High value added to waste product: Hydrochar as a novel bio-augmenting amendment for bio- and phytoremediation applications

Victoria Collins
NAIT Industry Solutions

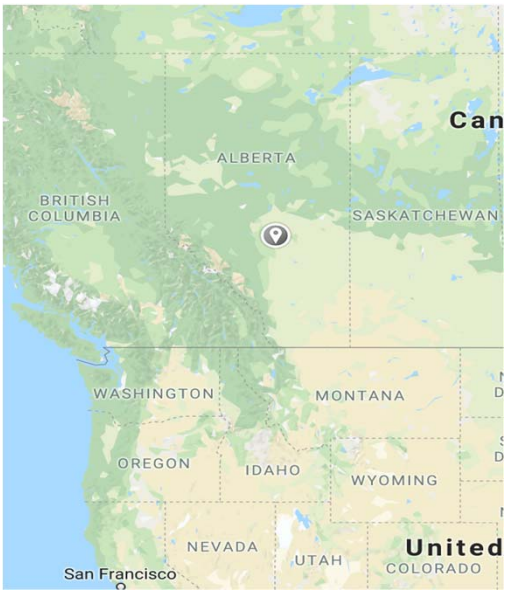
SMART Remediation
Edmonton, AB | March 11, 2020

High value added to waste product: Hydrochar as a novel bio-augmenting amendment for bio- and phytoremediation applications

Dr. Paolo Mussone
Northern Alberta Institute of Technology

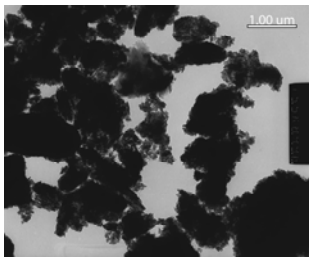
1

- *in situ* hydrocarbon remediation in cold calcareous subsoils often stalls due to difficulty in delivering nutrients, especially P
- Lab and landfarm trials suggested bone-based biochars could be effective amendments, but they are difficult to apply *in situ* to subsurfaces

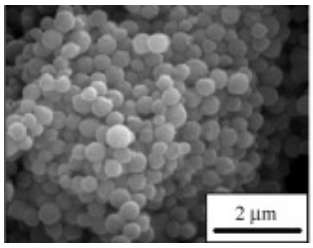


2

Bonemeal



DOI:
10.1002/chem.200802097



Biochars

- Carbon-rich solids produced by pyrolysis at high temperatures
- Bone-based biochars can be effective P sources as amendments in bioremediation
- Biochars are difficult to apply (powdery, hydrophobic)
- Biochars of guaranteed quality are difficult to find

Hydrochars

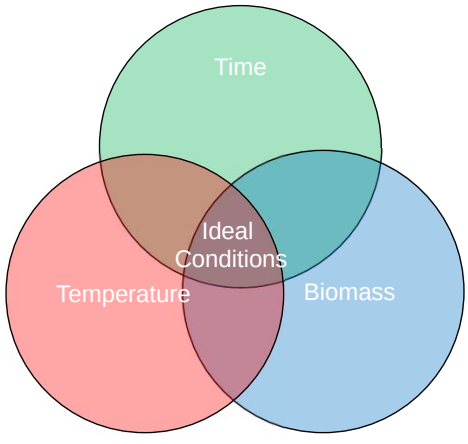
- Hydrochars are carbon rich solids produced hydrothermally
- Hydrochars can be synthesized with desired P mineralogy and size with good process control and are more soluble for injections
- Can relate synthesis, structure, and sorption using rational design

