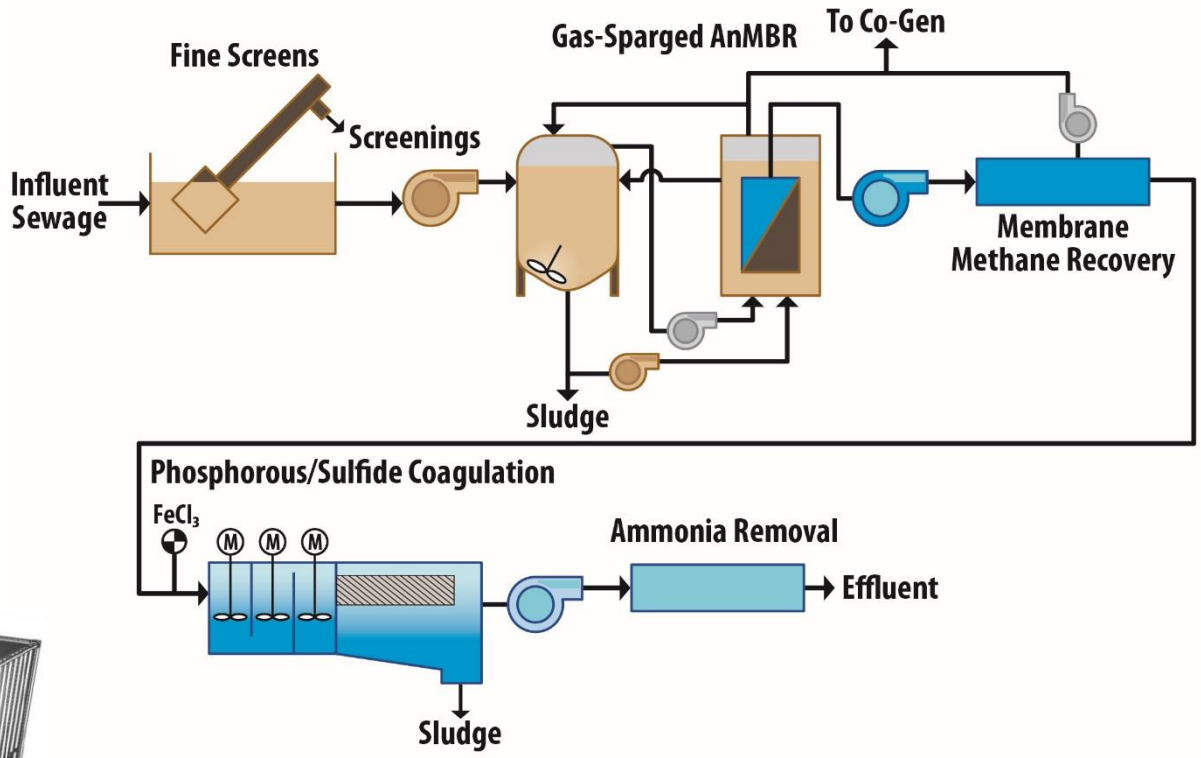
- Ft. Riley, Kansas
  - Demonstration originally planned for Camp Funston
  - Now planned for Camp Forsyth
  - Excellent site access
  - Screened domestic wastewater

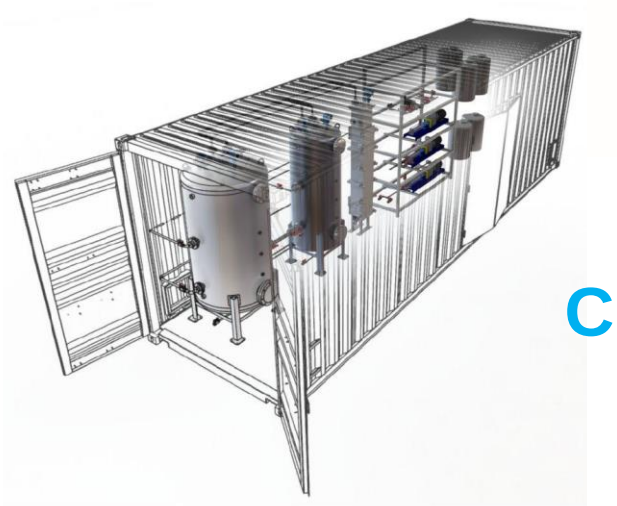
- Bucheon Wastewater Treatment Plant, South Korea
  - Near Seoul and Inha University
  - Existing pilot facility
  - Screened domestic wastewater

