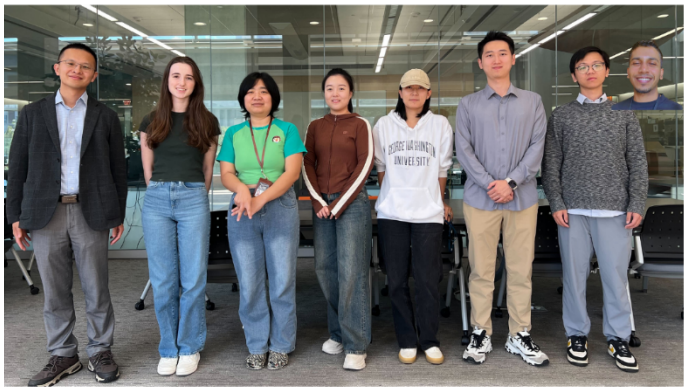
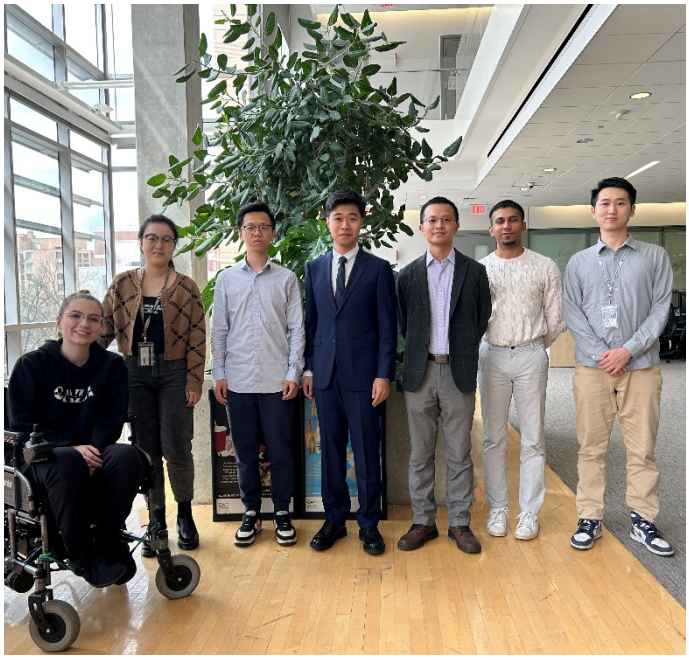
THE GEORGE WASHINGTON UNIVERSITY

Liu Research Group
Environmental Interfacial Technology

2024 Annual Report





Environmental Interfacial Technology

Liu Research Group

Message from the Principal Investigator

Dear Colleagues, Collaborators, and Friends,

As we conclude 2024, I am delighted to reflect on a year of achievements and progress for the Environmental Interfacial Technologies Liu Research Group.

Reflecting 2024

Our research efforts have resulted in six publications, addressing challenges in groundwater remediation, desalination, and resource recovery. Notably, our work on polymer-stabilized colloidal activated carbon for in situ groundwater remediation and the techno-economic assessment of electrochemical desalination are published in *ES&T* and *ACS EST Water*. Our collaborative work on the affinity of viral pathogens for contact surfaces was featured as the front cover of *Environment & Health*.

Our team has presented at conferences, including ACS, AEESP, and SNO. Individual highlights include Kejia Hu winning the 2024 Ellen Gonter Environmental Chemistry Award, and Zhaoyang Wang receiving the 2024 SNO Student Award. Additionally, our technology for chemical-free lithium extraction earned first place in the GW TCO Innovation Competition. Our team LayerPure Technologies led by Sam participated in the GW I-Corps short course program.

We celebrated the graduation of Dr. Lingchen Kong, who will embark on a new journey to commercialize lithium extraction technology. New members joined our lab, broadening our expertise in desalination and electrochemical resource recovery.

Looking Ahead to 2025

The coming year promises to be equally exciting. We aim to further our research on sustainable water treatment technologies and critical mineral recovery.

On behalf of the entire team, thank you for your support and collaboration in 2024. We look forward to another productive and impactful year in 2025.