INDUSTRY SOLUTIONS

3

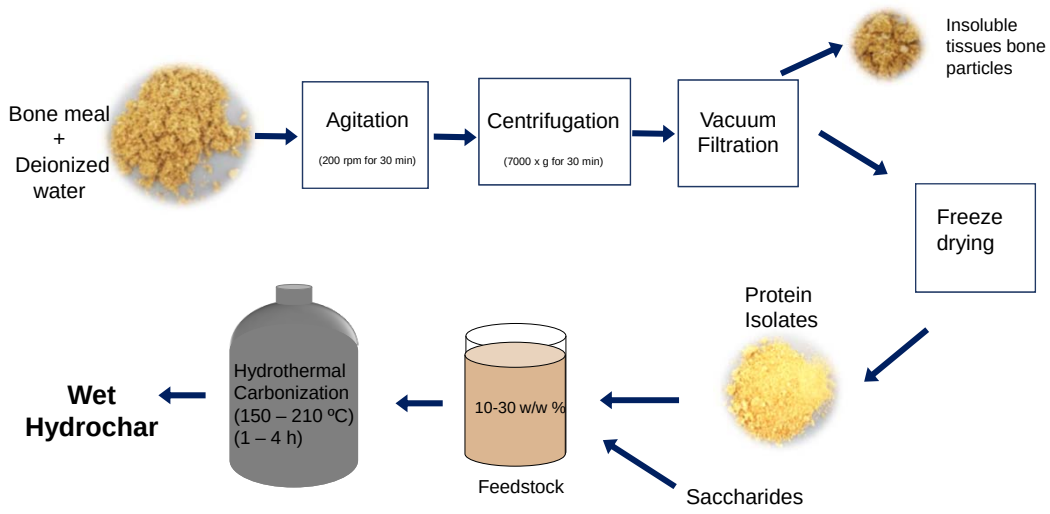
Structure Property Relationships

- Modification of individual steps to produce the desired results
- Systematic change to material structure and observe change in properties
- In this case, we want to optimize for properties of hydrocarbons adsorption, flow, and hazard characteristics by changing the structure of hydrochars
- Modify the structure by changing synthesis conditions of the Hydrothermal Carbonization



INDUSTRY SOLUTIONS

4


Bone meal
+
Deionized
water
Agitation
(200 rpm for 30 min)
Centrifugation
(7000 x g for 30 min)
Vacuum
Filtration
Insoluble
tissues bone
particles
Freeze
drying
Protein
Isolates
Saccharides
Feedstock
10-30 w/w %
Hydrothermal
Carbonization
(150 – 210 ºC)
(1 – 4 h)
Wet
Hydrochar

