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

SPECIAL EDITION

Brine pools for lithium mining in Silver Peak, Nevada

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

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Director's Message

Impaired Waters: A Challenge and an Opportunity to Support the Emerging Green Economy

Energy production and use in the United States generates billions of gallons of impaired water that needs to be treated prior to being discharged back into the environment. This includes produced water from oil and gas development, brines from geological carbon dioxide storage, discharges from coal mining, electric-generating power plant effluents and releases from coal byproduct impoundments such as ash ponds. Also, uncontrolled discharges from abandoned mining operations continues to impact thousands of miles of rivers and streams throughout Appalachia and other coal and hard rock mining regions of the country.

Treatment of these wastewaters remains a challenge as effluent standards become increasingly more stringent to address ecological and human health concerns and new efforts are directed at the environmental legacy from coal mining and fossil energy production on local communities. However, this challenge comes with the opportunity not only to improve the environment but also to recover the critical minerals and materials such as lithium, nickel, cobalt and manganese found in these impaired waters that are needed to address domestic supply chain issues and drive the emerging green economy.

The National Energy Technology Laboratory (NETL) is carrying out a comprehensive research effort to extract, recover and refine rare earth elements and critical materials from coal, coal refuse and other non-traditional feedstocks. This work includes the recovery of these materials from produced water, acid mine drainage and other aqueous process streams.

This special edition of the NETL Water-Energy Nexus News will feature stories on the progress and results of the laboratory's intramural and extramural research and development on the treatment and recovery of critical minerals and materials from impaired waters.

Sean Plasynski, Ph.D.
Acting NETL Director

Highlights: DOE Establishes Community of Interest for Applied AI Research and Deployment

As part of its goals for digital transformation and to support its research and development investments in artificial intelligence (AI), the U.S. Department of Energy (DOE) Office of Fossil Energy and Carbon Management's Water Management Program worked with other AI practitioners across DOE to form the DOE Community of Interest for Applied Artificial Intelligence Research and Deployment. The community of interest (COI) aims to encourage the exchange of ideas, insights and lessons learned and to facilitate the active sharing and leveraging of data, tools and other AI resources across organizations. To make this powerful technology more understandable and relevant to a broader DOE audience, the COI periodically holds agency-wide forums and invites guest speakers to talk about AI-related topics. The COI also provides a space for the Water Management Program to share its AI/machine learning (ML) best practices, tools and resources with the broader DOE community including the application of AI/ML to the recovery of critical materials. Membership now includes AI practitioners spanning DOE's program offices, including NETL. The COI will help make resources more accessible across the Water Management Program, where best practices and case studies can be shared to inform AI capabilities within DOE.

Highlights: DOE Awarded Two SBIR/STTR Projects Focused on Advanced Remediation of Produced Water to Monitor Contaminants in Real-Time, Produce Freshwater and Harvest Metals

Two recent Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Phase 1 awards, **DE-SC002309**, focus on advanced remediation of produced water, the largest volume byproduct stream associated with oil and gas (O&G) exploration and production.

Quantitative BioSciences, Inc. (QBI) was awarded $256,500 for an SBIR Phase 1 project titled "A Real-Time Water Monitor for Contaminants in Produced Water." Access to clean water is critical to quality of life and the economy; ensuring this access for future generations will require novel sensor technologies that are practical and affordable. QBI will develop and demonstrate an in-line sensor that can reliably provide real-time, continuous, quantitative measurements of a suite of contaminants. This project aims to expand sensing capabilities for methanol, toluene and benzene, as well as feature a highly trained AI-based computational platform to discern and discriminate between contaminants to quantify individual analytes in complex water backgrounds.

Scion Plasma LLC was awarded $250,000 for an STTR Phase 1 project titled "Dielectrophoresis-Enhanced Capture of Metal Cations in Produced Water." This produced water is unusable for municipal, agricultural and industrial applications due to the high concentrations of metal cations. This electro-active adsorption project aims to develop a highly efficient deionization technology that not only produces freshwater but also harvests metals from produced water. If this project is successful, this innovative deionization technology can be further developed for seawater desalination and treating toxic **per- and poly-fluoroalkyl substances** in contaminated water.

