Emerging Water Reuse Frameworks for Military Sustainment and Resiliency

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  - Dr. Don Cropek (Direct Potable Reuse)
  - Mr. Andy Hur (Life Cycle Cost Analysis)

- **Highland Engineering**
  - John Boland, Engineer (Gray Water Pilot Controls)

- **GE Global Research and Suez**
  - Paul Bandstra, Global Water Pilot Lead
  - Dr. David Moore, Materials R&D Lead

- **University of Illinois at Urbana Champaign**
  - Dr. Michael Plewa (Toxicity Analysis)
Water Reuse in Military Settings

**Challenges**
- Water is often not readily available in field security or disaster response operations.
- Water supply and wastewater treatment can be burdensome in field training areas as well.
- At large permanent facilities, the Army alone uses about 45 billion gallons (175 Mm³) of water per year.

**Opportunities**
- Water reuse technologies to reduce net demand
- Army policy and regulations allow for shower, laundry, latrine reuse in field settings.
- Resiliency and emergency operations policies that promote water sustainment have been adopted at permanent facilities.
Distributed Water Reuse Systems

- **Constraints/Challenges**
  - **Field settings:** Mobility; Climate
  - **Facility settings:** Cost; Infrastructure modifications
  - **All settings:** Training, Automation, Social, Regulatory, Cross-contamination

- **Frameworks and Maturity**
  - Shower and laundry reuse in field settings (Prototypes available)
  - Direct potable reuse in field settings and fixed facilities (Under investigation)
Current Standards for Shower Water Recycling

1. Gray water source, no black water.
2. Non-potable use only.
3. Criteria:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5-9</td>
</tr>
<tr>
<td>Turbidity</td>
<td>&lt; 1 NTU</td>
</tr>
<tr>
<td>Hardness</td>
<td>&lt; 500 mg/L</td>
</tr>
<tr>
<td>TDS</td>
<td>&lt; 1500 mg/L</td>
</tr>
<tr>
<td>Coliforms</td>
<td>Absent</td>
</tr>
<tr>
<td>Free chlorine residual</td>
<td>1-4 mg/L after 30 min</td>
</tr>
</tbody>
</table>

**Treatment Guidance**

1. Best practical physical/chemical treatment processes that might include coagulation, sedimentation, filtration, activated carbon, and reverse osmosis treatment.
2. Primary and residual disinfection is required in all cases.

*Reverse osmosis treatment is generally practiced.*
Strategy for Water Reuse Risk Management

Key Assumptions (summarized)
1. Best practices will be established in larger camps and pushed forward over time.
2. No natural buffers will be used.
3. Users are primarily healthy, fit adults.
4. Exposure pathways can be tailored to military operating environment.
5. Civilian regulatory codes as guidelines for best practices.

Limitations
1. No potable reuse, though high contact non-potable reuse such as showering allowed.
2. Health-based risks only (does not cover environmental)
This microbial risk assessment evaluates health risks associated with wastewater reuse in a deployment setting. It provides risk-based water concentrations (RBWCs) for treated wastewater unrestricted reuse scenarios. This document only provides RBWCs for *Escherichia coli*.

### Table 21. Field Wastewater Unrestricted Risk-Based Concentrations

<table>
<thead>
<tr>
<th>Daily Gastrointestinal Illness Rate (Portion of showering population experiencing GI symptoms due to exposure to shower water)</th>
<th>Units</th>
<th><em>Escherichia coli</em> Water Concentration*</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alternative A</td>
<td>Baseline</td>
<td>Alternative B</td>
</tr>
<tr>
<td>Two showers per day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFU 100 mL</td>
<td>5</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>CFU 1 liter</td>
<td>50</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>CFU 10 liters</td>
<td>500</td>
<td>1,000</td>
<td>3,000</td>
</tr>
<tr>
<td>One shower every 2 days (shower every other day)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFU 100 mL</td>
<td>N/A*</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CFU 1 liter</td>
<td>5</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>CFU 10 liters</td>
<td>50</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>One shower per week</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFU 100 mL</td>
<td>N/A*</td>
<td>N/A*</td>
<td>N/A*</td>
</tr>
<tr>
<td>CFU 1 liter</td>
<td>N/A*</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CFU 10 liters</td>
<td>5</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

**Notes:**

*Concentrations are rounded to one significant figure. See paragraphs 7.4.2, 7.5.1, 7.5.2, and 7.5.3 for the unrounded concentrations.*

