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Engineer Research and Development Center

Deployable Membrane Bioreactor-Reverse Osmosis Systems for Water Reuse

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SERDP • ESTCP
SYMPOSIUM
2018 | Enhancing DoD's Mission Effectiveness

Agenda

- Research Motivation
- Increasing Water Productivity
- LEAP-ing Ahead
- Low-energy RO
- Current Demonstration/ Treatment Train
- Next Steps
- Conclusions
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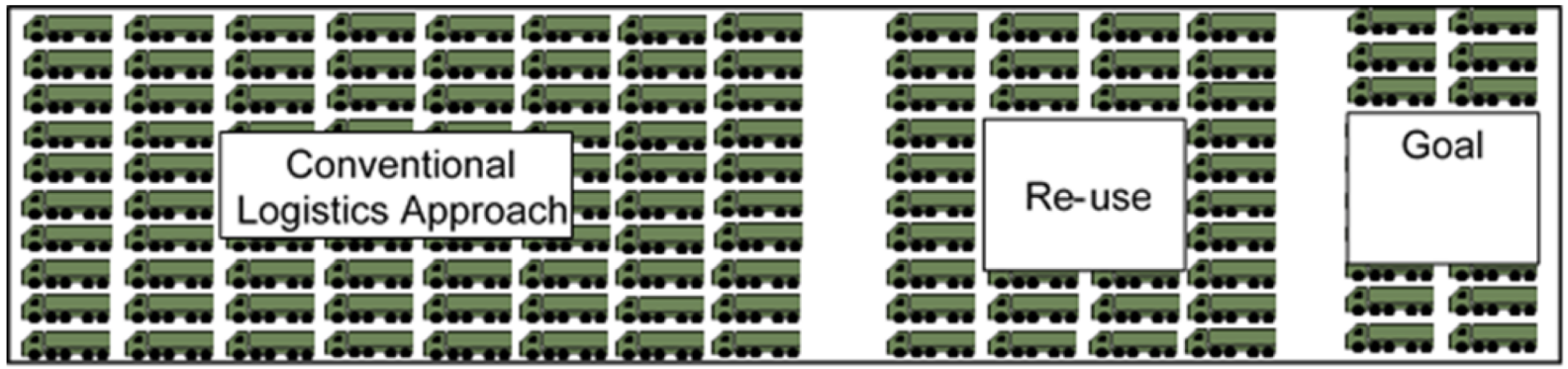
Research Motivation

- Logistics burden of water supply and wastewater removal

- The Army has established that water, fuel, and ammunition constitute the highest demand signatures, so focusing on those demands will provide the largest impact toward Multi-Domain Battle (MDB) against near-peer adversaries.
- The current goal for the Army is to be able to operate a BCT (3000 personnel) for 7 days without resupply of water, fuel, or ammo.

Research Motivation

- 5000-gallon trucks required for providing 20 gallons per day per Soldier for 7 days to an entire Brigade Combat Team (BCT).
- Clearly, it would not be practical for a BCT to have 80 semi-trailers on the convoy just to bring enough water along. This may force BCTs to only travel to places near surface water sources, **which would limit operational reach.**



Increasing Water Productivity

- ***Army Modernization Priority #6*** *(*TRADOC Multi-Domain Battle Concept)
  - Increase operational reach and sustaining personnel in the near-peer battle space
  - Reduce Soldier exposure to attacks associated with logistical tails
- ***Solutions***
  - More efficient resource management
  - Alternative Water Sourcing
  - **Water recycling must be part of the equation**
  - **Promoting reuse opportunities from marginal and non-traditional sources**

