Distributed Low-Energy Wastewater Treatment (D-LEWT) for Fuel Generation and Water Reuse

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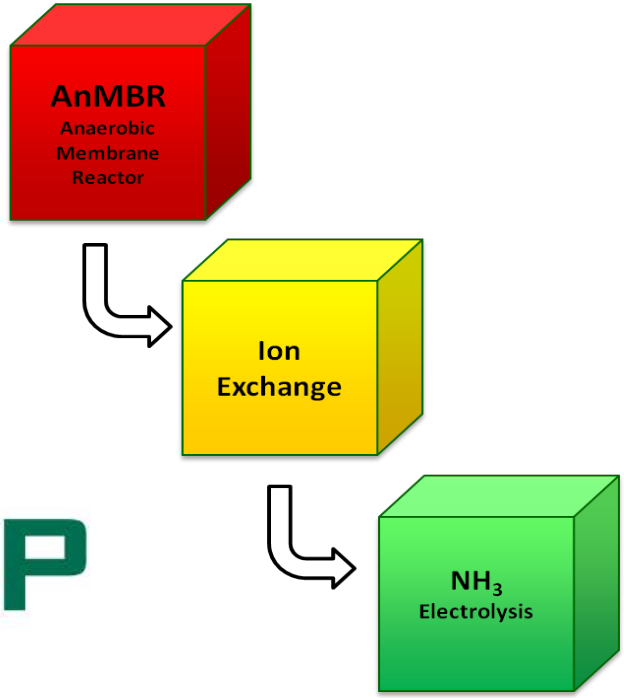

ESTCP

Project Team

Member	Role	Organization
Dr. Kathryn Guy	Principal Investigator	ERDC-CERL
Shane Hirschi	Project Manager	ERDC-CERL
Nicholas Josefik	Industrial Engineer	ERDC-CERL
Tapan Patel	Mechanical Engineer	ERDC-CERL
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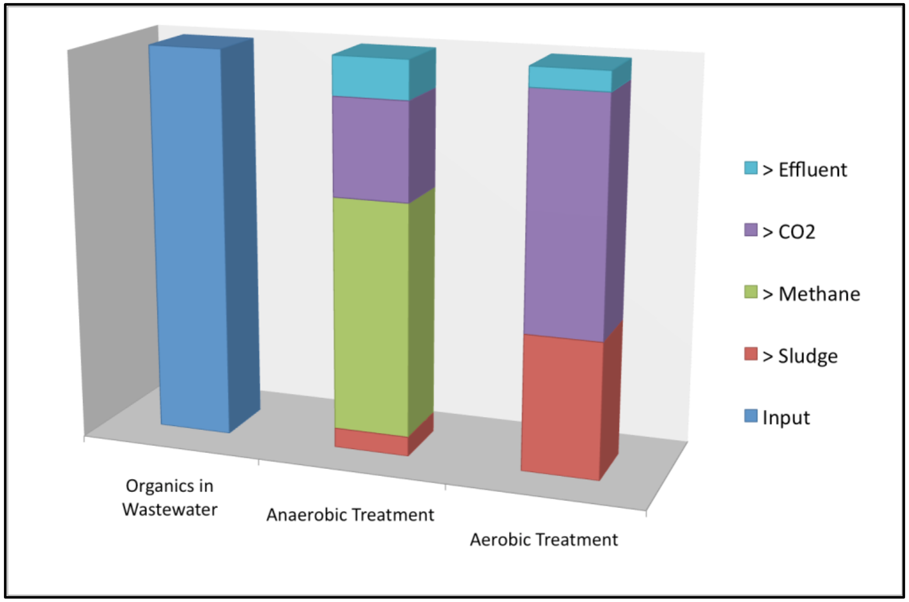
Dr. Lance Schideman	Environmental Engineer	U of Illinois-UC
Dr. Ana Martin	Environmental Engineer	U of Illinois-UC
Danicza Lopez	Environmental Engineer	Mountain Home AFB