*Daily GI illness rate in the population. See appendix C for yearly risk analysis.*

*Conventional in water monitoring is to report microbial content in CFU per 100 mL of water. CFU per 1 liter and 10 liters are reported to show concentrations that are less than 1 CFU/100 mL.*

*Not applicable, concentrations whose volumes lead to fractional CFU. A larger sampling volume results in a whole number CFU per volume concentration.*
Conventional Field Framework

- Supply, Use Once, and Dispose (no reuse)

Supply*: 151 L/day (40 gpd) per Soldier

Use: 151 L/day (40 gpd) per Soldier

Waste: 151 L/day (40 gpd) per Soldier

*Water demand ranges from 30-40 gpd (114-151 Lpd) at expeditionary camps that provide hygiene, medical, and dining support capabilities.
Near Term Field Framework

- Gray Water Reuse and On-site Wastewater Treatment

**Supply:**
49 L/day (13 gpd) per Soldier

**Use:**
26 L/day (7 gpd) per Soldier

**Reuse:**
102 L/day (27 gpd) per Soldier

**Waste:**
49 L/day (13 gpd) per Soldier

**Use:**
23 L/day (6 gpd) per Soldier
**Objective.** Design, assemble, and evaluate a robust, operationally-efficient gray water reuse system that can reduce water demand for expeditionary environments.

**Capability.** The G-WTRS provides a 65% reduction in the base water supply by treating gray water from showers and laundry systems with 90% recovery for reuse.

**Benefit.** The G-WTRS will reduce logistics and has an estimated payback period of 3 months.
G-WTRS Development

6.4 Field Assessments
- Long term performance in operational training area at Fort Leonard Wood
- Potable water quality
- FY17-19

6.3 Pilot Integration
- 80% water recovery
- < 10 Wh/gal
- Synthetic gray water → potable water quality
- TTA PdM-PAWS
- FY15-16

6.2 Bench Studies
- Patent-pending biofiltration pretreatment system
- Low energy reverse osmosis membranes and design
- FY13-14

Innovative solutions for a safer, better world
G-WTRS Treatment Process Train

- Coagulation
- Mechanical Screen Filtration
- Biofiltration
- Ultrafiltration
- Reverse Osmosis
- Chlorination

G-WTRS container

UF feed tank

RO feed tank

Product water

Gray water
Intermittently-Operated Biologically Activated Carbon (IOBAC) Filtration

Cycling of adsorption and passive aerobic biodegradation has capability to remove high levels of organics

Step 1: Upflow GAC adsorption

Step 2: Drain filter and grow biomass, regenerating sites.

Step 3: Remove biomass & go back to Step 1.
IOBAC Performance: Municipal Wastewater

<table>
<thead>
<tr>
<th>Bioregen Temp</th>
<th>% COD Removal</th>
<th>Effluent COD Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°C</td>
<td>45-53%</td>
<td>70-85 mg/L</td>
</tr>
<tr>
<td>28°C</td>
<td>60-70%</td>
<td>52-61 mg/L</td>
</tr>
</tbody>
</table>

Notes:
- 4-week continuous challenge test at 10°C
- Influent COD was low (< 200 mg/L)
- Fraction COD removal similar to synthetic wastewater tests
- Performance will improve with greater bed depth
Innovative solutions for a safer, better world

CBITEC Water Sustainment Test Bed

202 Goal: Integrate and demonstrate systems with capability for 90% reduction of net water demand in expeditionary settings.

<table>
<thead>
<tr>
<th>Ongoing Demonstrations</th>
<th>FY 16</th>
<th>FY 17</th>
<th>FY 18</th>
<th>FY 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray Water Reuse</td>
<td></td>
<td></td>
<td></td>
<td>NDCEE funded</td>
</tr>
<tr>
<td>Shower Water Heat Recovery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMMS Water Metering</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Unique Site Capabilities:
1. Real gray and wastewater from > 300 personnel in training environment for system assessments
2. Continuous challenge test loop with synthetic gray/wastewater makeup capability to add load
3. Hot/cold climate testing (0-100°F)
4. Approved leech field for local discharge
5. Generator power and DMMS integration

Current water supply cost: $0.06/L ($0.22/gal)!
**G-WTRS Validation Approach and Test Bed Setup**

**Phase I**- Synthetic challenge with modified NSF 350 gray water at pilot scale (7500 gpd, 1 month).

*Added:* DEET, Permethrin, Sunscreen, Motor Oil, MS2 phage and F-pilus- *E. coli.*

**Phase II**- Continuous flow challenge with Soldier-generated gray water plus recirculated product water spiked with modified NSF 350 concentrate formula (15,000 gpd, 3 months).