Bucheon Wastewater Treatment Plant

Technology/Methodology Description

Integrated Gas-Sparged AnMBR Process Flow Diagram





CONEX trailer system

AnMBR Trailer Installation at Ft. Riley

AnMBR Trailer – Classified Section

Dissolved CH4 Transfer Membrane

UF Membrane Tank

Bioreactor

AnMBR Trailer – Unclassified Section

Chemical Pumps

Clinoptilolite Ammonia Removal Column

Sedimentation

Coagulation - Flocculation

Control Panel

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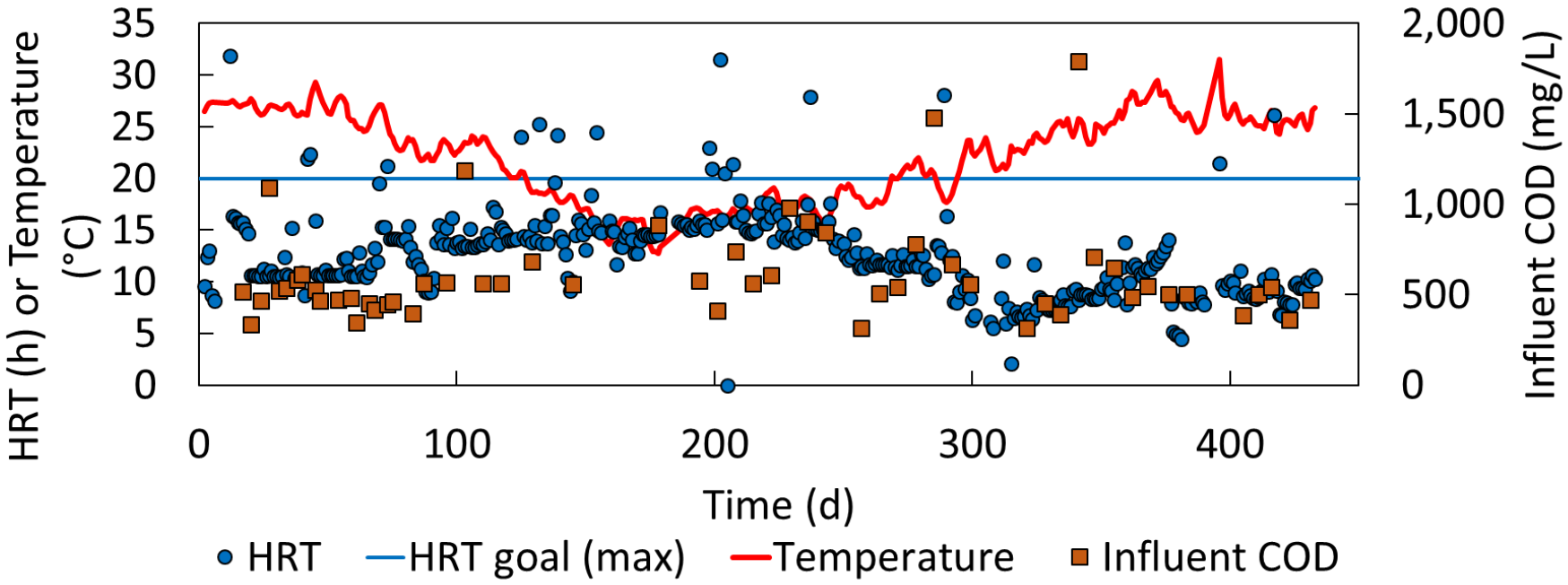
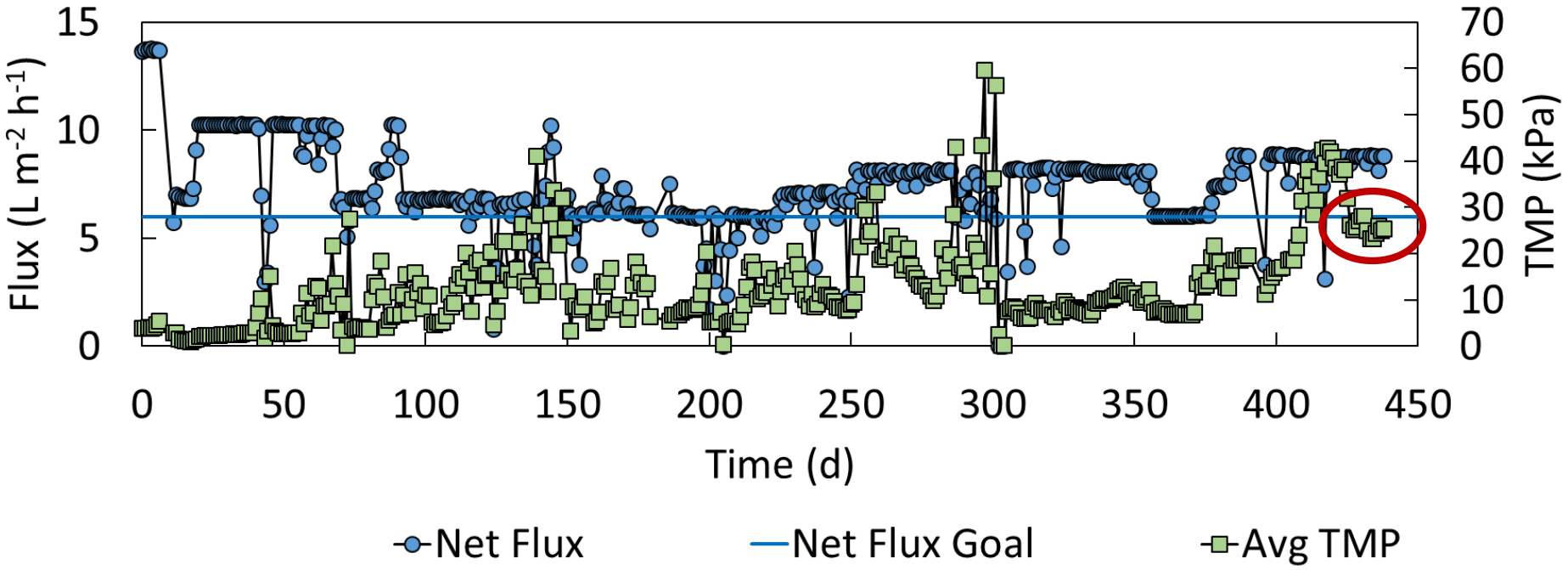
Gas-Sparged AnMBR Operating Conditions