Problem Statement

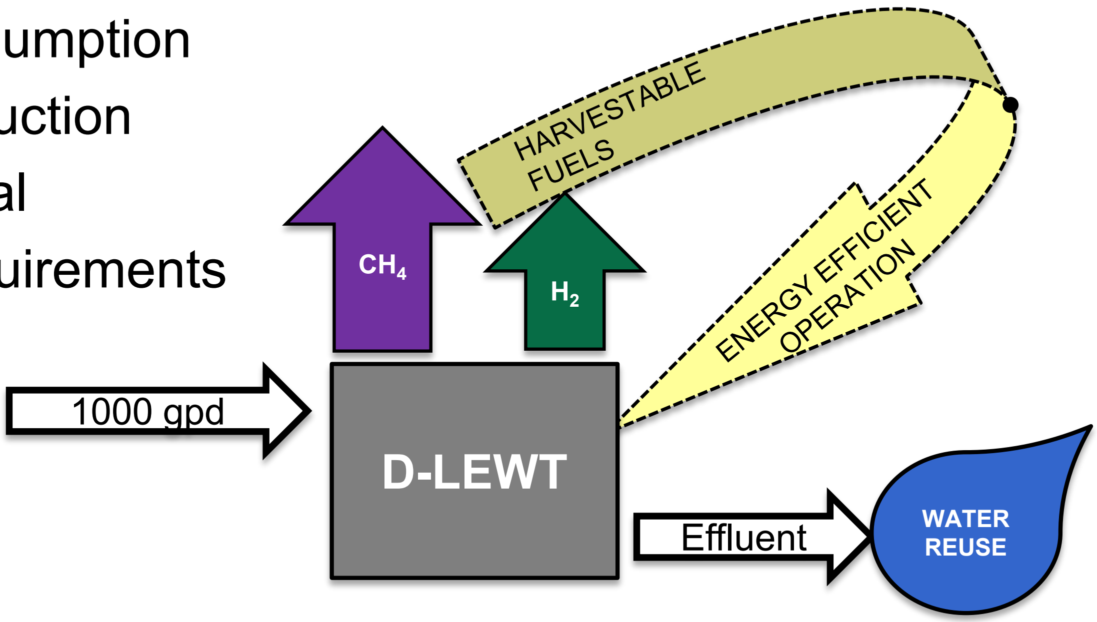
- Current wastewater treatment options:
  - ♦ Energy intensive to operate
    - DoD $250M/yr treatment (>50% aeration)
  - ♦ Miss energy generation opportunities
  - ♦ Discharge permit focused
  - ♦ Expansive infrastructure
- Over 100 installations with onsite water treatment
- Mandates and regulations
  - ♦ EO 13514
  - ♦ EPACT 2005
  - ♦ EISA 2007



http://ebsbiowizard.com/wp-content/uploads/2011/08/aerobic_v_anaerobic.png

Technical Objectives

- Demonstrate
  - ♦ Decentralized waste water treatment (1000 gpd)
  - ♦ Harvestable fuel generation (H_2 & CH_4)
- Validate
  - ♦ Reduced energy consumption
  - ♦ Reduced sludge production
  - ♦ Effluent reuse potential
  - ♦ Low maintenance requirements

