



Water soluble lignin and aqueous based applications

Pedram Fatehi, PhD, P. Eng.
Associate Professor
Canada Research Chair (Tier II)
Industrial Research Chair
Chemical Engineering Department



- Lack of knowledge
- Lack of courage

Vision

- Make lignin lab a global center of lignin R & D
- Be a part of commercialization of lignin globally
- Be a training hub for lignin experts
- Open to collaboration at different levels

Facts

- Lakehead U does not cover student's expenses (\$ 35,000/year)

Flocculant applications

- Water and wastewater purification
 - Municipal and industrial
- Tailing waste
 - Oil sand and mining
- Mining industry; thickeners/clarifiers



Challenges

- ❖ A large volume of flocculants in use
 - ❑ Inorganic coagulants (e.g., Alum)
 - High dosage
 - Sludge production
 - ❑ Synthetic flocculants
 - Expensive
 - Ineffective
 - Oil based
 - ❑ Polyacrylamide based
 - Sales in 2013: \$3.95 billion (USD)
 - Sales in 2019: \$6.91 billion (USD)

Dispersants

□ Applications

- Water based paints and stains
- Froth flotation of the mining industry
- Construction industry; water reducing agent in concrete admixtures
- Textile industry; dye dispersion
- Coal/water slurry
- Ceramic industry; clay suspension



Dispersants

❑ Current chemicals

- Polyacrylic acid, poly methacrylic acid, poly phosphates
- Sodium naphthalene

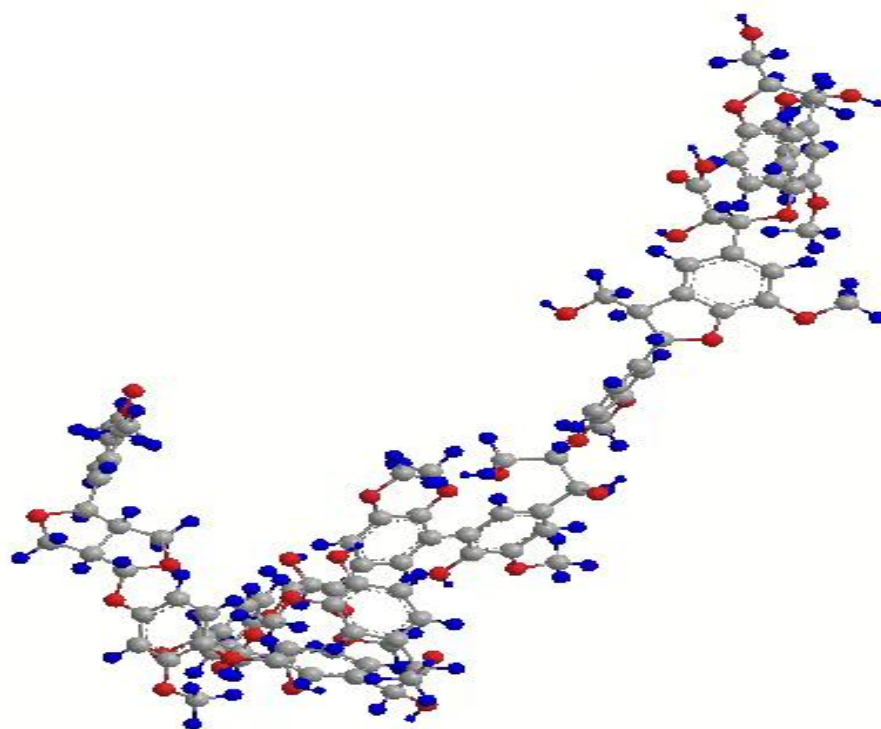
❑ Status

- Expensive
- Oil based

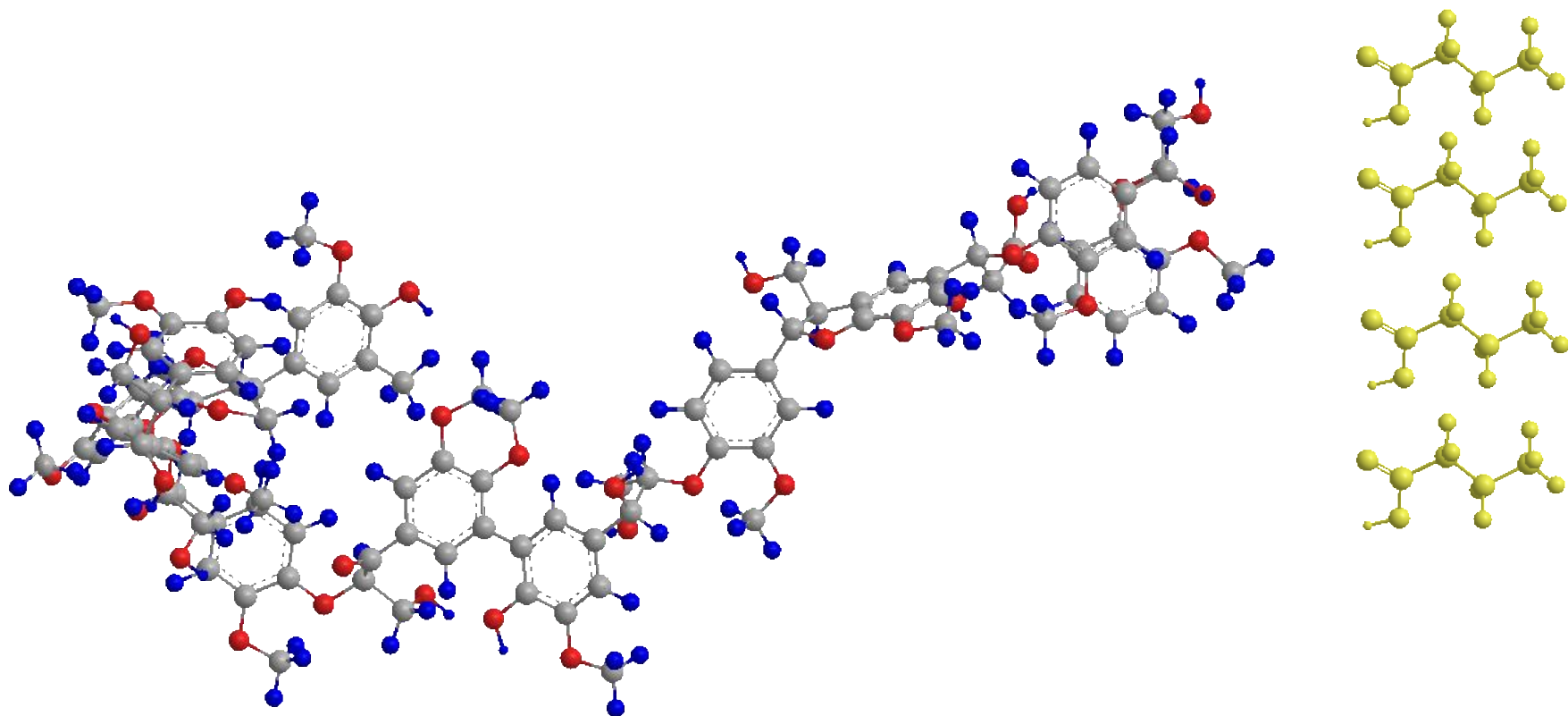


Other applications

- Multifunctional lignin-based films
- Functional nano-lignin
- Corrosion inhibitors
- Adsorbents
- Hydrogels
- Aerogels
- Batteries
- Many more



