

Quantifying the Removal and Transformation of C₆₀ Nanomaterials During Conventional Water Treatment: Implications for Human Exposure

Emily Huth

Department of Civil & Architectural Engineering

Undergraduate Research Day

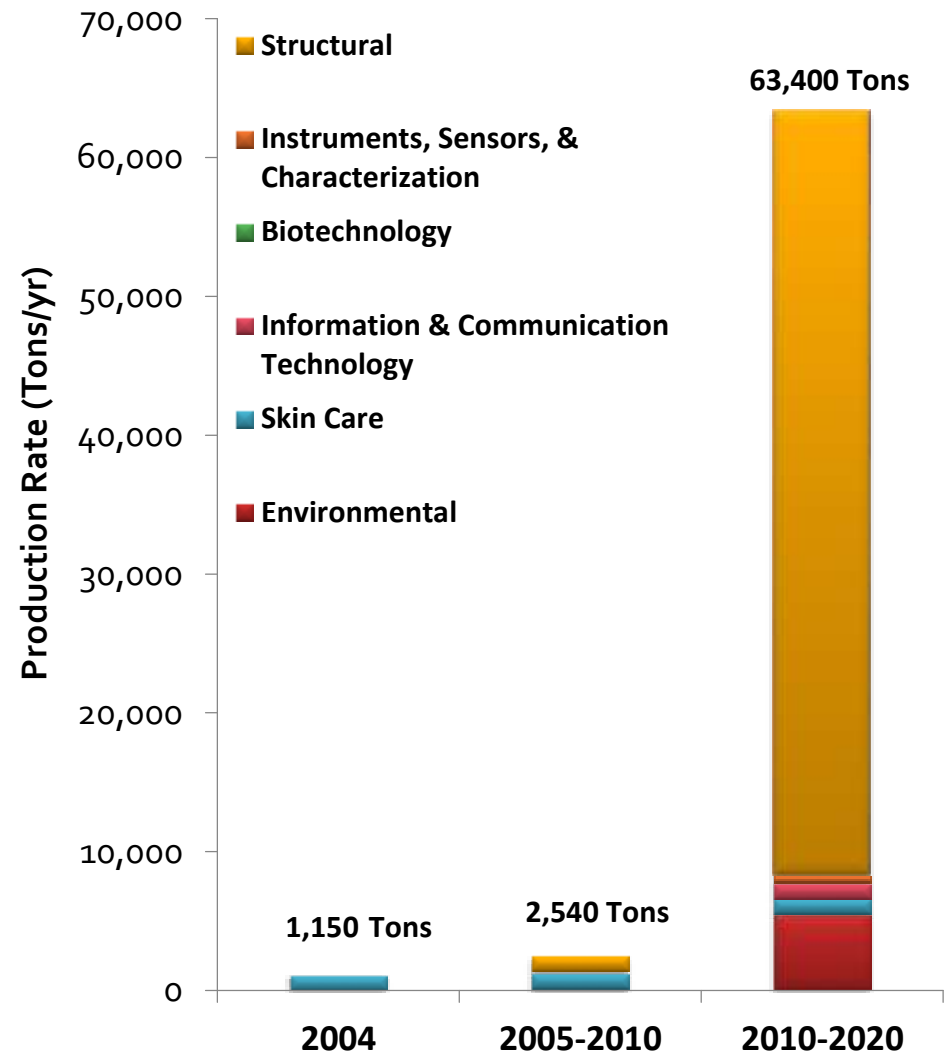
April 30, 2011

Presentation Outline

- **Background**
 - Manufactured nanomaterials as emerging drinking water contaminants
 - Research objectives
- **Materials and Methods**
 - Nanomaterials and organic matter
 - Analytical methods for evaluating samples
 - Simulating conventional water treatment using jar tests
- **Results and Discussion**
 - Interaction between nanomaterial and organic matter
 - Removal of materials during jar tests
- **Conclusions**

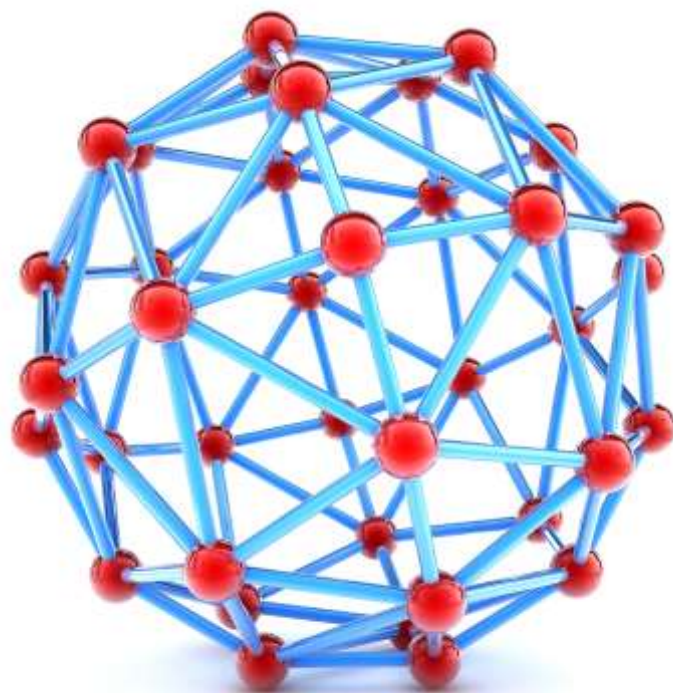
Manufactured Nanomaterials

- **Distinguishing manufactured nanomaterials from naturally occurring colloids**
 - One critical dimension between 1 and 100 nm
 - Unique properties relative to macroscopic analogs
 - Engineered to perform specific functions
- **Global nanomaterial market estimated to reach \$27 billion by 2013**



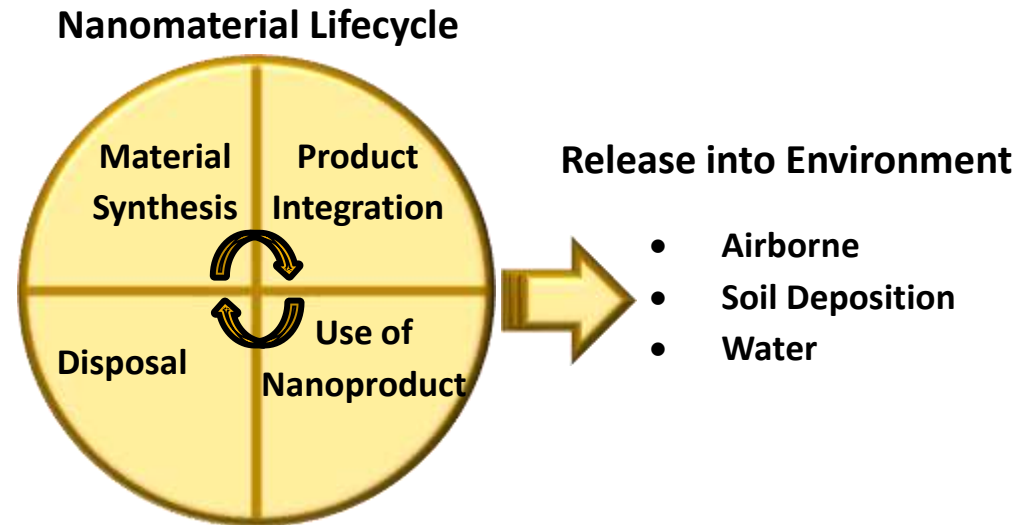
Buckminsterfullerene (C_{60})

- **What is Buckminsterfullerene?**
 - Discovered by Harold Kroto, Robert Curl and Richard Smalley in 1985
 - Caged fullerene composed of 60 carbon atoms
 - Naturally hydrophobic and uncharged molecule
- **Numerous commercial applications for C_{60} and its derivatives**
 - 2007: 1,500 metric tons of C_{60} produced by Mitsubishi
 - Commercial applications include drug delivery, electronics materials, energy conversion and superconductors



Emerging Contaminants

- Risk to environment and human health a function of two variables
 - Hazard – toxicity
 - Exposure – contaminant dose
- C₆₀ has been found to cause toxic effects in numerous types of cells



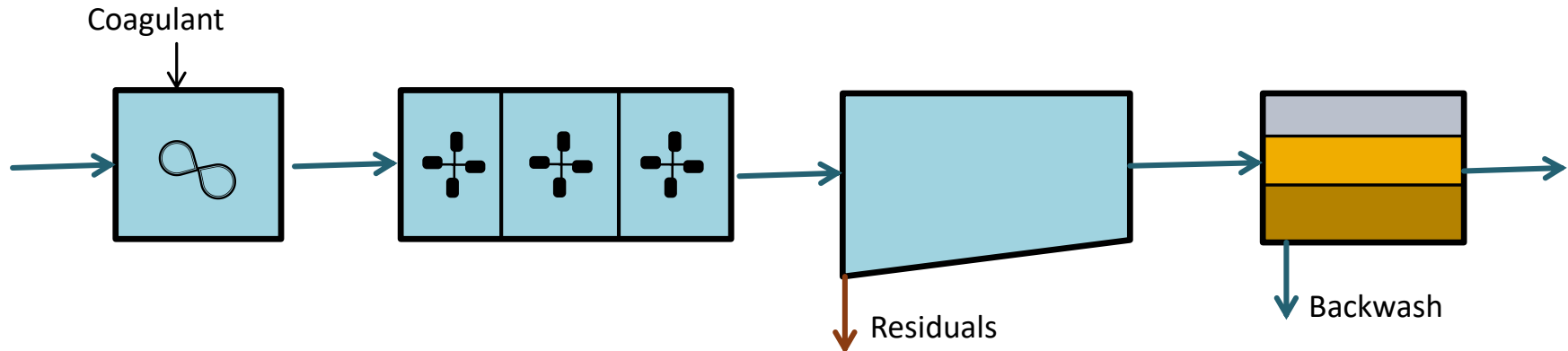
Conventional Water Treatment

■ Coagulation

■ Flocculation

■ Sedimentation

■ Filtration



- Rapid mix – homogeneous mix of chemicals
- Destabilize particles to promote particle aggregation

- Slow mix – allow suspended solids to aggregate

- Particles settle out by gravity
- Residual production

- Filter out floaters from sedimentation basin
- Some microbial removal

Research Objectives

1. Quantify the removal of Buckminsterfullerene nanoparticles (nC_{60}) by coagulation, flocculation, and sedimentation processes
2. Assess the impact of NOM on the removal of nC_{60} during conventional drinking water treatment



Nanoparticles and Organics

■ Fullerol

- Polyhydroxylated C_{60} ($C_{60}OH_{18-24}$) purchased from BuckyUSA, Houston, TX
- Initial 2 g/L stock solution
- Mixed with magnetic stirrer for 30 days

■ Humic acid (HA)

- 50 – 60% as HA, Acros Organics
- Surrogate NOM in jar tests

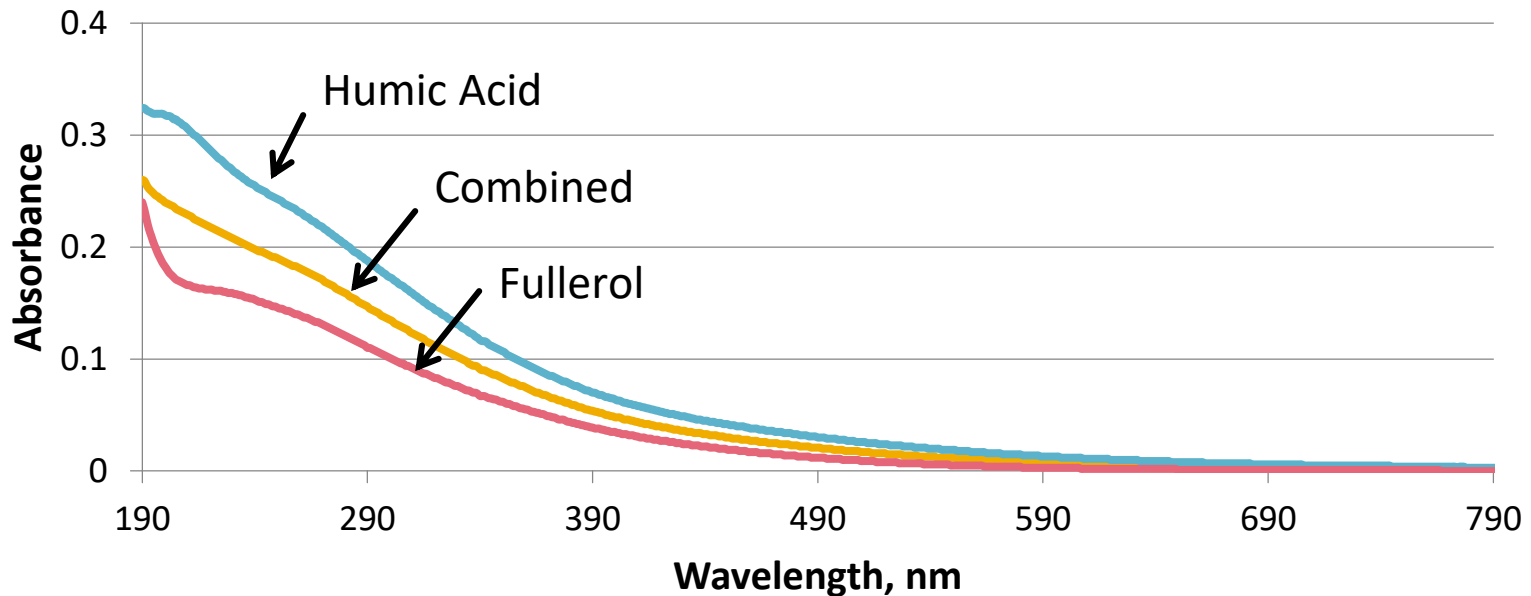
■ Aluminum Sulfate (alum)