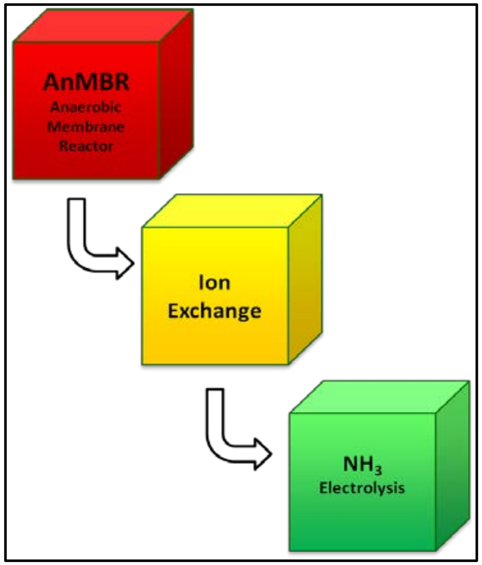


Expected Benefits

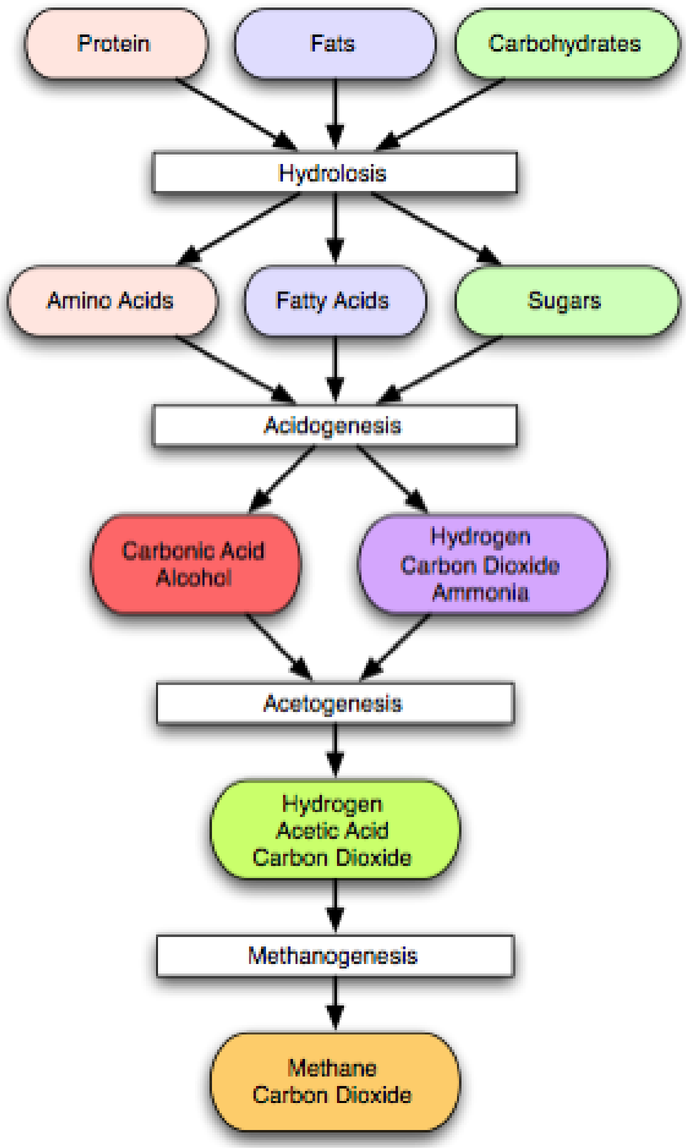
- D-LEWT system
  - Energy efficient operation while generating harvestable fuels (*potential 80% energy reduction*)
  - Treated water available for reuse applications (>*85% reuse*)
  - Segregated waste streams based on building function (simplified/consistent)
- Supports Army Net-Zero water, energy, and waste goals
- Opportunities for D-LEWT implementation
  - >100 existing on-site treatment facilities across DoD
  - New decentralized construction
  - Contingency basing applications
  - Disaster relief efforts

Technology/Methodology Description

- AnMBR
  - Degrades organics and generates CH_4
  - CH_4 can be harvested for electrical and thermal energy
- Clinoptilolite ion exchange
  - Captures NH_3
  - Generates feedstock for NH_3 electrolysis
- NH_3 electrolysis
  - Converts the NH_3 into N_2 and H_2 gases
  - H_2 can be harvested for electrical and thermal energy generation

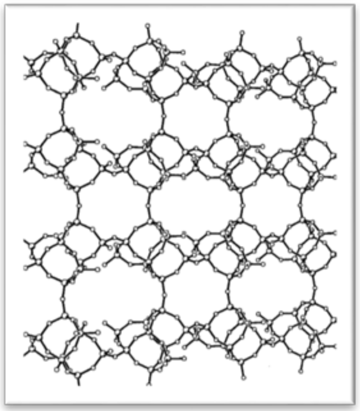


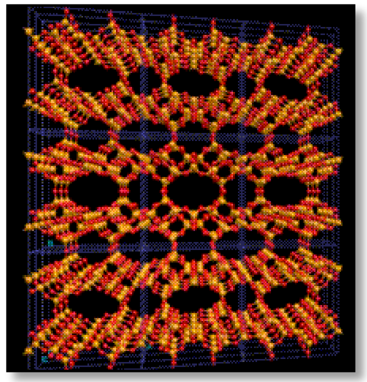
Technical Background - AnMBR



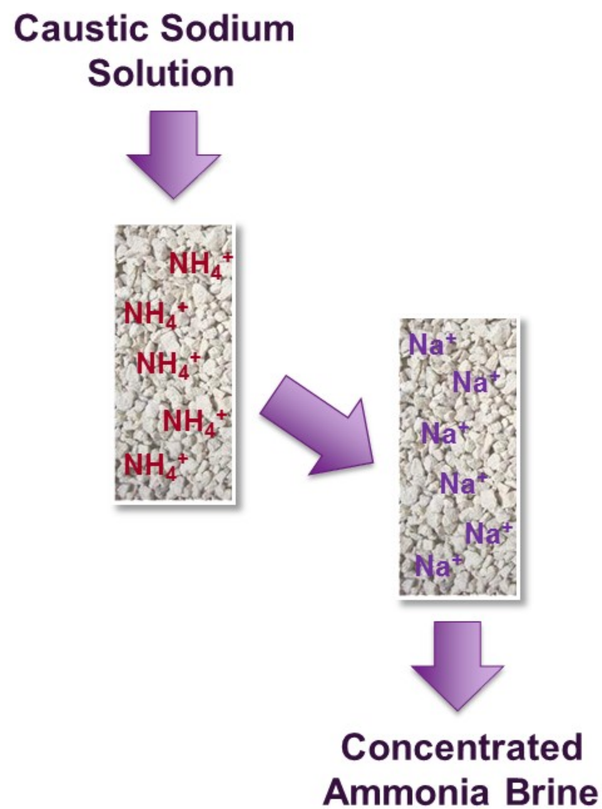
- Anaerobic biological processes remove organics from wastewater
- Organics are converted into harvestable methane gas with low sludge production
  - Approximately 90% less sludge produced compared to aerobic treatment
- Anaerobic bioreactors work well for high organic loadings (i.e., wastewater plus food wastes)
- High rate anaerobic membrane bioreactors (AnMBRs) allow for retention of particulates with shorter hydraulic retention times