Grafting reactions



Challenges

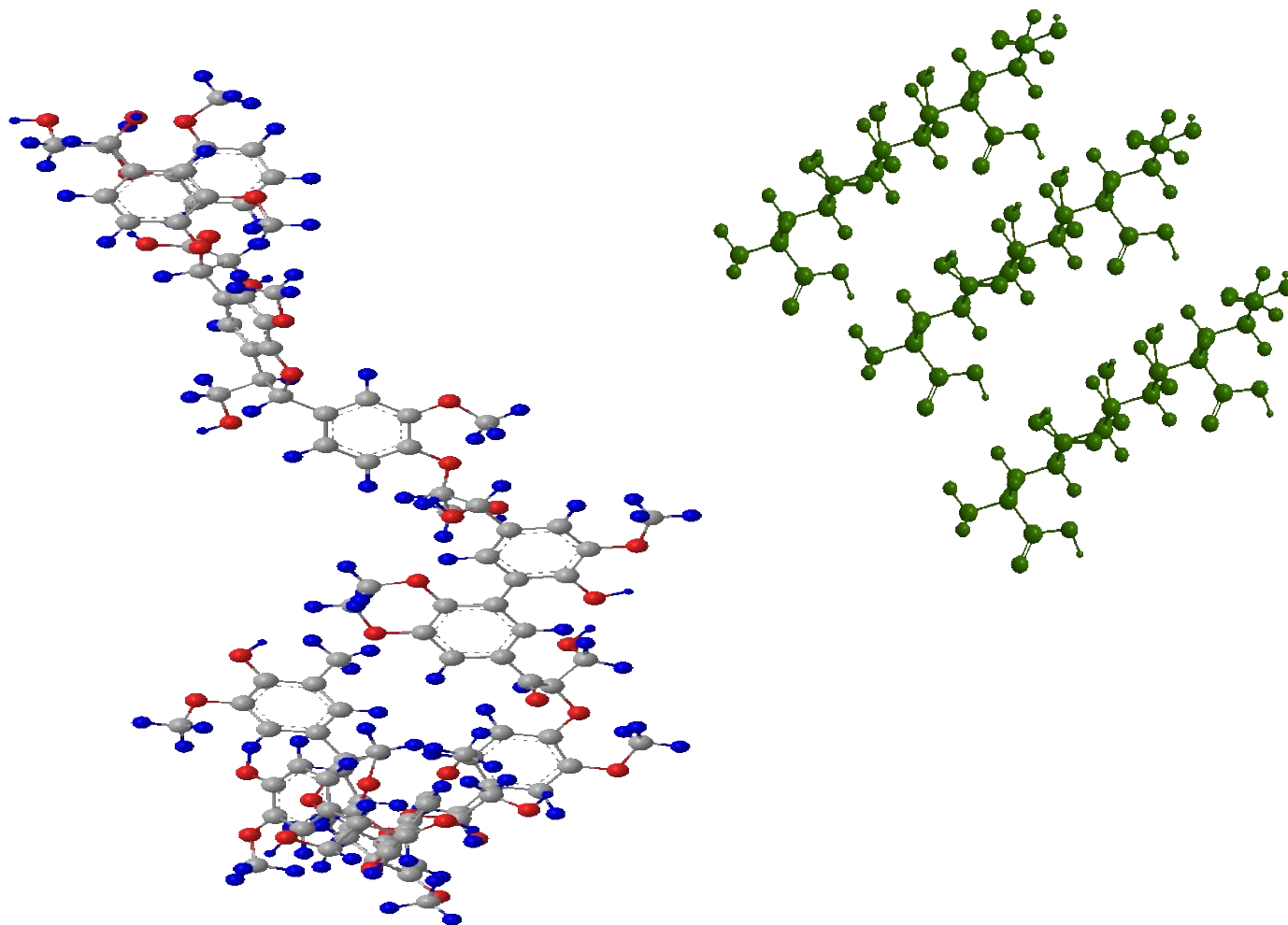
- Not all chemical sites may be available for reactions
- Physical or chemical constrains

Low to medium MW products for dispersant application

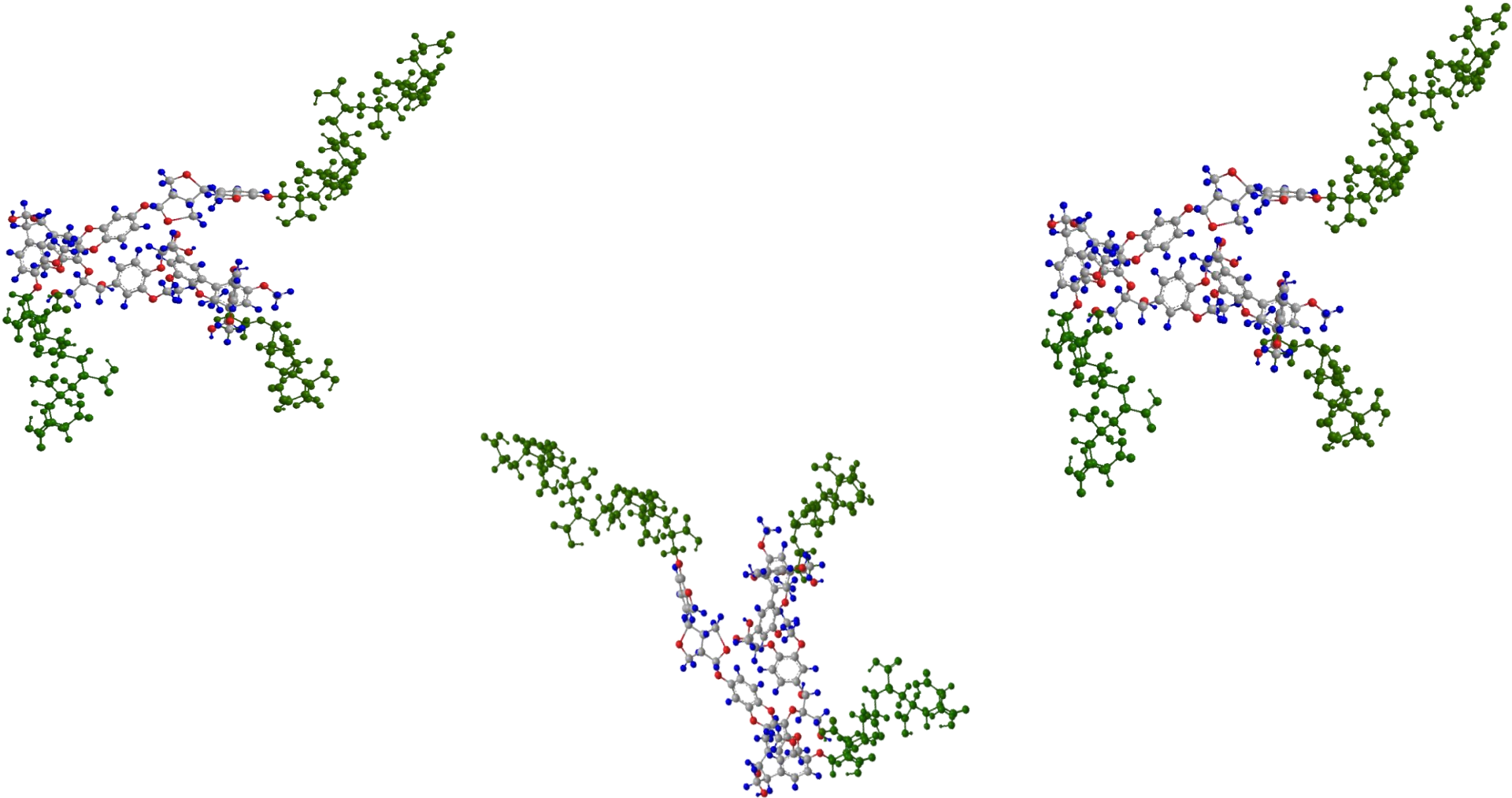
- Grafting in acidic, alkaline, aqueous and non aqueous systems (e.g., sulfoalkylation and carboxyalkylation)
- Oxidation (e.g., peroxide, periodate, nitric acid)
- More routes to come
- Suitable for pulping and chemical companies
- Low to medium MW (<50,000 g/mol)
- Highly charged product (up to almost 4 meq/g)
- Atmospheric, below 100 C
- Yield, complexity, solvent use, effectiveness, functionality, molecular design