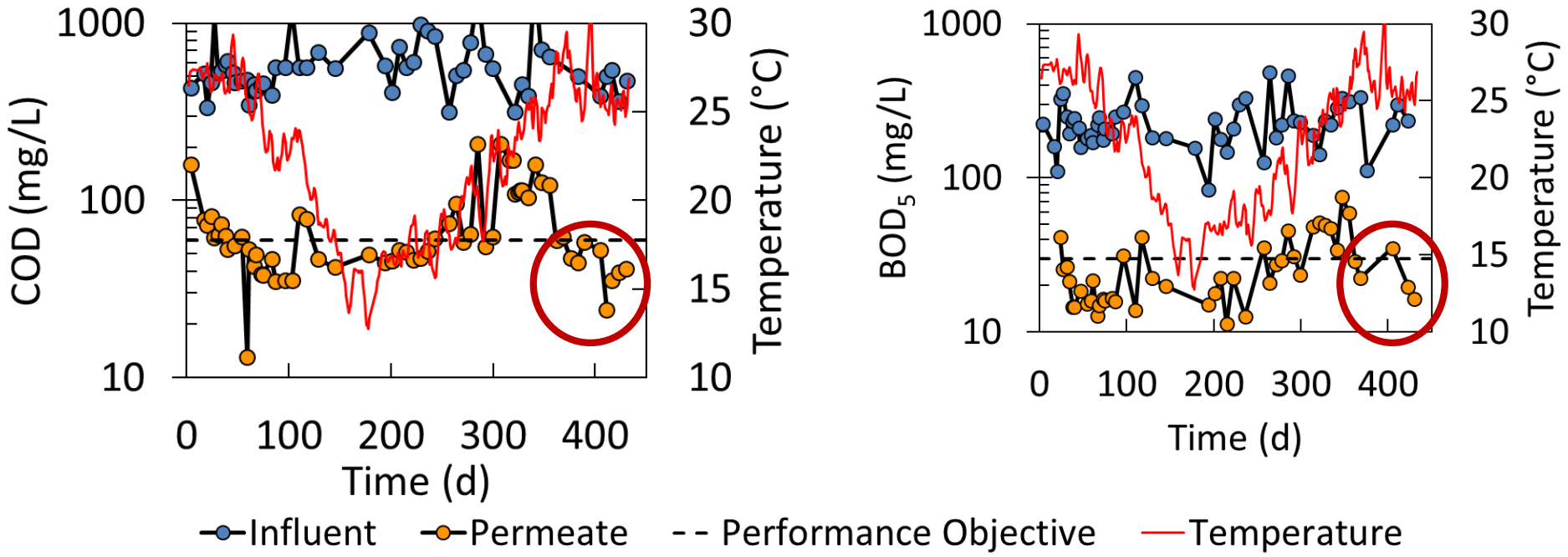
- Influent COD 610±270 mg/L
- HRT initially 10-15 h, later 7-10 h
- Temperature 13 to 32°C

Gas-Sparged AnMBR Ultrafiltration Conditions