Technical Background - Clinoptilolite





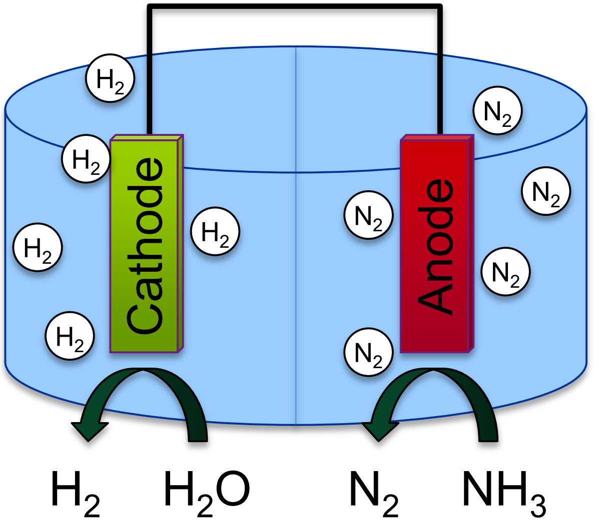
- Clinoptilolite is a naturally occurring high-siliceous, ion exchanging zeolite (Si:Al ~5.7)



- Open channel framework with high surface area carrying a distributed negative charge
- Cations such as Na^{+} are loosely held in extraframework positions
- Integration of clinoptilolite ion exchange into integrated wastewater systems has been limited due to additional brine disposal or treatment requirements

Technical Background – NH_3 Electrolysis

- Ammonia electrolysis breaks down ammonia into nitrogen and hydrogen gases
- Clean hydrogen can be captured for use in fuel cells
- Requires significantly less energy input than water electrolysis
  - ~95% less based on theoretical calculations
- Operates most efficiently at high pH with high NH_3 concentrations