Warm regards,

Xitong Liu
Principal Investigator
Environmental Interfacial Technology Group
George Washington University

Current lab members

***Xun Guan**'s research is primarily focused on investigating the mechanisms involved in the deposition and remobilization of colloidal-activated carbon, which is utilized in the in-situ remediation of groundwater. Additionally, she has a strong interest in studying the interactions at the colloid-surface interfaces.*

***Bridget Anger**'s research is focusing on researching the role of surface chemistry and pretreatment in membrane fouling during desalination. In her free time, she enjoys gardening, crocheting, and nature hikes.*

***Kejia Hu.** Kejia is interested in modeling electrochemical water treatment processes, including modeling physical processes, conducting techno-economic analysis, and evaluating the feasibility of treated water for irrigation use. When she has extra time, she likes to watch detective series.*

***Yongchang Yu.** His primary research interest lies in the extraction of ions from wastewater and unconventional water sources through electrochemical intercalation material reactions. Outside the lab, he enjoys hiking and playing tennis.*

People

Samarpan Deb Majumder *He earned his undergraduate degree in Mechanical Engineering from the Institute of Engineering and Management (IEM) in Kolkata, India. His primary research interests lie in membrane technology, with a particular focus on how the molecular layer-by-layer (mLbL) process can revolutionize membrane manufacturing, and how tuning the surface chemistry of a membrane can extend its lifetime.*

Zhaoyang Wang*'s research focuses on investigating the issues of membrane fouling and scaling in water treatment processes. His current research project is related to efficiently removing antibiotic-resistant genes from the environment using the adsorption capability of semi-permeable membranes.*

Junhan Li *Her current research focuses on electrochemical lithium-ion extraction from brine. Earlier this year, she worked in Dr. Ruggero Rossi's lab as a research assistant, focusing on microbial fuel cells and studying the effects of different organic substrates on electrochemically active microbes.*

Fiona Berg *is an undergraduate studying Civil Engineering.*

She was recently inducted into GWU's chapter of Tau Beta Pi.

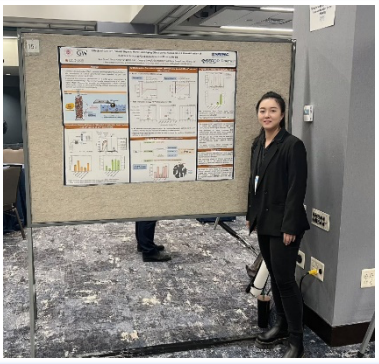
Conferences and Awards

AEESP Distinguished Lecture by Prof. Lynn Katz – November 2024

In November 2024, our team attended the AEESP Distinguished Lecture at Johns Hopkins University, where we presented our research topics in a poster session. The event, featuring a lecture by Prof. Lynn Katz, provided valuable networking opportunities and facilitated discussions on our ongoing projects.

DoD Energy and Environment Innovation Symposium at Washington, DC

Xun Guan presented on the effects of calcium, natural organic matter, and aging on colloidal activated carbon transport at the DoD Energy and Environment Innovation Symposium, the AEESP Distinguished Lecture at Johns Hopkins University, and the 2024 SEAS Showcase.



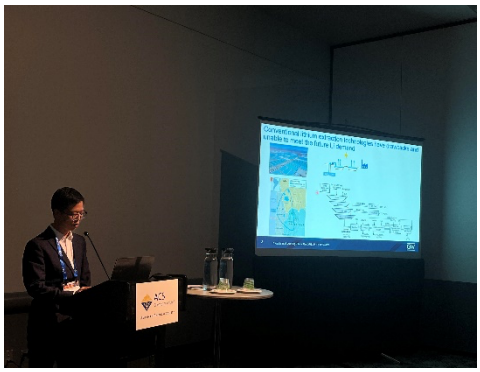
2024 Ellen Gonter Graduate Student Research Paper Award

Kejia Hu was honored with the 2024 Ellen Gonter Graduate Student Research Paper Award from the Division of Environmental Chemistry of the American Chemical Society. This prestigious award recognizes outstanding student research. In August, Kejia presented her work at the ACS conference in Denver and later attended the AGU 2024 meeting in DC, where she presented on agricultural economic modeling of desalination technologies.

Conferences and Awards

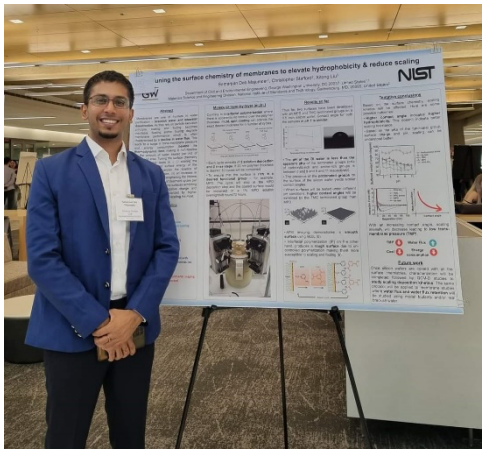
ACS Conference Presentation – August 2024

Yongchang Yu presented at the ACS conference in Denver in August, discussing the challenges and potential of electrochemical intercalation for lithium extraction from geothermal brines. His study focused on the impact of mineral ions (Na, Fe, Mn, Si) on lithium extraction efficiency and stability using lithium iron phosphate (LFP) electrodes.