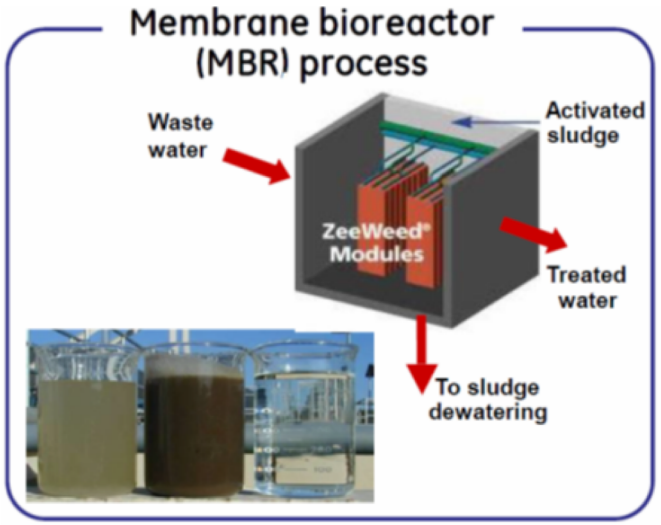
Convoys suffered high casualty rates throughout engagements in Iraq and Afghanistan, and these vulnerabilities will be augmented in a near-peer conflict.

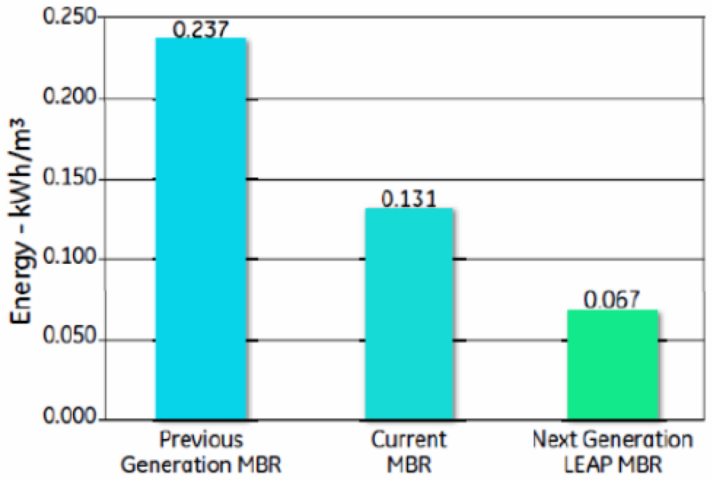
Increasing Water Productivity

- The objective of this project is to demonstrate and validate the performance of an energy-efficient gray water treatment and reuse system.
- The graywater treatment system is comprised of a Low Energy Advanced Primary Membrane BioReactor (LEAP-MBR) followed by Ultra-Low-Energy Reverse Osmosis (ULERO) purification.
- These technologies were developed by GE Water and GE Global Research and were tested successfully for gray water treatment as part of a recent **SERDP effort by GE Global Research (Project # ER-2238).**

LEAPing Ahead

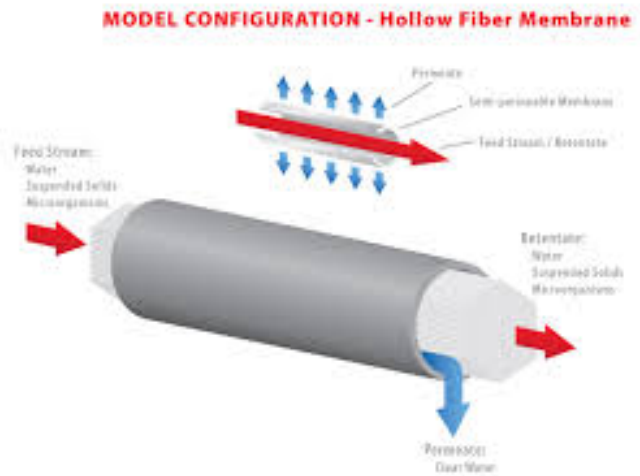
- **Low Energy Advanced Primary (LEAP) Membrane BioReactor**
- LEAP aeration efficiently remove organics, particulates, and ammonia while providing turbulent “air scouring” of UF membrane surface.
- Very compact system footprint and reducing energy consumption.





