Development of an Ionic Liquid Modified Carbon Adsorbent for Treating Emerging Contaminants in Recycled Water on the International Space Station

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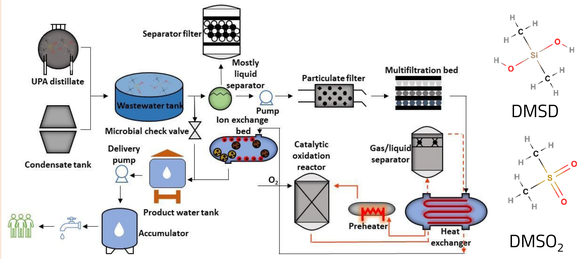
Introduction

- The International Space Station (ISS) operates as a closed system
- Water is recycled from humidity and urine and held in a wastewater tank; part of the Water Processing Assembly (WPA)
- Potable treated water is used indirectly in the Sabatier Reactor
- The Sabatier Reactor is a key component in the Environmental Control and Life Support System (ECLSS)
- Three main functions of ECLSS: water recovery, air revitalization, and oxygen generation
- Sabatier Reactor recently failed due to contamination of $DMSO_2$, dimethyl sulfone, and DMSD, dimethylsilanediol
- $DMSO_2$ and DMSD are emerging contaminants that are not removed by the media used in the WPA due to their low affinity
- $DMSO_2$ and DMSD are introduced into the water system through personal hygiene products such as lotion, conditioner, and wipes, which all contain volatile methyl siloxanes (VMS)
- VMS are decomposed into $DMSO_2$ or DMSD and are found in urine



International Space Station Water Processing Assembly - Graphic Credit: Dr. Khan's Lab

- Ambersorb 4652, a styrenic polymer adsorbent that is not biobased or sustainable, is the current media used in the multifiltration beds in WPA on the ISS
- Costly and unsustainable, Ambersorb 4652 is challenged to remove DMSD and $DMSO_2$ from recycled water
- Granular activated carbon (GAC) works similarly to a styrenic polymer adsorbent and can be made from biobased materials
- Ionic liquids are liquid molten salts at temperatures < 100 °C that are typically composed of large and unsymmetrical organic cations and organic or inorganic ions
- Composed of a hydrogen bond acceptor (HBA) and a hydrogen bond donor (HBD)
- Remarkable solvation ability for a broad range of natural and synthetic materials and compounds

Granular Activated Carbon (GAC)

Synthesized Ionic Liquids

Research Objectives

Objectives:

- Synthesize at least 3 biobased ionic liquids
- Analyze and quantify how much $DMSO_2$ is removed by the ionic liquids through liquid-liquid extractions
- Coat GAC with the most effective biobased ionic liquids
- Analyze and quantify how much $DMSO_2$ is removed with uncoated GAC and ionic liquid coated GAC through batch adsorption testing

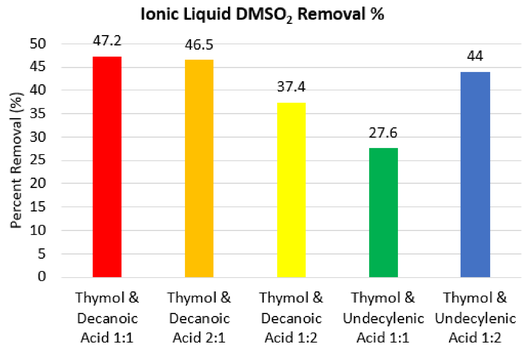
Preliminary Work

- The following ionic liquids were synthesized: a liquid result is successful, but any recrystallization is an unsuccessful result

HBA	HBD	Molar Ratio	Result
Thymol	Decanoic Acid	1:1	Liquid, oil-like viscosity
Thymol	Decanoic Acid	2:1	Liquid, oil-like viscosity
Thymol	Decanoic Acid	1:2	Liquid, water-like viscosity
Thymol	Undecylenic Acid	1:1	Liquid, water-like viscosity
Thymol	Undecylenic Acid	2:1	Liquid with some recrystallization
Thymol	Undecylenic Acid	1:2	Liquid, water-like viscosity
Thymol	Dodecanoic Acid	1:1	Completely recrystallized solid
Thymol	Dodecanoic Acid	2:1	Liquid with some recrystallization
Thymol	Dodecanoic Acid	1:2	Completely recrystallized solid

