Thank you for signing in early

The webinar will begin promptly at 12:00 pm ET, 9:00 am PT
SERDP and ESTCP Webinar Series

The webinar will begin promptly at 12:00 pm ET, 9:00 am PT

- You have two options for accessing the webinar
  1. Listen to the broadcast audio if your computer is equipped with speakers
  2. Call into the conference line: 303-248-0285
     Required conference ID: 6102000

- For any question or issues, please email serdp-estcp@noblis.org or call 571-372-6565
Energy Sustainable Wastewater Treatment Systems for Forward Operating DoD Installations

August 9, 2018
Welcome and Introductions

Rula A. Deeb, Ph.D.
Webinar Coordinator
Webinar Agenda

- Webinar Logistics (5 minutes)
  Dr. Rula Deeb, Geosyntec Consultants

- Overview of SERDP and ESTCP (5 minutes)
  Dr. Andrea Leeson, SERDP and ESTCP

- Federal Directives Supporting Low-Energy Wastewater Solutions (25 minutes + Q&A)
  Dr. Kathryn Guy, USACE ERDC

- Wastewater Treatment for Forward Operating Bases Using Microbial Fuel Cells (25 minutes + Q&A)
  Dr. Pat Evans, CDM Smith

- Final Q&A session
How to Ask Questions

Type and send questions at any time using the Q&A panel.
In Case of Technical Difficulties

- Delays in the broadcast audio
  - Click the mute/connect button
  - Wait 3-5 seconds
  - Click the mute/connect button again
  - If delays continue, call into the conference line
    - Call into the conference line: 303-248-0285
    - Required conference ID: 6102000

- Submit a question using the chat box
SERDP and ESTCP Overview

Andrea Leeson, Ph.D.
SERDP and ESTCP
SERDP

- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management
ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance
Program Areas

1. Environmental Restoration
2. Installation Energy and Water
3. Munitions Response
4. Resource Conservation and Resiliency
5. Weapons Systems and Platforms
Environmental Restoration

- Major focus areas
  - Contaminated groundwater
  - Contaminants on ranges
  - Contaminated sediments
  - Wastewater treatment
  - Risk assessment
## SERDP and ESTCP Webinar Series

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For upcoming webinars, please visit

Save the Date!

A three-day symposium showcasing the latest technologies that enhance DoD's mission through improved environmental and energy performance

November 27-29, 2018
Washington Hilton Hotel

Registration is open
Federal Directives Supporting Low-Energy Wastewater Solutions

Kathryn Guy, Ph.D.
U.S. Army Corps of Engineers
Engineer Research and Development Center
Agenda

- Federal requirements/regulations for reducing:
  - Water consumption
  - Energy usage
  - Waste generation
- Distributed Low-Energy Wastewater Treatment (D-LEWT) for Fuel Generation and Water Reuse
  - Technology description
  - Current status
- Conclusions (why DoD cares)
Federal Requirements and Regulations

- **Executive Orders (EOs)**
  - EO 13693 (Planning for Federal Sustainability in the Next Decade), March 19, 2015. Revoked by:
  - EO 13834 (Efficient Federal Operations), May 17, 2018

- **Army Directives**
  - 2014-02 (Net Zero Installations Policy)
  - 2017-17 (Installation Energy and Water Security Policy)

- **Public Laws**
  - Energy Independence and Security Act (EISA) of 2007 (Public Law 110-140)
EO 13693
Planning for Federal Sustainability in the Next Decade

- Federal agencies must:
  - Replace 25% of total building electric and thermal energy with renewable electric / alternative energy by 2025
  - Install “appropriate green infrastructure features on federally owned property to help with stormwater and wastewater management”
EO 13834

Efficient Federal Operations

- Reduce waste
- Cut costs
- Enhance infrastructure and operations resilience
- Enable effective mission accomplishment
- Reduce potable / non-potable water consumption
- Comply with stormwater management requirements
- Implement waste prevention / recycling measures
Army Directive 2014-02

Net Zero Installations Policy

- Reduce overall energy / water use
- Implement energy recovery / cogeneration opportunities
- Produce renewable energy onsite
- Use water-efficient technology
- Recycle and reuse water
- Convert solid waste streams to resource values
Army Directive 2017-17

*Installation Energy and Water Security Policy*

- Secure critical missions
  - Energy and water for 14 days
- Sustain all missions
  - Assured Access to Resource Supply
    - Redundant / diverse sources
    - Renewable energy and alternative water
  - Reliable Infrastructure Condition
    - Provides onsite energy and water storage
    - Flexible and redundant distribution networks
  - Reliably meet mission requirements
Public Law 109-58
Energy Policy Act of 2005

- **Title I: Energy efficiency**
  - Improved national energy efficiency encouraged through:
    - Statutory standards
    - Requirements for federal action
    - Incentives for voluntary improvements

- **Title II: Renewable energy**
  - Increase production and use
  - Advance technology development
  - Promote commercial development of renewable energy
Public Law 110-140