LEAPing Ahead

- **MBR conclusions from preceding SERDP effort**
- MBR low Hydraulic Retention Time (2-4 hours)
- MBR high Sludge Retention Time (20-25 days)
- Rapid seeding/ start-up procedures
- High quality effluent in less than 5 days
- 99% reduction of organic content
- Complete removal of suspended solids
- Effluent with less than 0.5 mg/L of ammonia, <3 mg/L of total nitrogen, and <0.05 mg/L of total phosphate
- Energy cost of about 0.45 kWh/m^3 (or 1.7 kWh/kgal)



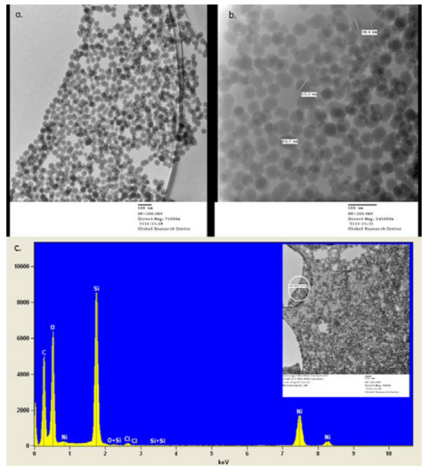
Low-Energy RO

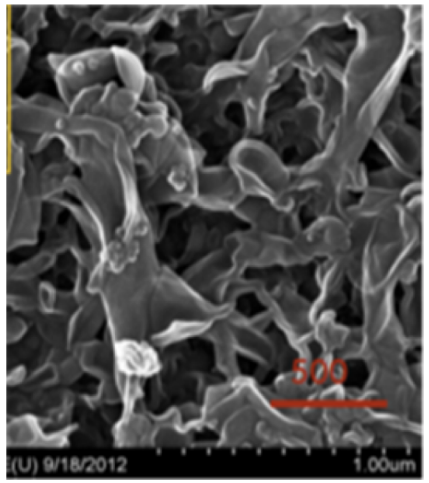
- The DoD explicitly recommends that potable water “be used for nearly all water-requiring activities if it is available” (US Army, Navy, and Air Force, 2010).
- The ULERO membrane operating pressure is only **60 psi**, which is about 50% of that of competing commercially-available technologies, thereby reducing energy requirements by a similar margin.
- High recovery configuration (3-pass, 80% recovery), with the 20% rejection stream discharged into the sewer system for dilution and conventional wastewater treatment.

Low-Energy RO

- The advanced ULE RO membrane, incorporating engineered nanomaterials, demonstrated a 2- to 3-fold permeance enhancement, while maintaining the 99.5% or higher salt rejection characteristic of current commercial RO membranes.
- The product water from the ULERO system is expected to meet or exceed USEPA drinking water quality criteria.

SERDP # ER-2238





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Current Demonstration ESTCP ER-201636

- Camp Shelby Joint Forces Training Center (CSJFTC) gray water test bed
- Specific to this site are **3 Operational Training Areas** representative of a FOB
- Source separated gray water stored in 2 x 10,000 gallon tanks at each TTB which is transported by tanker truck at $0.21 per gallon to wastewater treatment.

Tactical Training Base 1 (TTB 1)
872 PAX Capacity

Tech Transfer

Primary Feed

Tactical Training Base 4 (TTB 4)
1192 PAX Capacity

Supplemental Feed

Tactical Training Base 3 (TTB 3)
712 PAX Capacity (Navy)