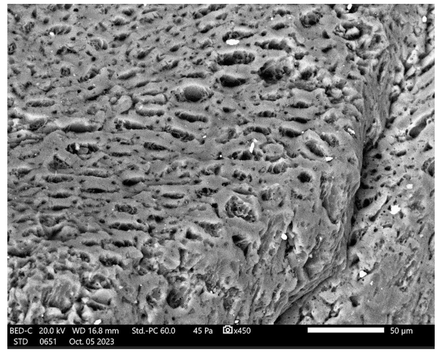
Synthesized Ionic Liquid Results

- Liquid-liquid extractions (LEE) were conducted to determine the efficacy of ionic liquids to remove DMSO2 from water
- Ionic liquids were mixed with DMSO2 contaminated water, centrifuged, and separated to remove ionic liquid from water phase



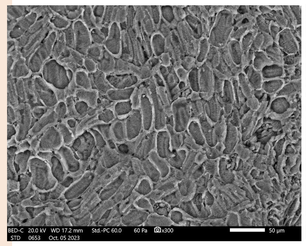
Ionic Liquid DMSO2 Removal Percentage

- GAC was coated by combining 1 g GAC, 0.5 g ionic liquid, 15 mL methanol, and shaken in an orbital shaker for 24 hours
- GAC was separated using vacuum filtration and oven dried at 103°C for 1 hour
- Scanning electron microscopy (SEM) was conducted to ensure coating of ionic liquids onto GAC

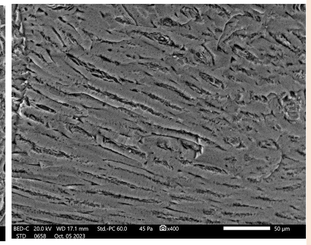


Naked/Uncoated GAC

Preliminary Work Cont.



Thymol & Decanoic Acid 1:1 Coated GAC

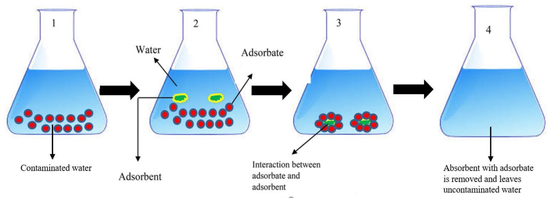


Thymol & Undecylenic Acid 1:2 Coated GAC

Methodology

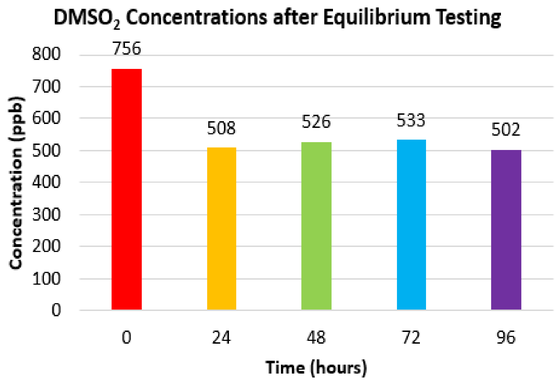
Equilibrium Batch Adsorption Testing with Uncoated GAC:

- 100 mg of coconut granular activated carbon ranging in sizes from 400-595 microns is added to a 45 mL vial containing 800 ppb $DMSO_2$
- Solution is shaken until reaching equilibrium
- Equilibrium time is determined by taking samples over time - 24, 48, 72, and 96 hours
- Samples are filtered to separate GAC from water
- Samples are analyzed by gas chromatography mass spectrometry (GCMS) to measure the concentration of $DMSO_2$



Batch Adsorption Testing

Results



Uncoated GAC Equilibrium Batch Adsorption Test Results

Discussion/Conclusion

Batch Adsorption Testing:

- 0 hours started with 756 ppb of $DMSO_2$
- Over 24-96 hours, concentration stayed relatively the same around 515 ppb $DMSO_2$
- 24 hours can be determined as the equilibrium time with only a 32% removal
- Demonstrates a need for ionic liquid coated GAC since uncoated GAC is not sufficient in removing $DMSO_2$ from water

Future Work

- Naked/Uncoated GAC will finish going through batch adsorption tests – isotherm and kinetics testing
- The two ionic liquid coated GACs will go through batch adsorption tests - equilibrium, isotherm, and kinetics testing
- The results of the adsorption experiments will be analyzed to determine the removal of $DMSO_2$
- If removal was successful, the ionic liquid coated biochar would be a good recommendation to fix the Sabatier Reactor
- Naked and coated GACs will also go through same rounds of batch adsorption for DMSD
- Method will be developed on the GC-MS to quantify amounts of DMSD leftover in water after batch adsorption testing

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References

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