- Coagulant in jar tests
- 5 – 30 mg/L

Analytical Methods

- **Measure Suspended Solids**
 - Turbidity (NTU)
 - Hach Ratio Tubidimeter
- **Measure Size of Particles**
 - Dynamic Light Scattering (ZetaPALS)
- **Measure Concentrations of Fullerol and HA**
 - UV-vis Spectrophotometer (Shimadzu)
 - Absorbance spectrum and standard curve

UV-vis Spectra



- All similar except for peak in fullerol spectrum
 - Peak at wavelength 202 nm
- Spectrum of combined solution – used for analyzing jar test decant

Jar Tests - Procedure

- **Rapid mix – 220 rpm for 60 seconds**
- **Slow mix – 17 rpm for 30 minutes**
- **Settled – 60 minutes**
- **Decant drawn 1 cm from top of water surface**



Phipps and Bird Model PB 700 Jar Tester

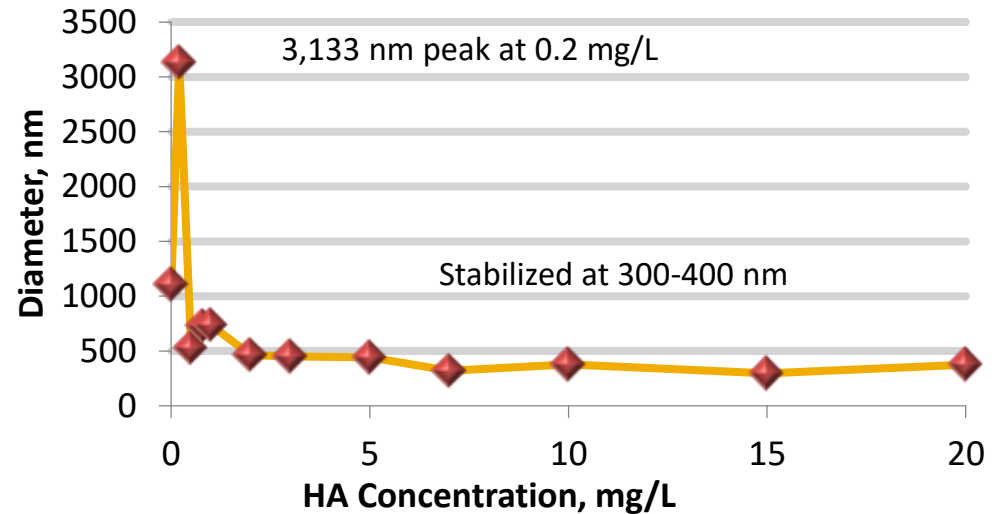
Jar Tests – Water Chemistry

- Synthetic water created similar to typical surface water
- HA and fullerol constant – 5 mg/L
- Alum concentration ranged from 5 – 30 mg/L
- 1,000 mL working volume for jar tests

Parameter	Units	Value
Calcium Hardness	mg/L as CaCO ₃	50
Magnesium Hardness	mg/L as CaCO ₃	30
Alkalinity	mg/L as CaCO ₃	150
pH		7

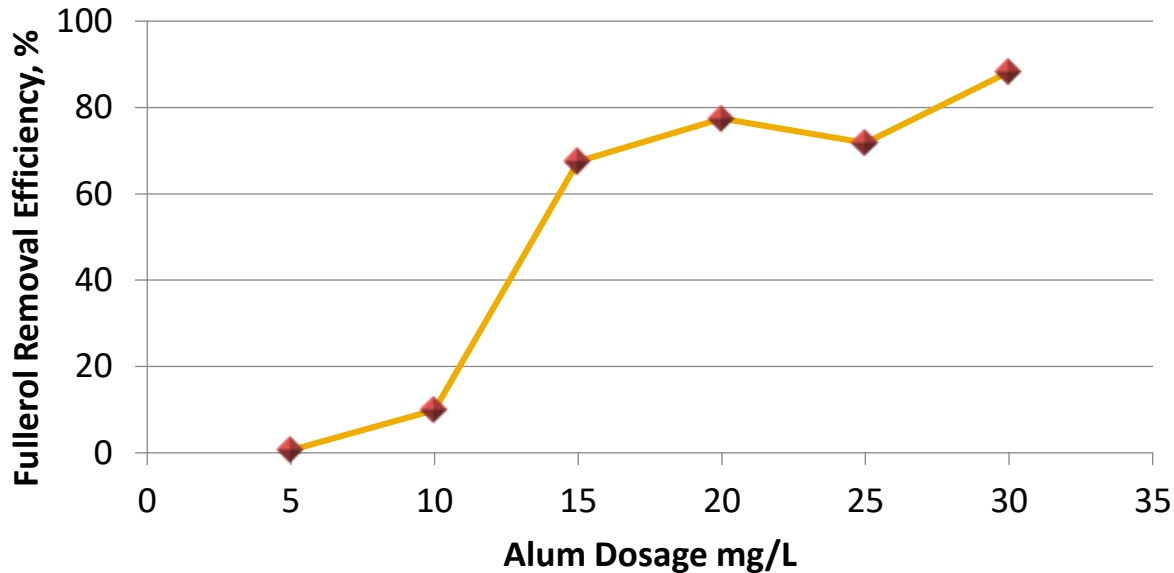
Aggregation Tests

- Examine types of aggregates formed by fullerol and HA
- Fullerol concentration constant – 5 mg/L
- HA concentration 0 – 20 mg/L
- 10 mM NaCl
- 7.5 pH
- Mixed 30 minutes at 25 rpm, settled for 1 hour



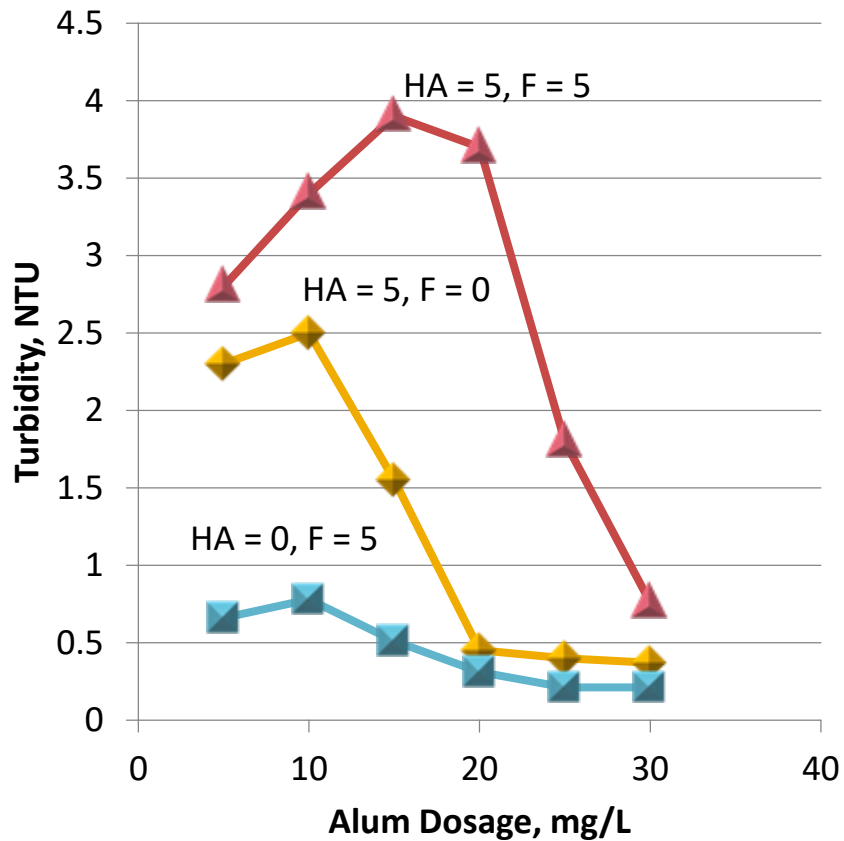
- Bridge Flocculation at lower HA concentrations
- Stable Aggregates formed at higher HA Concentrations
- HA concentration of 5 mg/L chosen for jar tests