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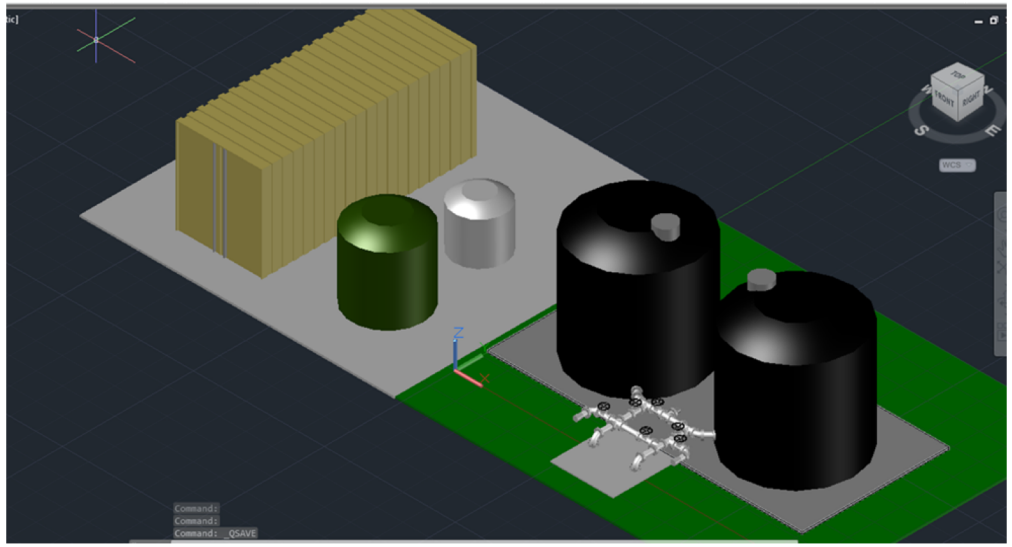
ESTCP ER-201636

- Remote multi-user bathing facilities with segregated gray water (**2-10 GPM**)
- 8 shower units x 12 shower heads/unit x 2 gpm/shower head = 192 gpm
- 500 PAX/ 10,000 GPD training rotations at peak use