Samarpan presenting his work in SEAS showcase

Samarpan completed two research projects: (1) optimizing polyamide surface chemistry to resist silica scaling, and (2) scaling up conventional mLbL for industrial membrane manufacturing. He presented his work at the SEAS showcase at GWU and the AEESP Distinguished Lecture Series at JHU.



Zhaoyang Wang won SNO Award

Zhaoyang Wang presented a poster at the 13th Sustainable Nanotechnology Conference in Providence on November 8th, 2024. He was awarded the Sustainable Nanotechnology Organization (SNO) Student Award in 2024.

PhD graduation and Lab celebrations

Congratulations, Dr. Kong!

We celebrated Lingchen's Ph.D. defense in the GW SEAS hooding ceremony and a lab BBQ at Burke Lake Park. Lingchen will embark on a new journey of commercializing direct lithium extraction technology.

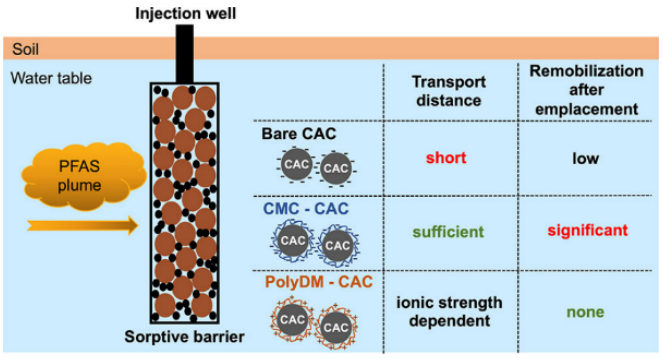
In April, our technology "Chemical-Free Extraction of Lithium from Brines" has won the 1st place prize in the GW TCO Innovation Competition & NAI GW Chapter Induction Ceremony.

Dr. Kai Loon Chen from DC Water visited GW and gave a seminar "Drinking Water Research in DC Water: From Lead Service Line Replacements to Water Quality Monitoring in Distribution System".

Research Highlights

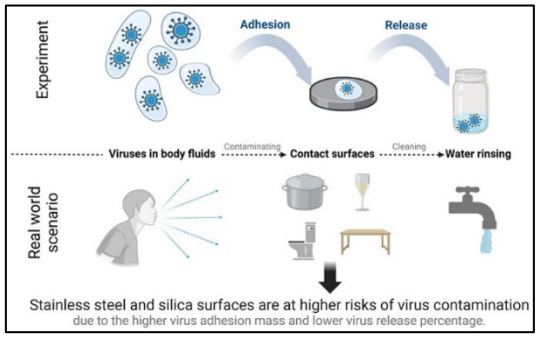
Polymer Coatings Affect Transport and Remobilization Colloidal Activated Carbon in Saturated Sand Columns: Implications for In Situ Groundwater Remediation

Abstract. Colloidal activated carbon (CAC) is an emerging technology for the in-situ remediation of groundwater impacted by per- and polyfluorinated substances (PFAS). In assessing the long-term effectiveness of a CAC barrier, it is crucial to evaluate the potential of emplaced CAC particles to be remobilized and migrate away from the sorptive barrier. We examine the effect of two polymer stabilizers, carboxymethyl cellulose (CMC) and polydiallyldimethylammonium chloride (PolyDM), on CAC deposition and remobilization in saturated sand columns. CMC-modified CAC showed high mobility in a wide ionic strength (IS) range from 0.1 mM to 100 mM, which is favorable for CAC delivery at a sufficient scale. Interestingly, the mobility of PolyDM-modified CAC was high at low IS (0.1 mM) but greatly reduced at high IS (100 mM). Notably, significant remobilization (release) of deposited CMC-CAC particles occurred upon the introduction of solution with low IS following deposition at high IS. In contrast, PolyDM-CAC did not undergo any remobilization following deposition due to its favorable interactions with the quartz sand. We further elucidated the CAC deposition and remobilization behaviors by analyzing colloid-collector interactions through the application of DLVO theory, and the inclusion of a discrete representation of charge heterogeneity on the quartz sand surface. The classical colloid filtration theory was also employed to estimate the travel distance of CAC in saturated columns. Our results underscore the roles of polymer coatings and solution chemistry in CAC transport, providing valuable guidelines for the design of in situ CAC remediation with maximized delivery efficiency and barrier longevity.



