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Biochar: Product development in remote regions from mixed residues

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Pyrolysis research in forestry bioproducts at Cape Breton and Memorial University

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Chemistry: Bob Helleur (Professor), Stephanie MacQuarrie (Professor) Shofuir Rahman (post-doc), Andrew Carrier (post-doc)

Peter Fransham (Collaborator, ABRI-Tech Inc.)

Remote/Rural Challenges/Opportunities

- Feasibility of any biomass processing to bio productsis a function of location of feedstock, state of feedstock, available infrastructure, distance to market, and regional needs.
- Remote/rural operators (forestry, fisheries, mining) have a number of challenges when managing waste/residues:
  - Treatment/storage/disposal costs are high and management options limited
  - State of residues/waste (high moisture and cross contamination)
  - Transport of residues/wastes high in moisture is costly
  - Limited infrastructure on-site to process/treat waste
- The overarching objective behind this research is to develop and optimize biomass conversion systems (from pretreatment to product) based on above factors.

Current Projects in Biorefining

Shellfish and waste fish oil

Forestry residues (bark, sawdust, shavings)

↓

Pyrolysis (lab and auger reactor)

Biochar ←

- Adsorbent development
- Development of catalysts
- Speciality soil ammendments

→ ***Bio-oil***

- Extraction of value added chemicals
- biofuel for fuel cells
- Fuel quality and blending

Biochar Production

Lab scale 2-5 g
$250<T<600^{o}C$
Solids residence time >30 min
Gas residence time 5-30 s

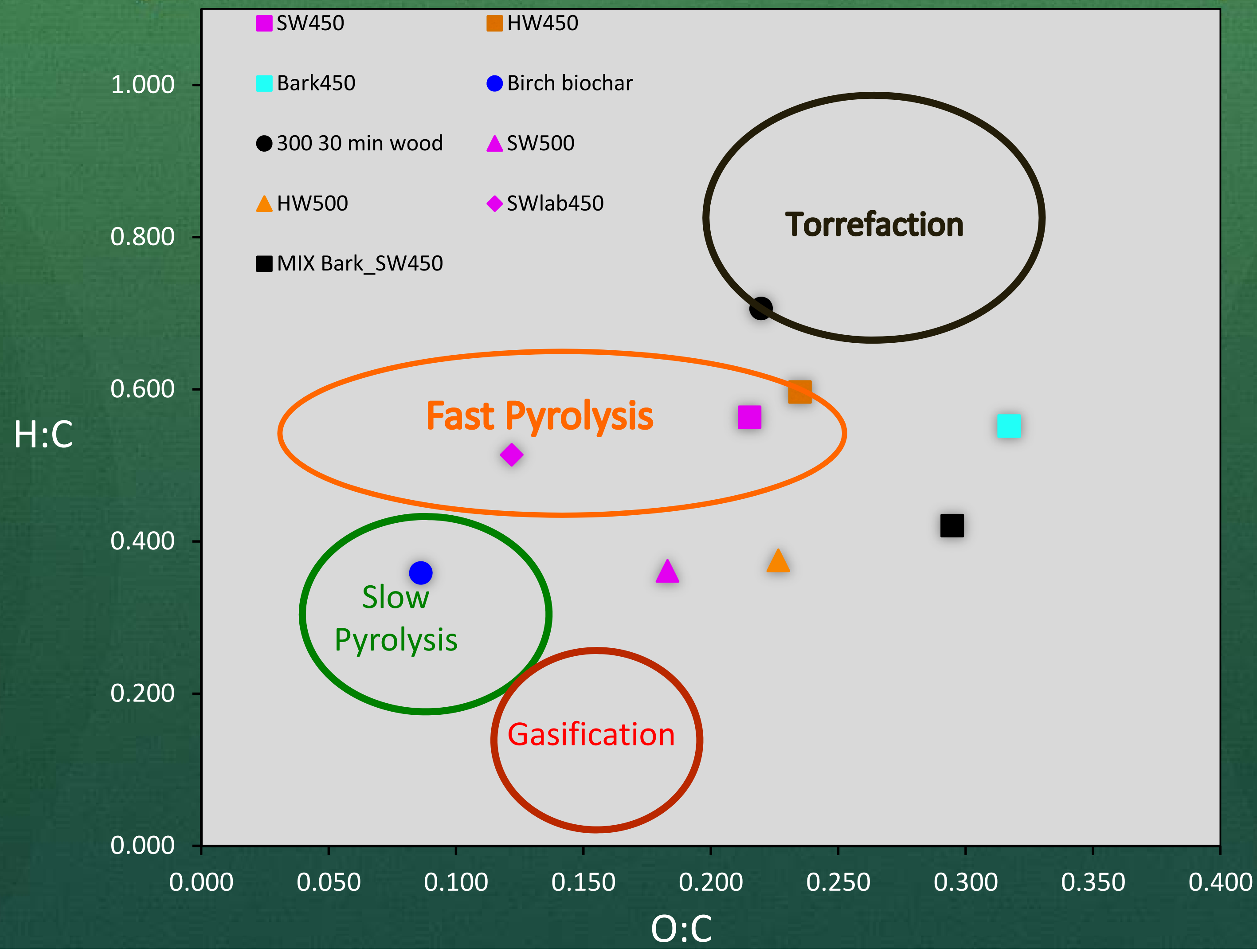
Auger reactor
2-4 kg/hr
300-400°C

Slow carbonization
1 tonne/d
300-400°C

Biochar characterization

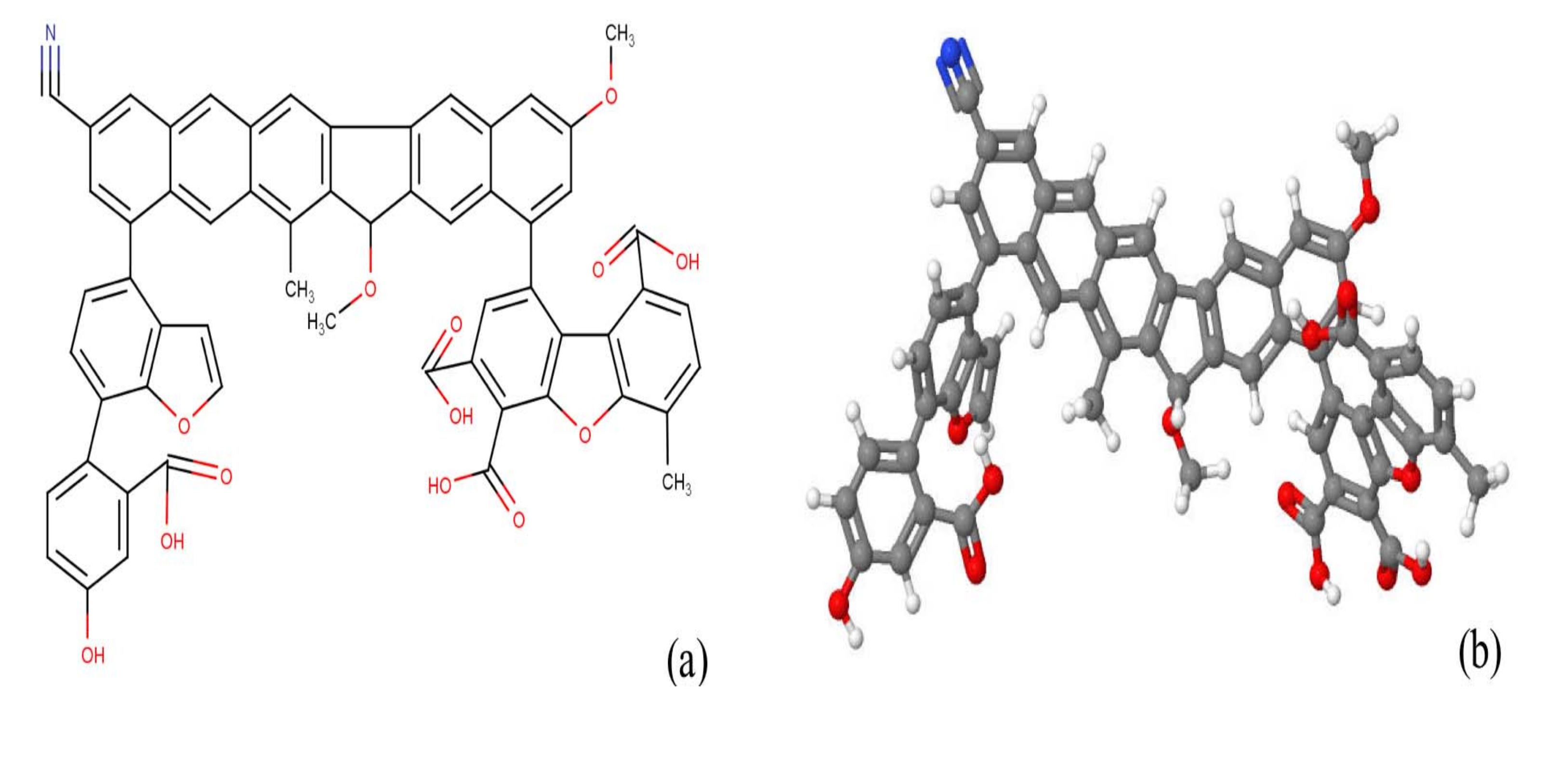
- pH
- CHN/O elemental
- Bulk Density
- TGA
- BET-N2 Surface Area
- FTIR
- SEM
- XRD

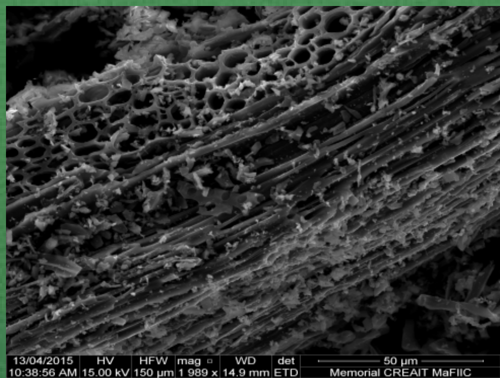
Van Krevelen Diagram



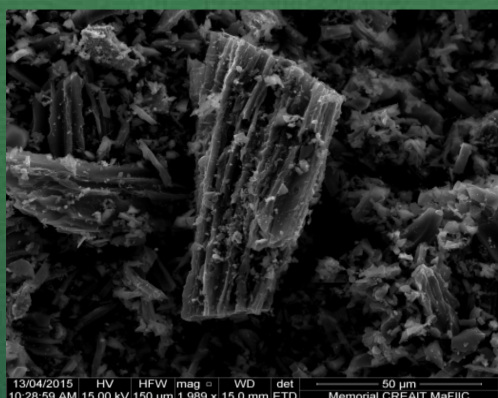
Adsorbent Studies

- Focus on acid gases, acidic aqueous stream, metals
- Molecular Modeling of char surface as a tool in adsorbent studies (a) 2D model of biochar structure, (b) 3D model of optimized biochar





Hardwood biochar 450C



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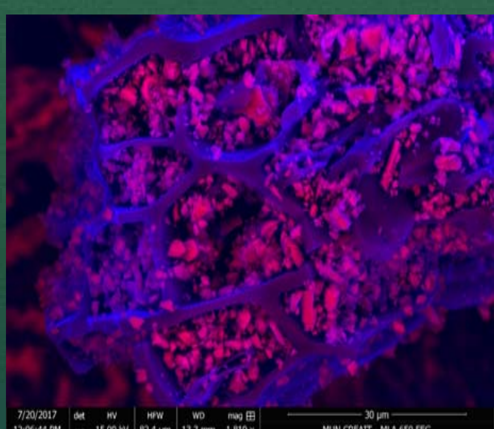
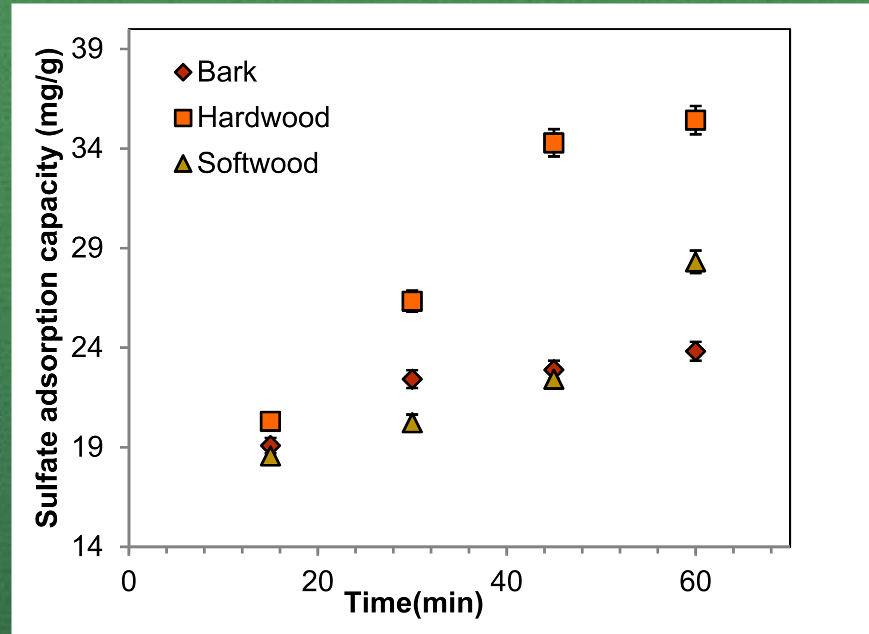
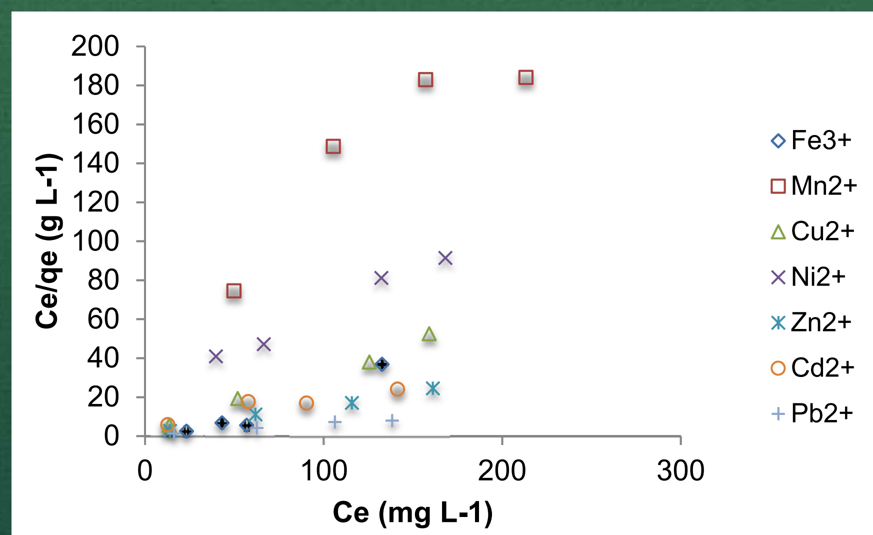


Softwood+mussel shell biochar 450C



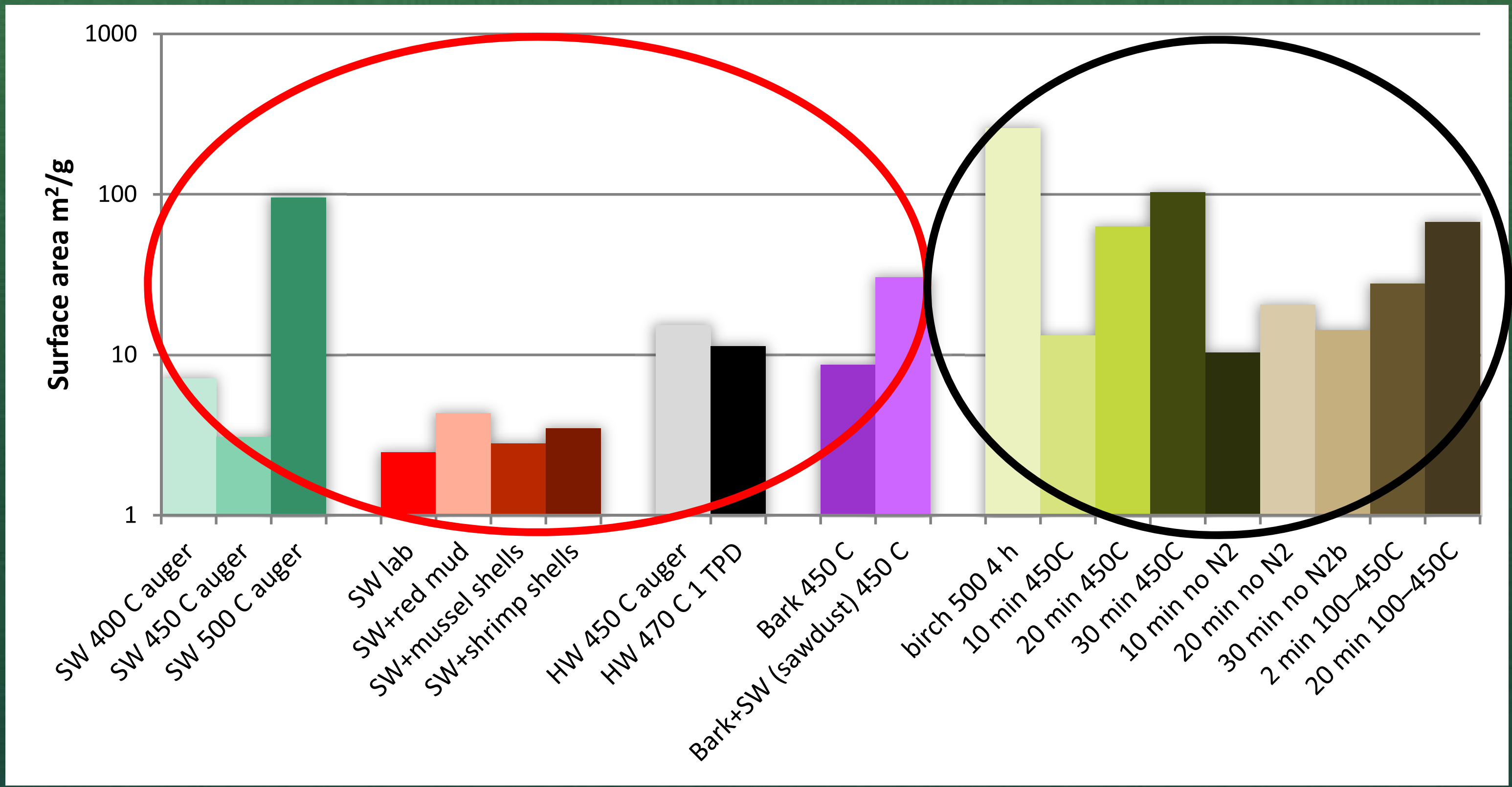
Adsorption with “fast” biochar



Adsorption with “slow” biochar

Char Properties

- pH varied between 9-11 for “fast” chars and neutral to slightly basic for carbonized chars (400-500ºC and hours)



Elemental Analysis

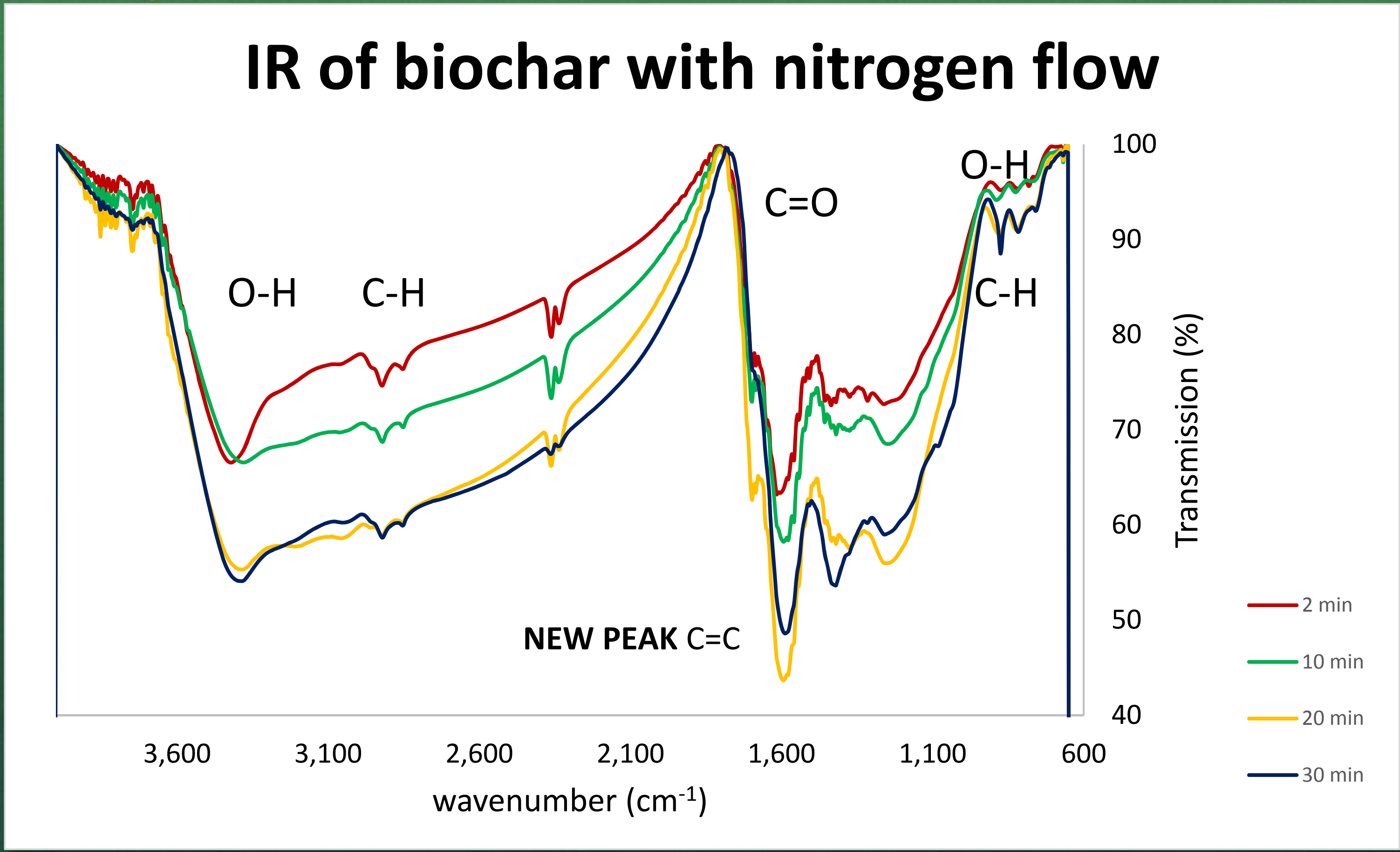
wt%	Birch (300C 30 min)	Softwood 450C auger reactor (fast)	SW 500C auger (fast)	Hardwood Biochar 450C auger (fast)	HW 500C auger (fast)	Bark 450C auger (fast)	MIX Bark-SW450 auger (fast)	SW lab scale (fast)
C	87	74.8	78.4	73.3	74.8	67.7	69.9	79.4
H	2.6	3.5	2.4	3.6	2.3	3.1	2.5	3.4
N	0.3	0.2	0.2	0.2	0.2	0.4	0.2	0.1
O	10	21.5	19.1	[illegible]	[illegible]	[illegible]	27.5	12.9
H:C	0.03	0.05	0.03	[illegible]	[illegible]	[illegible]	0.04	0.04
O:C	0.1	0.3	0.2	0.3	0.3	0.4	0.4	0.2
(O+N):C	0.1	0.3	0.2	0.3	0.3	0.4	0.4	0.2