- Greater energy independence / security for the United States (U.S.)
- Increase and develop clean renewable fuel production
- Research and deploy greenhouse gas capture / storage options
- Improve Federal Government energy performance
- Increase U.S. energy security
D-LEWT

*Distributed Low-Energy Wastewater Treatment*

- **Demonstrate**
  - Decentralized wastewater treatment (1,000 gallons per day [gpd])
  - Harvestable fuel generation (hydrogen gas [H$_2$] and methane [CH$_4$])

- **Validate**
  - Reduced energy consumption
  - Reduced sludge production
  - Effluent reuse potential
D-LEWT

Distributed Low-Energy Wastewater Treatment

1,000 gpd

CH₄

H₂

D-LEWT

HARVESTABLE FUELS

ENERGY EFFICIENT OPERATION

WATER REUSE

effluent

SERDP & ESTCP Webinar Series (#76)
Technology Description

- Integrates technologies to:
  - Treat wastewater
  - Reduce energy consumption
  - Generate useful fuels
D-LEWT Schematic

Monitor volume and composition (% CH₄)

Monitor volume and composition (% H₂, N₂)

AnMBR

Clinoptilolite

NH₃ Brine Collection

Regenerant Brine

NaOH

Waste Water

Treated Water

CH₄

N₂ H₂

Lines
Solid = continuous flow
Dash = periodic process
Dots = gas flow

Ammonia Electrolysis Cells

Electrolysis Cells

Electrolysis

Ammonia
Current Status – AnMBR
Anaerobic Membrane Bioreactor

- Cost share with University of Illinois
- Updated controls and new membrane
- Ready for integration into D-LEWT
Current Status – Clinoptilolite

*Clinoptilolite is a Naturally Occurring Mineral*

- System nearly complete
- Four columns of clear polyvinyl chloride (PVC)
- Autonomous operation via valve positioning and timing
Current Status – Electrolysis
Producing Hydrogen from Ammonia

- Additional 12 cells obtained from Ohio University
- Awaiting integration into D-LEWT
Mountain Home Air Force Base (AFB)  
*Expected 2019*

Headworks Buildings  
**A:** Inlet and grate  
**B:** Grinder and pumping station
Mountain Home Air Force Base (AFB)

*Expected 2019*

Open channel flowing influent (post grinder, pre-pump station)
## Performance Objectives

<table>
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<tr>
<th>Objective</th>
<th>Success Criteria</th>
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<tr>
<td>Energy Consumption</td>
<td>$\leq 4.45 \text{ kWh/kgal}$</td>
</tr>
<tr>
<td>Energy Production</td>
<td>$\geq 0.017 \text{ kg/kgal} \text{ hydrogen (H}_2\text{) yield}$</td>
</tr>
<tr>
<td></td>
<td>$\geq 0.26 \text{ kg/kgal} \text{ methane (CH}_4\text{) yield}$</td>
</tr>
<tr>
<td>Net Energy Consumption</td>
<td>$\geq 6.0 \text{ kWh/kgal reduction}$</td>
</tr>
<tr>
<td>Sludge Reduction</td>
<td>$\geq 60% \text{ reduction in mass of sludge}$</td>
</tr>
<tr>
<td>Effluent Water Quality</td>
<td>$\leq 30 \text{ mg/l chemical oxygen demand (COD)}$</td>
</tr>
<tr>
<td></td>
<td>$\leq 5 \text{ mg/l ammonia (NH}_3\text{)}$</td>
</tr>
</tbody>
</table>
Conclusions

- Decentralized wastewater treatment system
- Generates useful CH$_4$ and H$_2$
- Reduced energy consumption / sludge production vs. aerated systems
- Effluent water for reuse
- Supports water, energy and waste Net-Zero goals
DoD Benefits

- Save money
- Save lives
- Maintain operations in emergencies
- Meet regulations
- Adjust to diminishing supply
- Right thing to do
SERDP & ESTCP Webinar Series

For additional information, please visit https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Wastewater-and-Drinking-Water/ER-201728

Speaker Contact Information
Kathryn.A.Guy@usace.army.mil; 217-373-3378
Q&A Session 1
Wastewater Treatment for Forward Operating Bases Using Microbial Fuel Cells

Pat Evans, Ph.D.
CDM Smith
Agenda

- How does a microbial fuel cell (MFC) work?
- Improving performance: Electrode materials
- Anode and cathode design and tests
- Continuous wastewater (WW) treatment
- Second process to improve effluent quality
- Going forward to pilot scale tests
Electrical Power Generation in an MFC

Anode
Fuel (wastes)
Oxidation products (CO₂)
Bacteria making electrical current

Cathode
Oxidant (O₂)
Reduced oxidant (H₂O)