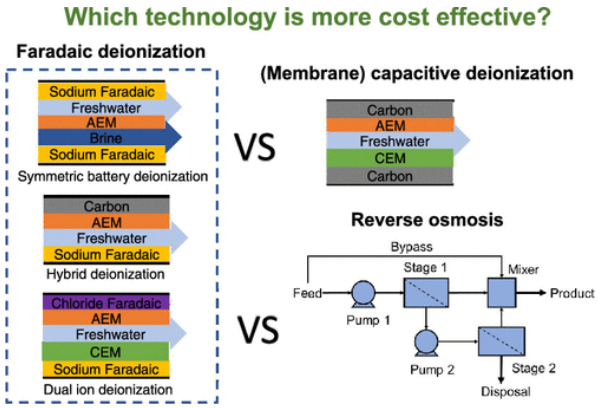
Probing the Affinity of Coronavirus with Contact Surfaces in Simulated Body Fluids

Abstract. Transmission of viral pathogens has raised serious public health concerns, but the affinity and strength of viruses adhering to high-touch surfaces are not clear. We systematically investigated the propensities of a coronavirus, Murine hepatitis virus A59 (MHV), adhering onto and releasing from four representative contact surfaces, silica, stainless steel, cellulose, and polystyrene, in simulated saliva and urine using quartz crystal microbalance with dissipation monitoring (QCM-D). We also quantified the interactions between MHV and contact surfaces using atomic force microscopy (AFM). Both initial adhesion rates and saturated adhesion mass of MHV were higher in urine buffer than in saliva buffer, which is attributed to the higher repulsions between the virus and surfaces in the presence of mucin. The maximum adhesion mass of MHV follows the order of stainless steel > silica > cellulose ≈ polystyrene in both urine and saliva buffers. Stainless steel and silica are surfaces with likely higher risks of virus contamination due to their highest maximum adhesion mass in both urine and saliva buffers and lower virus release percentages upon water rinse. The results of this study will provide insights into risk assessment and control of pathogens associated with contact surfaces.



Techno-Economic Assessment of Brackish Water Electrochemical Desalination with Faradaic Electrodes

Abstract



Capacitive deionization (CDI) has been widely studied for low-salinity desalination because of low-voltage operation, tunable salinity removal, and likely tolerance against fouling and scaling. Replacing carbonaceous electrodes with faradaic electrodes in CDI systems can increase both the energy efficiency and salt adsorption capacity. However, the techno-economic competitiveness of faradaic-based deionization systems versus carbon-electrode-based CDI and reverse osmosis (RO) remains unclear. In this study, we develop a parametric model to estimate the levelized cost of water (LCOW) produced by CDI, membrane CDI, and three architectures of faradaic-based deionization systems (hybrid deionization, dual-ion deionization, and battery deionization). We also investigate how different faradaic materials, operation conditions, and cell designs would impact the LCOW. Battery deionization outperforms hybrid deionization and dual-ion deionization in terms of LCOW. Additionally, in the scenario of a fixed 0.5-year lifespan, a lower LCOW of battery deionization is achieved at a higher ASAR with a lower thermodynamic energy efficiency; as such, operating at a higher current density can be a helpful strategy for reducing the cost of water production. Finally, sensitivity analysis indicates that electrode longevity and ion exchange membrane price are crucial parameters toward cost reduction of BDI to be cost-competitive with RO.

Publications

1. **Hu, K**.;[#] **Chen, J**.;[#] Shanbhag, S.; **Liu, X.*** Techno-economic assessment of brackish water electrochemical desalination with faradaic electrodes. *ACS ES&T Water*, **2024**, 4, 12, 5856–5867
2. Park, S.; **Liu, X**.; Li, T.; Livingston, J. L.; Zhang, J.; Tong, T. Protein-Decorated Reverse Osmosis Membranes with High Gypsum Scaling Resistance. *ACS Environmental Au* **2024**.
3. **Guan, X.**;[#] **Kong, L.;**[#] **Liu, C.**;[#] Fan, D.; **Anger, B**.;[#] Johnson, W. P.; Lowry, G. V.; Li, G.; Danko, A.; **Liu, X.*** Polymer Coatings Affect Transport and Remobilization of Colloidal Activated Carbon in Saturated Sand Columns: Implications for In Situ Groundwater Remediation. *Environmental Science & Technology* **2024**, 58, (19), 8531-8541.
4. Molé, R. A.; Velosa, A. C.; Carey, G. R.; **Liu, X**.; Li, G.; Fan, D.; Danko, A.; Lowry, G. V., Groundwater solutes influence the adsorption of short-chain perfluoroalkyl acids (PFAA) to colloidal activated carbon and impact performance for in situ groundwater remediation. *Journal of Hazardous Materials* **2024**, 134746.
5. **Qi, Y.;**[#] **Guan, X.**,[#] Shen, Y.,[‡] **Liu, X.**[‡]* Probing the Affinity of Coronavirus with Contact Surfaces in Simulated Body Fluids, *Environment & Health*, **2024**, 2, 5, 269–277. **(‡ Co-corresponding Author)** ***(Featured as Journal Front Cover)***
6. Bae, Y.; **Liu, X.*** Unveiling the effects of protein corona formation on the aggregation kinetics of gold nanoparticles in monovalent and divalent electrolytes. *Environmental Pollution* **2024**, 123552.

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