Slightly elevated relative to more fully carbonized birch - polarity

Characterization of BioChar

Functional Groups Present of Birch Based Carbons

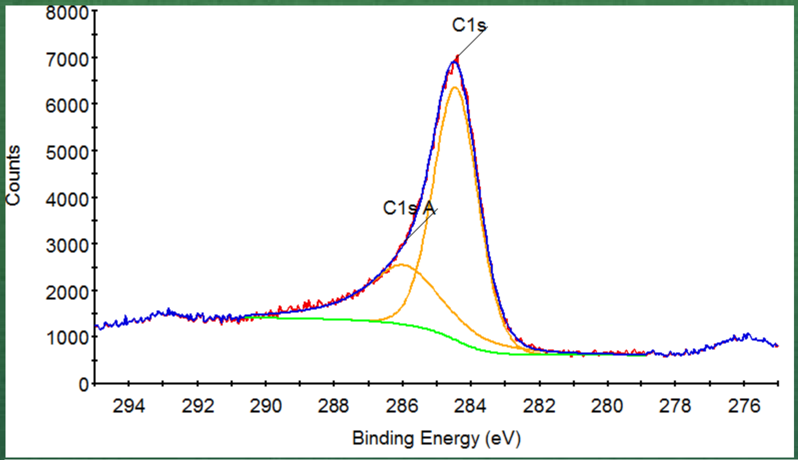
Infrared Spectroscopy

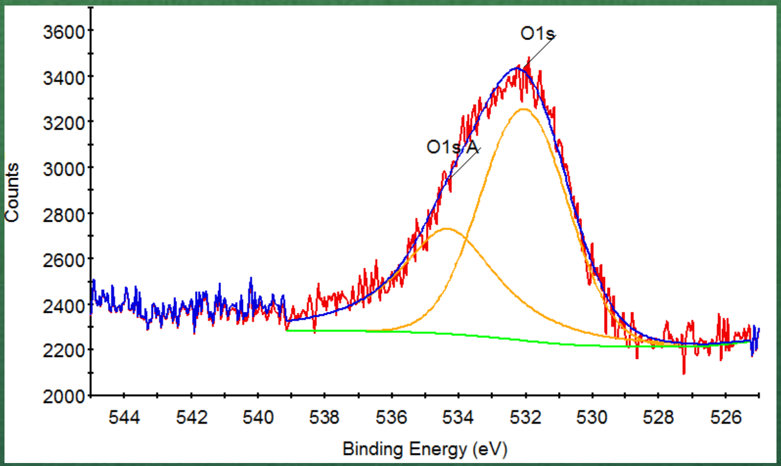


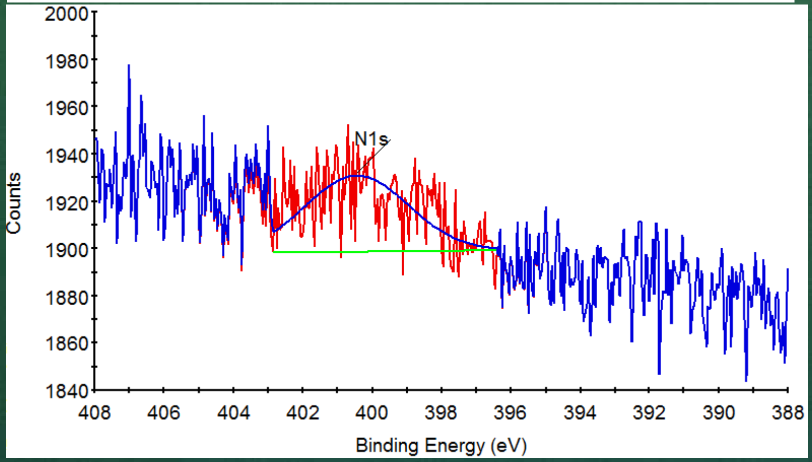
Characterization of BioChar

Surface Chemistry –XPS

Pyrolysis in the absence of air at ca. 500 °C (42% biochar)





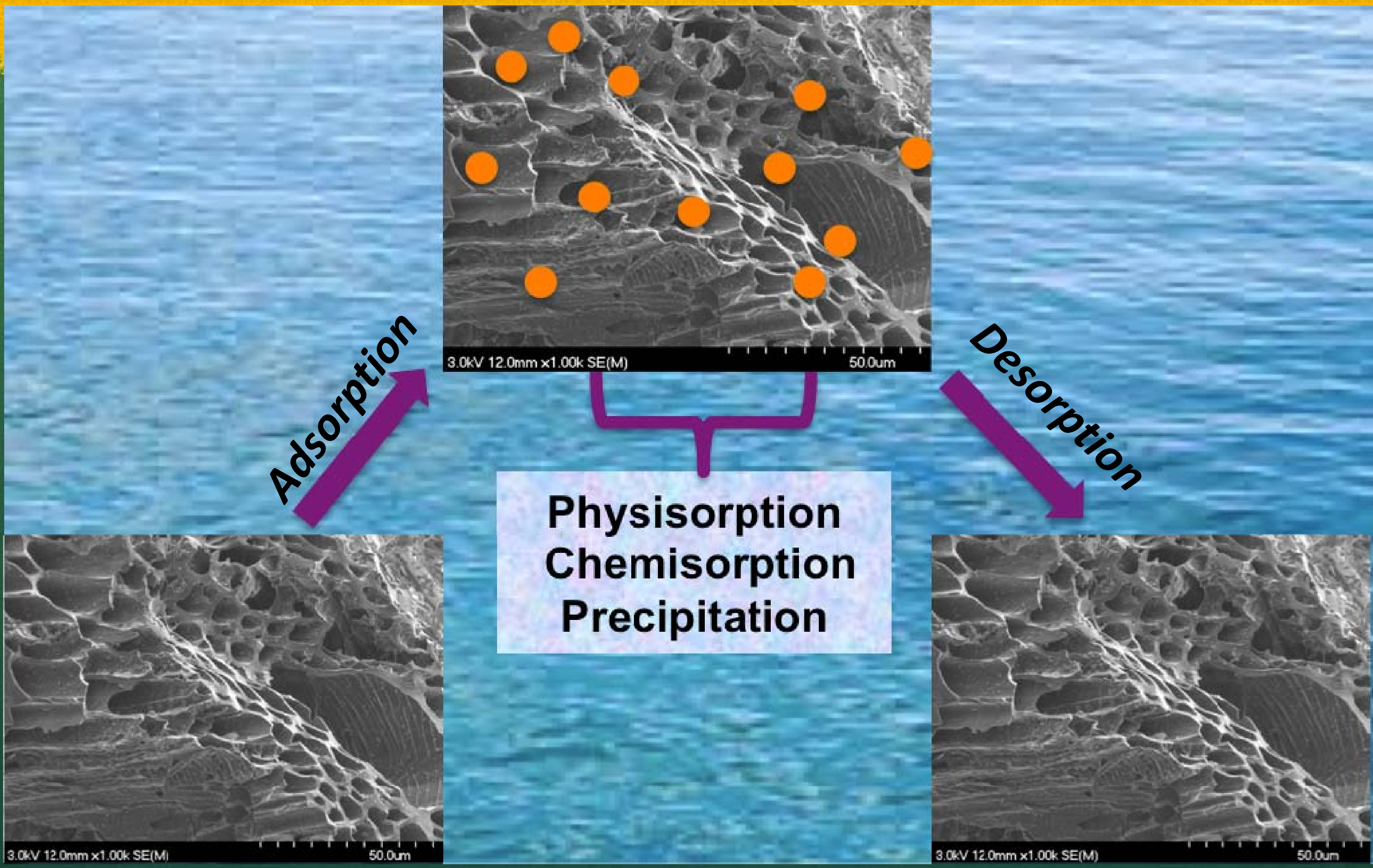


No significant N

Courtesy of:
Dr. Hugh Horton and Dr Gabriele Schatte

Mode of Adsorption

How strong is the M^{2+} ions BioChar Interaction?



Mode of Adsorption (XPS)

How are the M^{2+} ions stuck to the biochar? Physisorption

Peak	Binding Energy (eV)	Relative Area	Assignment
$Fe2p_{3/2}$	712.03	1	FeO(OH), Fe_2O_3
$Mn2p_{3/2}$	642.69	1	Mn^{2+}, MnO_2
$Mn2p_{3/2}$	647.05	0.52	MnO_4^-
$Cu2p_{3/2}$	935.01	1	$Cu(OAc)_2$
$Cu2p_{3/2}$	939.2	0.39	Auger
$Cu2p_{3/2}$	944.14	0.48	CuO
$Ni2p_{3/2}$	856.49	1	$Ni(OAc)_2$
$Ni2p_{3/2}$	860.65	0.44	$Ni(OH)_2$
$Ni2p_{3/2}$	863.83	0.34	Auger
$Zn2p_{3/2}$	1023.1	1	Zn^{2+}
$Zn2p_{3/2}$	1026.22	0.34	$Zn(OAc)_2$
$Cd3d_{5/2}$	406.17	1	Cd^{2+}
$Cd3d_{5/2}$	412.88	0.58	$Cd(OAc)_2$
$Pb4f_{7/2}$	139.46	1	Pb^{2+}
$Pb4f_{5/2}$	144.23	0.68	PbO

Mode of Adsorption (XPS)

How are the M^{2+} ions stuck to the biochar? Insoluble Oxides

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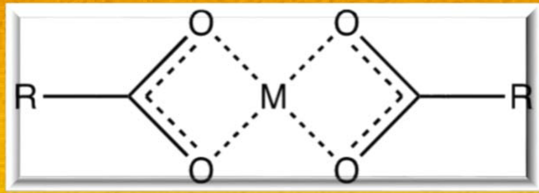
Mode of Adsorption (XPS)

How are the M^{2+} ions stuck to the biochar?



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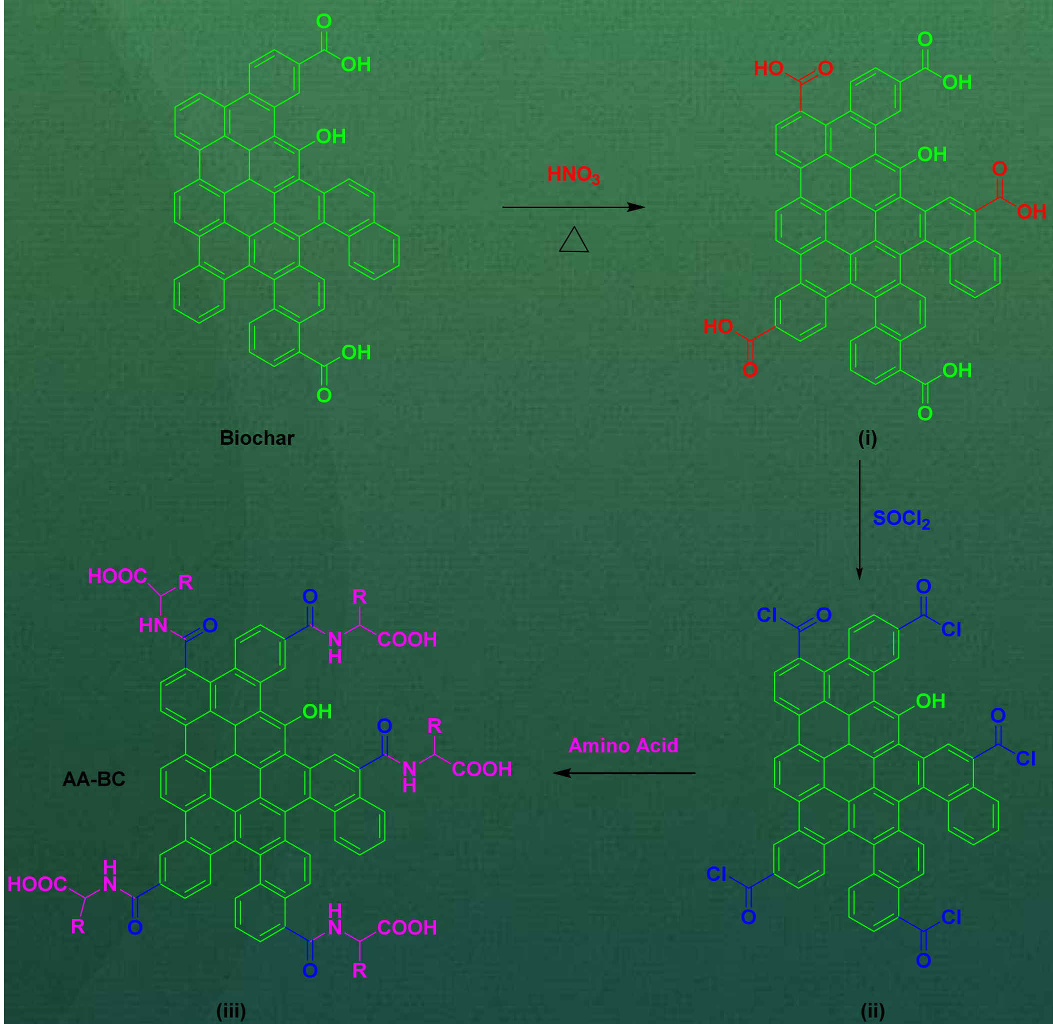
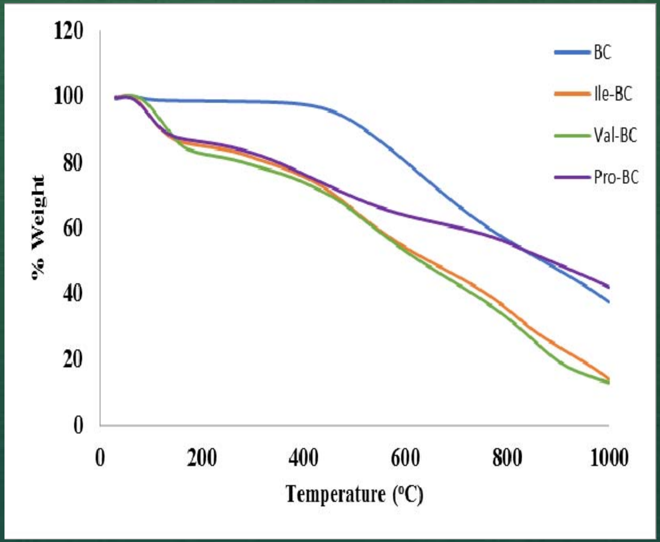
Further Functionalization



Sample	Nitrogen Content (mmol/g)	Amino Acid Loading (Weight %)
Pristine Biochar	0.42	—
Ile-BC	3.48	32.6
Val-BC	3.00	25.1
Pro-BC	4.75	39.0



Acknowledgements

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Peter Fransham (Collaborator, ABRI-Tech Inc.)

Newfoundland Labrador

naia

ABRI-TECH

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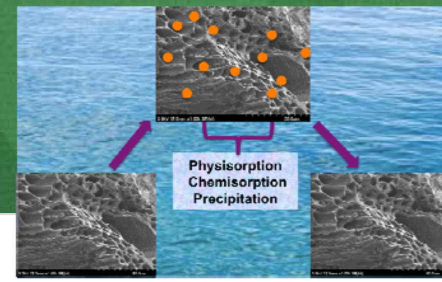
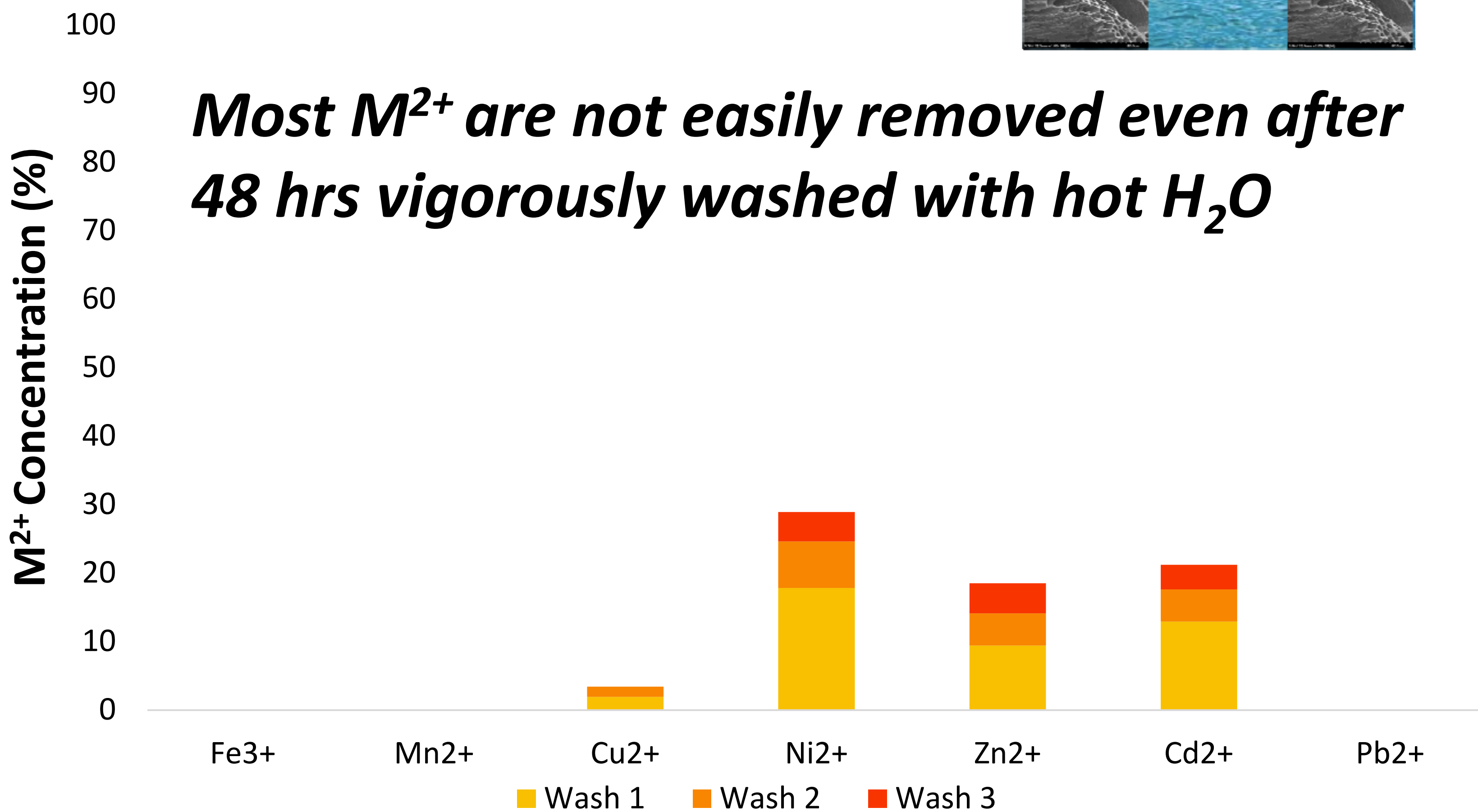
Extra slides

