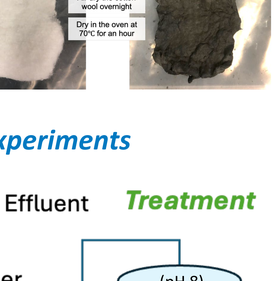
5.18 Multifunctional Membranes for Oxyanion Removal

Anushka Mishrra[a],, Val Frenkel[b], David Sedlak[a], Baoxia Mi[a*]
[a] University of California, Berkeley
[b] TYLin,* mib@berkeley.edu

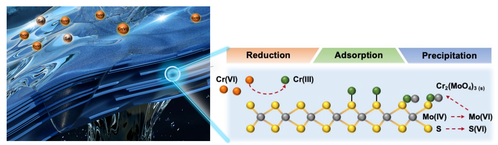
Relevance and Background

- Oxyanions (e.g. Cr(VI) and Se(VI)/Se(IV)) have been widely detected in California groundwaters and their removal presents significant technical challenges.
- MoS_2 packed in column has the lowest levelized cost.
- MoS_2 in membranes is comparable to WBA.
- Weak-base anion (WBA) exchange has high manufacturing/replacement cost



Objective

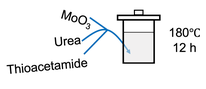
To develop a multifunctional filter using MoS_2 that enables selective removal of oxyanions through an in-situ reduction-adsorption-precipitation process.

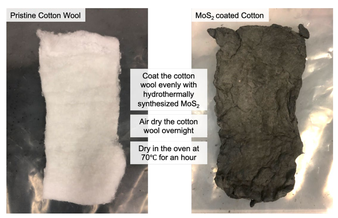


Approach

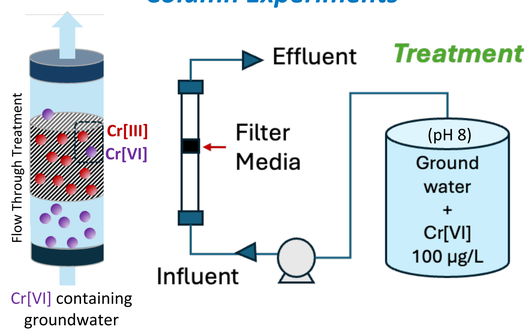
Material Synthesis

Hydrothermal Synthesis of MoS_2 (1T/2H phase)





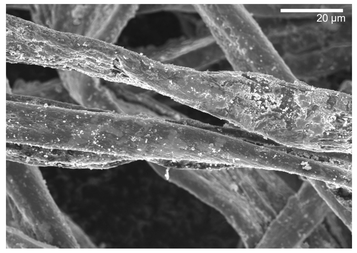
Column Experiments

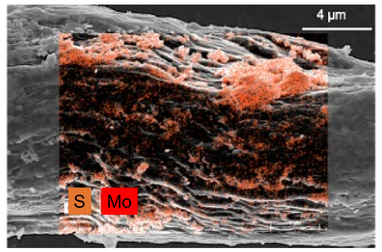


Results

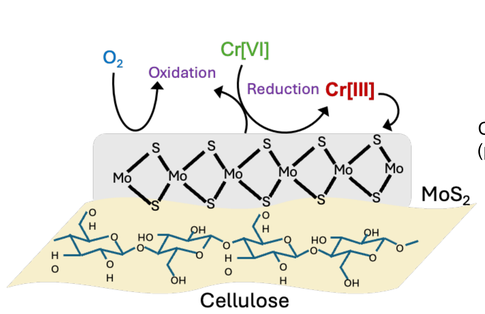
Morphology, Phase and Particle Size distribution of MoS_2 on Cotton

- SEM image of MoS_2-cotton Fibers Overlayed EDS maps of Mo and S on SEM image.
- Phase: 70% 1T and 30% 2H obtained.
- Size distribution: 220 – 255 nm and 5 µm particles.