Anode: $2NH_3(aq) + 6OH^- \rightarrow N_2(g) + 6H_2O + 6e^-$

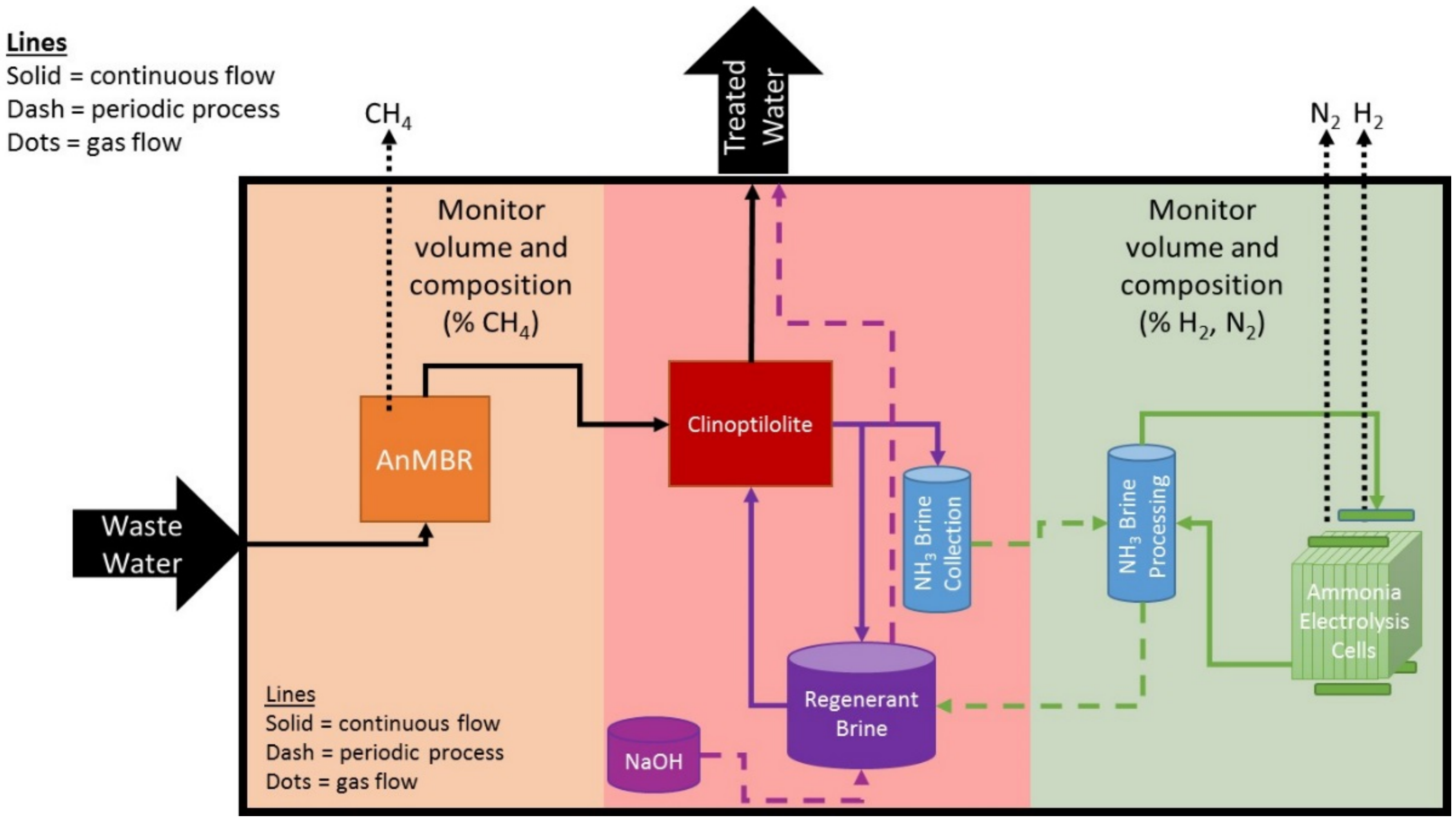
Cathode: $6H_2O + 6e^- \rightarrow 3H_2(g) + 6OH^-$

Total: $2NH_3(aq) \rightarrow N_2(g) + 3H_2(g)$

Technology/Methodology Maturity

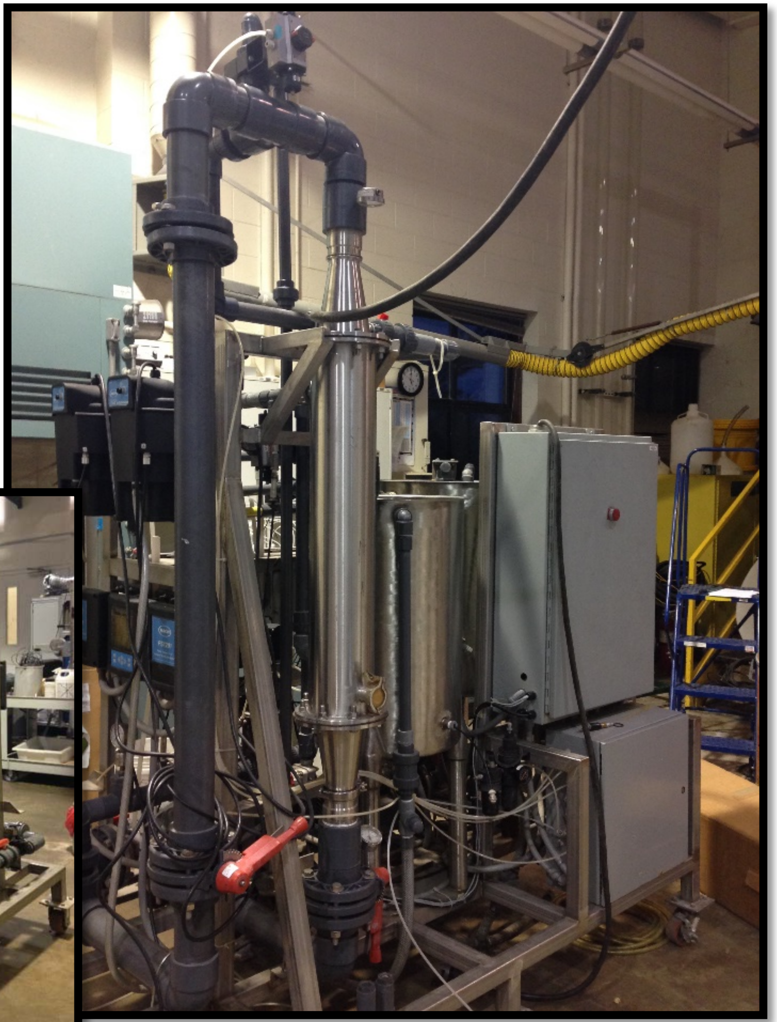
- Successful demonstration of D-LEWT technology at bench scale under SERDP ER-2218
  - ♦ Individual component technologies of the wastewater treatment system have been optimized for batch processes
  - ♦ All subsystems are COTS available technologies or assemblies of COTS materials
  - ♦ SERDP results indicate technology is mature enough to pursue demonstration and validation
- D-LEWT project focuses on automation, subsystem linkages, and balance of plant to achieve operational autonomy