Polymerization for flocculant productions

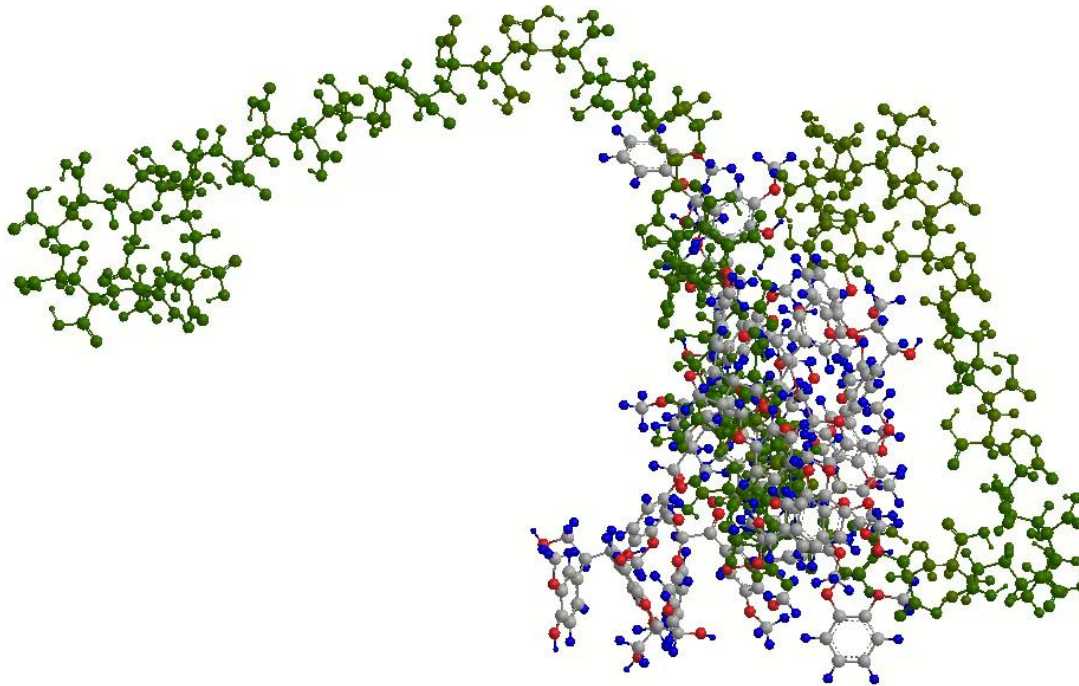
Polymerization



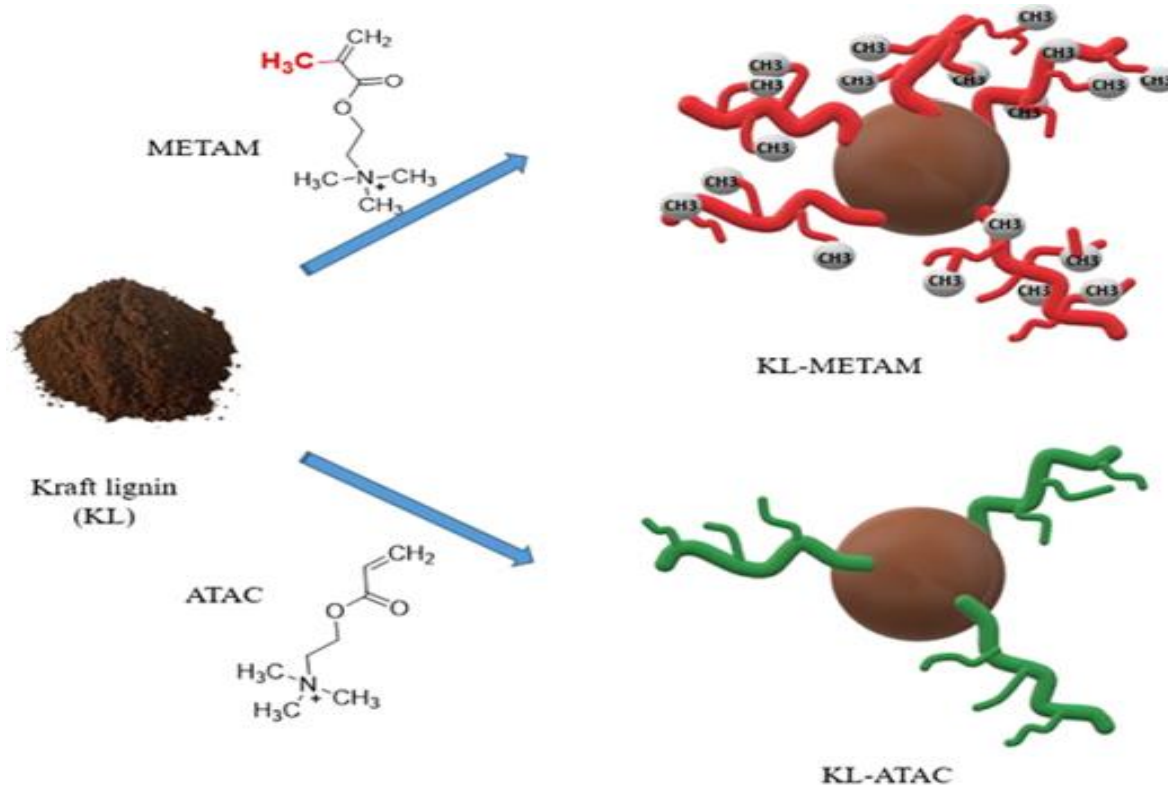
Polymerization



3-dimensional macromolecules with hydrophobic and hydrophilic features

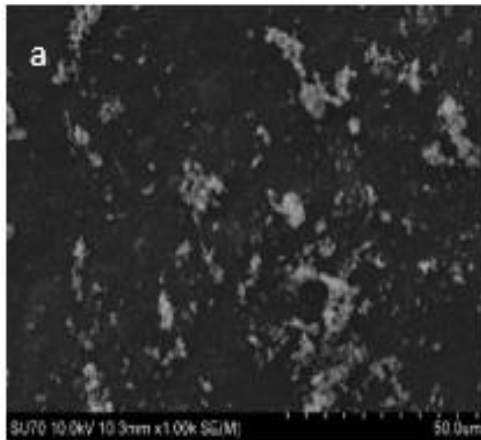


Design of polymers

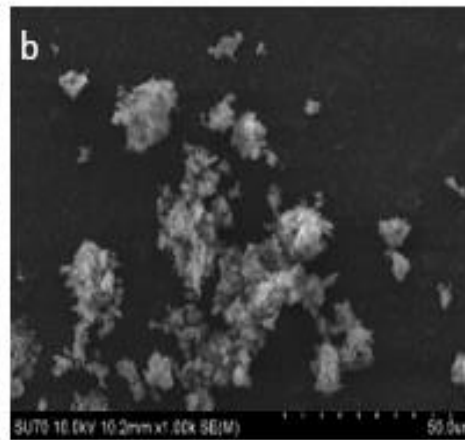


Kinetic of flocculation

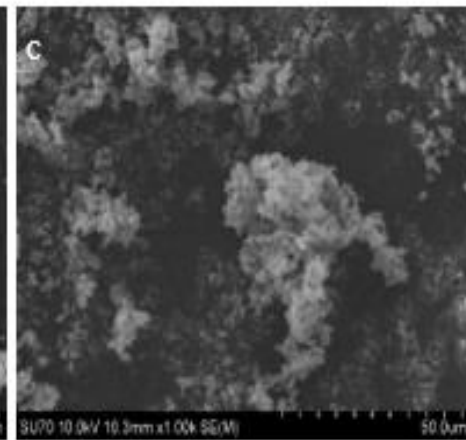
(a) kaolin



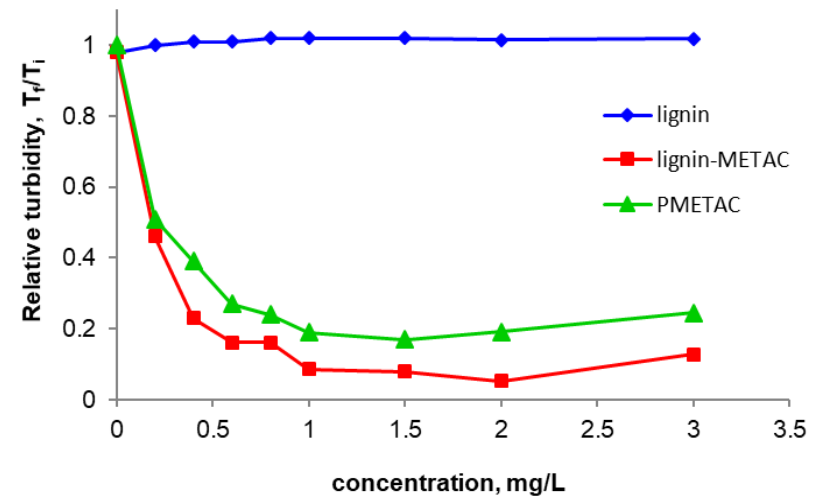
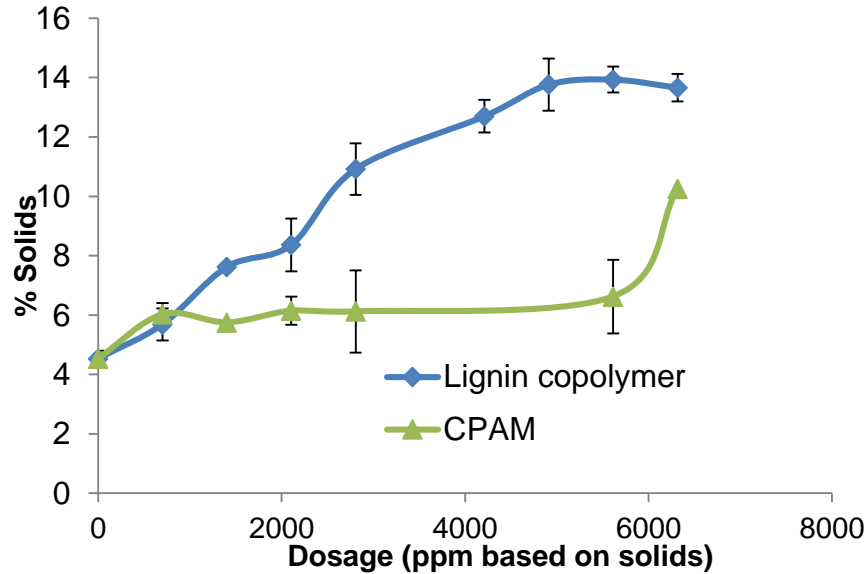
(b) kaolin/KL-ATAC



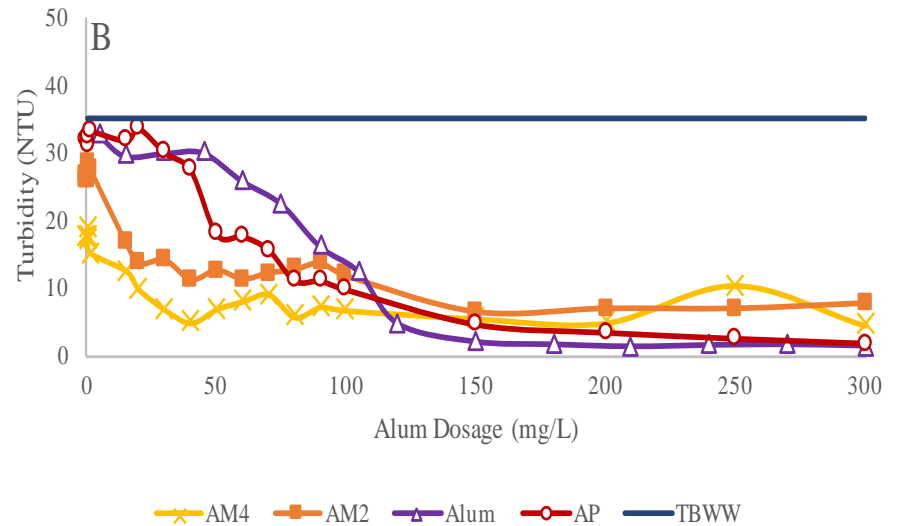
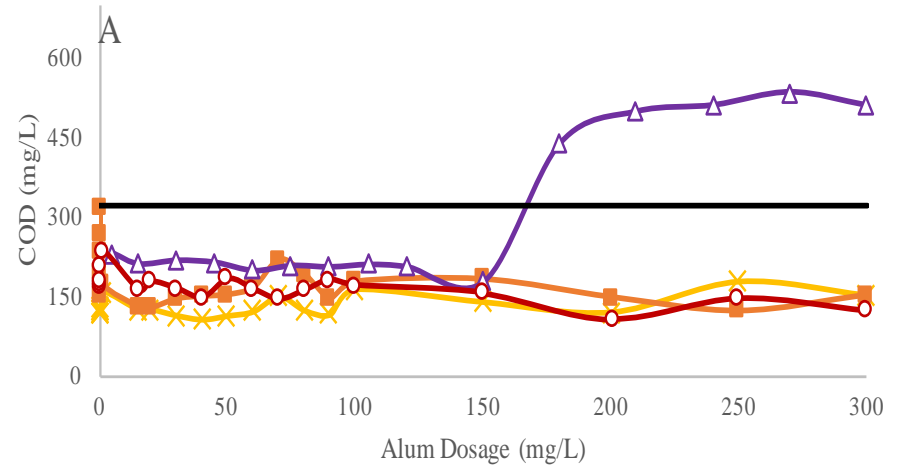
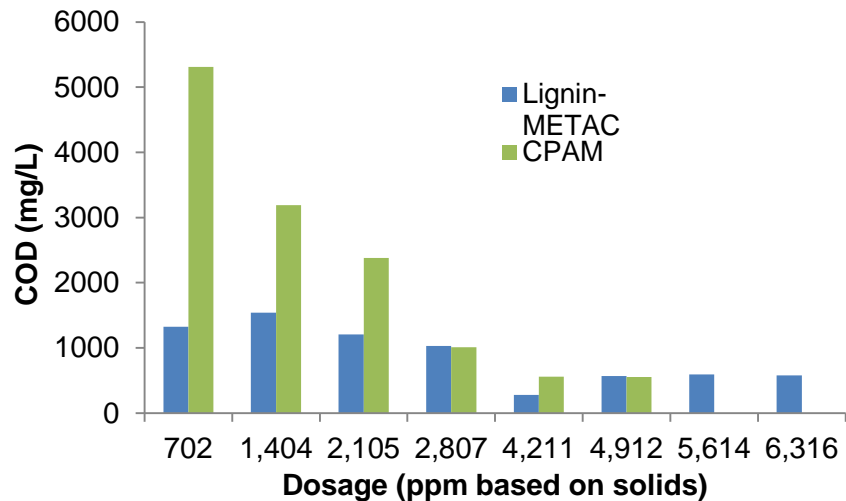
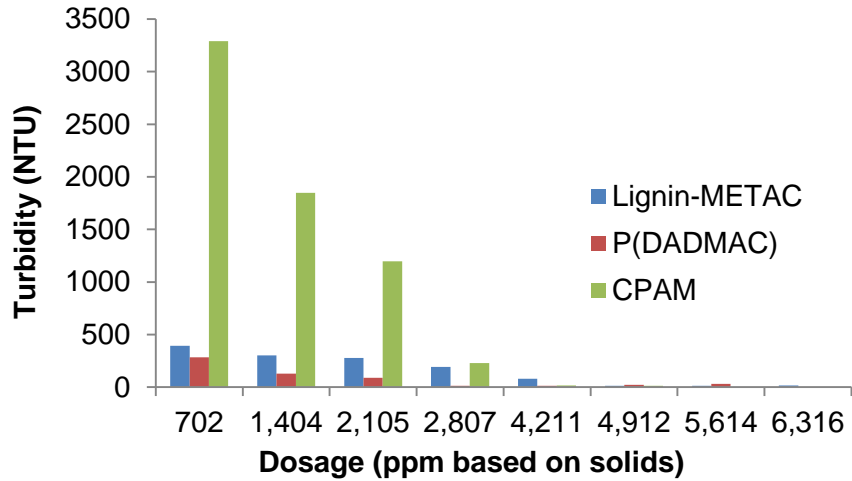
(c) kaolin-KL-METAM



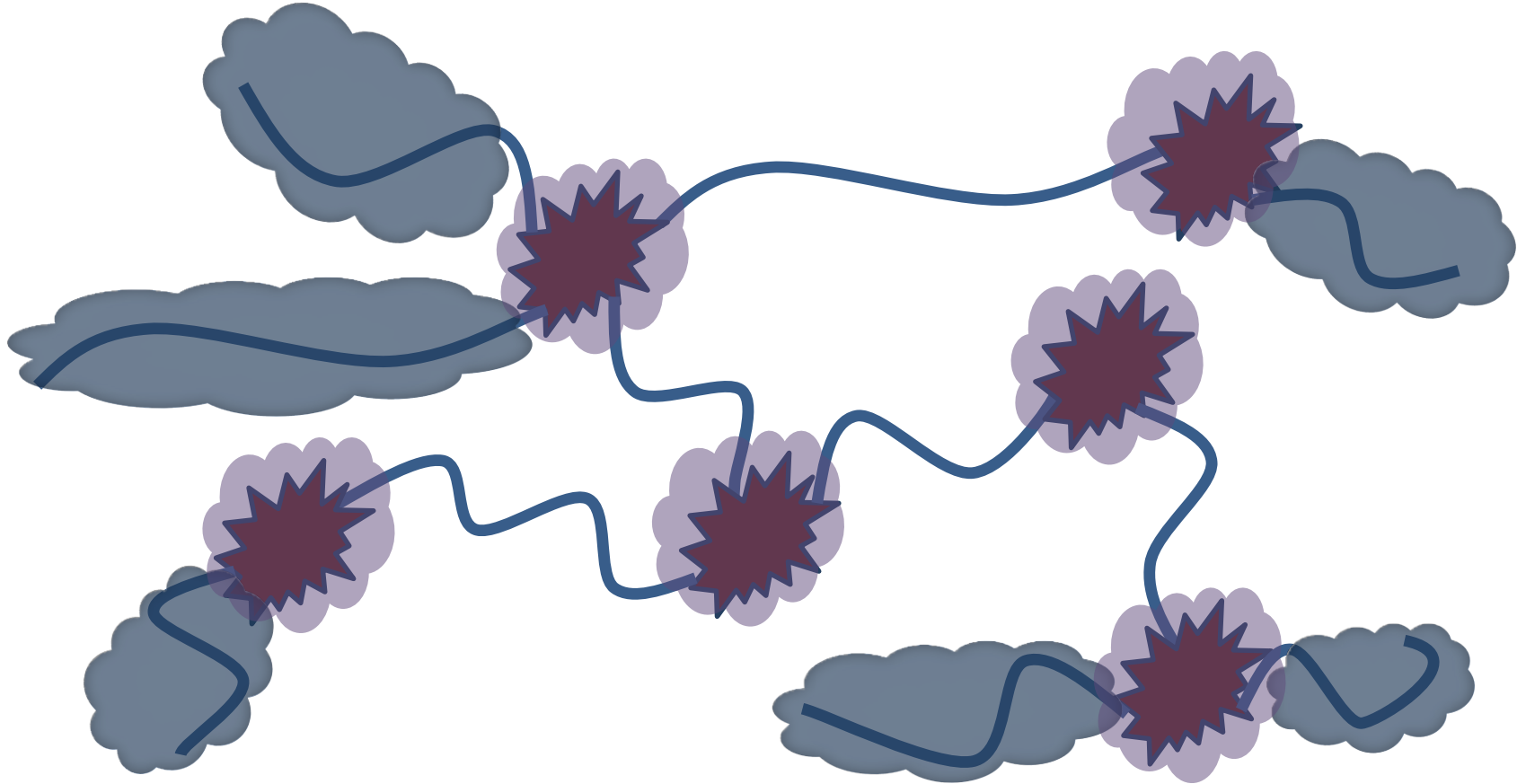
Lignin polymer application



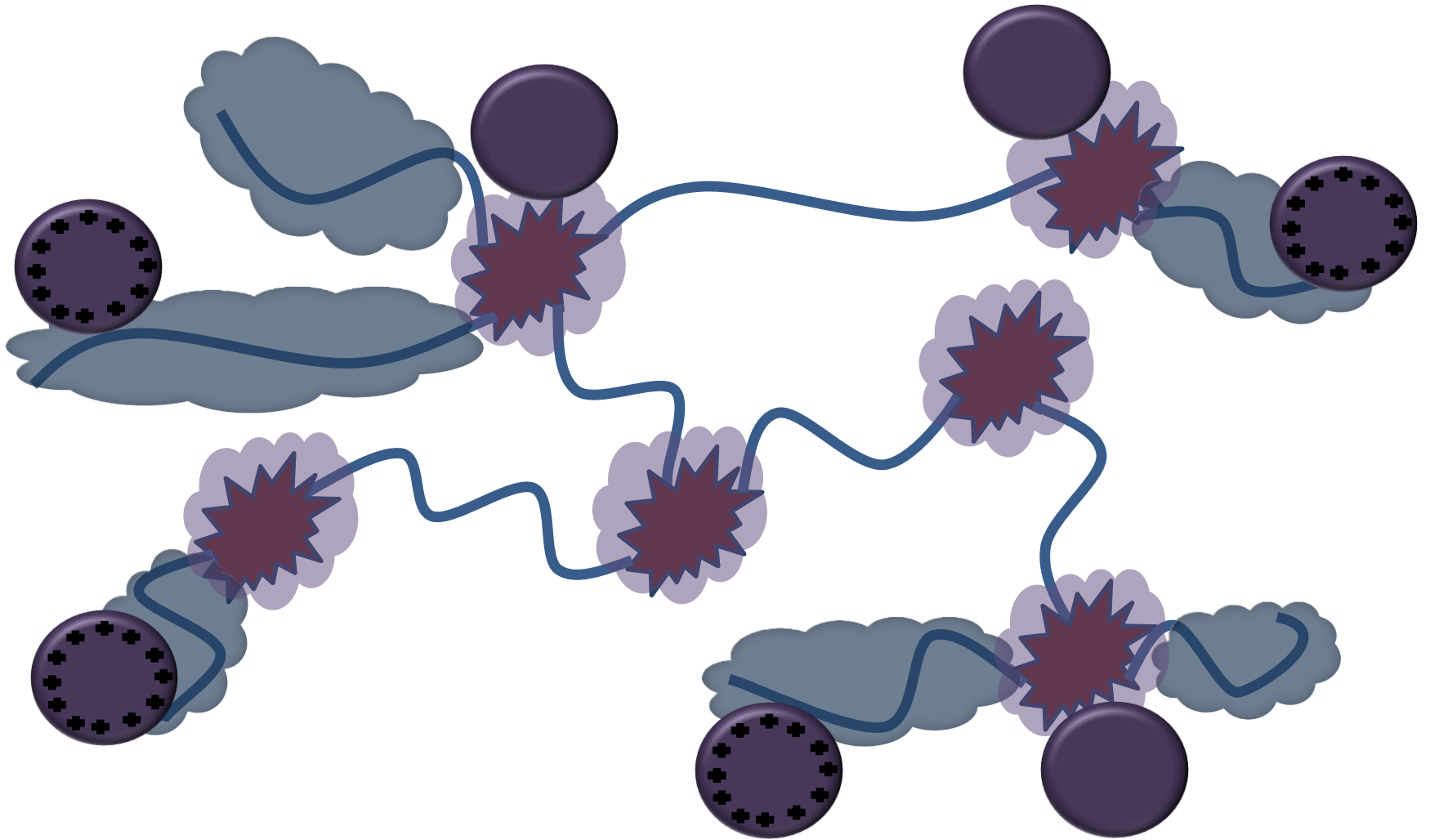
Application in wastewater effluents



Polymer network with hydrophobic/hydrophilic features

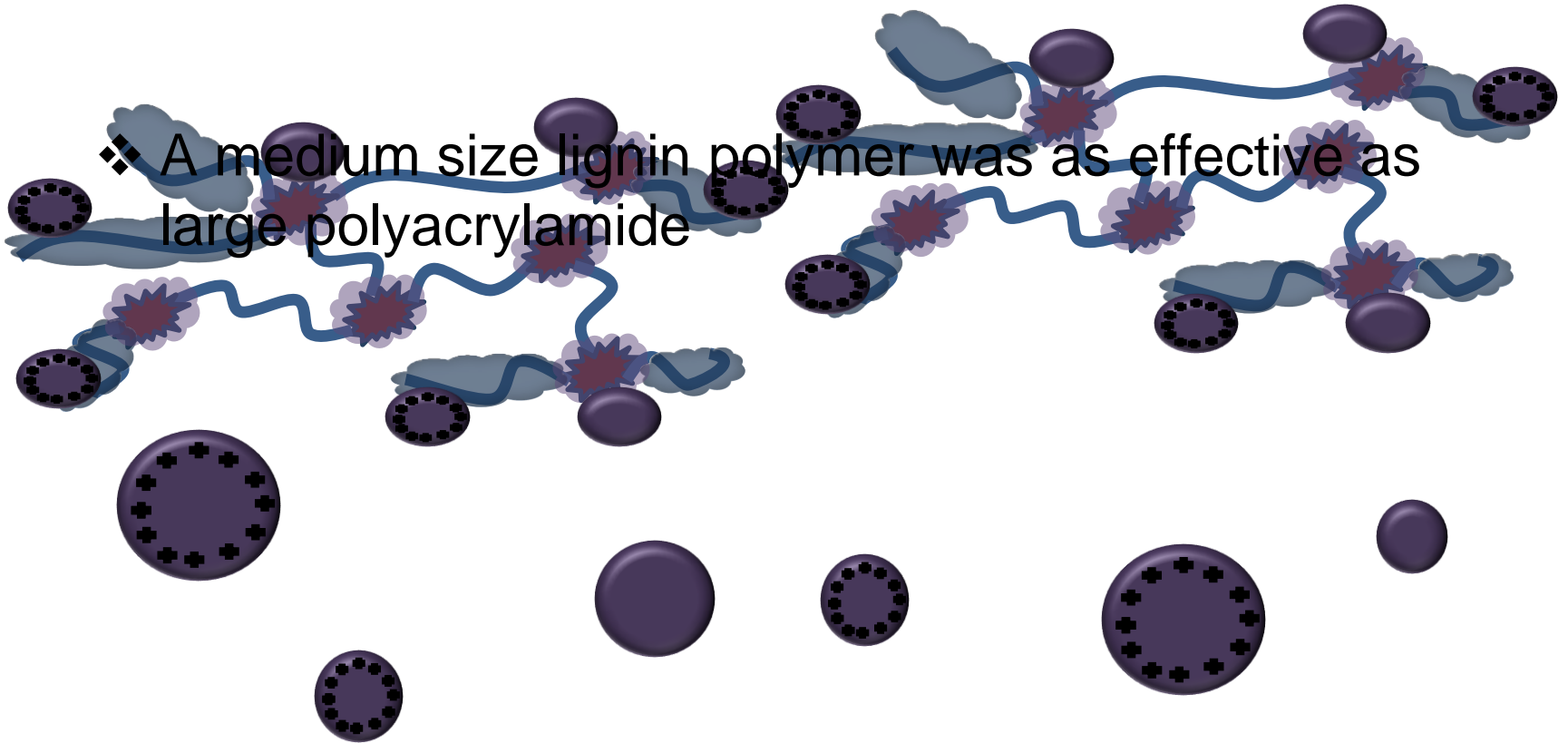






Blanket effect

- ❖ A medium size lignin polymer was as effective as large polyacrylamide

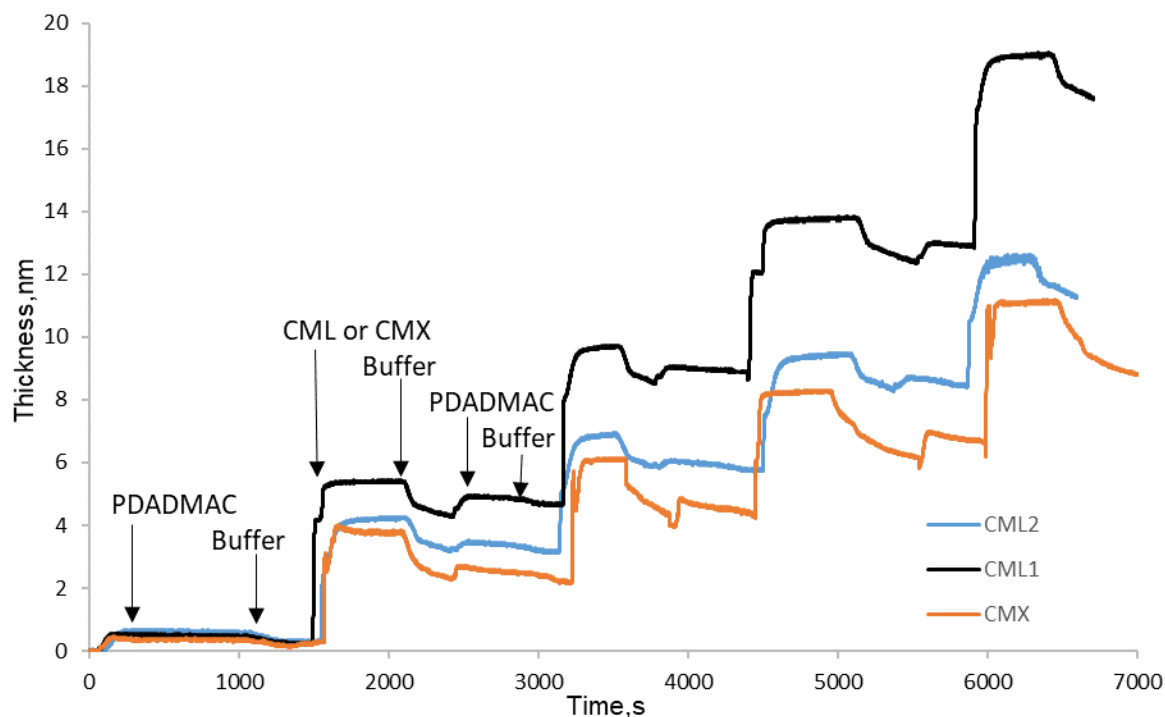


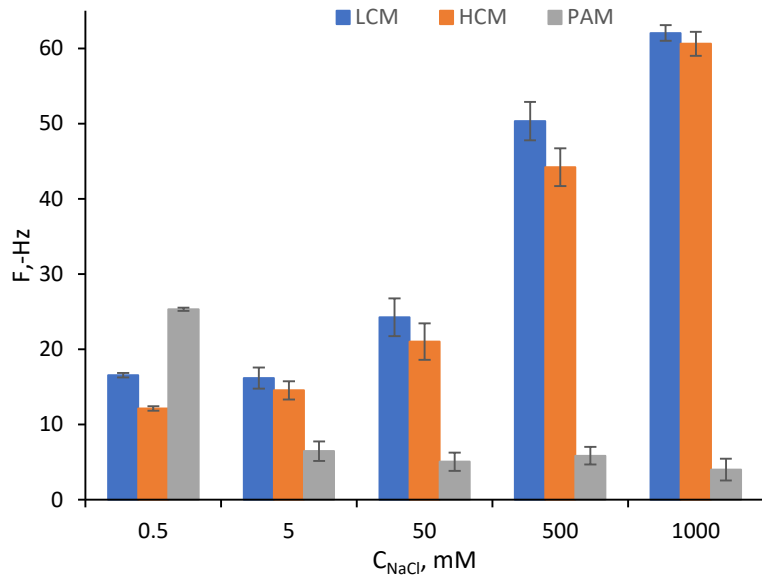
Opportunities

- Not just a green and biochemical
- Celebrate its features and functionality
- Can provide unique functionality in different applications
- 3-dimensional network
- Porous structure
- Particle size
- Bulkiness
- Multifunctional group
- Molecular weight 5-10 kg/mol

