NATIONAL ENERGY TECHNOLOGY LABORATORY

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WATER-ENERGY NEXUS NEWS

U.S. DEPARTMENT OF ENERGY | OFFICE OF FOSSIL ENERGY AND CARBON MANAGEMENT | NATIONAL ENERGY TECHNOLOGY LABORATORY

IN THIS ISSUE

An Update on the National Energy Technology Laboratory's Water-Energy Research and Related Activities

Project Highlights

Highlights: NETL to Manage First Round of Funding Selections Announced for Water Research and Development Focused on Reuse and Resource Recovery

In December 2023, the Department of Energy's (DOE) Office of Fossil Energy and Carbon Management (FECM) announced a first round award selections of nearly $10 million for Funding Opportunity Announcement (FOA) 2796: Water Research and Development for Oil and Gas Produced Water and Coal Combustion Residuals Wastewater Associated with Coal Power Plants. Additional selections may be made at a later date.

The funding opportunity focuses on developing improved wastewater characterization to better understand how to process oilfield water for reuse and resource recovery; improving technologies for the effective management and treatment of wastewaters; and leveraging systems engineering for oil and natural gas produced water management operations, including field implementation, operation, and validation.

DOE's National Energy Technology Laboratory (NETL) will manage the following selected research and development (R&D) projects, under the purview of FECM:

Desalinated Produced Water as Irrigation Source for Non-Consumptive Agriculture and Adjacencies for Ammonia Mining and Carbon Sequestration Field Trials plans to further the beneficial reuse of produced water for various applications, with expected expansion of the study to evaluate valuable mineral and ammonia extraction.

Treatment of Produced Water for Beneficial Use with Concurrent Resource Recovery Utilizing Coal- and Waste Coal-derived Material focuses on development of an economically feasible process to expand reuse to industries beyond oil and natural gas.

Produced Water Consortium for Ultralightweight Composite Manufacturing by Accelerated Carbon Mineralization aims to develop a hypersaline desalination approach for separation of fresh water from concentrated-produced water for use in manufacturing.

Advanced Characterization of Wastewaters with a Focus on the Environment & Economics plans to advance characterization of characterized coal combustion residual (CCR) effluents, determine the environmental impact of characterized CCR effluents on ground and surface water, and examine design options for effluent treatment and resource recovery.

Further details on the selected projects are available here.

Highlights: NETL Pursues Membrane Distillation to Treat Produced Water

In September 2023, researchers with NETL's Produced Water Research Partnership tested the effectiveness of membrane distillation (MD) at treating produced water from three sources: the Denver-Julesburg (DJ) Basin (in Colorado) and the Permian Basin and Eagle Ford Formation (both in Texas). For this study, totes of produced water from all three locations were sent to the University of North Dakota's **brine extraction and storage test (BEST) site**, a DOE-funded field site near Watford City, North Dakota. After the totes arrived at the BEST site, a team of researchers used a pilot-scale MD system—which the **University of Pittsburgh** owns and operates—to concentrate the produced water they contained. At present, the team has completed MD pilot-plant trials with produced water from the Permian Basin and Eagle Ford Formation and is currently further concentrating the DJ Basin reverse osmosis concentrate using nanofiltration membranes. Results will be presented at the NETL Resource Sustainability Review Meeting in Pittsburgh, Pennsylvania on April 2-4, 2024.

This project exemplifies how public-private collaborations can innovate wastewater management, storage, and disposal. It also highlights the importance of developing new ways to handle the approximately 12 billion barrels of produced water that the U.S. oil-and-gas industry injects—unused—into saltwater disposal wells each year. NETL researchers and their partners are working to turn this byproduct into a valuable source of road salt, fresh water, critical minerals and other profitable materials.

Highlights: NETL's Water Management Program Gives New Insights into Leachate Treatment

According to the U.S. Environmental Protection Agency, coal ash is one of the largest types of industrial waste generated in the United States. In 2021, U.S. coal-fired electric utility boilers produced more than 77 million tons of **coal ash**. Of the 77 million tons, about 59 percent was recycled for beneficial uses such as a substitute for Portland cement. The remaining 24 million tons was disposed of in landfills ponds and impoundments. Coal ash contains heavy metals like lithium, cadmium, mercury and arsenic. If not disposed of or beneficially reused properly, these metals can leach into streams, rivers and groundwater aquifers. In addition, the leachates from coal ash also can also contain valuable rare earth elements (REE) and other critical minerals (CM).

To address the potential environmental risks associated with coal ash leachates, as well as the potential to recover REE and CM from these leachates, NETL is investigating advancements in how the energy sector manages coal ash. One such innovation is nanofiltration membranes that have pores small enough to filter out valuable multivalent metal ions. Another is machine-learning algorithms that can inform decision-making regarding best methods for the treatment of coal-ash wastewater.