Mode of Adsorption

How stuck are the M^{2+} ions in water?



Most M^{2+} are not easily removed even after 48 hrs vigorously washed with hot H_2O



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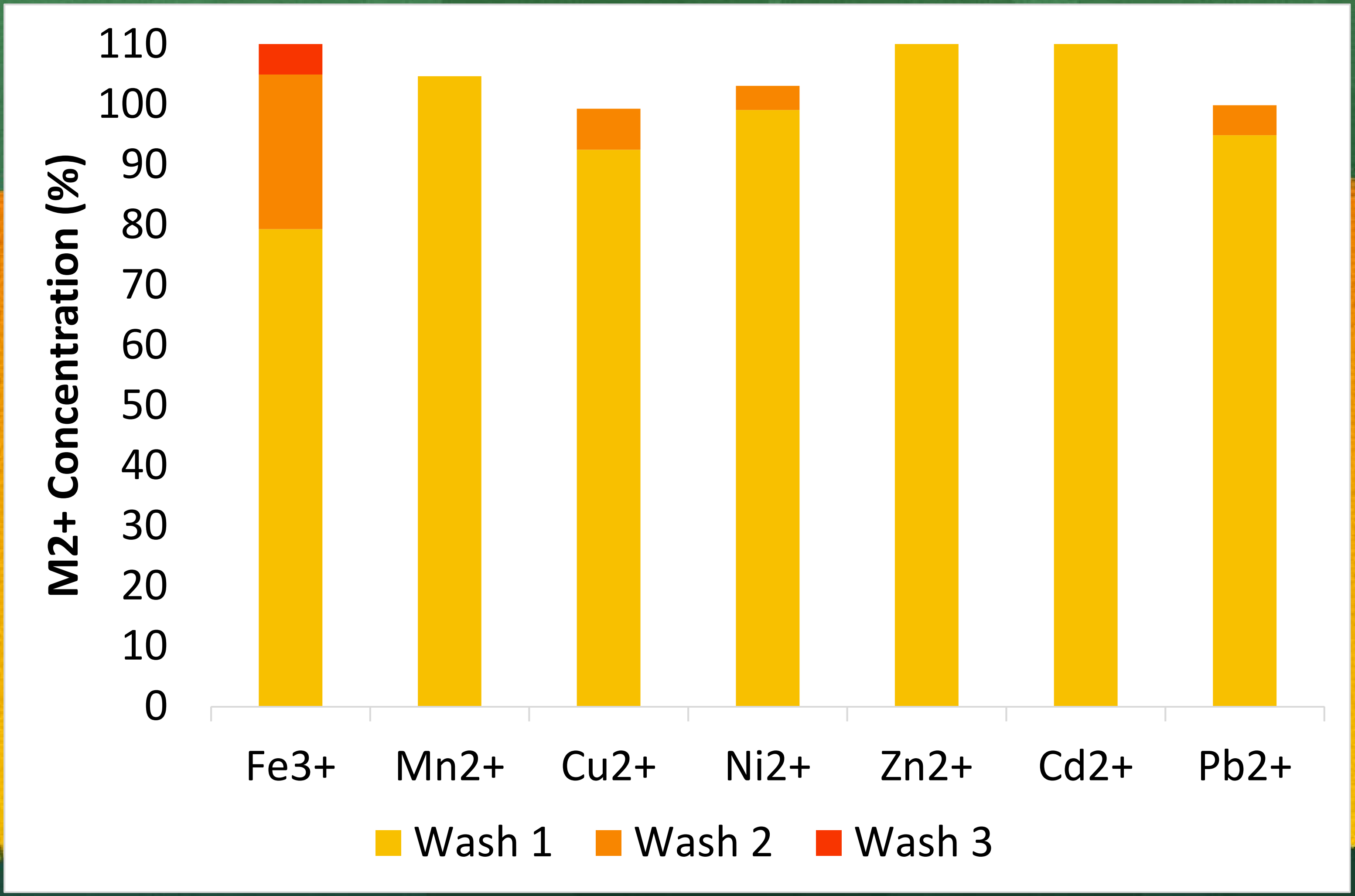
Mode of Adsorption

How stuck are the M^{2+} ions? In 0.1M HNO_3



Modification Methods

- Grafting with (3-amino)propyltriethylsilane