Preparation and Characterization of Porous Carbon Adsorbent Materials from Lignocellulosic Residuals

Chanel Casayuran, Chemical Engineering, Cornell University
Ian Dallmeyer, Weyerhaeuser, Cellulosic Fibers Technology
Dave Fish, Weyerhaeuser, Cellulosic Fibers Technology
Northwest Advanced Renewables Alliance – Summer Undergraduate Research Experience (NARA – SURE)

Introduction

- What is activated carbon? Activated carbon (AC) is porosity (empty space) enclosed by carbon atoms.
- What are some applications of activated carbon and how does it work? AC forms physical and chemical bonds with other molecules via adsorption. Other applications: Wastewater treatment, adsorption of organic and inorganic solutes, separation of gases, odor control and many more.
- Who cares about activated carbon? The US EPA, NARA project stakeholders, and everyone who breathes air and drinks water.

Objective

To add value to biomass, specifically lignin, produced from forest residual biorefineries. By carbonizing lignin, it can be used for vapor phase mercury adsorption, one of the fastest growing applications for activated carbon.

Method of Preparation

- Pretreated Lignin Varieties
  - Wet Oxidation (WOX)
  - Sulfite Pretreatment to Overcome Recalcitrance of Lignocellulose (SPORL)
  - Dilute Acid (DA)
  - Catchlight Energy (CLE)
- Preparation of activated carbon
  - Step 1: Carbonization in a tube furnace
  - Step 2: Washing with dilute HCl and H₂O
  - Step 3: Drying in an oven overnight at 105°C

Analysis Methods

- Mercury Adsorption
  - Simulated Hg Flue Gas: SO₂, NOₓ, HCl, H₂O, CO₂, O₂, Hg⁰
  - Activated Carbon mixed with sand
  - Mercury Concentration Measurement
- BET Nitrogen Adsorption
  - Reference Tube: Sample Tube
  - BET Apparatus
  - Vac-Prep Apparatus produces data below
- Nitrogen Adsorption Isotherm
- Pore Size Distribution

Results

- Vapor Phase Mercury Adsorption Results
  - DA: 1520, 1315, 1502, 1609, 1605, 1415, 1680, 1710
- Characterization Data
  - Porosity Data
    - Lignin: % Yield, Apparent BET SA (m²/g), Pore Volume (cm³/g), Pore Size (nm), Ash Content (%)
    - WOX: 35, 360, 0.2, 1.1 - 1.4, 5
    - SPORL: 42, 213, 0.1, 1.1 - 1.4, 12
    - DA: 30, 309, 0.1, 1.1 - 1.4, 5
    - CLE: 41, 220, 0.1, 1.1 - 1.4, 13
    - KOH: -
  - Surface Area Dependence
    - WOX, DA, CLE, SPORL
    - KOH: Similar Hg-adsorption capacities, but very different SA's
- Elemental Analysis
  - AC Type: Carbon (%), Hydrogen (%), Nitrogen (%), Sulfur (%), Ash Content (%), Oxygen (%)
    - WOX: 89.0, 1.3, 0.4, 0.05, 4.8, 4.5
    - SPORL: 81.8, 1.1, 0.5, 0.4, 12.1, 4.1
    - DA: 88.5, 1.1, 0.7, 0.03, 4.7, 4.9
    - CLE: 81.7, 1.0, 0.6, 1.7, 12.7, 2.4
    - *determined by difference

Conclusion

- AC made from NARA lignin are microporous (pore size <2nm) and are comparable Hg-adsorbents to the commercially available coal-based activated carbon Norit Darco-Hg.
- Hg-adsorption had a LOW dependence on sulfur content.
- Hg-adsorption had a LOW dependence on apparent BET Surface Area.

Future Research: Engaging in thermal or a chemical activation to increase the number of mesopores and macropores may help create highways to the micropores, increasing the accessible adsorption area and improving the Hg-adsorption capacity.

Acknowledgements

This work, as part of the Northwest Advanced Renewables Alliance (NARA), was funded by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.