Test Design – Integrated System

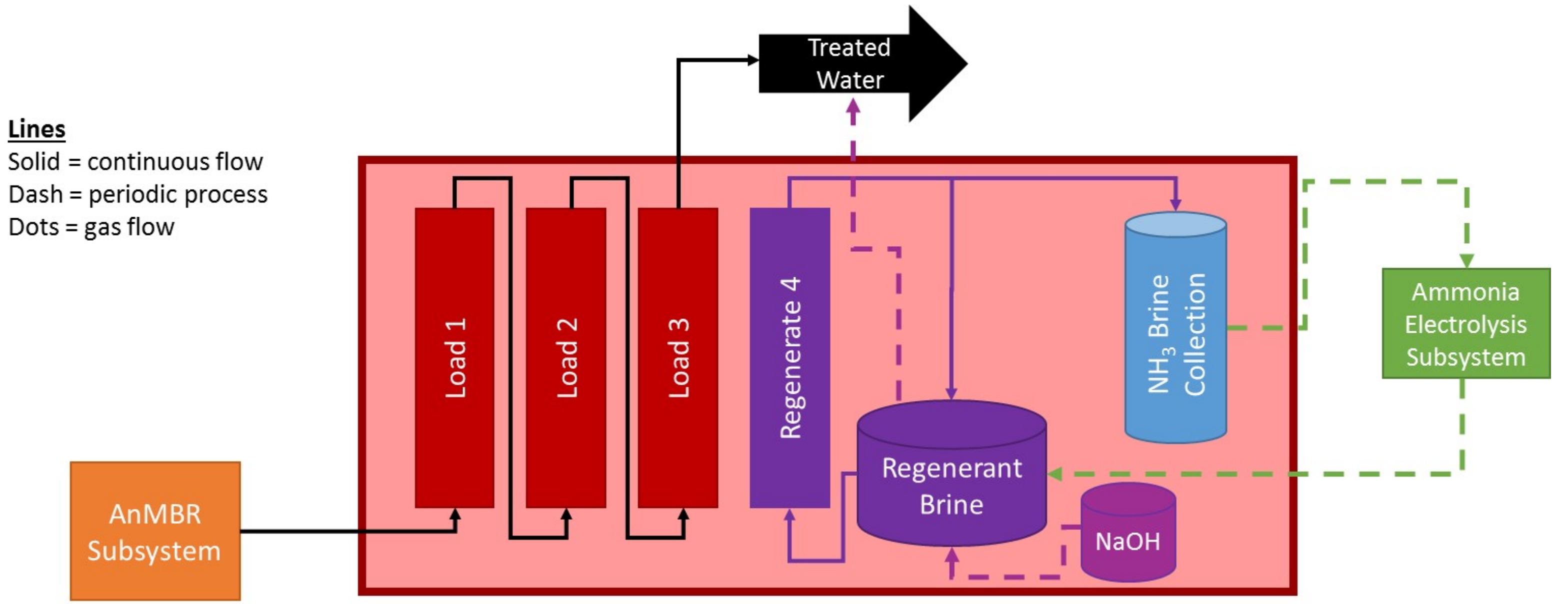


Test Design - AnMBR

- Partnership with AnMBR experts
- AnMBR provided as cost share with University of Illinois at Urbana-Champaign
- Treats 750-1000 gpd



Test Design – Ion Exchange



Loading

- Columns in positions 1-3
- Influent flows serially through all three columns
- Flow for all columns is bottom up

