EVALUATING BIOCHAR IN SUSTAINABLE STORMWATER TREATMENT OF HEAVY METALS

US BIOCHAR INITIATIVE 2016

#USBI2016

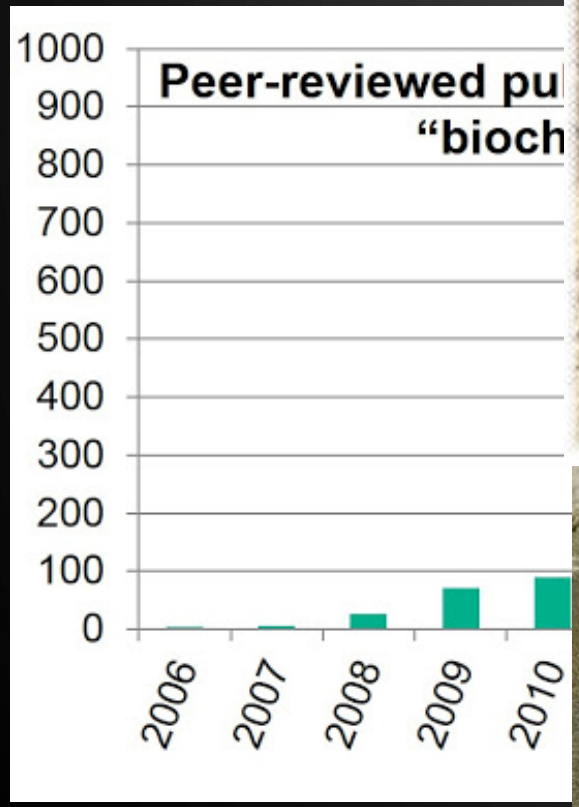
8/22/2016

SARAH BURCH

PRESENTATION GOALS

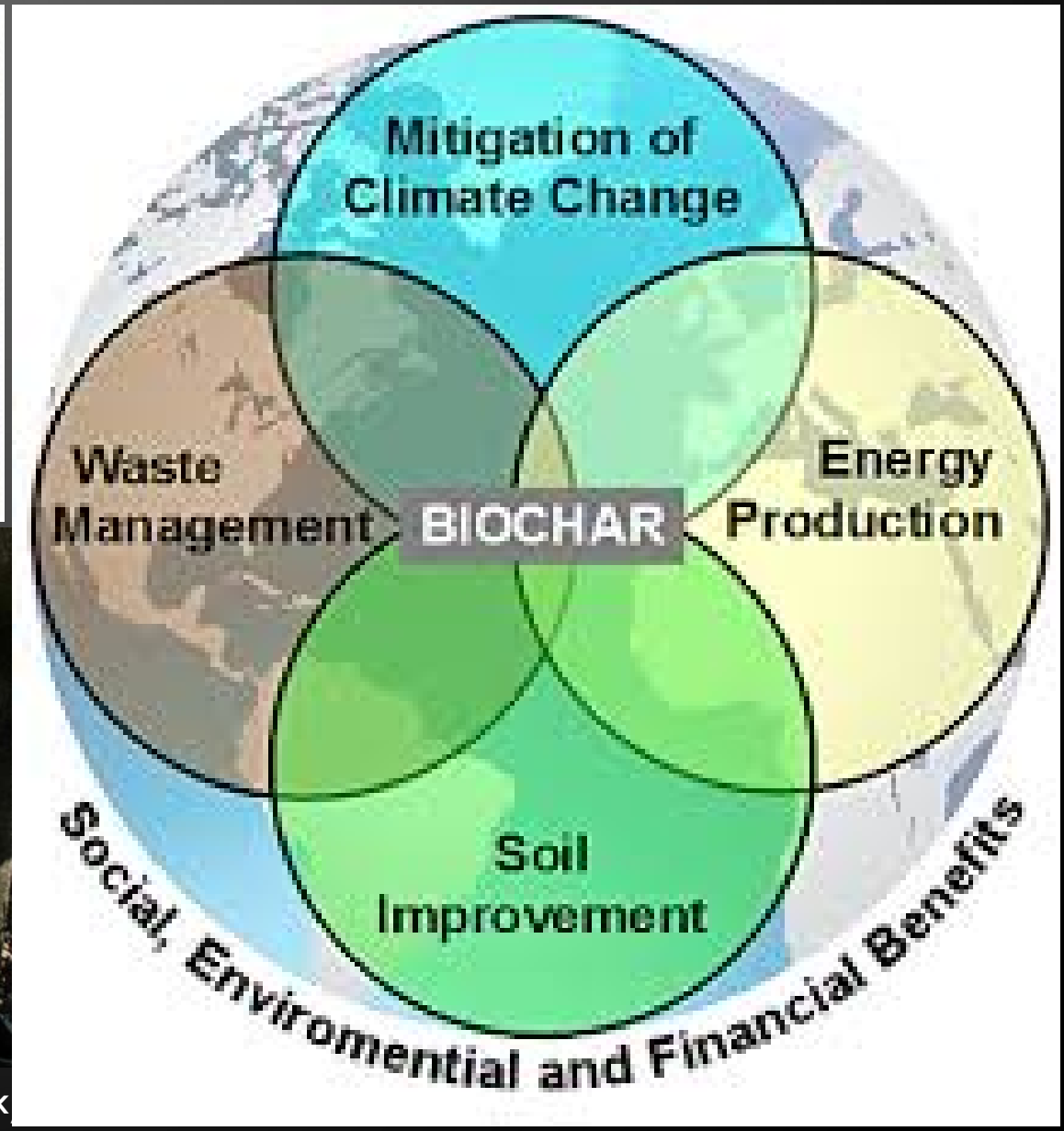
- HIGHLIGHT BIOCHAR SYSTEM BENEFITS
- STATE RESEARCH GOALS IN WATER TREATMENT
- DISCUSS METHODS TO ACHIEVE GOALS
- PRESENT PRELIMINARY RESULTS
- CONCLUDING EMPHASIS ON SUSTAINABILITY IN WATER-ENERGY-CARBON NEXUS

WHY HAS BIOCHAR RESEARCH INCREASED IN LAST 10 YEARS?



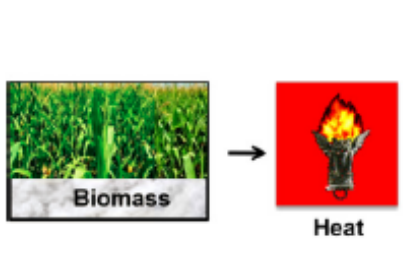

http://www.vitabiogroup.com/interna.php?pg=biomass

http://www.bigbiocharexperiment.co.uk



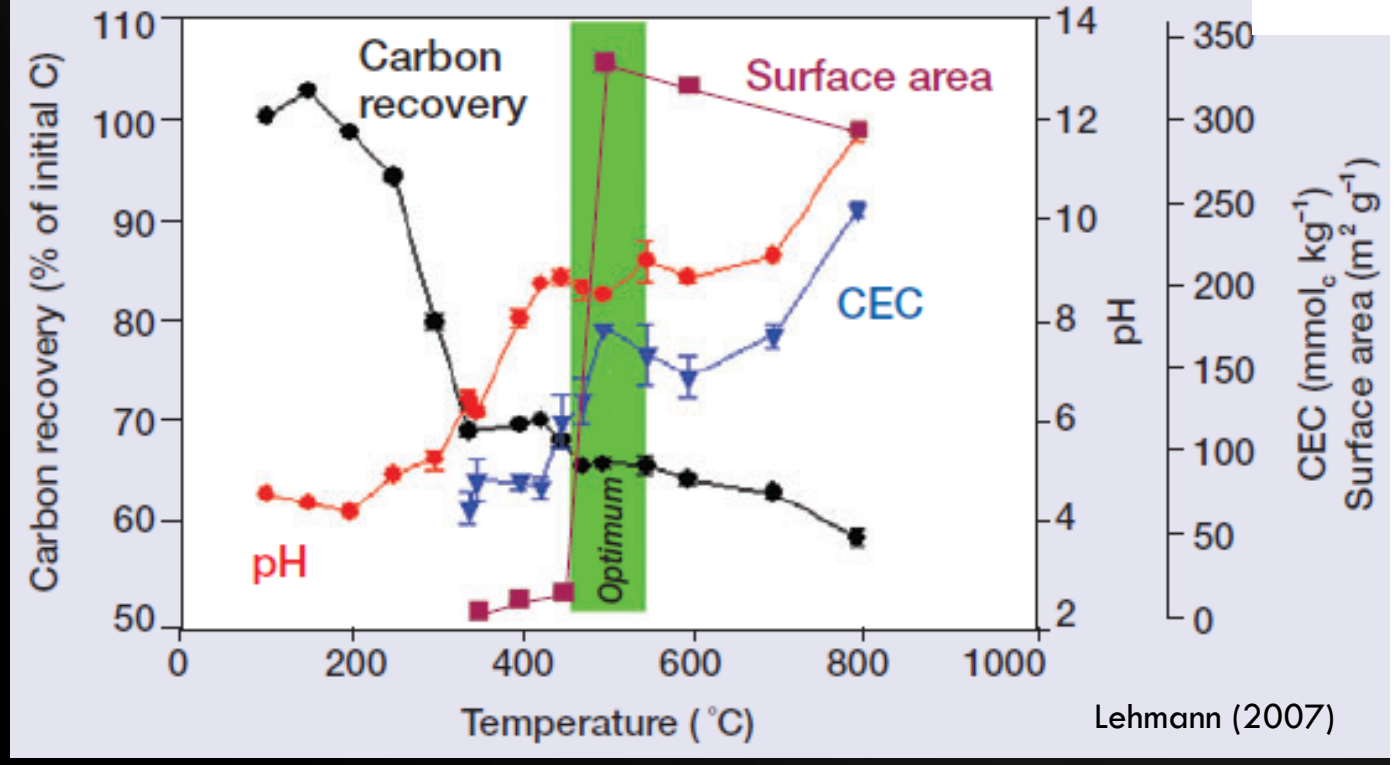
BIOCHAR IS NOT ALL THE SAME

(Mohan et al. 2014)

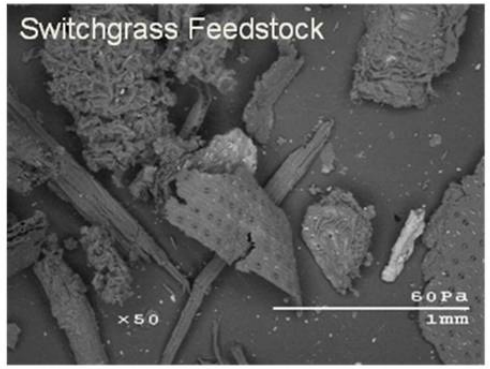


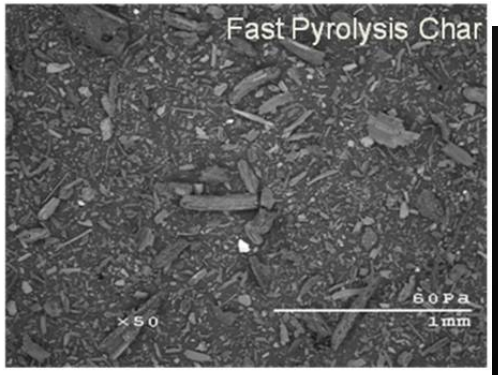
Product Distribution (wt%)

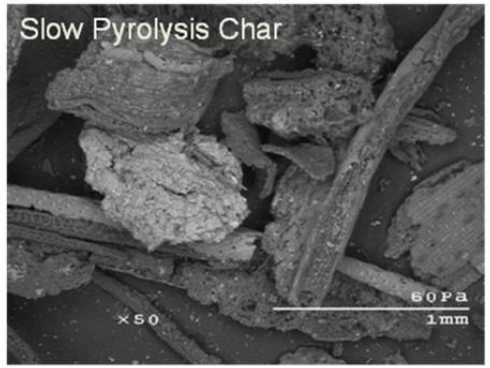
Solid Fraction	Liquid (bio-oil)	Gas
35*	30	35
10	70*	20
10	5	85*

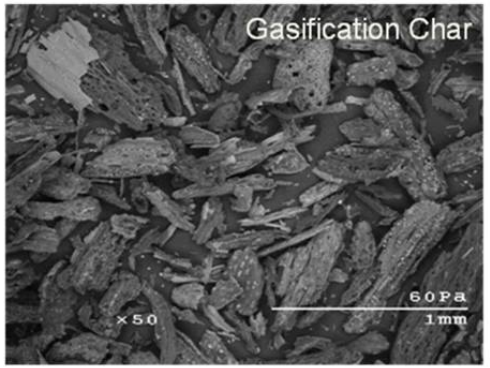


Lehmann (2007)

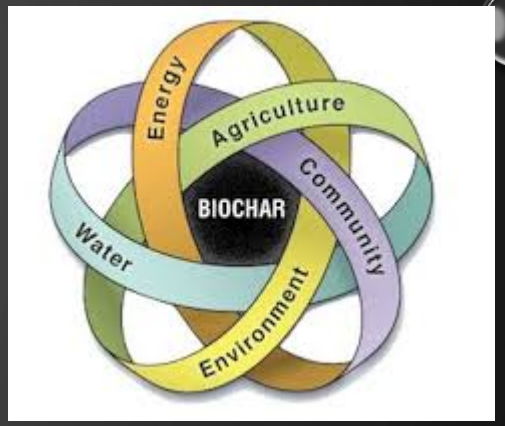




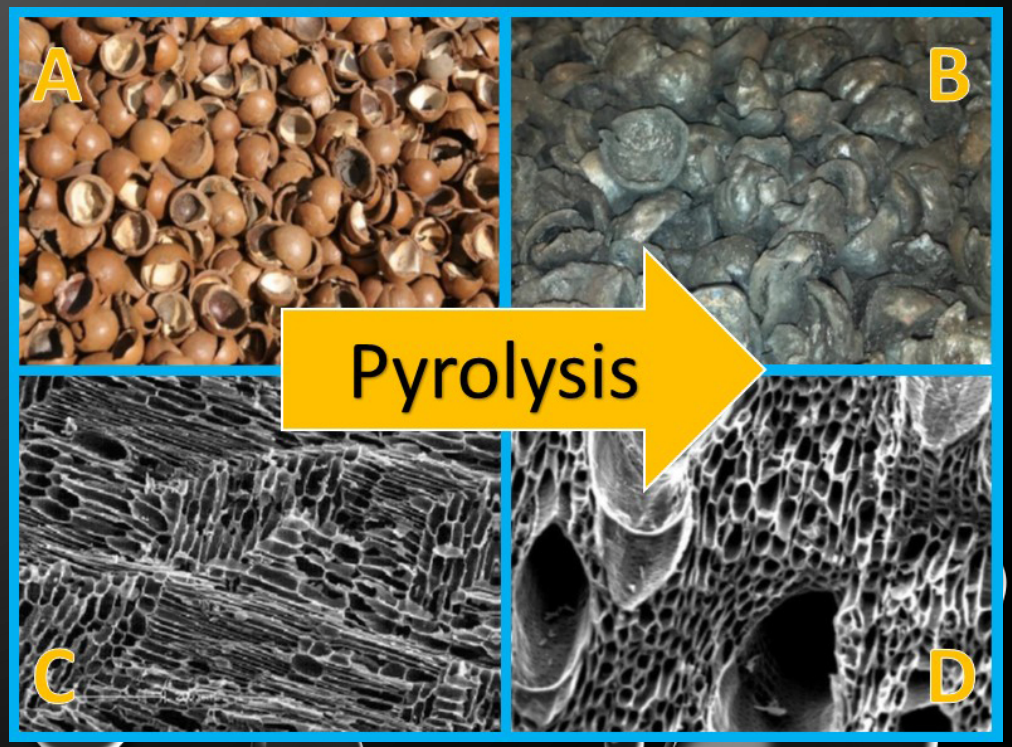




RESEARCH OBJECTIVES



- EVALUATE EFFICACY OF BIOCHAR AS A SUSTAINABLE ADSORBENT MEDIA
  - COMPARE REMOVAL WITH GRANULAR ACTIVATED CARBON (GAC)
- DETERMINE EFFECTS OF FEEDSTOCK AND PYROLYTIC CONDITIONS ON METALS REMOVAL
  - DOUGLAS FIR CHIPS AND HAZELNUT SHELLS
  - 300, 500, AND 700 C
- ELUCIDATE MECHANISM FOR METALS REMOVAL BY BIOCHAR
  - CHARACTERIZATION OF BIOCHARS
    - FTIR SPECTROSCOPY, TGA-MS, SEM IMAGING, XRD
    - PH, PROXIMATE CARBON ANALYSIS, BET SURFACE AREA
  - BATCH AND COLUMN ADSORPTION EXPERIMENTS
  - ADSORPTION MODELING



Images by Kurt Spokas, 2013 (http://istc.illinois.edu/research/biochar/index.cfm)

MOTIVATION: COPPER REMEDIATION

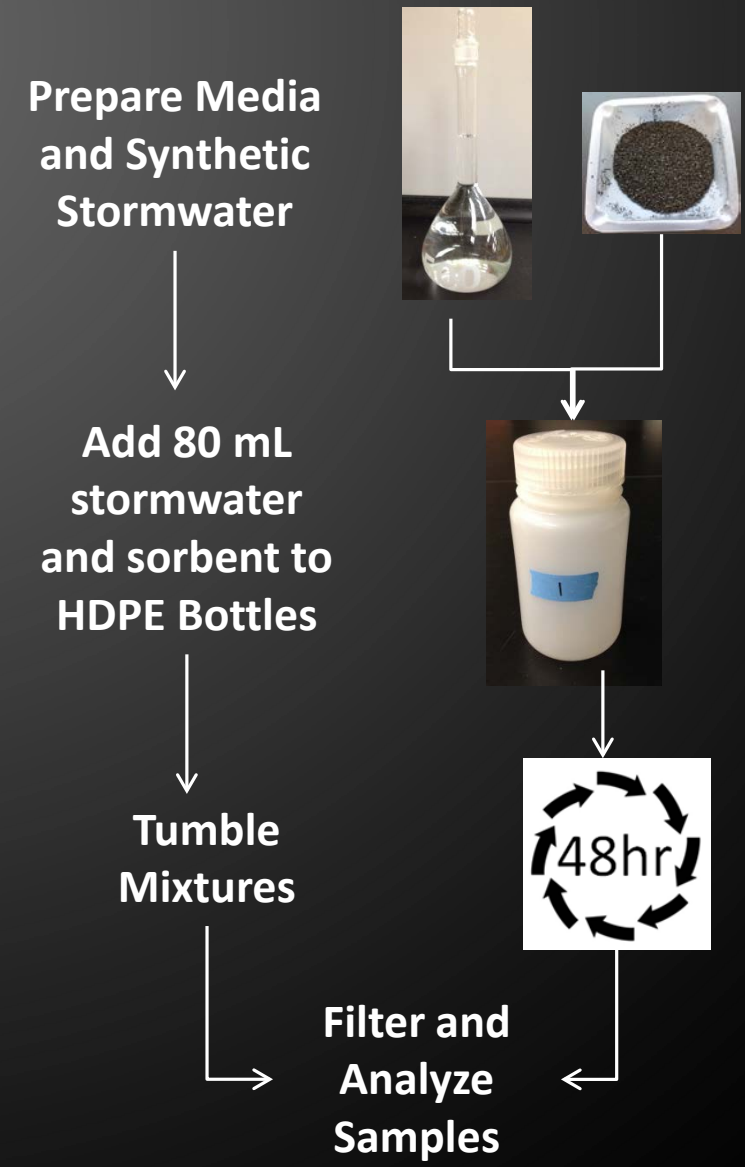
- COPPER PRESENT IN STORMWATER RUNOFF
  - BRAKE PAD WEAR
  - PIPES, FUNGICIDE, ALGAECIDE
- LOW CONCENTRATION OF COPPER TOXIC TO SOME AQUATIC ORGANISMS
- CONCENTRATIONS AS LOW AS 2 PARTS PER BILLION (PPB) INHIBIT OLFACTORY SYSTEM IN JUVENILE COHO SALMON
- CURRENT BMPS REDUCE COPPER TO AS LOW AS 5 PPB


http://static.ddmcdn.com/gif/brake-pads-4.jpg

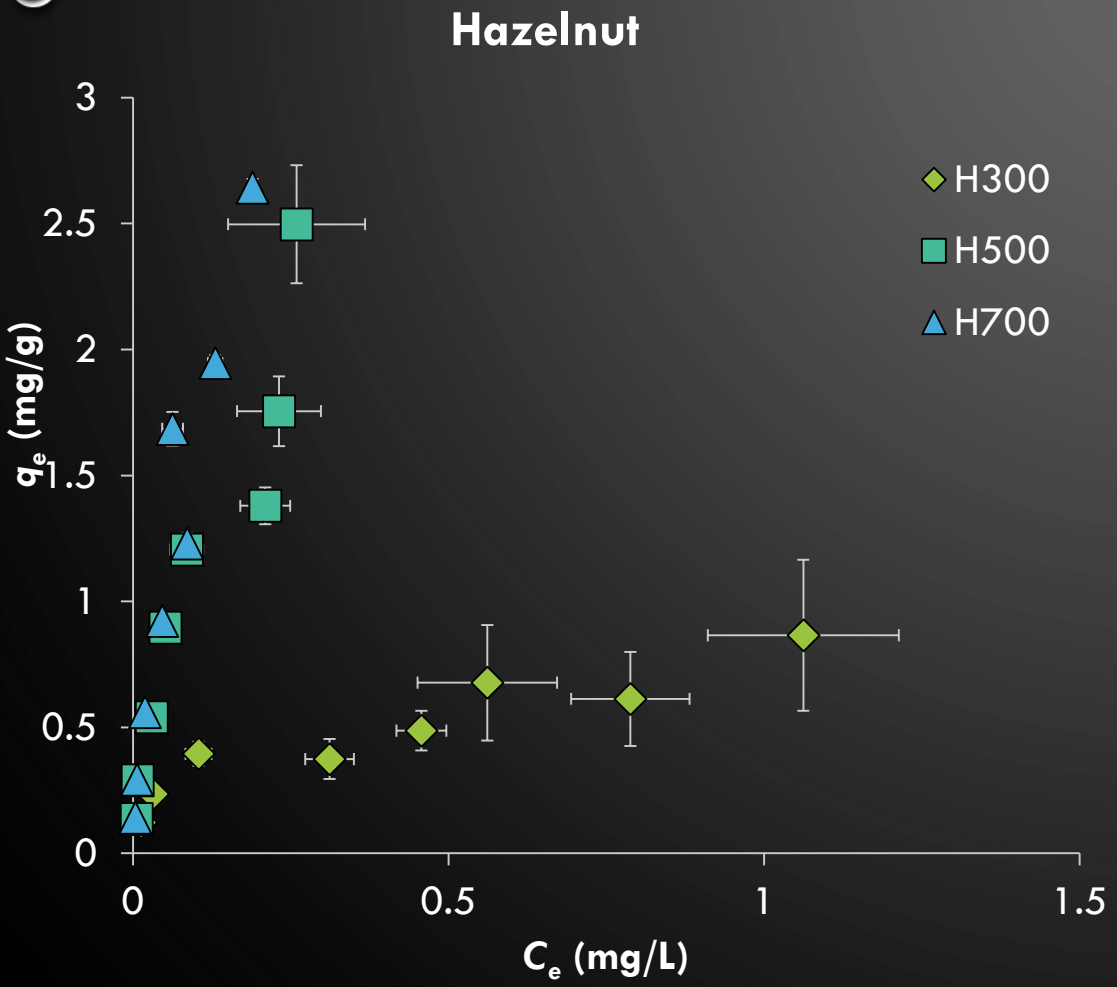

McIntyre et al. 2012

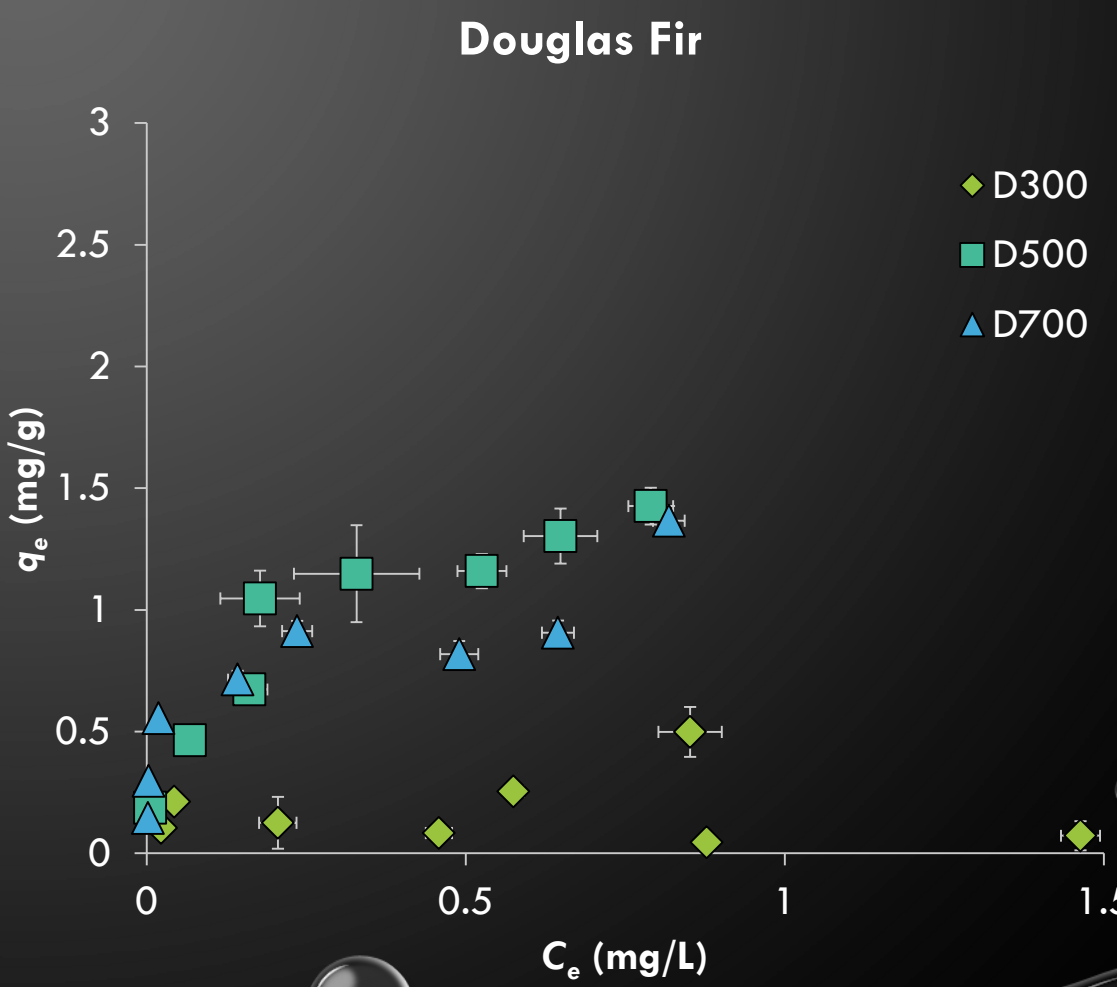
EXPERIMENTAL PROCEDURE BATCH EXPERIMENTS

- SYNTHETIC STORMWATER
  - 1 MM NACL
  - 0.185 MM $NAHCO_3$
  - 100-1500 PPB CU
  - PH 6
- SORBENT
  - 40 – 50 MESH SIZE SIEVED BIOCHAR
- TUMBLE/EQUILIBRATE FOR 48 HOURS
- ANALYZE
  - DISSOLVED COPPER WITH ICP-OES
  - PH

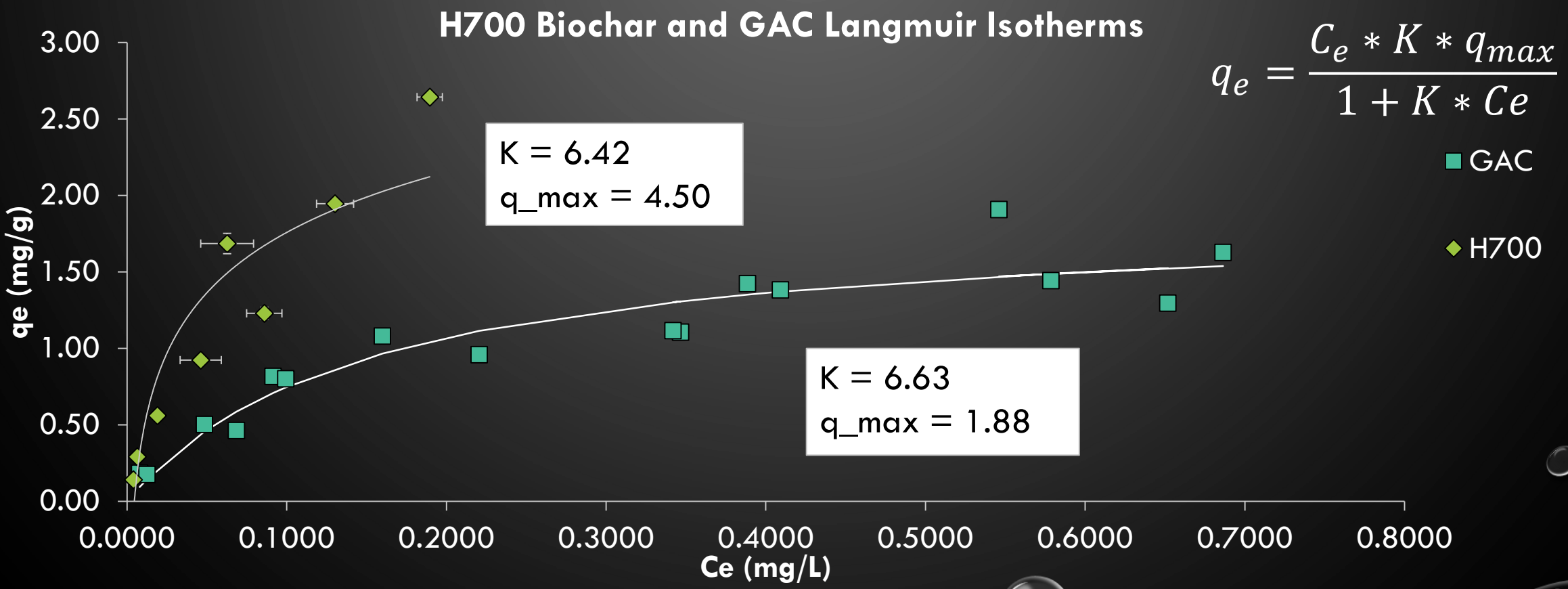


SELECTING BIOMASS FEEDSTOCK AND PRODUCTION TEMPERATURE: BATCH RESULTS

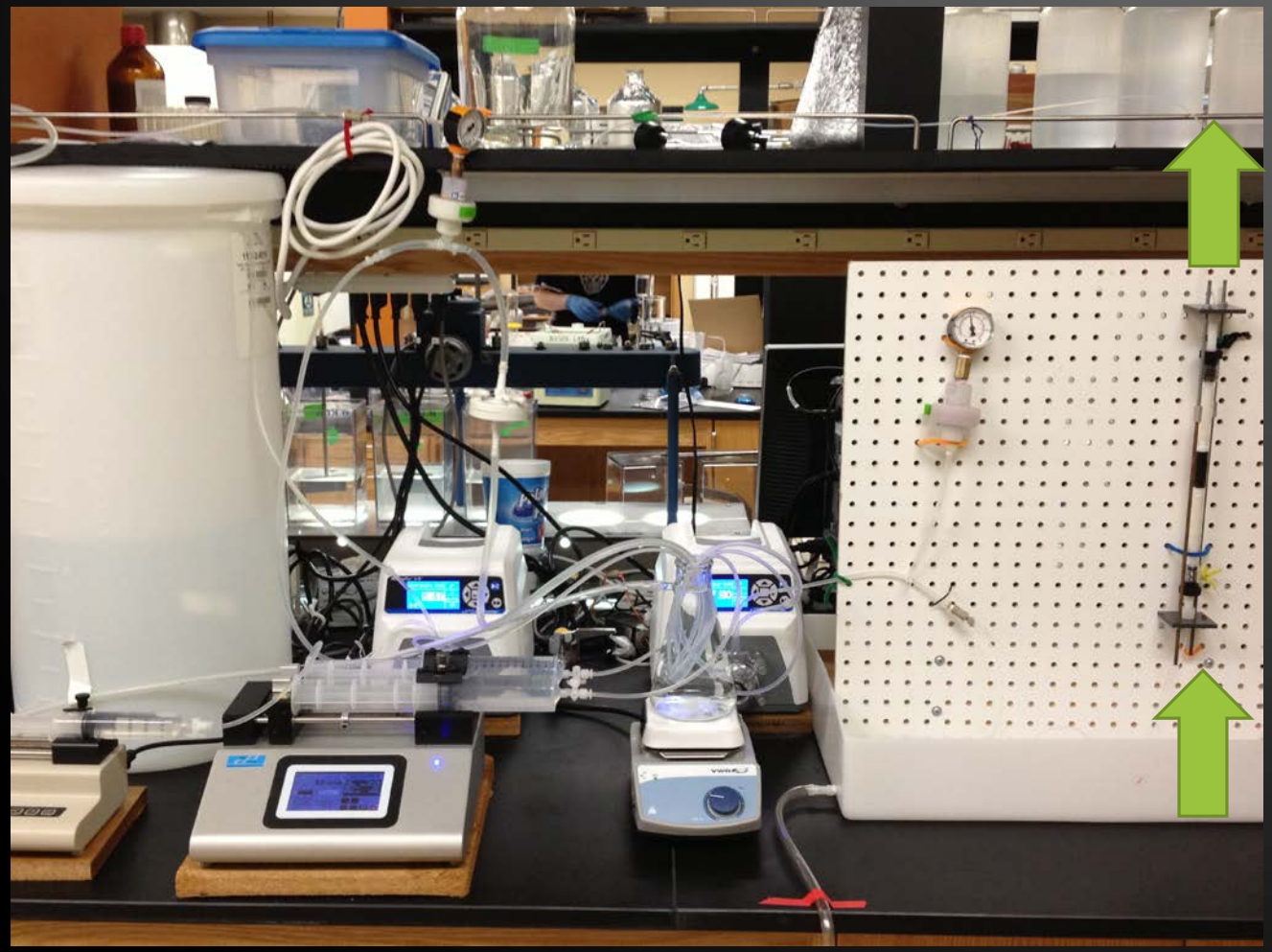


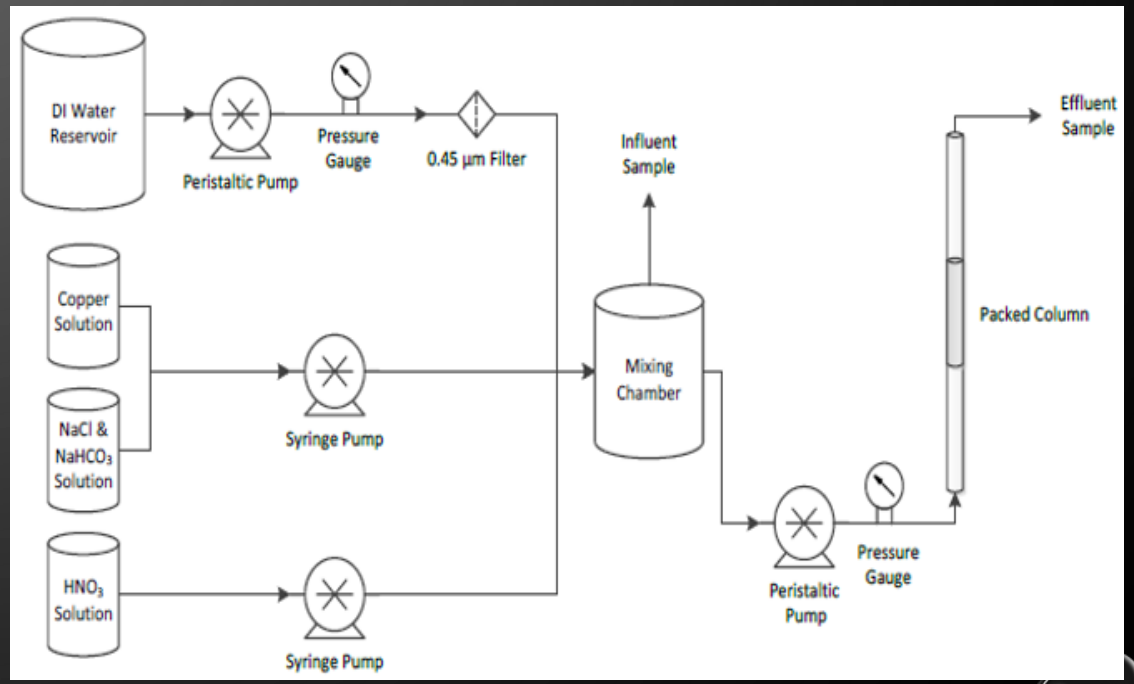


COMPARISON TO GRANULAR ACTIVATED CARBON (GAC)

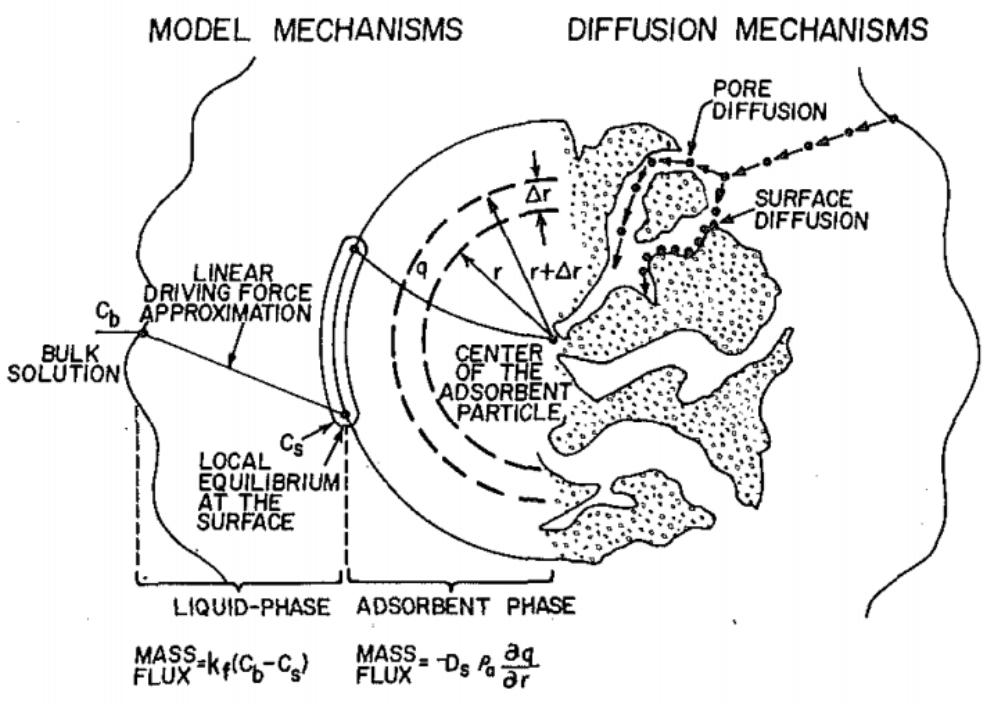


COLUMN EXPERIMENTAL SETUP

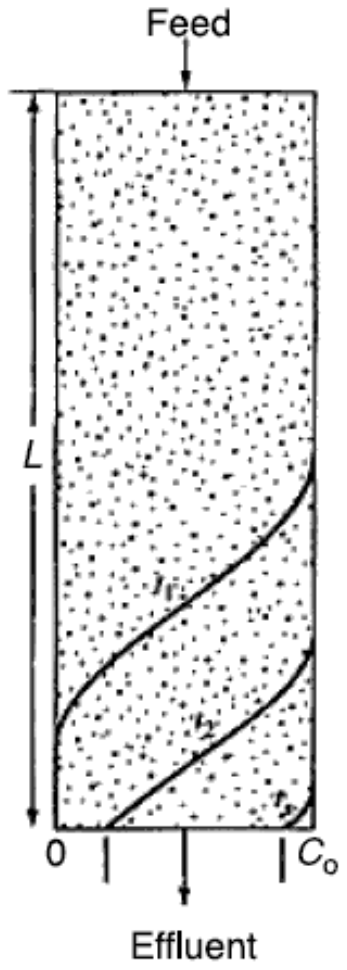


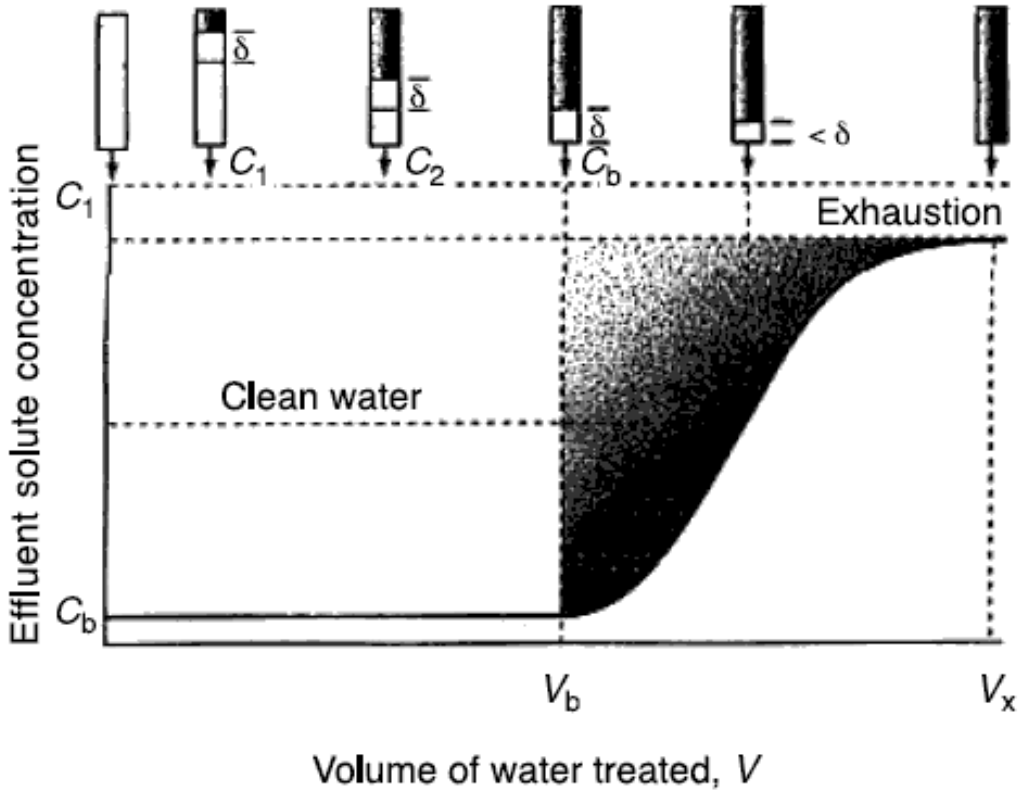


EVALUATING TRANSPORT PROCESSES

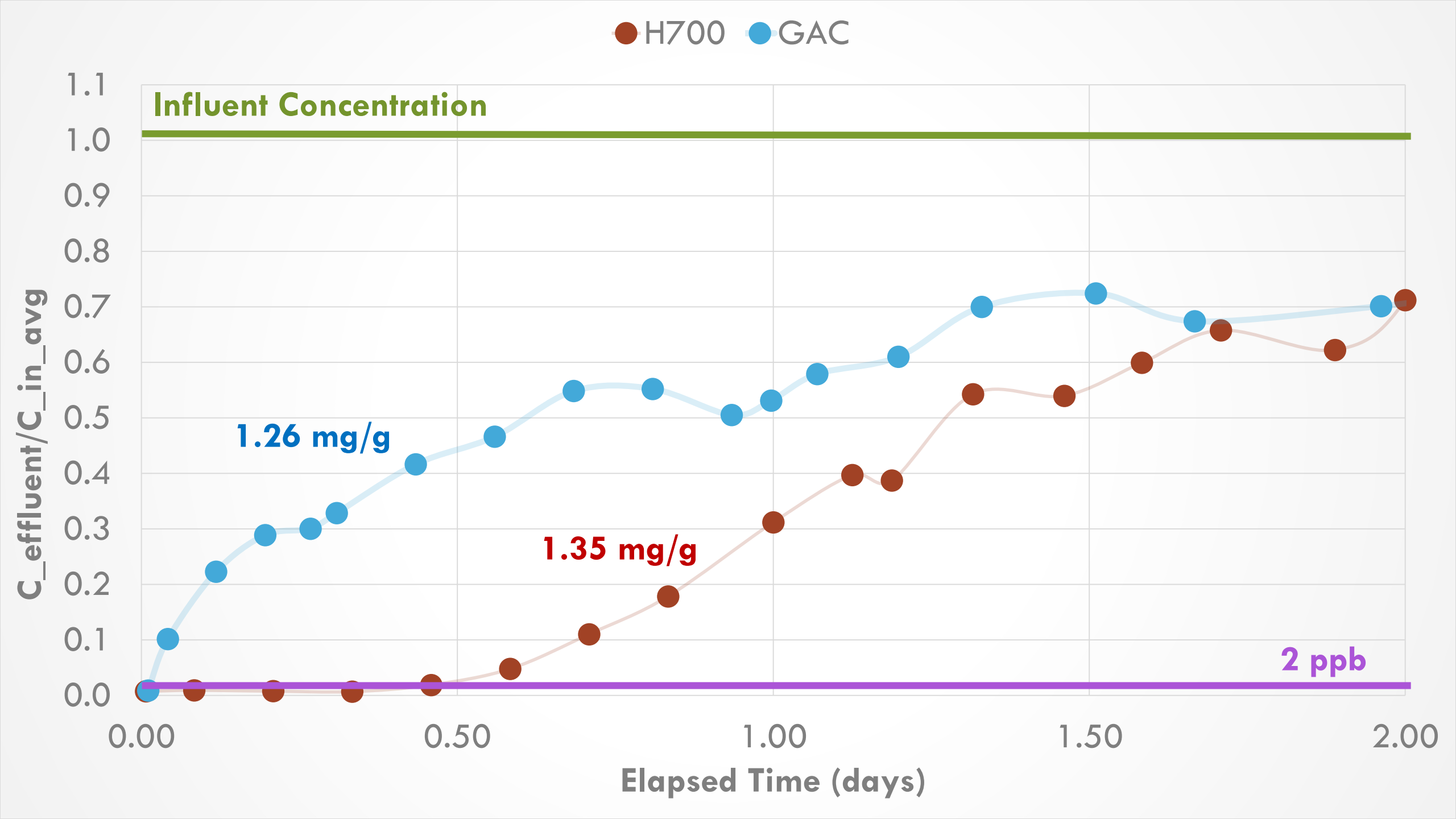


Hand, et. al. 1983

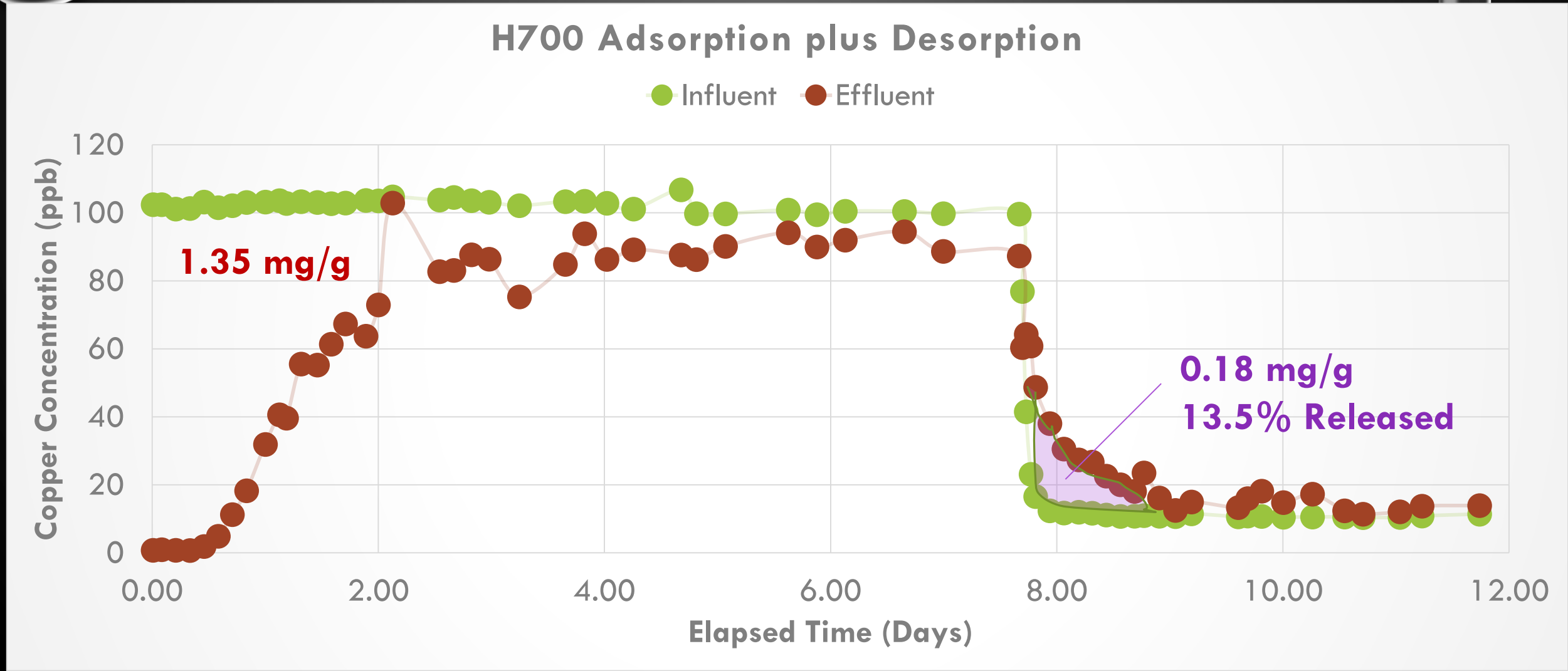




http://web.deu.edu.tr/atiksu/ana07/arit4.html


H700
GAC
Influent Concentration
1.26 mg/g
1.35 mg/g
2 ppb
C_effluent/C_in_avg
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.50
1.00
1.50
2.00
Elapsed Time (days)

POTENTIAL FOR RELEASE OF ADSORBED COPPER?



SURFACE COMPLEXATION MODELING

- INCORPORATES BOTH CHEMICAL BONDING (SURFACE) AND ELECTROSTATIC INTERACTIONS (SOLUTION)

$$\Delta G_{adsorption} = \Delta G_{intrinsic} + \Delta G_{coulombic}$$

$$K_{ads} = K_{int} * K_{coul}$$

- DIFFERING PH, IONIC STRENGTH, METAL LOADINGS, AND COMPETITION WITH OTHER IONS
- USED TO ACCURATELY PREDICT HEAVY METALS SORPTION FOR VARYING CONDITIONS ONTO:
  - HYDROUS FERRIC OXIDE, CALCITE
  - ALUMINUM OXIDE, MANGANESE DIOXIDE
  - GRANULAR ACTIVATED
  - NATURAL ORGANIC MATTER
- APPLICABLE TO BIOCHAR BASED ON IMPORTANCE OF SURFACE FUNCTIONAL GROUPS IN METALS REMOVAL

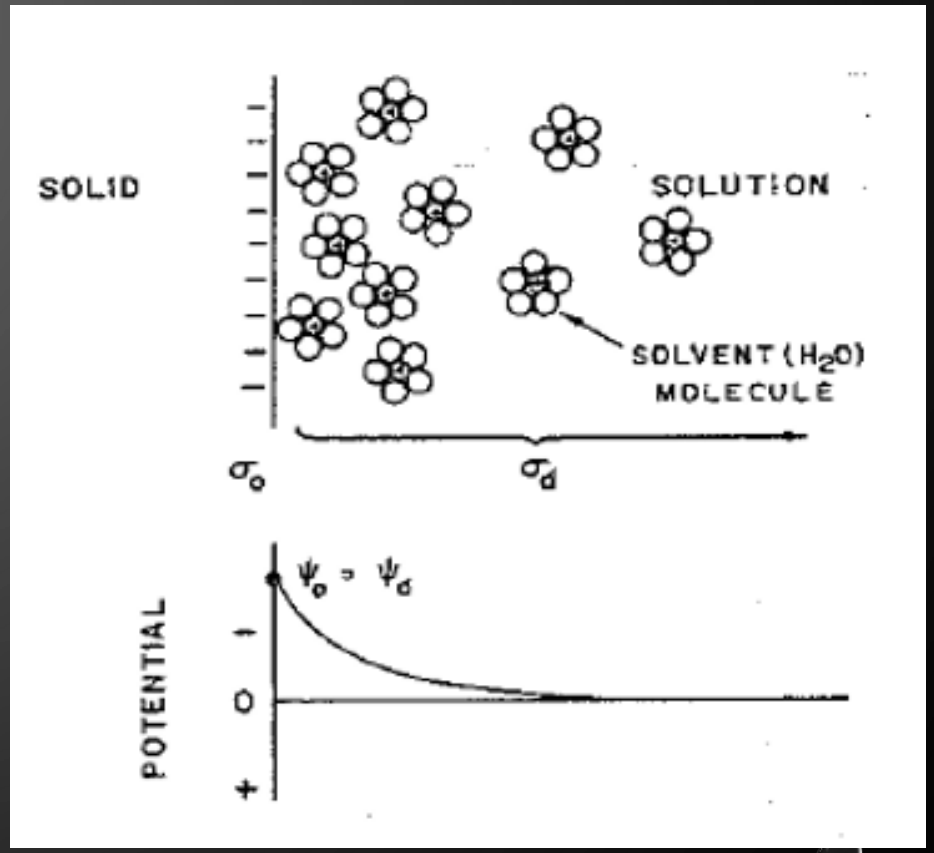
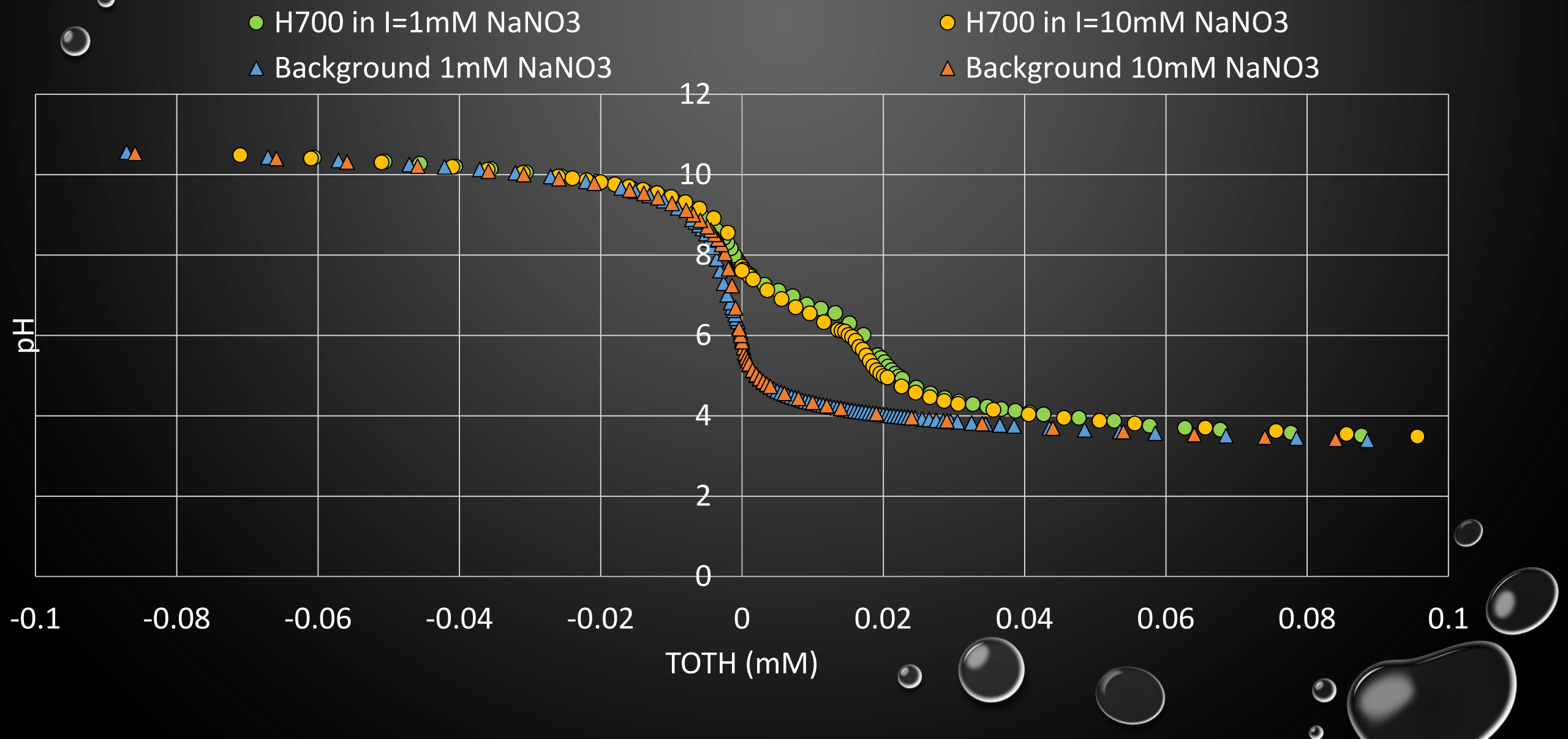
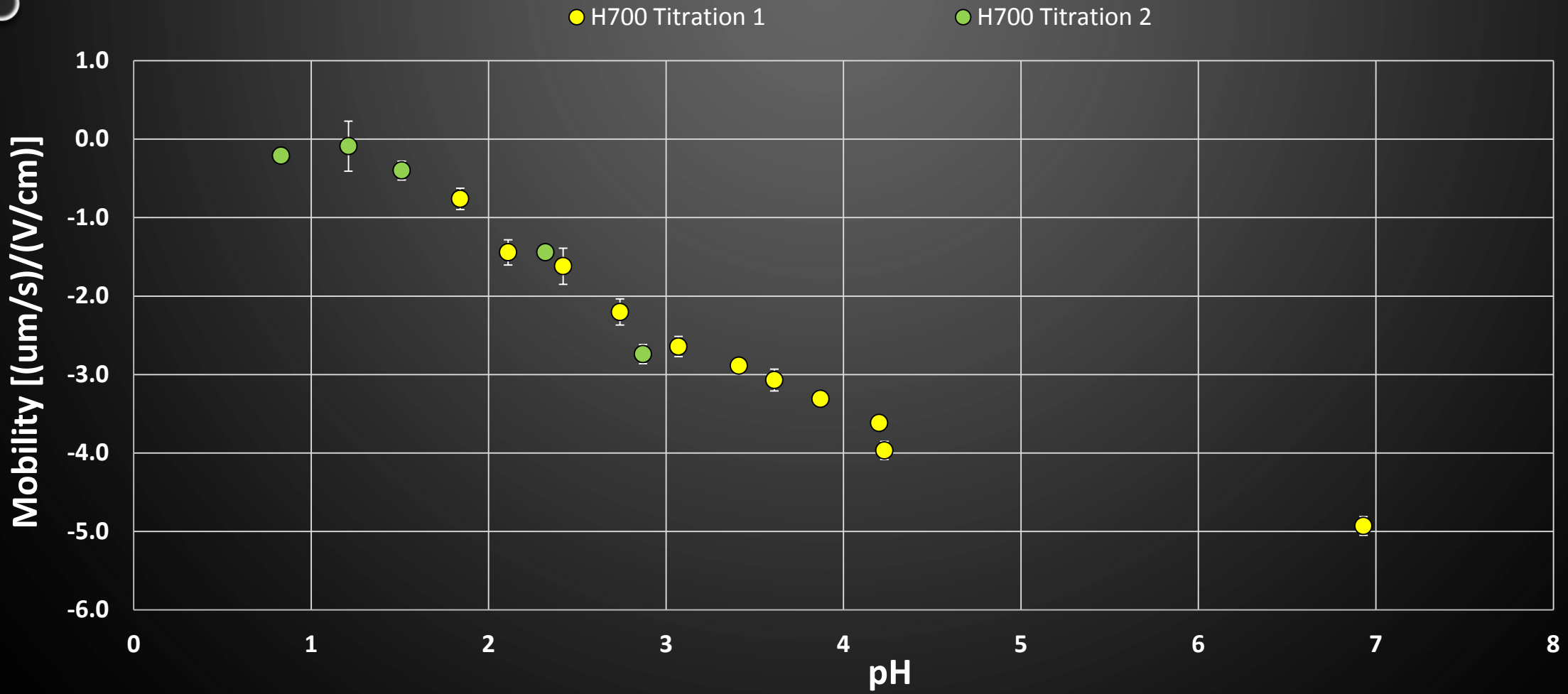


Figure: Schematic Representation of EDL Structure according to Gouy-Chapman [Dzombak and Morel, 1987]

PROTON ADSORPTION

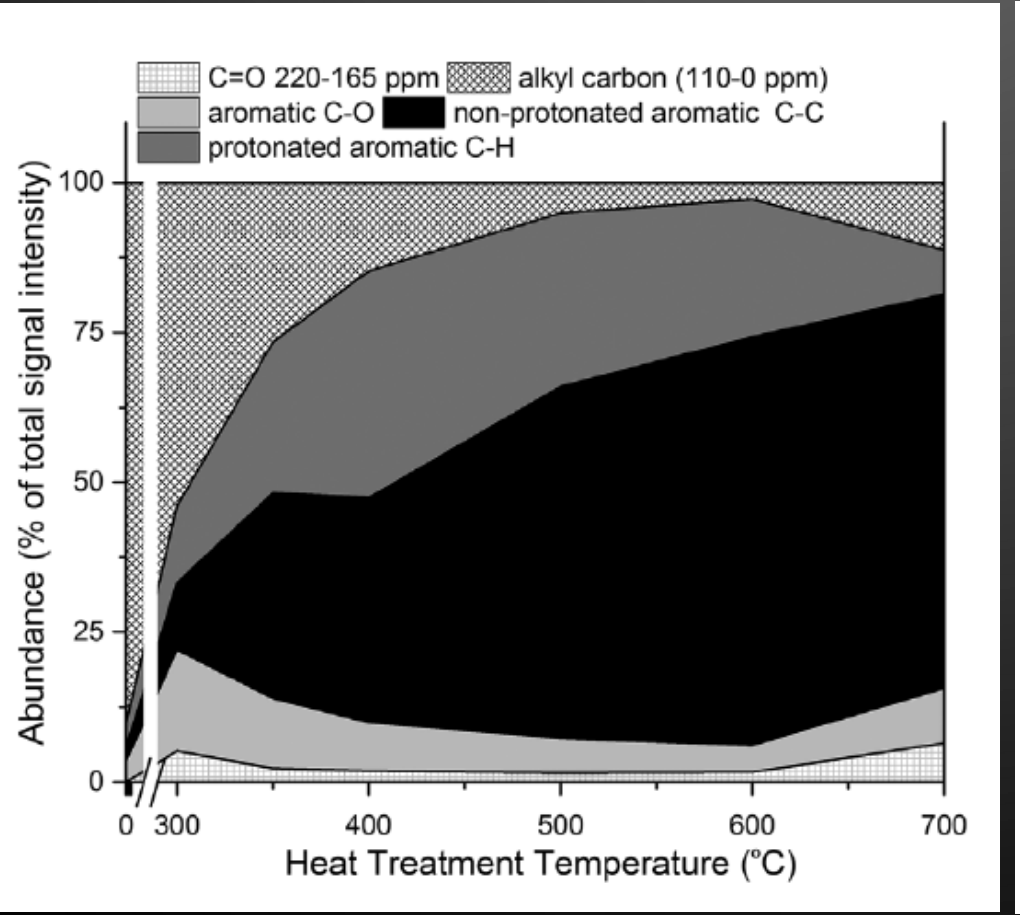


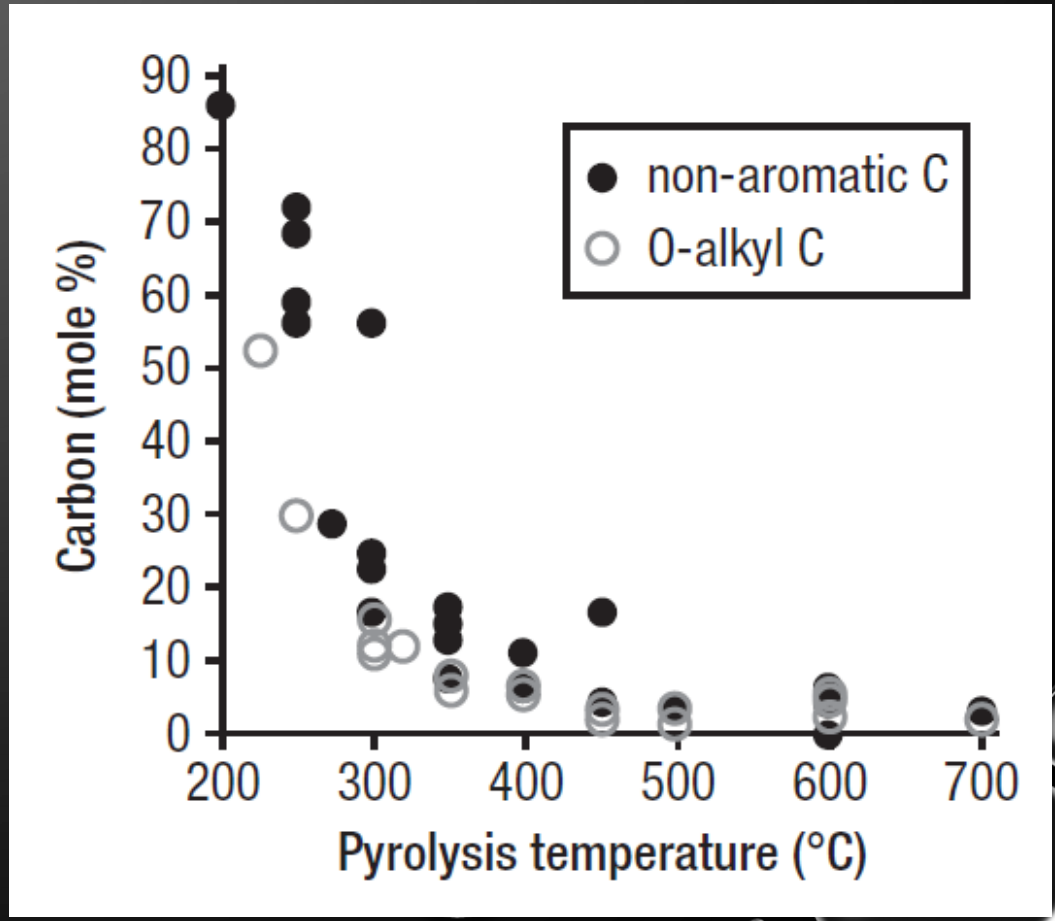
ELECTROPHORETIC MOBILITY (EPM) TITRATION



WORKING HYPOTHESIS

- AROMATIC C-C RINGS ARE MOST EFFECTIVE IN REMOVING DISSOLVED COPPER FROM AQUEOUS SOLUTION
  - THROUGH SURFACE COMPLEXATION MECHANISM OCCURRING IN DISTRIBUTED PI-BONDED ELECTRONEGATIVE FIELDS.

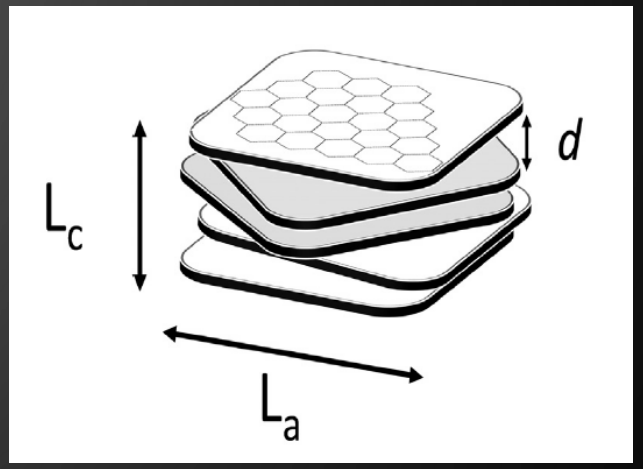




Kleber et al, 2014

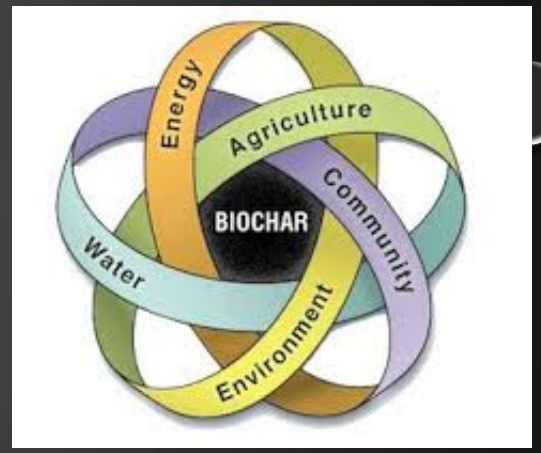
FUTURE WORK

- ADDITIONAL FTIR TESTING – BETTER DEFINITION OF FUNCTIONAL GROUPS
- X-RAY DIFFRACTION (XRD) – INVESTIGATE STRUCTURE
- C-13 NMR SPECTROSCOPY – ESTIMATE AROMATIC DOMAIN
- NEAR-EDGE X-RAY ADSORPTION FINE STRUCTURE (NEXAFS) – AROMATIC DOMAIN
- CHNO ANALYSIS – DEFINE ELEMENTAL COMPETITION, ESTIMATE AROMATICITY
- COLLECTED STORMWATER COLUMN STUDIES – INVESTIGATE ENVIRONMENTAL APPLICATION

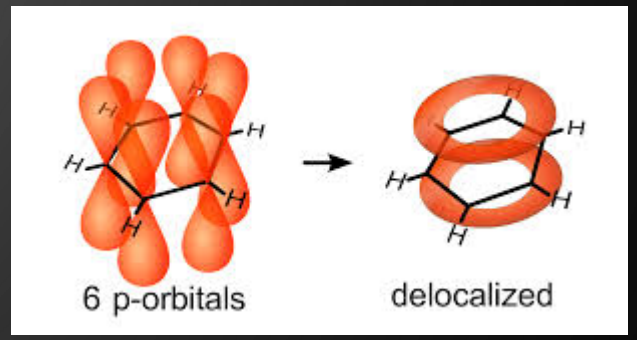


Kleber et al, 2014

CONCLUSIONS



- BIOCHAR EXCEEDS PERFORMANCE IN COPPER REMOVAL OF INDUSTRY STANDARD, GAC, IN BATCH AND FIXED-BED COLUMN EXPERIMENTS.



- MECHANISM FOR REMOVAL NEEDS TO BE EVALUATED TO OPTIMIZE PRODUCTION CONDITIONS.
- BIOCHAR HAS POTENTIAL TO ADVANCE SUSTAINABILITY THROUGH MULTIPLE SYSTEM BENEFITS.

ACKNOWLEDGEMENTS

- Jeff Nason, Oregon State University- PhD Advisor
- Markus Kleber, Todd Jarvis, Meghna Babbar-Sebens, David Myrold – PhD committee
- Mark Johnson, EPA- Biochar Production and Characterization assistance
- Joy-Marie Gerould, Oregon State University – Undergraduate Researcher, Batch experiments and preliminary characterization
- Nason Lab Group – shared laboratory equipment, skills, and knowledge

QUESTIONS: BURCHSA@OREGONSTATE.EDU