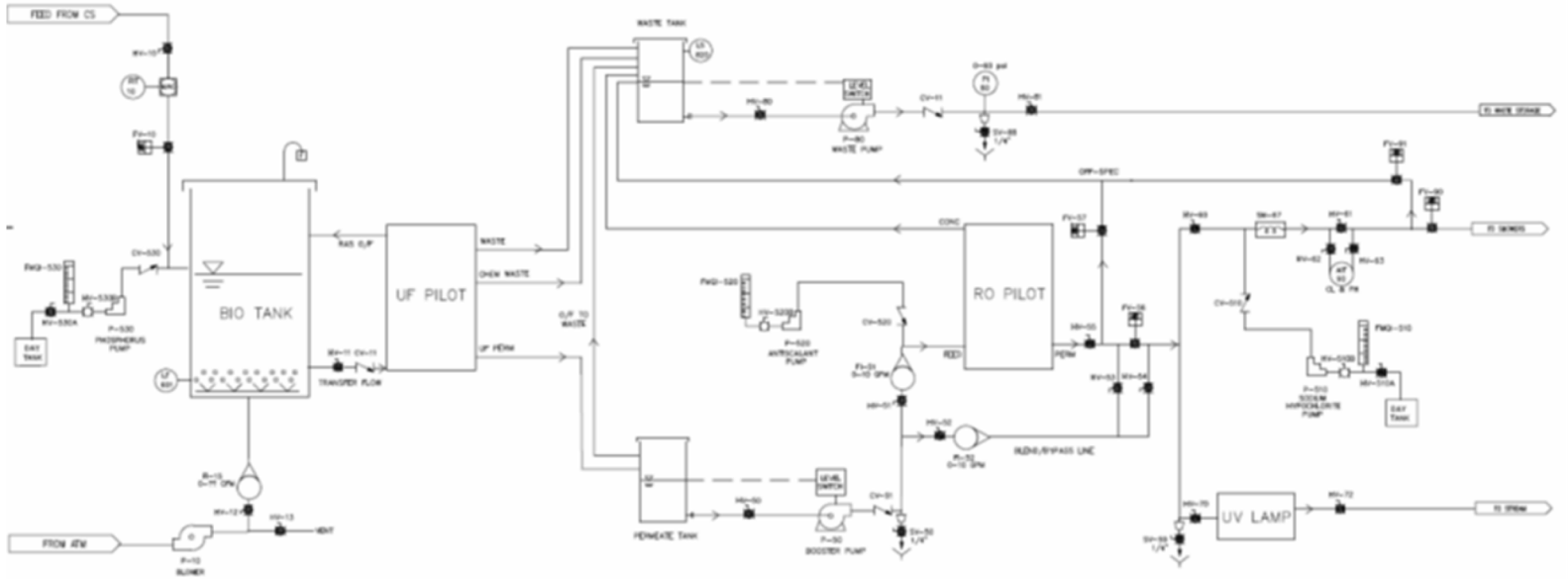


Treatment Train ESTCP ER-201636

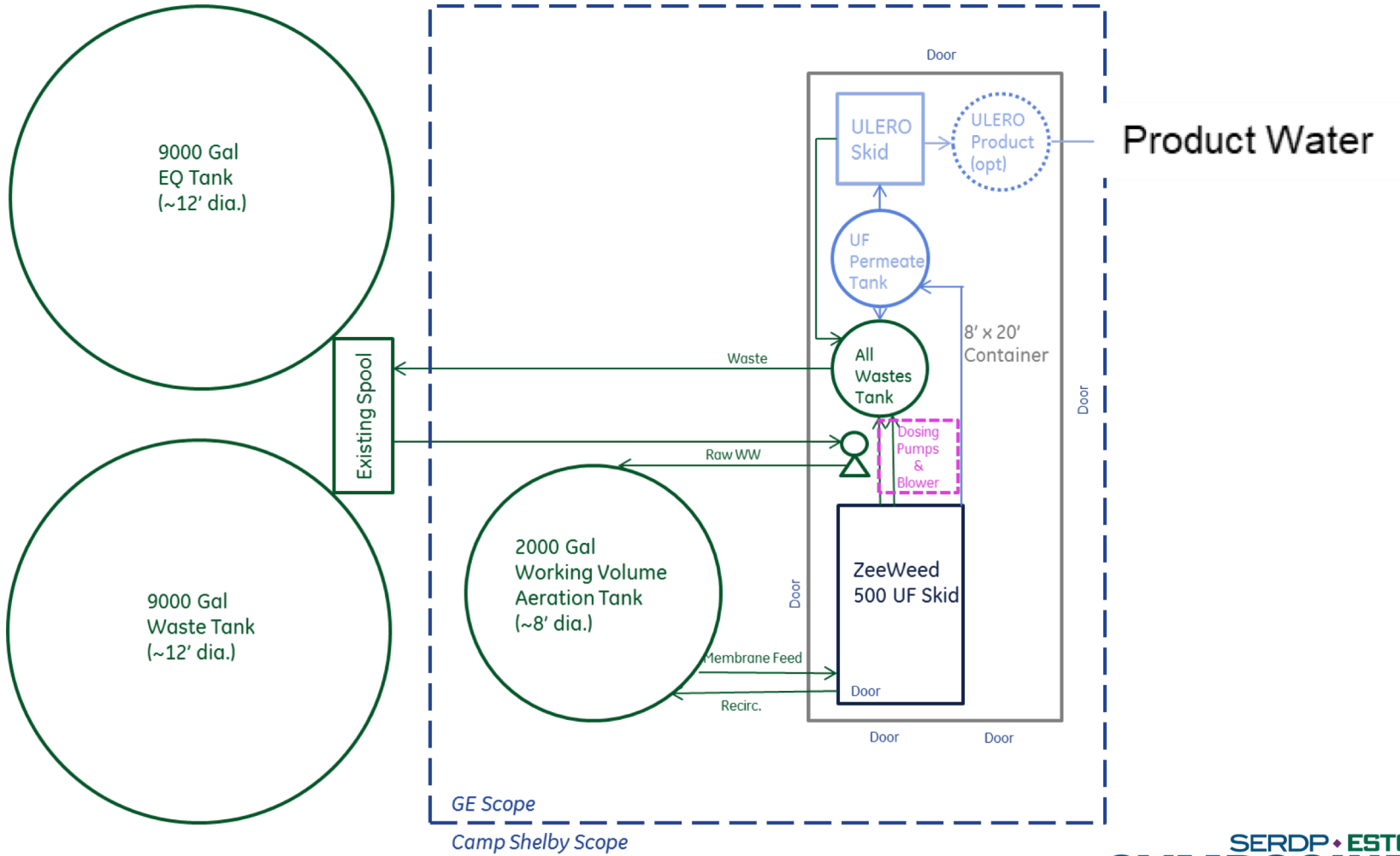
- The graywater treatment system is in a 20’ CONEX-type shipping container. The integrated water reuse system will include a waste heat recovery system, an energy-efficient membrane bioreactor for wastewater treatment, and a state-of-the-art reverse osmosis membrane module to produce potable-quality water.