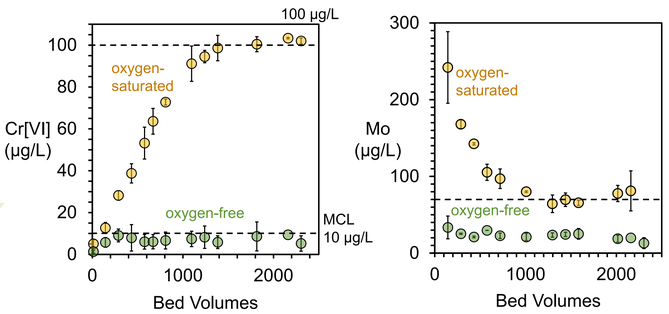


Mechanism of Cr[VI] removal and Effects of Dissolved Oxygen



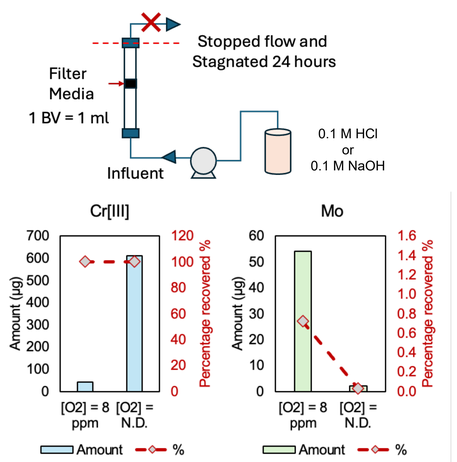
$$\equiv MoS_2 + 6HCrO_4^- + 6H_2O \rightarrow MoO_4^{2-} + 2SO_4^{2-} + 6Cr^{3+} + 18OH^-$$

$$\equiv MoS_2 + \frac{9}{2}O_2 + 3H_2O \rightarrow MoO_4^{2-} + 2SO_4^{2-} + 6H^+$$



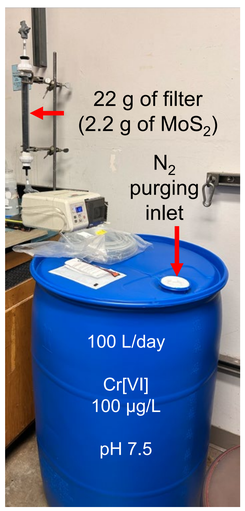
Cr[VI] removal capacity is 1400 BVs in oxygen-saturated groundwater and 20000 BVs in oxygen-free groundwater. Mo release decreases significantly in the absence of oxygen.

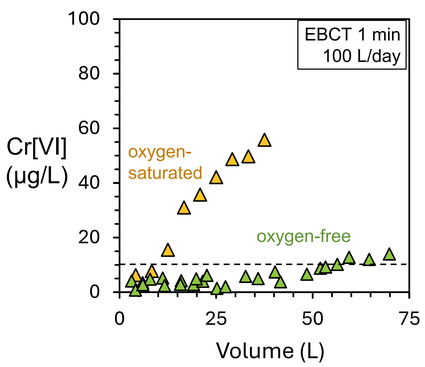
Recovery of Cr[VI] from filters



MoS_2 is preserved when treated with acid but undergoes oxidative dissolution in NaOH.

Cr[VI] removal at high flowrate 100 L/day





Cr[VI] treatment by MoS_2-cotton can be effectively at lower empty bed contact time at high pH conditions.

NAWI CONNECTIONS

Period of Performance: July 1, 2022 – June 30, 2025

Topic Area: Process Innovation & Intensification

Our project aims to develop a platform technology that selectively remove oxyanions to enable inexpensive treatment of nontraditional water sources.

NAWI Leverage

We plan to use WaterTAP to assess the technoeconomic outcome for our proposed technology. We use the lab resources from Molecular Foundry at Lawrence Berkeley National Laboratory.

KEY FINDINGS AND CONCLUSIONS

Key Findings:

- The removal of Cr(VI) by MoS_2-Cotton was achieved by a reduction of Cr(VI) to Cr(III) and a subsequent Cr(III) release into water and adsorption onto material in the columns.
- Treatment capacity was significantly improved in oxygen-removed water.
- Treatment with hydrochloric acid can help recover Cr[III] from the filter and shows promise for reusability.

Conclusions: MoS_2 on Cotton in column experiments demonstrated high removal capacity to adsorption-based filter medias used for Cr[VI] removal at high pH conditions.

REFERENCES

1. *Wang, Z. et.al., Superselective Removal of Lead from Water by Two-Dimensional MoS_2 Nanosheets and Layer-Stacked Membranes. Environmental Science & Technology 2020, 54 (19), 12602-12611.*
2. *Wang, Z. et.al., "Multifunctional water filters for metal and oxyanion removal," Invention Disclosure to UC Berkeley, 2022*
3. *Mi, B. "Potentials of Using 2d Nanomaterials in Membrane Technology for Solving Water-Energy Nexus," 13th World Filtration Congress, San Diego, CA, October 5-9, 2022, Keynote.*
4. Conway, Kelly M., and Baoxia Mi. "Sacrificial membranes in water purification: Concepts, current status, and outlook." *Separation and Purification Technology* (2025): 131748.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Alliance for Water Innovation (NAWI), funded by the U.S. Department of Energy, Energy Efficiency and Renewable Energy Office, Advanced Manufacturing Office under Funding Opportunity Announcement DE-FOA-0001905. We acknowledge the support from Dr. Jeffrey Urban at the Molecular Foundry. Work at the Molecular Foundry was supported by the Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under award no. DE-AC02-05CH11231.

This material is based upon work supported by the National Alliance for Water Innovation (NAWI), funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), Industrial Efficiency and Decarbonization Office, under Funding Opportunity Announcement DE-FOA-0001905.