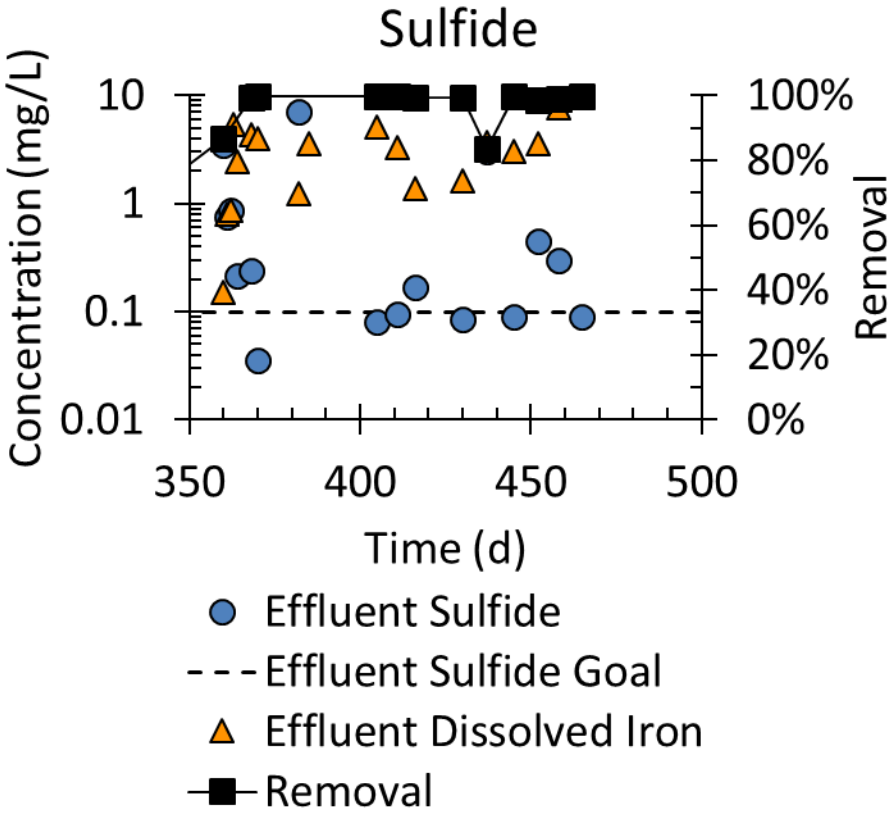
- Net flux of 6 LMH met or exceeded
- TMP dependent on VS, colloidal organics and maintenance cleaning

