Clean Energy Research Center - Water Energy Technologies

Treatment and Management of Non-Traditional Waters

CERC-WET Project Area 2

Treatment and Management of Non-Traditional Waters

NATIONAL ENERGY TECHNOLOGY LABORATORY

Outcomes

- This topic area explores and develops various approaches and modular technologies i.e., capacitive deionization, graphene membranes, forward osmosis and open water wetlands relevant to treatment of non-traditional waters.

- The R&D outcome includes scientific papers, patents, monographs and conference communications on new systems design, decision support tools, water source assessment and integrated system synergies.

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Projects:

Project 2.1: Capacitive Deionization of Brackish Waters, Ashok Gadgil, UC Berkeley/LBNL

Project 2.2: Selective Removal of Divalent Cations with Graphene Oxide Membranes, Baoxia Mi, UC Berkeley

Project 2.3: Forward Osmosis with Ionic Liquids, Robert Kostecki, LBNL

Project 2.4: Enhanced Treatment of Desalination Brines, David Sedlak, UC Berkeley

Project 2.5: A Systems-Level Analysis of Non-Traditional Water Management, Diego Rosso, UC Irvine

Project 2.6: Geochemical Approaches for Managing of Non-Traditional Waters, William Stringfellow, Nicholas Spycher and Mary Kay Camarillo, LBNL

Project 2.7: High Water Recovery Desalination of Non-Traditional Waters, Eric Hoek, Richard Kaner, UCLA

Project 2.9: Affordable, Effective Arsenic Remediation of AshPond Water from Coal-Fired Power Plants, Ashok Gadgil, UC Berkeley

CERC-WET Project Area 2

Treatment and Management of Non-Traditional Waters

Key Industry and Research Partners

Institute of Seawater Desalination and Multipurpose Utilization
Northeast Petroleum University
Research Institute of Petroleum Exploration and Development

CERC-WET Project Area 2

Treatment and Management of Non-Traditional Waters

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Challenges and Opportunities

1. Conventional approaches to reduce water consumption by thermoelectric plants cause significant reductions in the plant efficiency and increase the plant CO_2 emissions.

2. Water resources consumption in thermal power plants mainly includes system losses, flue gas losses, desulfurization wastewater, and cooling water.

3. Traditional methods have disadvantages of high energy consumption or pollution.

CERC-WET Project 2.1

Capacitive Deionization of Brackish Waters

Project 2.1 Objective:

Develop an energy-efficient FO desalination technology that will be powered using low-grade heat sources.

Synthesize and study a new class of thermally sensitive draw solutes based on ionic liquids (IL).

Demonstrate technical feasibility of IL-based FO desalination technology in continuous operation mode.

Major Accomplishments:

- Performance enhancement of IL-water phase separation driven water flux in FO/NF prototype cell.
- Desalination of feeds with salinity (0.25M NaCl) higher than salinity of brackish waters (0.1/0.15M NaCl) using IL draw solutes.
- Manuscript to be submitted to Environ. Sci. & Tech.

Collaboration Partners:

NextFab, Ben Franklin technology Partners, VentureWell

CERC-WET Project 2.1

Milestones

Task Name	Task Description	End Date
Milestone 2.1.4.A	Deliver a Technical Report on the ability of different configurations of our CDI system to remove salts from brackish waters.	06/30/20
Milestone 2.1.4.B	Deliver a Technical Report on the foulability of prototype polymer-embedded electrode in comparison with commercial CDI electrodes.	09/30/20
Milestone 2.1.5.A	Determine critical operational parameters and how they affect performance (flow rate, carbon loading, cycle time etc.)	06/30/21
Milestone 2.1.5.B	Investigate performance and ion selectivity of a F-ERI system	06/30/21

CERC-WET Project 2.2

Selective Removal of Divalent Cations with Graphene Oxide Membranes

Project 2.2 Objective:

Understand GO membrane structure and molecular transport

Design and fabricate layer-by-layer assembled GO-PAH membrane for simultaneous removal of divalent cations and anions

Optimize long-term performance and mitigate membrane fouling

Major Accomplishments:

- Developed a systematic approach to push the boundary of membrane permeability-selectivity tradeoff by optimizing the internal charged domains and layer packing density.
- Published a US-China collaborative paper: Liu, Y.; Zheng, S.; Gu, P.; Ng, A. J.; Wang, M.; Wei, Y. (*Chinese collaborator*); Urban, J. J.; Mi, B., Graphene-Polyelectrolyte Multilayer Membranes with Tunable Structure and Internal Charge. **Carbon 2020**, 160, 219-227.
- **Collaboration Partners:**