Load

Research Focus Areas

Anodes
Brush size, number, orientation

Separators
Most practical / commercially available

Continuous flow testing
Maximize power and treatment efficiency

Flow in
Anode

Flow out
Anode

Engineering Design
Scale-up

Spacer testing
Effect on performance

Cathodes
Inexpensive and compatible catalyst
Reactor Designs for Research

*Systematically Increasing Scale*

- **Generation 0**
  - 0.025 liters (L)
- **Generation 1**
  - ~0.13 L
- **Generation 2**
  - 2 L
- **Generation 3**
  - 5.7 L
Anode Testing
Smaller and Closer Brushes Work Better with Acetate

![Graph showing Power Density vs Current Density](image)

- **Power Density** (milliwatts per meter squared [mW/m²])
- **Current Density** (milliamps per centimeter squared [mA/cm²])

R8C, R8, R3, R5, R8, R8C
Smaller Brushes + WW – Reactor Instability

Need Larger 2.5-centimeter Brushes with WW

Maximum power:

260 mW/m² vs. 150 mW/m²

- Cathode performance similar (S1 and S3)
- Anode performance unstable (S3)
Separator Tests with WW Treatment Faster Without Separator

Separator (Separator Electrode Assembly, **SEA**) vs. No Separator (Spaced electrode assembly, **SPA**)

- **Separator**
  - Cathode
  - Anode
  - Separator: 0.5 cm
  - 2.0 cm

- **No Separator**
  - 0.8 cm

Graph:
- Power Density (mW/m²)
- Time (hours [h]): 0, 12, 24, 36, 48
- Dissolved Oxygen (DO) (milligrams per liter [mg/L]): 2.0, 1.5, 1.0, 0.5, 0.0

- **Power SEA**
- **Power SPA**
- **DO SEA**
- **DO SPA**

- SPA (12h)
- SEA (36h)

Ahn et al. (Submitted)
Wastewater Performance Over Time

*Treatment More Stable with Separator*

Initially: Similar Performance

After 5 Months: SEA > SPA

U = Upflow (1\textsuperscript{st} MFC in series)
D = Downflow (2\textsuperscript{nd} MFC in series)

Spacers

Air Flow to Cathode

Spacer and Domestic WW

*Wire Spacer Provided Best Performance*

![Graph depicting the performance of mesh, column, and wire spacers.](Image)

*MS – Mesh spacer; CS – Column spacer; WS – Wire spacer
V – Voltage; P – Power*

Cathode Testing

New Method to Improve Performance and Decrease Cost

- Polymer (PVDF) binder holds catalyst (activated carbon [AC])
  - Room temperature
  - Continuous manufacturing
  - $15/m² for materials

Yang et al. (2014) ES&T Letters
Cathode Testing

Same Performance as PTFE/Platinum Cathode

![Graph showing power density vs. current density for AC/PVDF and Pt/Carbon cathodes. The graph peaks at a current density of 1.2 A/m² for both materials.]
Continuous Flow Tests

Using Domestic WW (Grey Water)

Location: Penn State Wastewater Treatment Plant (WWTP)
Gen 3 MFC Tests
6.1 L MFC Operated in Penn State WWTP
Continuous Flow Tests

HRT Critical Factor in COD Removal

**Graph:**
- **COD Removal (%)** vs. **HRT (h)**
- Points for S2C_Theoretical HRT, S2C_Measured HRT, N1C_Theoretical HRT, N1C_Measured HRT
- Line with equation $R^2 = 0.9931$

**Text:**
Continuous Flow Tests

Need Polishing Step After MFC

Low COD limits current generation

AC = Acetate
WW = Wastewater

Polishing Step

**MFC and AFMBR**

AFMBR = anaerobic fluidized bed membrane bioreactor
MFC + AFMBR

Combined Process Yielded High-quality Effluent

- Effluent COD: 16 mg/L
- Effluent total suspended solids (TSS): <1 mg/L

Engineering Design

*Basis for Scale-Up*

- Plug flow
- Minimize short circuiting
- Maximize liquid distribution
- Modular construction
- Scalable
- Maintainable
- Solids management

Top View

Anode

Spacer for Air

2-Sided Cathode Module

Cathode with Separator
MFC Mechanical Design
Modular, Scalable and Maintainable System

Removable anode and cathode modules

Influent distributor
Valves
MFC tank cut-away
Next Steps

- ESTCP project funded: ER-201635
- Pilot test with MFC + Biofilter
- Lead: Don Cropek at U.S. Army Engineer Research and Development Center
- Location: Tobyhanna Army Depot
Conclusions

- Energy-neutral or power production possible
  - 0.08 kWh/m³
- Energy produced versus 0.6 kWh/m³ consumed for activated sludge
- Goal: ~50% COD removal in MFC
- Need second process: AFMBR or biofilter
- Modular design, very low energy requirements
Acknowledgements

- Bruce E. Logan, Penn State University
- Josh Goldman, CDM Smith
For additional information, please visit https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Wastewater-and-Drinking-Water/ER-2216

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evanspj@cdmsmith.com; 206-351-0228
Q&A Session 2
The next webinar is on August 23, 2018

Sediment Volume Search Sonar Development
Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends.