CARBON CAPTURE WITH NATURAL FIBER-BASED ACTIVATED CARBON COMPOSITES

MELIKE DIZBAY-ONAT[1], JOANNE BALANAY[2], CLAUDIU LUNGU[3]

[1]Department of Material Science & Engineering/Interdisciplinary Engineering, University of Alabama at Birmingham

[2]Environmental Health Sciences Program, East Carolina University

[3]Department of Environmental Health Sciences, University of Alabama at Birmingham

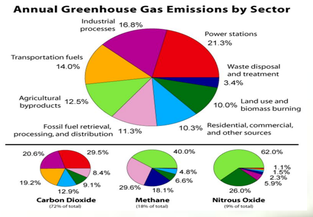
MPAD-Composites

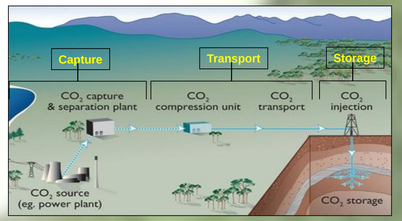
Materials Processing Application & Development

INTRODUCTION

Carbon dioxide (CO_2) emissions released from industrial sources is estimated at approximately 312 billion tons which is a 70% increase over the last forty years. CO_2 is an important factor in climate change. Automotive manufacturers contribute to global warming in two ways. The vehicle manufacturing process itself contributes to CO_2 emissions and transportation via burning fuel is the second consideration. Manufacturing a new car creates as much carbon pollution as the pollution created by driving one.

It is estimated that CO_2 capture accounts for 70-80% of the total cost of carbon capture, transport and storage system (CCS).





This study will present the research approach and progress in using natural carbon fiber composites for emission capture from a basic study standpoint.

OBJECTIVES

• Define the parameters such as micropore volume; micropore size and the Brunaunner, Emmet and Teller (BET) surface of carbonized natural fibers for CO_2 capture demonstration.

• Demonstrate efficiency of the capture of CO_2 from a simulated flue gas by using carbonized natural fibers under different system conditions.

MATERIALS

Natural-fiber composites with thermoplastic and thermoset matrices have been involved by automotive manufacturers and suppliers for door panels, seat backs, headliners, package trays, dashboards, and interior parts. They offer reductions in weight and cost. Natural fibers from plants, trees and shrubs absorb the same amount of carbon dioxide they produce. Natural fibers can play a key role in the emerging “green” economy based on energy efficiency, industrial processes that reduce carbon emissions and recyclable materials that minimize waste.

FIBER NAME	PLANT	FIBER	CURED W/RESIN	CARBONIZED & ACTIVATED
SISAL				
BANANA				
FLAX				
HEMP				

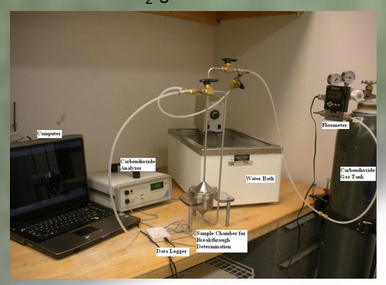
In this study, banana, hemp, flax and sisal fibers are used as natural fibers. These fibers are mixed with phenolic resin to prepare the natural fiber reinforced composite materials. The composite is cured and carbonized to convert the phenolic resin to carbon. After that, physical activation with CO_2 gas is performed to develop a connected network of micropores within the carbon fibers. Activated carbons are granulated and sieved.

Micromeritics ASAP 2020

Accelerated Surface Area and Porosimetry Analyzer

NATURAL FIBER TYPE	BET SURFACE AREA (m^2/g)
SISAL	0.03
CARBONIZED & ACTIVATED SISAL	355.1035
FLAX	0.0115
CARBONIZED & ACTIVATED FLAX	653.89
HEMP	0.1572
CARBONIZED & ACTIVATED HEMP	168.37

Natural fiber composites shown at the above table are carbonized with 5ºC/min with Nitrogen gas until 800ºC and physically activated at 800ºC for 3 hours with CO_2 gas.

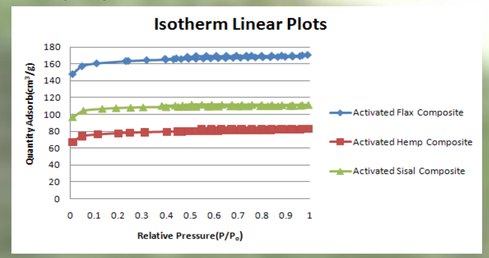


Experiment Set-Up for Adsorption Capacity Measurements

EXPERIMENTAL SET UP & RESULTS

At constant temperature, the relation between the amount of adsorbed gas and the relative pressure (or concentration) is known as the adsorption isotherm. Adsorption is usually described through isotherms.

In this experiment, adsorption isotherms are determined with using ASAP 2020 for natural fiber based activated carbon. BET surface areas are also measured. For all the measurements, Nitrogen gas is used at 77 K.



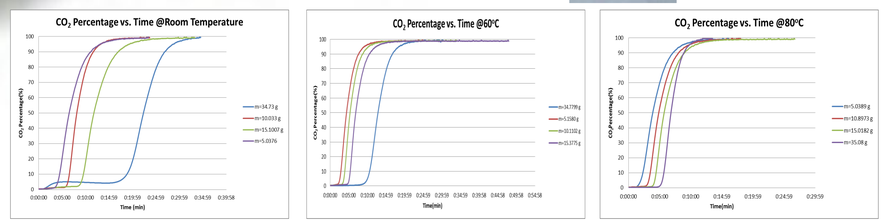
Natural Fiber-Based Activated Carbon Composite Isotherm Plot

According the isotherm plot above, the shape of isotherm indicates that it is a Type I isotherm.

Type I isotherm represents the Langmuir-type monolayer adsorption and it is characteristic of microporous adsorbents. As a result, this plot shows that the sample composite has microporous.

Samples are placed in a stainless-steel chamber and simulated gas flow through the chamber. The chamber is placed into a temperature-controlled water bath to control the temperature of the process. The breakthrough concentration of CO_2 is measured with Quantek 906 CO_2 analyzer to determine the adsorption capacity.

Granulated coconut activated carbon(Calgon Carbon Corporation, RVG-C, 80,12*20) is used as reference material.

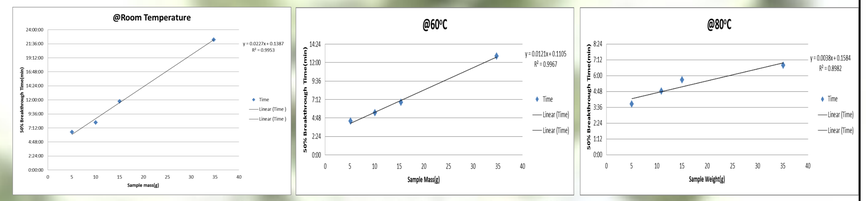


Granulated Coconut Activated Carbon Breakthrough Plots

Adsorption capacity (W_e) of granulated coconut activated carbon is calculated using modified Wheeler equation.

$$t_b = \frac{W_e}{C_0 Q}\left[W - \frac{\rho_B Q}{k_v} In(C_0/C_x)\right]$$

t_b–breakthrough time(min), C_x-exit concentration(g/cm³), C_0-inlet concentration(g/cm³), Q-volumetric flow rate(cm³) ,W-weight of adsorbent(g), ρ_B-bulk density of packed bed(g/cm³), k_v-kinetic adsorption rate constant(min⁻¹), W_e-kinetic adsorption capacity(g/g)



50% Breakthrough Time vs. Sample Mass plots at different temperatures

Slope is obtained from 50% breakthrough time vs. sample mass plot. Slope(a) is also equal to equation shown below

$$a = \frac{W_e}{QC_0}$$

The equation above is revised as $W_e = aQC_0$. In this experiment Q=0.08 sl/m and 100% pure CO_2 gas is used. Adsorption capacity of activated coconut carbon is calculated as 3.27mg/g, 2.738mg/g and 0.547mg/g at room temperature, 60ºC and 80ºC respectively.

CONCLUSIONS

- ✓ BET surface area increases after the carbonization and activation process for phenolic resin mixed natural fiber composites.
- ✓ Breakthrough time increases when sample weight is increased.
- ✓ Breakthrough time reduces if the temperature of the sample chamber is increased.
- ✓ Adsorption capacity reduces when the temperature of sample chamber is increased.

FUTURE WORK

- Micropore size and micropore volume will be obtained.
- The effect of different carbonization temperatures and activation flow rates on the pore structures as well as on the adsorption properties is going to be investigated.
- Images will be obtained from Scanning Electron Microscopy (SEM) analysis and they will be used to quantify porosity of the materials.
- Instead of 100% CO2, mixture of CO2 with air at different percentages will be applied.
- Miller-Nelson equipment will be added to the experiment to control the temperature and humidity of the gas.
- Determine the applications of CO_2 capture with natural fiber composites on an industrial (such as automotive industry) scale.

REFERENCES

1. Holbery, James, Houston, “Natural-Fiber-Reinforced Polymer Composites in Automotive Applications”
2. Duncan Austin and Amanda Sauer, ”Adapted from Chapter Three of Changing Drivers: The Impact of Climate Change on Competitiveness and Value Creation in the Automotive Industry”
3. Christine & Scott Gable, ‘ Auto Manufacturers and Global Warming”
4. www.co2crc.com.au/aboutccs/ and http://www.eco-friendly-emporium.com/eco-friendly-cars.html
5. Gregg SJ, Sing KSW (1982). Adsorption, Surface Area and Porosity, 2nd ed. Academic Press, London