Highlights: Co-treating Waste Streams from O&G Wells and Longview Power Plant Yields Valuable Products

In 2021, the United States relied on imports to meet more than 75% of its needs for **barite**, a mineral vital to the O&G industry. The price for imported barite has been rising, however, and its supply chain is susceptible to disruption. A greater domestic supply of barite would help to ensure that American industries can obtain it affordably and dependably, now and in the years to come.

To that end, researchers at NETL and West Virginia University (WVU) teamed up to demonstrate a single process that generates barite from two different waste products: flue gas desulfurization (FGD) effluent from Longview Power Plant in Maidsville, West Virginia, and produced water from O&G wells near Morgantown, West Virginia. In summer 2023, the researchers demonstrated that the process can co-treat both waste products and yield valuable materials, including barite, at the pilot scale.

"In a project with WVU, we will be making barite—a critical mineral—as part of the co-treatment process that also generates water, road salt, and limestone," said NETL's Dr. Nicholas Siefert, who leads the project. A research engineer, Dr. Siefert developed the initial design of the co-treatment process, using OLI Flowsheet aqueous modeling software. The experimental design and demonstration that followed were carried out at WVU and led by Dr. Lance Lin, a professor in WVU's Wadsworth Department of Civil and Environmental Engineering.

In June 2023, the research team conducted pilot-scale testing of the process, using synthetic FGD effluent and synthetic produced water. The following month, they repeated the testing with more than 1,000 gallons of real FGD effluent and produced-water brine. In both cases, the process—which included chemical treatment, membrane filtration and thermal evaporation—proved successful and cost-effective. Next, the researchers will analyze the results (using NETL's Pittsburgh Analytical Laboratory) and publish their findings. This demonstration shows the process's potential for recovering useful products from waste streams that are, on their own, essentially useless.

Just *how* useful are these products? Very. Barite plays a crucial role in preventing newly drilled wells from releasing O&G. The low-salinity water that the process creates is suitable for use in power plants' cooling towers. The road salt is ideal for spreading on roads in the winter to melt ice and snow. And the limestone offers value as a feedstock for FGD units at power plants or as a medium for storing CO_2.

Besides their usefulness, these products have something else in common: they are finite. Barite is particularly scarce. It is one of the 50 minerals that the United States Geological Survey (USGS) **deemed** "critical" in 2022. The availability of sufficient fresh water supplies to meet growing demands will continue to be a challenge, particularly in many western states. Converting the waste streams that power plants emit into useable water, barite and other materials with diminishing reserves—or with fragile supply chains—can promote the responsible stewardship of these valuable but vulnerable resources.

Highlights: Finding Resources in Refuse: NETL Researchers Extract Critical Minerals from Produced Water, Acid Mine Drainage

Traditionally, water produced from O&G extraction and the effluents from coal and hard-rock mining have been treated to a level sufficient for their safe disposal or discharge back into the environment. In some cases, such as abandoned coal mines, the acid mine drainage (AMD) goes untreated, seriously impacting streams and rivers. Today, these same wastewaters are seen as a potential source of valuable byproducts such as critical minerals (CMs), including rare earth elements (REEs), cobalt, nickel and lithium—to name a few.

Under its **Critical Minerals and Materials Program**, NETL's Research Innovation Center (RIC) is exploring new ways to extract CMs from produced water and AMD, thus, bolstering the domestic supply of these materials that are requisite to the nation's transition to a green economy while protecting the environment and improving the lives of those living in and around coal and other fossil energy communities. Further, the potential revenue from the recovery of CMs may help to offset the cost of treating impaired waters, encourage investment in the treatment of discharges from abandoned mining operations, and incentivize the production of alternative sources of clean water.

Below is a summary of several of the RIC projects directed at the recovery of CMs from O&G produced water and AMD.

Unearthing Value

RIC researchers are exploring ways to predict which sedimentary strata contain high concentrations of valuable minerals. The project involves both developing predictive models and identifying knowledge gaps that hinder resource predictions and filling those gaps by collecting and characterizing samples of sedimentary strata. In addition, a wide range of geological, geochemical, and geospatial datasets—from DOE, USGS, state agencies and other public sources—are being used to test and validate the models. It is anticipated that the models can be used to help predict AMD sources where cobalt, nickel, zinc, lithium and numerous other materials could be most cost-effectively recovered.

Microscopic Tools, Macroscopic Impacts

RIC researchers are also investigating the recovery of CMs using biotechnology. The unique approach entails the use of naturally occurring microorganisms to separate aluminum, magnesium, lithium and other critical materials associated with the solid wastes from AMD treatment. These treatment solids are normally disposed of before any valuable materials are extracted from them. The unrealized potential is considerable: AMD from the Appalachian Basin alone could meet approximately 30% of the nation's demand for rare earth oxides.

From Waste to Batteries? Estimating CM Contents from Shale Wastewater

RIC researchers are also applying numerical simulations to produced water chemistry and volume data sets provided by public and industry stakeholders to better predict the quantity of CMs that can be recovered from produced waters. Initial simulations of the Appalachian Basin suggest produced water from the Marcellus Shale alone could supply nearly half of the current domestic lithium consumption. Future efforts will expand this framework to estimate the CM resource potential in other major shale basins.

Water, Water, Everywhere

One team of RIC researchers is investigating a novel suite of sorbents to not only recover CMs from AMD, but also produce a clean water stream that may be suitable for a variety of end uses including as a supply of drinking water. The Multi-functional Sorbent Technology (MUST) incorporates low-cost, reusable sorbent materials to separate aluminum, chromium, nickel and other value products. It can also remove toxic metals such as arsenic, mercury and lead from AMD, thus, providing mining communities better access to clean water.

Polluted coal mine acid mine drainage river in Western Pennsylvania

Making Sorbent Materials to Recover Lithium from Produced Water Waste

A team of RIC researchers are developing a novel lithium sorbent derived from the solid waste stream produced by NETL's **Targeted Rare Earth Extraction (TREE)** AMD-treatment technology. Following REE extraction, the solids from the TREE process are converted into a functional material to recover and concentrate lithium found in produced waters and geothermal brines. The team has recently developed a prototype sorbent (mainly as hydrogen manganese oxides) with greatly improved lithium sorption capacity compared to polymers or activated carbon. If successful, it is anticipated that the novel sorbent will lower the cost of recovering lithium from produced waters and brines while providing an additional economic incentive to treat AMD impacting coal mining communities and regions.

Finding a Solution

RIC staff are also investigating carbonation to extract lithium and other CMs from the natural brines from O&G extraction. CO_2 is used to carbonate the brine which is then brought to a specific pressure and temperature causing the brine's impurities to precipitate and "fall out of" the solution. Because the process uses carbonation, rather than other additives, it has the advantage of being acid-free, requiring little energy and resulting in a waste product that can be useful in long-term safe carbon storage. Furthermore, the CO_2 that the process relies on can come from any industrial waste stream, and the process itself could be applied to produced water, seawater or other liquids.

In the News

Biden-Harris Administration Announces $150 Million to Strengthen Domestic Critical Material Supply Chains

New funding, provided by the Bipartisan Infrastructure Law, will help meet the growing demand for CMs and materials while reducing America's dependence on offshore supplies. Critical minerals and materials are key to manufacturing clean energy technologies—such as solar panels, wind turbines, electric vehicles, and hydrogen fuel cells—that will help America reach the Biden-Harris Administration's ambitious climate goals. DOE intends that the research, development and demonstration performed in this funding opportunity announcement will reduce resource use (e.g., energy, water, chemicals), negative environmental impacts (e.g., CO_2, air and water emissions) and costs, compared to currently used technologies. The application deadline for **DE-FOA-0003105** is Nov. 10, 2023.

WVU's WRI Receives Additional $11 Million for Rare Earth Research

WVU's Water Research Institute (WRI) recently initiated two new projects that will advance the production and processing of REE/CM concentrates from AMD. The new awards were made by DOE ($8 million) and the U.S. Department of Defense ($3 million) through funding supported by U.S. Senators Joe Manchin and Shelley Capito to advance work on increasing the domestic supply of REE/CMs.