Nitto Hydranautics

CERC-WET Project 2.2

Milestones

Task Name	Task Description	End Date
Milestone 2.2.3.A	Identify the main fouling mechanisms of graphene oxide membranes under conditions likely to be encountered in the integrated treatment system.	11/29/19
Milestone 2.2.3.C	Develop a quantitative model to assess energy consumption, water quality and water flux under conditions likely to be encountered in treatment systems for non-traditional waters.	03/31/21
Milestone 2.2.3.D	Evaluate results obtained for the optimized graphene oxide membranes to assess the potential for future development of the technology and its potential application in an integrated system for treatment of non-conventional waters.	06/30/21

CERC-WET Project 2.3

Forward Osmosis with Ionic Liquids

Project 2.3 Objective:

- Develop an energy-efficient FO desalination technology that will be powered using low-grade heat sources.
- Synthesize and study a new class of thermally sensitive draw solutes based on ionic liquids (IL).
- Demonstrate technical feasibility of IL-based FO desalination technology in continuous operation mode.

Major Accomplishments:

- Performance enhancement of IL-water phase separation driven water flux in FO/NF prototype cell.
- Desalination of feeds with salinity (0.25M NaCl) higher than salinity of brackish waters (0.1/0.15M NaCl) using IL draw solutes.
- Manuscript to be submitted to Environ. Sci. & Tech.

Collaboration Partners:

- Porifera

CERC-WET Project 2.3

Milestones

Task Name	Task Description	End Date
Milestone 2.3.2.E (Revised)	Experimental demonstration of IL-water phase separation driven water flux with a mass flux cutoff from dual membrane prototype cell. Obtain permeate flux from feeds with salinity ranging from brackish to saline water and validate the model prediction with experimental results for lower thickness (size) of the IL chamber	08/31/20
Milestone 2.3.2.F (Added)	Test performance of the prototype cell using newly synthesized ionic liquid draw solutes with specialized characteristics obtained from the international collaborator in dual membrane prototype cell and compare performance with previously used IL draw solutes	12/31/20

CERC-WET Project 2.4

Enhanced Treatment of Desalination Brines

Project 2.4 Objective:

- Develop more efficient approaches for removing contaminants from RO concentrate.
- Assess approaches for recovering water and nutrients from RO concentrate.

Major Accomplishments:

- Developed and tested a pilot-scale open water unit process wetland for RO concentrate.
- Identified approaches for enhancing the rate of nitrate and trace organic contaminant removal.
- Developed models for predicting the impact of enhanced water recovery on land area needed for open water wetlands.
- Two manuscript under review (ES&T, ES:WR&T)

Collaboration Partners:

Silicon Valley Advanced Water Purification Center

Valley Water

San Francisco Environmental Institute

CERC-WET Project 2.4

Milestones

Task Name	Task Description	End Date
Milestone 2.4.2.C	Assess the performance of open water system for the treatment of concentrate generated by treatment of authentic non-traditional water with a goal of achieving performance similar to that obtained with well-defined solutions.	08/31/20
Milestone 2.4.3.A	Complete development of a model capable of predicting required land area, construction and maintenance costs and water quality benefits.	08/31/20
Milestone 2.4.3.B	Compare performance with competing technologies and identify opportunities and needs for future development as part of an integrated treatment system.	06/30/21

CERC-WET Project 2.5

A Systems-Level Analysis of Non-Traditional Water Management

Project 2.5 Objective:

Develop structured dynamic models for decision-support in the development of management strategies of non-traditional waters

Identify energy saving strategies at multi-plant system level

Major Accomplishments:

- Case-study analysis of 8 facilities (LACSD)
- Collection of equipment and process data
- Detailed dynamic process models of each plant
- Exploit the hydraulic delay of the sewer network to shift the WW load between connected facilities
- Analysis of applicability to other sites
- Analysis of renewable decentralized treatment

Collaboration Partners:

RIPED, Horiba, Glacier Technologies, LAKeco, Sanitation Districts of Los Angeles County

CERC-WET Project 2.5

Milestones

Task Name	Task Description	End Date
Milestone 2.5.4.C	Conduct model calibration for the case study/studies	09/30/20
Milestone 2.5.4.D	Obtain dynamic output of variables of interest	09/30/20
Milestone 2.5.3.E	Formulate potential control strategy that help improve overall energy and carbon footprint. In addition, conduct an integrated cost analysis of plant operations.	09/30/20

CERC-WET Project 2.6

Geochemical Approaches for Managing of Non-Traditional Waters

Project 2.6 Objective:

- Use geochemical modeling approach to tailor treatment systems for unconventional waters to meet specific beneficial reuse objectives "*fit for use*".
- Use combined biological-physical-chemical to reduce mineral scaling & biofouling in downstream processes

Major Accomplishments:

- Model and testing zero-valent iron (ZVI) technology for pretreatment of sulfate to prohibit mineral scaling
- Measured ZVI-sulfate reaction kinetics
- Tested ZVI against oil-field brine (model)
- Conducted laboratory column experiments
- Filed invention disclosure September 2012

Collaboration Partners: Independent oil producers

CERC-WET Project 2.6

Milestones

Task Name	Task Description	End Date
Milestone 2.6.2.B	Evaluation & modeling of biological pre-treatment processes	09/30/20
Milestone 2.6.3.A	Develop a treatment train selection tool based on data from analysis of non-traditional waters, regulatory targets and the operation of candidate treatment train components. Deliverables include tables and charts useful for decision-support in selection of treatment technology based on geochemical profile of target non-traditional water source.	09/30/20
Milestone 2.6.3.B	Apply the model to predicting results from pilot & intermediate scale treatment systems in which pre-treatment technologies have been implemented.	09/30/20
Milestone 2.6.3.C	Identify at least four high priority approaches for integrating new pre-treatment approaches into full-scale or demonstration projects. In collaboration with other members of Topic Area 2, suggestions for full-scale or demonstration projects will be evaluated and described.	09/30/20

CERC-WET Project 2.7

High Water Recovery Desalination of Non-Traditional Waters

Project 2.7 Objective:

- Prevent or reduce membrane fouling and scaling, improve the efficiency of membrane processes and decrease operational costs.

Major Accomplishments:

- Developed a scalable roll-to-roll method to nondestructively modify the surfaces of commercially available RO membranes using perfluorophenylazide photochemistry.
- Demonstrated that modified membranes have enhanced hydrophilicity and performance in the presence of organic foulants.
- Surface Analysis of modification on commercial membranes.
- Systematic observation of scaling stages for modified and unmodified BWRO membranes.

Collaboration Partners:

Water Planet
Hydrophilix

CERC-WET Project 2.7

Milestones

Task Name	Task Description	End Date
Milestone 2.7.3.B	Assess brackish water management for inland desalination. COMPLETED	09/29/19
Milestone 2.7.2.D	Effectiveness of Nano-Structured Membranes in Mitigating Fouling Report in the California Market Final	04/30/20
Milestone 2.7.3.C	Assessment of the Integration of Multistage Membrane Treatment in California Report Draft	09/28/20
Milestone 2.7.3.D	Assessment of the Integration of Multistage Membrane Treatment in California Report Final	12/30/20

CERC-WET Project 2.9

Affordable, Effective Arsenic Remediation of AshPond Water from Coal-Fired Power Plants

Project 2.9 Objective:

Advance and mature a previously established arsenic remediation technology (ECAR) for use at coal-fired power plants.

- Demonstrate successful remediation of arsenic from ash-pond water with ECAR.
- Design, build, and test a high-throughput ECAR, per industry needs.

Major Accomplishments:

- Filed ACAIE international patent application
- Designed and build ACAIE reactors with novel flow configuration to improves hydrodynamics and reaction kinetics during electrolysis.
- Designed and built vertical dual air cathode ACAIE system to decrease the operating voltages in low-conductivity contaminated waters (e.g., ash pond water)
- Developed energy efficient spiral ECAR reactors for removing some other common contaminants (e.g., Cr(VI)).
- **Industry Collaboration:** Duke Energy

CERC-WET Project 2.9

Milestones

Task Name	Task Description	End Date
Milestone 2.9.1 A	Test the arsenic removal effectiveness of ECAR with different ash pond water samples. Investigate high-throughput conceptual design of an ECAR system for industrial use. Describe findings in a report.	12/30/18
Milestone 2.9.2 A	Test the arsenic removal effectiveness of ECAR with samples of interstitial ash pond water. Design and build a high throughtput design in a small laboratory prototype with synthetic pond water. Describe findings in a report.	09/30/19
Milestone 2.9.3 A	Describe findings in a letter report. Prepare and deliver Final report for the overall project to Industrial Partner and DOE.	09/29/20

Concluding Remarks

CERC-WET is an ongoing 5-year project. We received a No-Cost Extension through September 2021 and will continue to work toward successful conclusion of our projects.

Preparing Project for Next Steps

Technology-to-Market Path

CERC-WET has an active Industry Advisory Board. Our latest meeting took place on October 26, 2020 in a virtual format. We have ongoing collaborations with Industry and non-profit partners as noted in each individual project above.