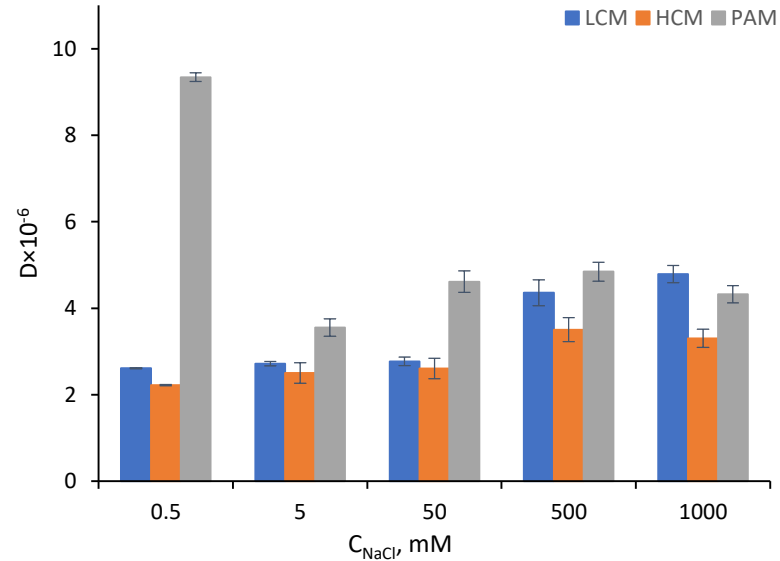
Adsorption Characteristics of Carboxymethylated Lignin on Rigid and Soft Surfaces Probed by Quartz Crystal Microbalance

Niloofar Alipoormazandarani and Pedram Fatehi*



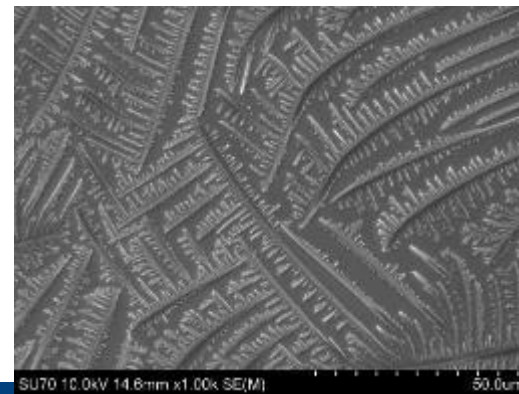
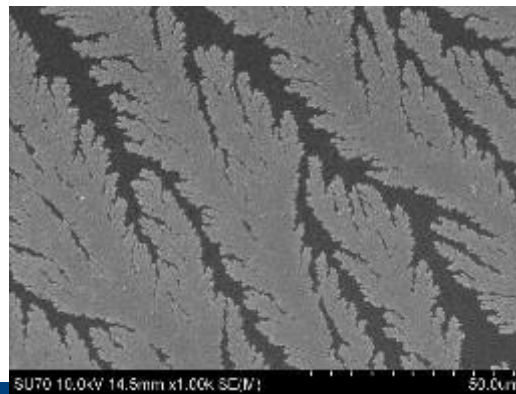
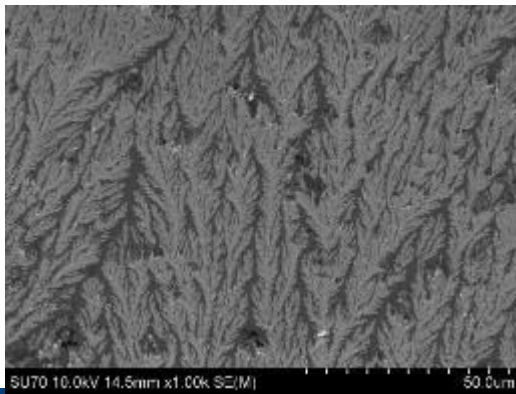


a) LCM



b) HCM

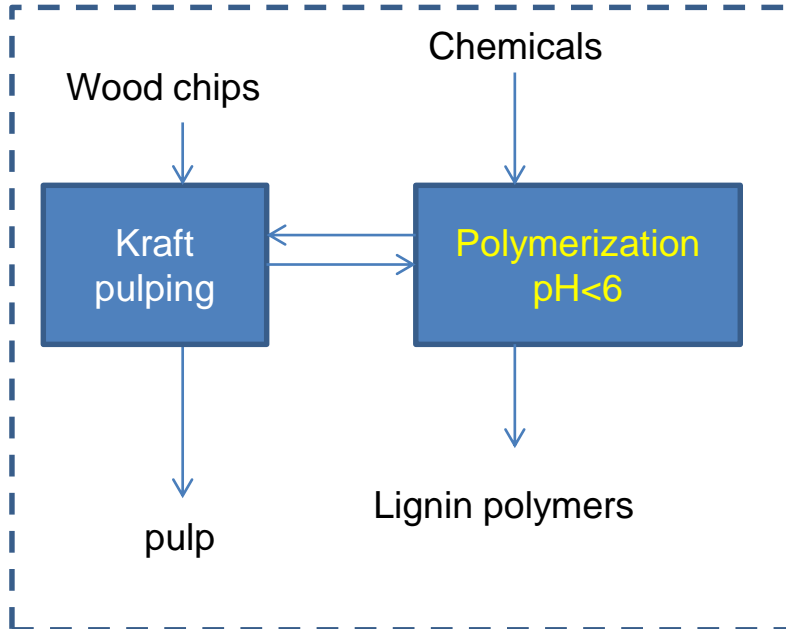
c) PAM



Commercialization strategies

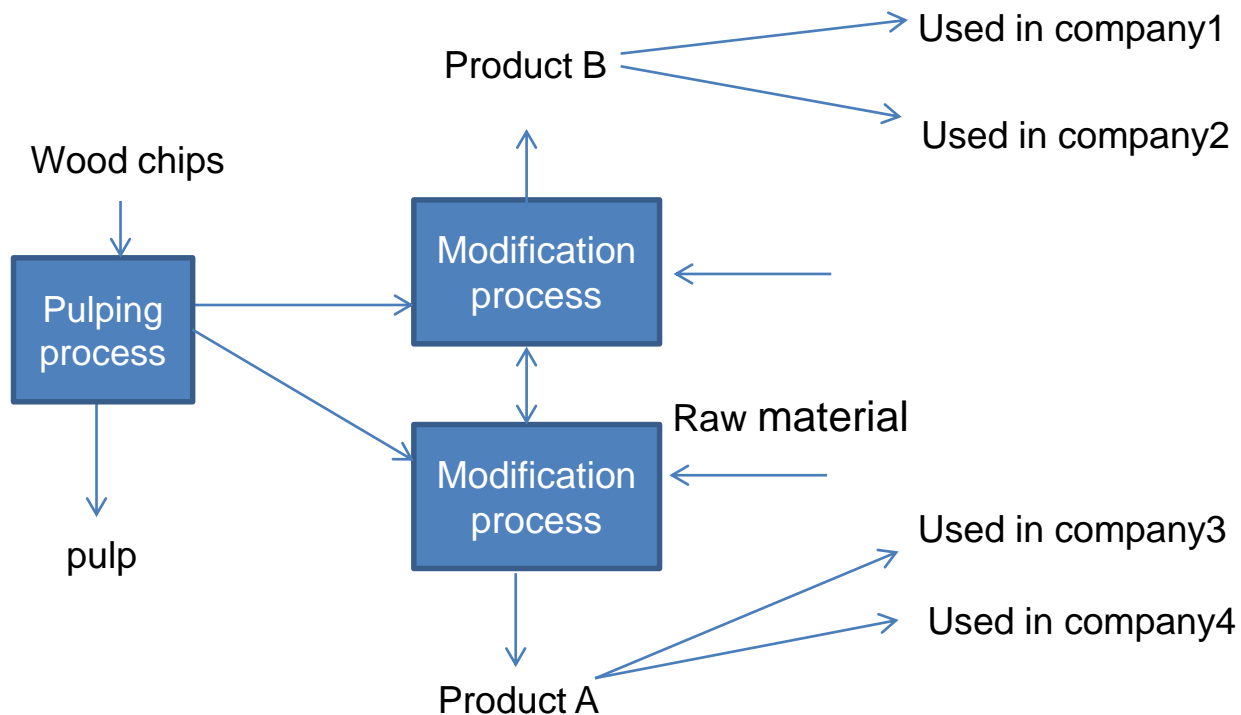
Lignin polymerization

- Lignin polymerization under **aqueous acidic environment**
- Suspension to start, solution to finish
- Inorganic elements are well in harmony with the chemistry of kraft process



- Many anionic, non ionic and cationic monomers
- Softwood, hardwood
- Kraft, alkali, hydrolysis, soda, lignosulfonate
- Many different sources
- **Concentration up to 50 wt.%**
- **65-75% lignin polymer**
- **Less than 5% monomer left**
- Minimum monomer use
- Maximum lignin use
- Minimize the price, maintain functionality

Production of value-added products for various customers



Future work

- ❑ **Fundamentals**

- ❑ Physicochemical properties
- ❑ Standard method development
- ❑ Reactivity factor

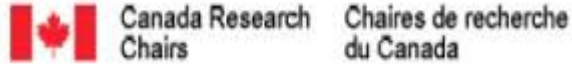
- ❑ **Applications**

- ❑ Performance-property correlations
- ❑ Formulation for different applications
- ❑ Water solubility vs hydrophobicity
- ❑ Should not underestimate the complexity of lignin molecules and reaction!

Impacts

- More than 170 papers
- More than 100 papers on lignin
- Many paper in top ranked journals and many featured articles
- Green Chemistry, ChemSusChem, Langmuir, Biomacromolecules, J. Colloid Interf. Sci.
- Many regional, provisional and national awards
- Hatch Innovation Award, 2019, Chemical Institute of Canada
- More than \$ 7 M research fund secured
- Largest, most equipped and productive lab on lignin in Canada (and probably in USA)
- More than 50 graduate students involved (more than 30 PhD)
- Member of NSERC evaluation group for Discovery grant application (equivalent of NSF in USA)
- Member of Canadian Standard association for developing methods to characterize lignin

Collaborations/sponsors



Canada Foundation for Innovation
Fondation canadienne pour l'innovation



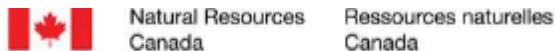
FPInnovations



AV Nackawic
Fibres from nature



NSERC
CRSNG



Canada



Ontario Centres of
Excellence





- Sell small scale modified lignin samples
 - Market analysis
 - Consultation and service
 - Formula development for different applications
- New Walmart or LignoSigma!



Thank you!