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Highlights: NETL's Water Management Program Gives New Insights into Leachate Treatment *(Continued)*

Small Particles, Big Risk

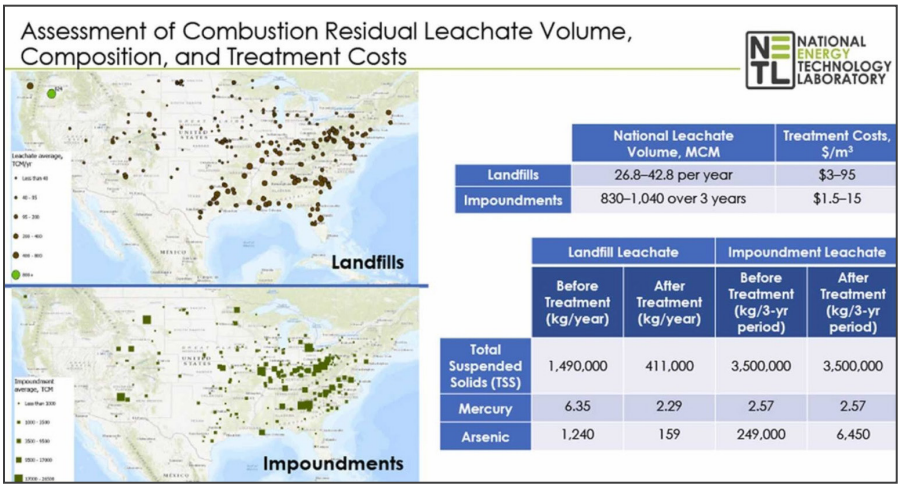
Nanofiltration was the focus of research that Michael Dunn—a University of Connecticut student—performed alongside NETL researchers in summer 2023. As a participant in DOE's Mickey Leland Energy Fellowship (MLEF), Dunn explored the use of nanofiltration membranes to separate CM from the coal ash leachates. Under the mentorship of Dr. Nicholas Siefert, Dunn investigated the ability of four different nanofiltration membranes to separate a suite of ions from ash wastewater stream. The ions of interest included REE and CM (such as lithium). The results of the study highlighted nanofiltration's potential for treating effluents from coal-based power systems.

Dunn presented his findings at the MLEF Technical Forum in August 2023. U.S. Secretary of Energy Jennifer Granholm, Principal Deputy Assistant Secretary (PDAS) Brad Crabtree and other DOE officials attended the event. Additionally, Secretary Granholm and PDAS Crabtree highlighted Dunn's findings during their own presentation.

The Cost of Recovering—or *Not* Recovering—Critical Minerals

NETL's interest in coal ash leachates, however, is not limited to developing new treatment methods. NETL is also pursuing new models to better understand the cost and impact of current leachate treatments. Chad Able (site support contractor), who leads NETL's water-sustainability efforts, and his colleagues recently used machine-learning algorithms to model the technoeconomic aspects of treating coal-ash leachate. The researchers aggregated regional standards from across the U.S., assessed the treatment technologies necessary to meet those standards and calculated the leachate volume from landfills and surface impoundments nationwide. They considered the concentrations of numerous constituents—including arsenic, magnesium, mercury and lithium—while accounting for rainfall, pollutant load and other variables.

They presented their findings before the American Institute of Chemical Engineers in November 2023. Their findings also appeared in the *Journal of Hazardous Materials* in September 2023.



	National Leachate Volume, MCM	Treatment Costs, $/m³
Landfills	26.8–42.8 per year	$3–95
Impoundments	830–1,040 over 3 years	$1.5–15

	Landfill Leachate		Impoundment Leachate	
	Before Treatment (kg/year)	After Treatment (kg/year)	Before Treatment (kg/3-yr period)	After Treatment (kg/3-yr period)
Total Suspended Solids (TSS)	1,490,000	411,000	3,500,000	3,500,000
Mercury	6.35	2.29	2.57	2.57
Arsenic	1,240	159	249,000	6,450

The team discovered that the annual volume of leachate in all U.S. landfills totals 2.68–4.28 million cubic meters. Treating it would cost $3.00–95.00 per cubic meter. In contrast, closing surface impoundments could yield 830–1,040 cubic meters of leachate nationally (over a three-year closure period), and the treatment costs would range $1.50–15.00 per cubic meter. Although treating such a large amount of leachate would be costly, the researchers note that the recovery of CM from it would help to offset this expense. For example, if the magnesium that pervades leachate were to be recovered from all landfills, it would represent a $39.2 million market. The magnesium from all impoundments could command an even higher price: $650 million. As an added benefit, leachate treatment would make the domestic supply of CM more reliable. Magnesium is especially prevalent in leachate, reaching concentrations of 2,000 parts per million (ppm) in landfills and 1,300 ppm in impoundments. Collecting it could improve access to a mineral that DOE deems critical for the energy industry.

