Advanced, Energy-Efficient Hybrid Membrane System for Industrial Water Reuse

DOE Cooperative Agreement No. DE-EE0005758
RTI International, Duke University, and Veolia Water Technologies, Inc.
Project Period: September 1, 2012 to December 31, 2016

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This presentation does not contain any proprietary, confidential, or otherwise restricted information.
Project Objective

- What are you trying to do?
  - To develop integrated FO-MD technology for high TDS water
- What is the problem?
  - Current RO Technology is not capable of producing clean water if the feed water TDS level exceeds 60,000 ppm
  - There has not been any new technology developed for high TDS water
- Why is it difficult?
  - RO is generally low energy desalination method. But at high TDS, RO cannot handle the water. Also it takes a significant amount of electrical energy.
How is it done today, and what are the limits of current practice?
- Up to 60,000 ppm TDS (seawater in the Middle East) feed water can be treated by RO
- Higher than 60,000 ppm TDS requires thermal evaporator which is very expensive to construct due to the high cost of exotic alloys

What's new in your approach, and why do you think it will be successful?
- Use waste heat instead of electricity for the major part of the energy required
- Use plastic material instead of high alloys
Technical Innovation

- Beneficial utilization of waste heat
- Synergistic coupling of FO (forward osmosis) and MD (membrane distillation)
  - FO (osmotically driven process): Pretreatment for MD
  - MD (thermally driven process): Regeneration of high-osmotic FO draw solution
- Low-pressure operation
  - Reduced energy requirements
- High water recovery/reuse potential
- Broad applicability to different industries
Technical Approach

- What is the technical approach for the project?
  - Forward Osmosis uses the salinity gradient, so that the water is collected without energy input
    - Current practice is to use high pressure to filter only water through semi-permeable RO membrane
  - Membrane Distillation uses low grade waste heat and uses mostly plastic material for construction
    - Current practice is to use thermal evaporator which is made of high alloys due to corrosion at high temperature
    - High energy consumption is due to the osmotic pressure of saline water

- Potential project risks and unknowns:
  - The membrane needs to be further developed for this process to be successful.
  - Development and manufacturing of new type of membrane for high TDS membrane has been led by European and Asian firms.
Technical Approach

Strong, Multidisciplinary Project Team:

- Duke: Basic membrane properties research, and modeling approach of the system
- RTI: Overall process concept and design. Pilot design and operation.
- Veolia: One of the largest water and desalination companies in the world. Advice on field testing
## Transition and Deployment-Updated Roadmap

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<td><strong>Yr</strong></td>
<td><strong>2012-14</strong></td>
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| Proof-of-Concept / Feasibility | Laboratory Validation  
✓ Membrane screening & evaluation  
✓ Process development, modeling, & integration  
✓ Bench integrated system (25-gpd) testing with real wastewaters | Relevant Environment Testing  
• Fabrication of field, pilot-scale testing skid (500-gpd)  
• Installation & commissioning of pilot-scale testing skid  
• Continuous, extended pilot-scale testing with real wastewater  
• Final techno-economic assessment | Membrane & module engineering improvements / optimization to increase process economic competitiveness & market relevance  
• Membrane / Module manufacturing  
• Advanced process heat (energy) integration design  
• Field process operational data (≥ 6 mos.)  
• Pre-commercial demonstration | Deployment |

Potential End Users: Membrane manufacturers, System integrators, Engineering firms, Utilities
Commercial Partners will expedite the acceptance of the new technology in the market
Measure of Success

Cost of Water Production ($/m³) vs. Total Dissolved Solids (mg/L)

Target
## Project Management & Budget

### Project Duration*
- **52 mos. (4.33 yrs.)** (anticipated)

### Total Project Budget

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<tr>
<td><strong>DOE Investment</strong></td>
<td>$4,800,000</td>
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<tr>
<td><strong>Cost Share</strong></td>
<td>$1,200,000</td>
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<td><strong>Project Total</strong></td>
<td>$6,000,000</td>
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### Project Task Structure (Simplified)

1. **MD membrane development**
2. **FO membrane process evaluation and optimization**
3. **Bench, integrated FO/MD System performance testing**
4. **Hybrid process model development and validation**
5. **Field demonstration of prototype, integrated system**
6. **Hybrid process design integration/Techno-economic analysis**

### Status Milestones

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<tr>
<td>Q1 – BP1: Q3 – Successful hydrophobic surface modification of ceramic MD membranes</td>
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<td>Q5 – BP2: Bench-scale, integrated FO/MD system design</td>
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<td>– Optimized FO membrane process with FO draw solution formulation(s) [Go/No-Go]</td>
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<td>– Preliminary techno-economic and environmental analysis [Go/No-Go]</td>
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<td>Q6 – BP3: Preliminary draft engineering design package for prototype, integrated FO/MD unit</td>
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<td>Q7 – Selection of at least one MD membrane having &gt;95% rejection of dissolved solids in complex wastewater feeds [Go/No-Go]</td>
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<td>Q8 – Fully operational bench, integrated FO/MD test system (25-gpd) [Go/No-Go]</td>
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<td>Q9 – Development of hierarchal, omniphobic surface for MD membranes</td>
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<td>– Hybrid FO/MD process model validation [Go/No-Go]</td>
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<td>Q10 – Selection of host test site [Go/No-Go]</td>
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<td>– Final engineering design package for field prototype, integrated FO/MD unit</td>
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<td>Q12 – BP4: Field prototype, integrated system (500-gpd) installation/ commissioning</td>
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<td>Q14 – BP5: Hybrid FO/MD process modeling tool fully validated with field data</td>
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<td>Q15 – Field-testing of prototype, integrated system</td>
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<td>Q16 – Final techno-economic and environmental analysis</td>
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* 6-mo. no-cost time extension through Dec. 2016 being processed by DOE.
Project Status / Accomplishments Since May 2015

Peer Review

- Currently in Month 46 of project (Budget Period 3)
- Field-test site changed from industrial facility to site on RTI campus (Real industrial wastewater to be shipped from O&G production facility to RTI as feed)
- Build of pilot-scale, integrated FO/MD prototype (500-gpd) in trailer nearly completed (mid-June)

Planned Future Work

- Field-testing of pilot-scale, integrated prototype completed
- Final techno-economic and environmental analyses