Treatment Train/ What's in the Box?

- The system is automated to allow for awareness and control of each process, multiple discharge modes, by-pass of unit-ops, and automatic emergency shutdown functions. Will be locally operated and remotely monitored



Treatment Train ESTCP ER-201636



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Current Demonstration ESTCP ER-201636

- The objective of the SERDP project ER-2238 was to develop an innovative, easily deployable membrane bioreactor (MBR) and ultra-low energy (ULE) reverse osmosis (RO) system for onsite wastewater treatment that produces high-quality water for high-tier reuse




Shakedown and Commission: We are up and running!

Next Steps

- The data is the key deliverable as this “real” source separated gray water will fill knowledge gaps not available from synthetic/ simulated feed waters.

Site Feed Water Analysis

Analyte	Result	Units
Nitrate as N	0.046	mg/L
Sulfate	5	mg/L
Chloride	58	mg/L
E coli	>2419.6	Fecal Coliform MPN per 100ml

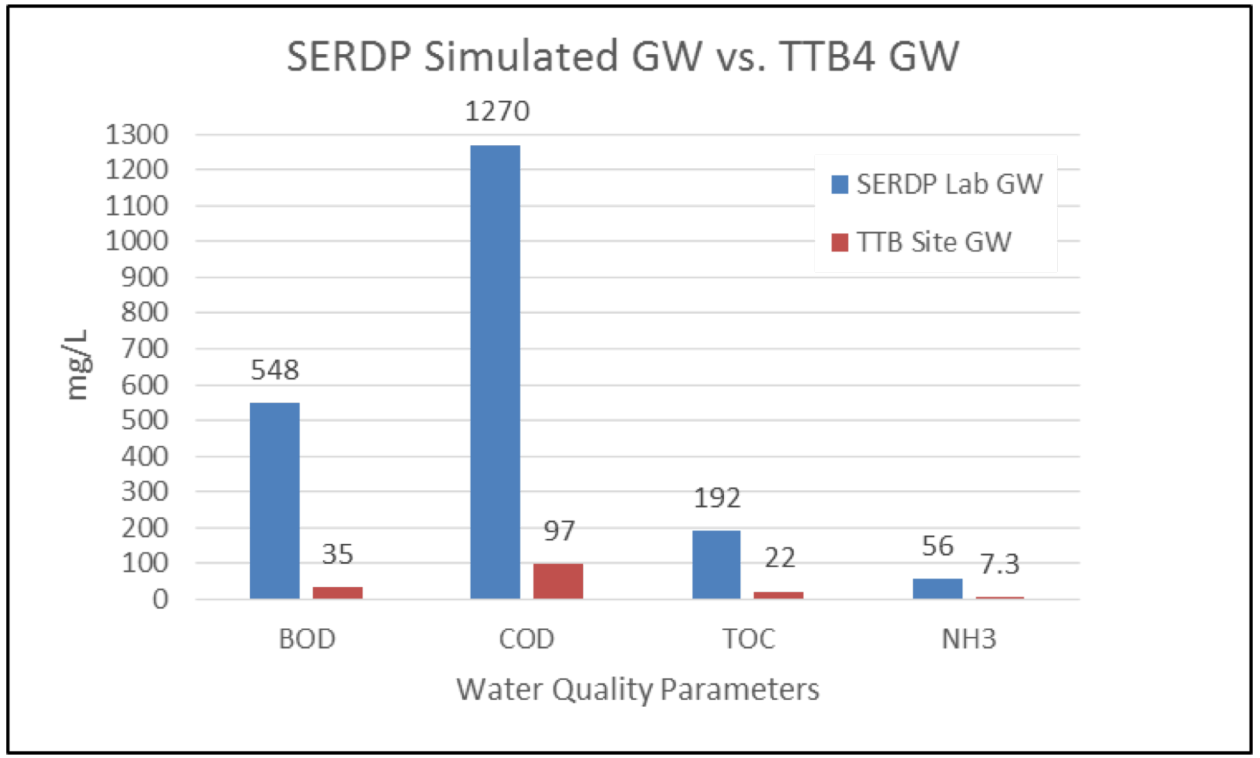
Analyte	Results	Units
Alkalinity	210	mg/L
Ammonia	7.3	mg/L
Ortho-Phosphate	0.18	mg/L
Chemical Oxygen Demand	97	mg/L
Total Organic Carbon	22	mg/L
Methylene Blue Active Substances	6.3	mg/L