**Phase III**- Continuous flow challenge with Soldier-generated gray water and on-site reuse (7,500-15,000 gpd).
G-WTRS Field Water Treatment Performance Results:

> 15 log removal of pathogen surrogates (99.9999999999999%)
> 99% removal of organics and particulates
> 99.9% removal of DEET; No detection of other micropollutants

Over 300 contaminants monitored during testing
ALL H2O Future Field Capability

Potable Reuse: 26 L/day (7 gpd) per Soldier

Waste Heat Atmospheric Water Generator & Recovery

Advanced Wastewater Treatment

Advanced Water Purification

Class A and A+ Reuse: 125 L/day (33 gpd) per Soldier

Note: Direct potable reuse is only being studied as a potential future capability. It is not currently approved by Army Public Health Center.
ERDC Water Engineering Testbed (ERDC-WET)
Assembly Ongoing
Current Installation Reuse Frameworks

Net Zero Installation

- Environment
  - DWTP
  - Mission Support
  - Personnel Support

- WWTP
- Field Training
- Irrigation

Industrial & Utility

10-30% water savings

Building Cascade

- Supply
  - Drinking and Cooking
  - Bathing & Laundry
  - Toilet Flushing
  - Irrigation

- Rain Water

10-30% water savings

Mission Support

Personnel Support

Environment

Irrigation

Disposal

Environment

20
Future Installation Reuse Frameworks

Net Zero Installation

- Environment
- DWTP
- AWTP
- Industrial & Utility
- Mission Support
- Personnel Support
- Field Training
- Irrigation
- Environment

Resilient Building

- Supply
- Drinking and Cooking
- Rain Water
- IRD
- Drinking & Cooking
- Toilet Flushing
- Bathing & Laundry
- Irrigation
- On-Site DPR
- Irrigation

60% water savings

80% water savings

60% water savings

80% water savings
Direct Potable Reuse for Fixed Facilities

- **Issues**
  - Potential for unique contaminants or contaminant profiles
  - Advanced technologies need vetting
    - Contaminant permeation
    - Unknown trace hazardous byproducts and potential composite effects.
  - Small scale risk factors

- **Ongoing R&D**
  - Pilot testing of advanced treatment processes for DPR
    - Assessing ultra low energy membranes.
  - Comparing water quality and composite toxicity of DPR system product water to current tap water at bases.
DPR Pilot Study Progress

- **Systems Evaluated**
  - G-WTRS; Tangent WaterCycle; Army Pilot Site samples

![Graph showing different water types and their parameters](image)

- **Parameter Value**
  - Total Organic Carbon
  - Thiol Reactivity
  - Cytotoxicity
  - Genotoxicity

- **Water Type Examples**
  - Tap Water
  - Source Water
  - Waste Water
  - Waste Water Effluent
  - Gray Water
  - Recycled Gray Water
  - Direct Potable Reuse Water

- **Advanced Treated Reuse Water**

- **Graphs**
  - Gray water cytotoxicity
  - Recycled gray water cytotoxicity

- **Additional Notes**
  - Innovative solutions for a safer, better world
  - BUILDING STRONG®
Shower Water Recycling at Installations

**Goal:** Reduce shower water heating requirement by 30%. Recycle 80% of shower water using < 5 Wh/gal.

LEAP Membrane Bioreactor

ULERO membrane technology

Ultra-Low-Energy RO membranes that can operate at 60 psi and reduce total dissolved solids by > 98%

MBR feed, reactor, and permeate water samples.

Conceptual layout for multi-user bathing/shower facilities.
Key Takeaways

- The military has very strong drivers for adopting water reuse - expeditionary logistics and resilient facilities.
- Innovative technologies and systems are being developed and validated for water reuse (including reuse in showers) at small scale.
- Even given the strong drivers, adoption rates have been limited due to challenges with training and automation.
- Associated health risk analyses may be a useful reference to states considering water reuse.
- Progressive regions with military facilities could be candidates for demonstration programs.
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