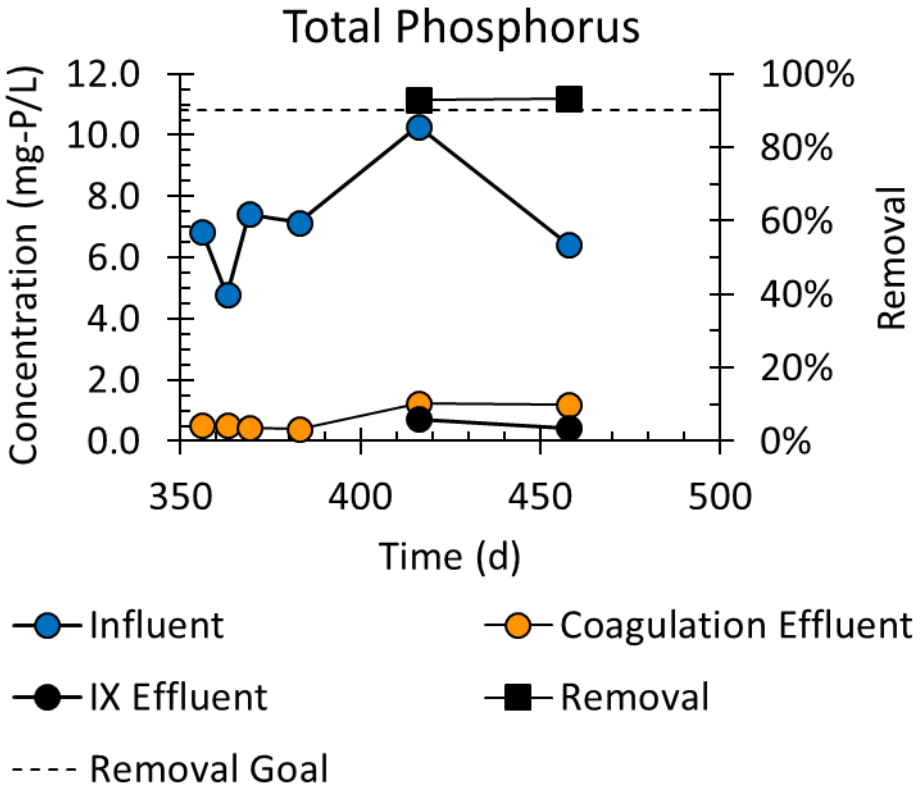
Gas-Sparged AnMBR BOD & COD Removal



- COD and BOD_5 generally < 60/30 mg/L Elevated COD/BOD following wasting event

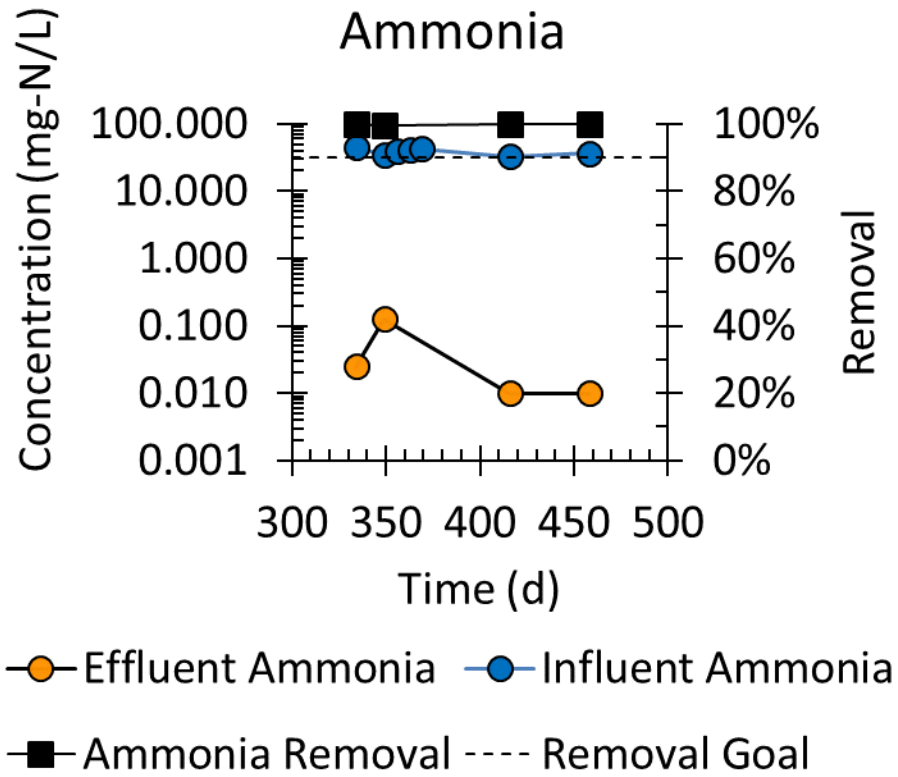
Gas-Sparged AnMBR Sulfide and P Removal





- 110-125 mg-Fe/L as $FeCl_3$, 30 mg-Al/L as ACH, 1 mg/L polymer
- Sulfide removal may be underestimated
- Phosphorus removal goal met