In the News

NETL Advances Transformation in North Dakota Through Revolutionary Uses for Lignite in the Extraction of REE and CM

NETL experts recently joined U.S. DOE FECM leaders in North Dakota to learn about the development of technologies that can harness the state's massive reserves of lignite coal to extract key REE and CM, which are needed to manufacture nearly all high-tech devices and are critical to the clean energy economy. DOE partners in North Dakota are advancing the use of a solvent to extract REE and CM from lignite feedstock. The goal is to minimize the environmental impact of the process by reducing water usage, recycling water and responsibly disposing of wastewater and solid wastes.

NETL Oversees Landmark Research to Protect Caprock Integrity at Carbon Storage Sites

A groundbreaking experiment completed at the Mont Terri Underground Research Laboratory in Switzerland, with NETL oversight, is expected to generate important insights about the behavior of faults and other seismic activity when a mixture of water and carbon dioxide (CO_2) is injected into geologic formations. Analysis of the data generated by the injection of the CO_2-water solution will help researchers better understand fault slip processes, provide new insights into the leakage potential of complex fault zones and help the NETL Carbon Storage Program attain a rate of 99% CO_2 storage permanence.

NETL Experts Helping Limerick, Ireland, Develop Hydronic Heating/ Geothermal Energy Project

NETL is part of an international team at work in Limerick, Ireland, developing a project to demonstrate the feasibility of district-level hydronic heating using subsurface geothermal energy. The project seeks to demonstrate the effectiveness of using low-temperature geothermal heat sources on a district-wide level. NETL is offering technical solutions and expertise as the project team seeks to optimize the heat-extraction effectiveness in a geo-fluid loop while maintaining ecological safety as environmental benefits are assessed.

Conferences and Events

Listed below are upcoming conferences and events that align with the NETL's water-energy research efforts.

WEF/AWWAA Utility Management Conference

Description: The Water Environment Federation (WEF) and American Water Works Association (AWWA) are again partnering to offer this gathering of utility executives and managers. Over the past three decades, members of AWWA and WEF have established The Utility Management Conference™ as one of the leading, most informative and prestigious management conferences.

Date: Feb. 13–16, 2024

Location: Portland, Oregon

Website: https://www.wef.org/UtilityManagement

World Water-Tech Innovation Summit

Description: The 13th annual World Water-Tech Innovation Summit is back in London, with the theme of Investing in Climate Resilient Water Systems. The event brings together progressive water enterprises, regulatory bodies, engineering firms, technology giants, investors and visionaries to address the decade's most pressing challenges.

Date: Feb. 20–21, 2024

Location: London, United Kingdom

Website: https://worldwatertechinnovation.com/

The Permian Basin Water in Energy Conference

Description: The Permian Basin Water in Energy Conference (PBWIEC) facilitates collaboration and innovative strategy development for the improved use, recovery and recycling of water in the oil industry. The PBWIEC is a program of The University of Texas Permian Basin and housed at the university's Shepperd Leadership Institute.

Date: Mar. 5–7, 2024

Location: Midland, Texas

Website: https://waterinenergy.com/

33rd Annual International Conference on Soil, Water, Energy, and Air

Description: The 33rd International Conference on Soil, Water, Energy, and Air offers attendees an opportunity to exchange findings, ideas and recommendations in a professional setting.

Date: Mar. 18–21, 2024

Location: San Diego, California

Website: https://www.aehsfoundation.org/westcoast

2024 NETL Resource Sustainability Project Review Meeting

Description: This review meeting will present the results from over 100 research projects across FECM technical program areas: Carbon Ore Processing; Critical Minerals and Materials; Environmentally Prudent Stewardship; Water Management Technologies, Gas Hydrates; Methane Mitigation Technologies; and Natural Gas Decarbonization & Hydrogen Technologies.

Date: Apr. 2–4, 2024

Location: Pittsburgh, Pennsylvania

Website: https://netl.doe.gov/events/24RS

Researcher Spotlight

Timothy Bartholomew

Research General Engineer
Timothy.Bartholomew@netl.doe.gov

Dr. Timothy Bartholomew is a Research General Engineer on NETL's Process Systems Engineering Research team. He received his Ph.D. from Carnegie Mellon University (CMU) in Civil and Environmental Engineering in 2019, with research focused on addressing water challenges in the energy sector. He earned his B.S. from Washington University in St. Louis in chemical engineering in 2015.

Bartholomew currently leads the development of the Water treatment Technoeconomic Assessment Platform (**WaterTAP**). WaterTAP is an open-source software tool funded by the National Alliance for Water Innovation (NAWI) and other organizations with the objective to support researchers in evaluating water treatment options and identifying high impact opportunities for innovation within materials, process and systems. Previously, Bartholomew conducted technoeconomic assessments of emerging water treatment technologies as a part of his Ph.D. at CMU. During his Ph.D., he was also an Oak Ridge Institute for Science and Education fellow at NETL.