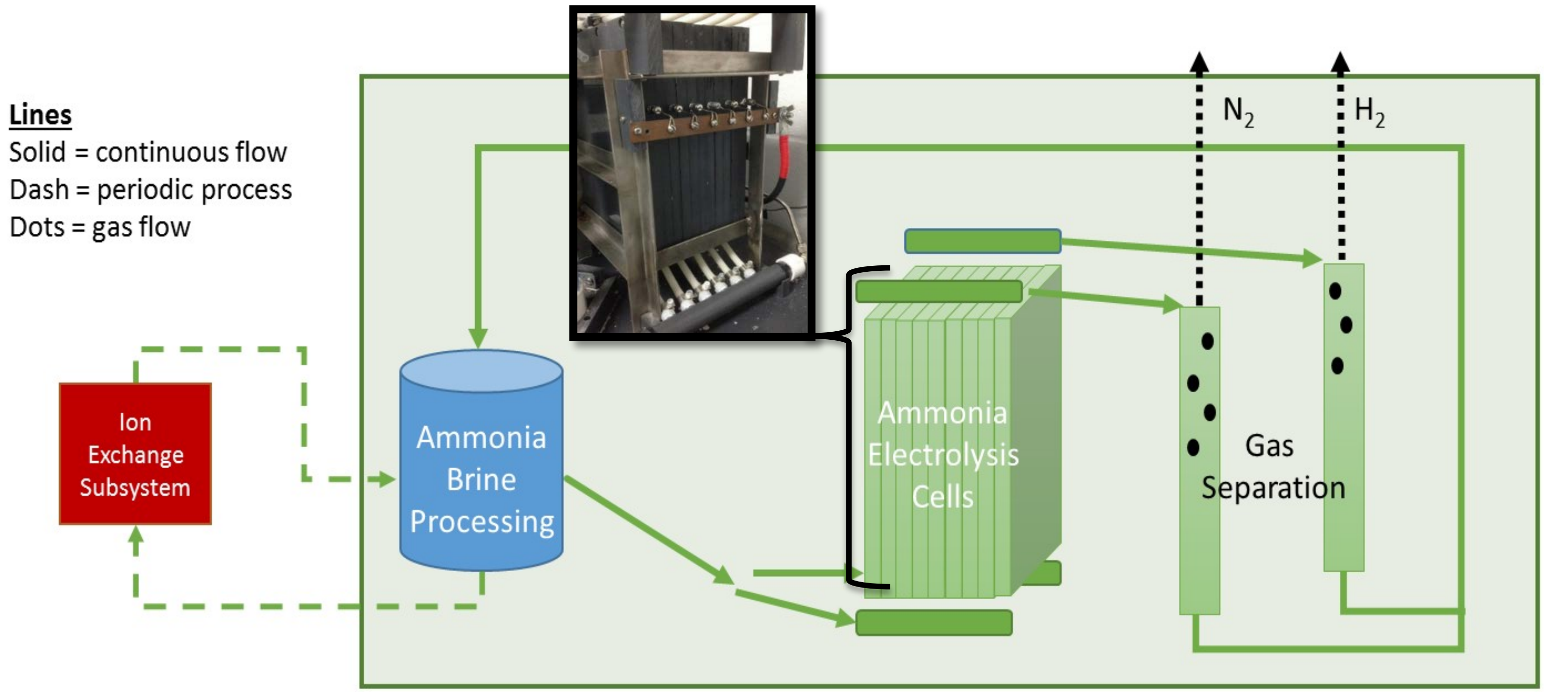
Switching

- After a user defined period of time, all columns switch functional positions
- Column 1 → Column 4
- Column 2 → Column 1
- Column 3 → Column 2
- Column 4 → Column 3

Regeneration

- Simultaneous with loading
- Column in position 4
- Regenerant brine introduced in a flow-hold-flow pattern with user defined time periods
- Two effluent options (Regenerant Brine, NH_3 Brine Collection) switched at user defined times

Test Design – Ammonia Electrolysis



- Ammonia brine generated from multiple clinoptilolite regeneration cycles treated in batches
- Solution must be heated to 40-70°C based on user input
- Solution recycled back to ammonia brine processing tank following electrolysis until user defined time to discharge to regenerant brine tank

- User defined adjustable flow (100-500 mL/min) to both sides of electrolysis cells
- Maximum 0.925 Volts applied across each cell
- Flow enters and exits cells through manifolds
- Cells provided as GFE

- Hydrogen and nitrogen gasses are separated from the brine solution
- Composition, purity, and volume of gas generated is measured
- Vented outside of the container unit
- Degassed brine returned to ammonia brine processing tank