Jar Test Results



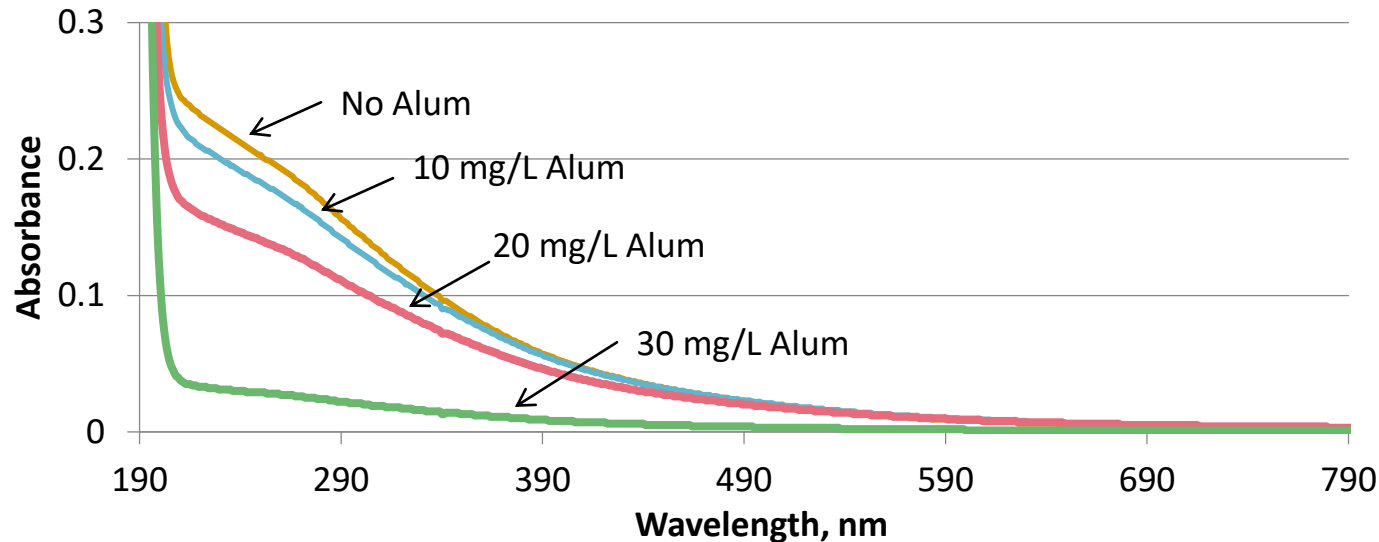
- Examined fullerol removal in water treatment
- Baseline – see how presence of organics affects removal
- Optimum alum dosage: 15-20 mg/L

Jar Test Results



- Evaluated removal with different starting conditions
- Mixture initially additive of HA and F solutions - less so as alum increased
- Not reach plateau for mixture
- Needed more coagulant for mixture

Jar Test Results



- Spectra of combined solutions after jar tests
- As alum dosage increases, spectrum looks more like spectrum of pure fullerol
- Removal of free standing HA
 - Fullerol and sorbed HA remain in suspension

Preliminary Conclusions

- Fullerol can be effectively removed during the conventional water treatment processes coagulation, flocculation and sedimentation
- Presence of organics does seem to decrease removal efficiency of fullerol
- Different analytical techniques needed to differentiate between fullerol and HA

Acknowledgements

- EPSCoR Undergraduate Research Fellowship Program
- Dr. Jonathan Brant
- Fellow research students – Coleman Henry and Qiuhong Jia

Questions

Emily Huth

**University of Wyoming
Department of Civil &
Architectural Engineering
1000 E. University Avenue
Laramie, WY 82071**

Email: ehuth@uwyo.edu