Analyte	Results	Units
Turbidity	16	NTU
Hardness as calcium carbonate	46	mg/L
Specific Conductance	600	umhis/cm
Total Dissolved Solids	330	mg/L
Biochemical Oxygen Demand	35	mg/L

Next Steps

Key Parameters at 198 days from **Project # ER-2238**

Parameter	Influent	MBR Effluent	RO Effluent	% removal
BOD (mg/L)	548	17	<4	>99.3
COD (mg/L)	1270	9	<5	>99.6
TOC (mg/L)	192	5.1	<1	>99.5
NH_3 (mg/L)	55.7	2.1	0.1	99.8



Next Steps

- We are tracking at least seven training events at the site where water will be treated and analyzed.
- **This will provide a robust precedent using "real" gray water from hygiene complete with pathogens, PCPP, and micropollutants. (DEET, caffeine, Gemfibrozil, ibuprofen)**
- The data generated in this demonstration will help support in-depth health risk assessment to show that high tier reuse can be done safely in the future.

COL/TTB #4_TTB	FOB DEFENSE/URBAN OPERATIONS	12/06/2018 06:00 L	12/09/2018 17:00 L	RES
COL/TTB #4_TTB	FOB DEFENSE/URBAN OPERATIONS	02/28/2019 06:00 L	03/03/2019 17:00 L	RES
COL/TTB #4_TTB	MILITARY OPERATIONS IN URBAN TERRAIN (MOUT)	03/13/2019 00:00 L	05/05/2019 00:00 L	PEN-RC
COL/TTB #4_TTB	BIVOUAC	05/20/2019 07:00 L	05/28/2019 16:30 L	RES
COL/TTB #4_TTB	FOB DEFENSE/URBAN OPERATIONS	06/05/2019 06:00 L	06/08/2019 17:00 L	PEN-RC
COL/TTB #4_TTB	FOB DEFENSE/URBAN OPERATIONS	06/22/2019 07:00 L	06/27/2019 17:00 L	RES
COL/TTB #4_TTB	FOB DEFENSE/URBAN OPERATIONS	09/18/2019 06:00 L	09/21/2019 17:00 L	PEN-RC

Conclusions

- Water is inherent to daily life, and the development of impactful and innovative solutions in this technology space can truly have world-wide benefits.
- Although initially designed minimizing the need to transport water and wastewater to and from the FOBs the same technology concepts could work well for installation applications, decentralized wastewater treatment and reuse.
- This project will develop leap-ahead space- and transport-efficient field hygiene capabilities that are much more compact to meet new operational requirements.

Acknowledgements

- Dr. Martin Page ERDC-CERL
- Dr. Hua Wang PI: SERDP-ER2238
- Mr. Paul Bandstra SUEZ Water

For More Information:
ESTCP ER-201636

We are interested in collaborating to develop the best solutions for water reuse!

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https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Wastewater-and-Drinking-Water/ER-201636/ER-201636/(language)/eng-US