Technical Approach

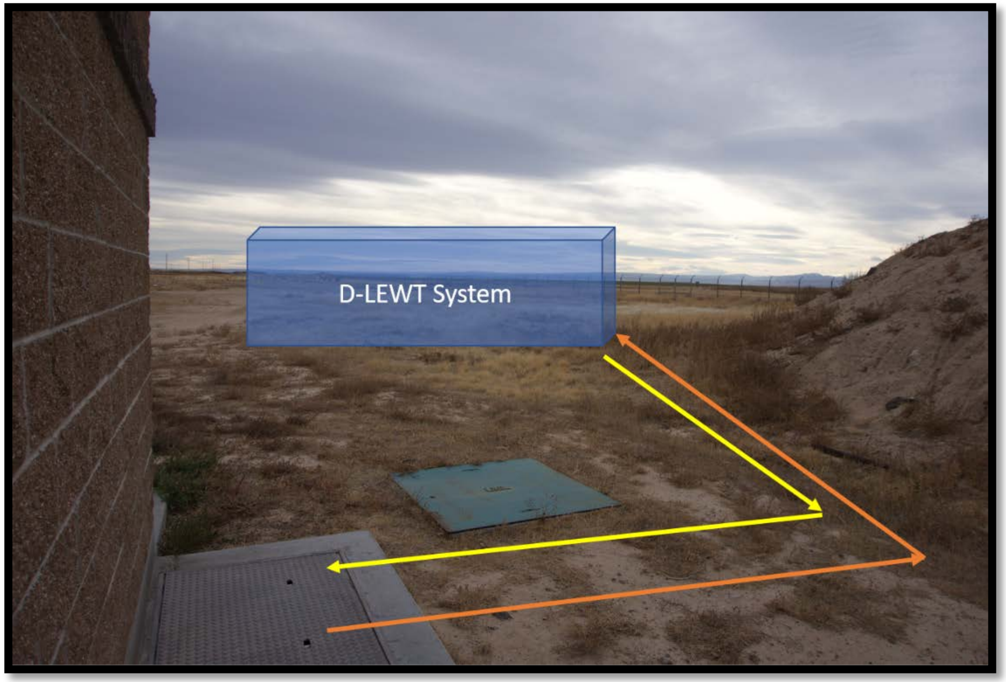
Pre-validation Testing

- Performed at ERDC-CERL
- Based upon the performance objectives:
  - Energy consumption
  - Energy production potential
  - Effluent water quality and water reuse potential
  - Sludge mass
  - Maintenance requirements
- Performance metrics verified to minimize risks associated with onsite demonstration and validation

Technical Approach

Field Demonstration

- Mountain Home Air Force Base (MHAFB)
- Parallel integration with the existing wastewater treatment infrastructure at headworks
- Bypass valve to minimize risk in the event of system shutdown
- Minimal ancillary onsite infrastructure improvements required



Site Description (MHAFB)

MHAFB headworks buildings—inlet & grate (A), grinder & pumping station (B)

Open channel post grinder, pre-pump station

Technical Approach

Performance Objectives

Parameter	Objective
Capacity	1000 gpd
Energy Consumption	$\leq$ 4.45 kWh/kgal
H_2 Yield	$\geq$ 0.017 kg/kgal
CH_4 Yield	$\geq$ 0.026 kg/kgal
Net Energy Consumption Reduction	$\geq$ 6.0 kWh/kgal
Sludge Reduction	> 60%
Water Re-Use Potential	> 85%
BOD	< 30 mg/l
COD	< 30 mg/l
NH_3	< 5 mg/l

Current Status

- AnMBR
  - ♦ University of Illinois updating AnMBR with new piping and a second membrane module
  - ♦ Upgrading controls to enable integration with the parent D-LEWT system
  - ♦ Conditioning sludge for seeding the AnMBR
- Clinoptilolite
  - ♦ Subsystem designed by Highland Engineering
  - ♦ Assembly is underway with a completion date of March 2018
- Ammonia Electrolysis
  - ♦ Electrolysis cells assembled with improved catalyst
  - ♦ Received 2/5/2018

Ceramic membrane module for AnMBR

Assembled clinoptilolite column

Next Steps

- Integrated system complete – July 2018
- Pre-validation testing complete – January 2019
- Install at MHAFB – February 2019
- Field demonstration complete – March 2020
- Final report – April 2020

Key Points

- Decentralized waste water treatment system that generates useful methane and hydrogen fuels
- Reduced energy consumption and sludge production compared to aerated systems
- Effluent water available for reuse
- Containerized system suitable for decentralized use and deployed applications
- Supports water, energy, and waste Net-Zero goals

Questions?