Through his research, Bartholomew strives to advance technologies to address water challenges. Specifically, he seeks to combine his expertise in water treatment, process systems engineering methods and software development to provide decision support to DOE water research programs. This support includes helping to prioritize R&D investment, identify high impact opportunities and technical bottlenecks and set quantitative research targets for technologies.

Select journal publications that Bartholomew has co-authored include **Cost optimization of low-salt-rejection reverse osmosis**, **High-impact innovations for high-salinity membrane desalination**, **Cost optimization of osmotically assisted reverse osmosis**, and **Energy and CO_2 Emissions Penalty Ranges for Geologic Carbon Storage Brine Management**. Bartholomew has also presented a recorded and publicly accessible **overview and demonstration of WaterTAP** for the 2022 NAWI Alliance Virtual Fall Meeting.

Publications and Presentations

Below are several water-related Publications and Presentations authored or co-authored by NETL staff.

Unique biological amino acids turn CO_2 emission into novel nanomaterials with three switchable product pathways

Xianfeng Wang, West Virginia University (WVU); Zhenghong Bao, WVU; Novruz Akhmedov, WVU; David Hopkinson, NETL; James Hoffman, NETL; Yuhua Duan, NETL; Adefemi Egbebi, URS Corporation (URS); Kevin Resnik, URS; Bingyun Li, WVU. (NOVEMBER 2023)

▸ https://doi.org/10.1016/j.eti.2023.103279

Modeling aqueous association constants and mineral solubilities at subcritical and supercritical temperatures

Derek Hall, Pennsylvania State University (PSU); Serguei Lvov, PSU; Andrzej Anderko, OLI Systems Inc; Isaac K. Gamwo, NETL. (SEPTEMBER 2023)

▸ https://doi.org/10.1016/j.molliq.2023.123061

Assessment of Carbonated Brine Injection as Low-risk Strategy for Geologic Carbon Storage

Wei Xiong, NETL Site Support Contractor; Zineb Belarbi, NETL Site Support Contractor; Randal B. Thomas, NETL; Dustin Crandall, NETL; Merry Tesfu, University of North Dakota Energy & Environmental Research Center (UNDEERC); Meghan Taunton, UNDEERC; Ryan Klapperich, UNDEERC; Marc Kurz, UNDEERC. (OCTOBER 2023)

▸ https://netl.doe.gov/energy-analysis/details?id=974c91d1-8b0f-41c0-be43-509265659634

Ce(III) and Ce(IV) Distribution in Acid Mine Drainage Solids: Implications for Rare Earth Element Recovery

Colleen Hoffman, NETL Site Support Contractor; Benjamin Hedin, Hedin Environmental; Mengling Stuckman, NETL; Christina Lopano, NETL. (OCTOBER 2023)

▸ https://www.netl.doe.gov/energy-analysis/details?id=3e8ce8a0-5d37-4c57-a40a-f8d4103d924e

Predicting Lithium Fluxes from a Heterogenous Brine Source Marcellus Shale

Justin Mackey, NETL Site Support Contractor; Daniel Bain, University of Pittsburgh; James Gardiner, NETL; Greg Lackey, NETL; Djuna Gulliver, NETL; Barbara Kutchko, NETL. (OCTOBER 2023)

▸ https://www.netl.doe.gov/energy-analysis/details?id=842c0ec8-7196-420d-abca-c0301fe0711a

Assessment of Combustion Residual Leachate: Treatment Standards, Wastewater Volumes, and Critical Mineral Recovery

Chad Able, NETL Site Support Contractor; Alison Fritz, NETL; Eric Grol, NETL. (NOVEMBER 2023)

▸ https://netl.doe.gov/energy-analysis/details?id=57438abb-ad66-45e7-b7ba-4cee2511312b

Partnering with NETL

NETL's partnership activities are central to DOE's core mission. NETL utilizes a complete suite of contractual vehicles, as well as its inherent authority as a GOGO laboratory, to pursue technology development and eventual transfer of technology to the marketplace. NETL's success in developing technology solutions that can be applied to the intersection of water and energy depends upon strong relationships with both public and private entities. From targeted competitive announcements to cooperative research and development agreements, NETL offers a variety of cost-shared funding and partnership arrangements to help move technology and intellectual property through the maturation cycle into the marketplace.

For more information on partnering with NETL in the water-energy space, contact:

Thomas J. Feeley, III
Research Partnerships & Tech Transfer
Thomas.Feeley@netl.doe.gov
412-386-6134

Contact Us

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1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochran Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

Program staff are also located in **Houston, Texas,** and **Anchorage, Alaska.**

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