Gas-Sparged AnMBR Ammonia Removal

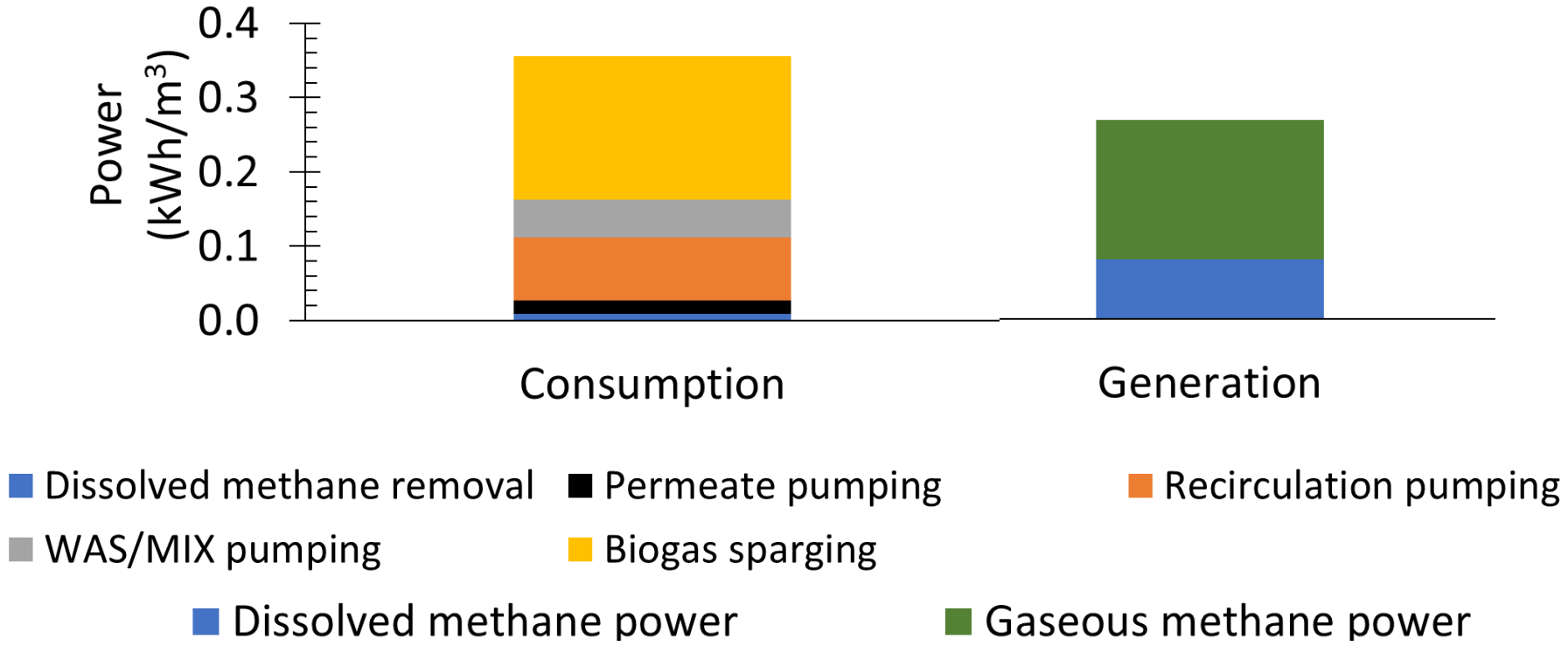


- Clinoptilolite ion exchange
- Ammonia removal goal met
- Performance sustained after 2 to 3 regeneration cycles to date
- 4.8 to 6.4 g-N/kg loading

Final effluent characteristics

Parameter	Finished Water
ORP	-149 mV
Chlorine residual (mg/L)	0.68
Chlorine demand (mg/L)	11.32
Total coliforms (MPN/100 mL)	214
Fecal coliforms (MPN/100 mL)	0
Hardness (mg/L as CaCO3)	9.5
Alkalinity (mg/L as CaCO3)	464
Total N (mg/L)	1.99
Total P (mg/L)	0.43
Sulfide (mg/L)	0.205
Dissolved Fe (mg/L)	0.36
COD (mg/L)	84
TOC (mg/L)	pending
pH	9.39
Conductivity (μS/cm)	1288

Gas-Sparged AnMBR Energy Balance



- Majority of power consumption is biogas sparging
- 74% of energy input is recovered

Parameter	Goal	Gas-Sparged
Effluent BOD_5 (mg/L)	≤ 30/10*	24±14
Effluent COD (mg/L)	≤ 60	53±16
HRT (h)	≤ 20	13±8
COD Loading (kg-COD m^{-3} d^{-1})	≥ 0.6	1.3±0.7
Energy Produced/Consumed	≥ 100%	74
Biosolids (g-VSS/g-COD_{loaded})	≤ 0.2	0.07±0.07
Net Flux (L m^{-2} h^{-1})	≥ 6	7.4±2.0
TMP (kPa)	≤ 30	13±9
Sulfide (mg/L)	≤ 0.1	< 0.14±0.08
Ammonia Removal (%)	≥ 90	99.8±0.2
Total Phosphorus Removal (%)	≥ 90	90±1
Dissolved Methane Removal (%)	≥ 90	65

Met

Met

ANAEROBIC MEMBRANE BIOREACTOR (AnMBR) FOR SUSTAINABLE WASTEWATER TREATMENT

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