Five Ways NAWI is Advancing Water Treatment and Desalination Technologies

The National Alliance for Water Innovation's (NAWI) robust research portfolio spans analysis for water-energy grid integration to development of algorithms, models and adaptive process controls for resilient operations. Now in its third year of operation, NAWI is supporting pilot projects that will treat unconventional water sources to provide usable water in real-world environments. NAWI is led by DOE's Lawrence Berkeley National Laboratory (LBNL) in collaboration with NETL, the National Renewable Energy Laboratory (NREL) and the Oak Ridge National Laboratory (ORNL) and is funded by the Office of Energy Efficiency and Renewable Energy's Industrial Efficiency and Decarbonization Office.

NETL Leads Team to Evaluate Costs and Benefits of Desalination Technologies

NETL is using a state-of-the-art tool it developed to help a new research team evaluate the economic costs and benefits of capturing and purifying minerals that can be reused to create valuable products as part of desalination—the process of removing salt from brackish wastewater. Brackish water is water that is saltier than fresh water, but not as salty as seawater. The effort is one of 12 projects recently funded by DOE and **NAWI** designed to improve desalination and water reuse technologies across the country. The project uses the Water treatment Technoeconomic Assessment Platform (WaterTAP) developed by NETL and colleagues at LBNL, NREL and ORNL.

Researchers Look Into Cooling Power Plants That Use Brackish Groundwater

A new study lead by a University of Wyoming professor finds that brackish or salty groundwater has the potential to replace fresh water in cooling coal and natural gas-fired power plants and increase energy infrastructure resilience; however, there is a cost to doing so. The research appears in the journal Nature Water, with University of Wyoming Ph.D. student, Zitao Wu, as the lead author of the paper. Other contributors are from NETL.

Conferences and Events

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

American Water Resources Association (AWRA) 2023 Annual Water Resources Conference

Description: The AWRA conference is one of the most diverse and inclusive conferences in water resources management. AWRA provides attendees with innovative, practical and applied water resource management solutions, management techniques and current research.
Date: Nov. 6–8, 2023
Location: Raleigh, North Carolina
Website: https://www.awra.org/Members/Events_and_Education/Events/2023-Annual-Conference/2023_Annual_Conference.aspx

2023 American Institute of Chemical Engineers (AIChE) Annual Meeting

Description: The AIChE Annual Meeting is the premier educational forum for chemical engineers interested in innovation and professional growth. Academic and industry experts will cover wide range of topics relevant to cutting-edge research, new technologies and emerging growth areas in chemical engineering.
Date: Nov. 5–10, 2023
Location: Orlando, Florida
Website: https://www.aiche.org/conferences/aiche-annual-meeting/2023

The International Water Conference® (IWC)

Description: The IWC is a robust educational conference, founded with an emphasis on commercial-free discussions on technology. It is dedicated to advancing new developments in the treatment, use and reuse of water for industrial and other engineering purposes.
Date: Nov. 12–16, 2023
Location: San Antonio, Texas
Website: https://eswp.com/water/overview/

Association of California Water Agencies (ACWA) 2023 Fall Conference and Exhibition

Description: ACWA conferences are the premier destination for water industry professionals to learn and connect. New programming will showcase case-study presentations, product demonstrations or other dynamic looks at how others in the industry are addressing today's challenges.
Date: Nov. 28–30, 2023
Location: Indian Wells, California
Website: https://www.acwa.com/events/2023-fall-conference-expo/

Researcher Spotlight

Alison Fritz

Research Engineer
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Alison Fritz is a Research Engineer on NETL's Energy Process Analysis Team. She recently defended her Ph.D. in Civil and Environmental Engineering from Stanford University, conferred September 2023. She earned her Bachelor of Science in Environmental Engineering from Yale.

Fritz is currently the federal point of contact for the energy process and cost work in the water management and critical mineral portfolios at NETL. She is also leading a multi-disciplinary team funded by NAWI to evaluate mineral recovery from inland brackish groundwater desalination, which could offset costs for treatment systems in areas with limited access to safe drinking water. Previously, Fritz was an Oak Ridge Institute for Science and Education fellow at NETL, where she applied techno-economic analysis and statistical modeling to assess the economic viability of alternative REE feedstocks.

Fritz's research work and interests include analyses of wastewater discharge and water consumption tradeoffs of the current transitioning energy grid, and techno-economic performance of critical mineral extraction from secondary sources including coal by-products and industrial wastewaters. She also believes it is important to improve representation in in science, technology, engineering and math. She has recently mentored a Mickey Leland Energy Fellow and received the Justice, Equity, Diversity & Inclusion Graduation Award for contribution to promoting justice, equity, diversity and inclusion.

Recent publications Fritz has co-authored include journal articles—***Aqueous Bromide Discharges from U.S. Coal-Fired Power Plants: Points of Origin, Concentration Ranges, and Effluent Treatment Costs***, ***Assessing the economic viability of unconventional rare earth element feedstocks***, ***Technoeconomic Assessment of a Sequential Step-Leaching Process for Rare Earth Element Extraction from Acid Mine Drainage Precipitates***—and her dissertation titled, "Opportunities for Circular Management of Industrial Waters to Support the Clean Energy Transition."

Publications and Presentations

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

Assessment of combustion residual leachate volume, composition, and treatment costs

Chad Able, NETL support contractor; Daniel Rellergert, NETL support contractor; Vincent Mazzoni, NETL support contractor; Eric Grol, NETL (SEPTEMBER 2023)

▸ https://doi.org/10.1016/j.jhazmat.2023.131731

Tradeoffs in life cycle water use and greenhouse gas emissions of hydrogen production pathways

Megan S. Henriksen, NETL support contractor; Scott Matthews, NETL support contractor; John White, NETL support contractor; Liam Walsh, NETL support contractor; Eric Grol, NETL; Matthew Jamieson, NETL; Timothy J. Skone, DOE Headquarters (AUGUST 2023)

▸ https://doi.org/10.1016/j.ijhydene.2023.08.079

2023 Water Brief for Energy Applications

Erik Shuster, NETL (AUGUST 2023)

▸ https://netl.doe.gov/energy-analysis/details?id=37f79201-02a9-40c3-b325-8b166ae6c763

Functionalized Silica Sorbent Strategies for the Recovery of Critical Minerals from Coal Wastewaters: Particles, Chemisorption Fibers, and Fibrous Amine-Functionalized Matrix

Qiuming Wang, NETL support contractor; Walter Wilfong, NETL support contractor; Fan Shi, NETL; McMahan Gray, NETL (AUGUST 2023)

▸ https://netl.doe.gov/energy-analysis/details?id=4e8c8df9-bad6-4c97-9dfa-5635eab235aa

Analysis of backwash settings to maximize net water production in an engineering-scale ultrafiltration system for water reuse

Mohammed A. Alhussaini, University of Arizona; Zachary M. Binger, University of Arizona; Bianca M. Souza-Chaves, University of Arizona; Oluwamayowa O. Amusat, LBNL; Jangho Park, LBNL; Timothy V. Bartholomew, NETL; Dan Gunter, LBNL; Andrea Achilli, University of Arizona (JULY 2023)

▸ https://doi.org/10.1016/j.jwpe.2023.103761

Assessing the economic viability of unconventional rare earth element feedstocks

Alison Fritz, NETL; Thomas Tarka, NETL; Meagan Mauter, Stanford University (JUNE 2023)

▸ https://doi.org/10.1038/s41893-023-01145-1

Nano-porous transport membrane condenser for flue gas water recovery: Modeling and parametric membrane design analysis

Fabian Rosner, University of California and LBNL; Chun Yin Chan, University of California; Brandon Paul, University of California and NETL support contractor; Scott Samuelsen, University of California (MAY 2023)

▸ https://doi.org/10.1016/j.ijthermalsci.2023.108365

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There are several ways to join the conversation and connect with NETL's Water-Energy Research Program:

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:

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