5

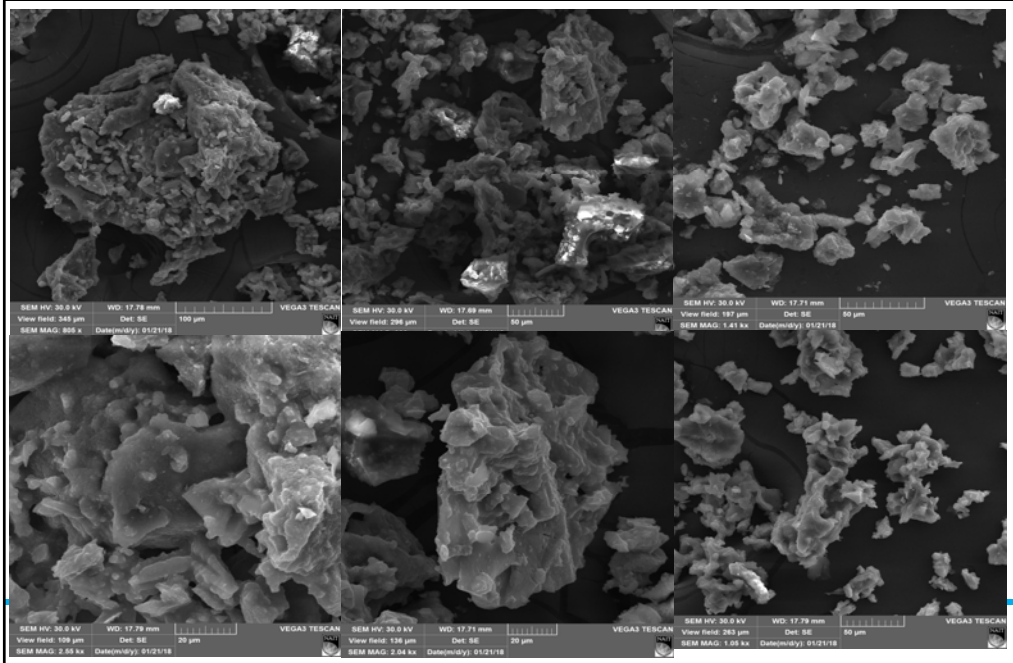
6

Table 1. Reaction Parameter Variables Used for the Synthesis of Hydrochars

Sample ID	Reaction Time (h)	Percentage of Porcine Meal Protein Isolate in Sludge (% m/m)	Percentage of Glucose in Sludge (% m/m)	Percentage of Starch in Sludge (% m/m)	Reaction Temperature (°C)
H-1-10-150	1	10	0	0	150
H-2-20-180	2	20	0	0	180
H-4-30-210	4	30	0	0	210
H-1-5-150 5% Glucose	1	5	5	0	150
H-2-10-180 10% Glucose	2	10	10	0	180
H-4-15-210 15% Glucose	4	15	15	0	210
H-1-5-150 5% Starch	1	5	0	5	150
H-2-10-180 10% Starch	2	10	0	10	180
H-4-15-210 15% Starch	4	15	0	15	210

INDUSTRY SOLUTIONS

7

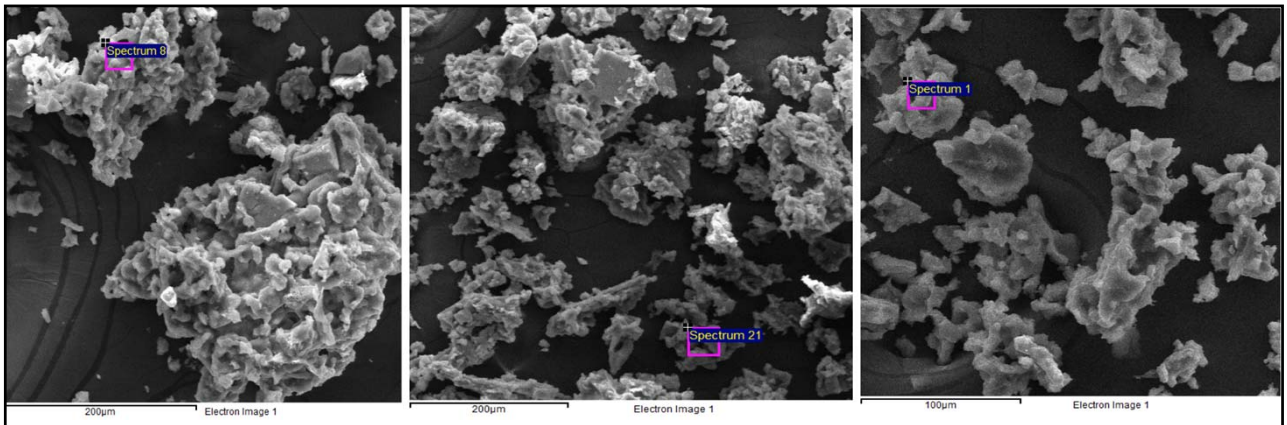


L: H-1-10-150
C: H-2-20-180
R: H-4-30-210

- Structural changes though reaction time
- Higher reaction times increase surface area
- Shifts from plate like to needle like

INDUSTRY SOLUTIONS

8



Sample ID	Sample Location	O	P	K
		Weights %		
H-1-10-150	1	29.3	51.6	19.1
	2	70.0	11.9	18.1
	3	75.1	15.7	9.3
	4	68.9	31.1	-
	5	68.6	31.4	-
	6	70.0	18.9	11.1
	7	76.3	15.9	7.8

Sample ID	Sample Location	O	P	K
		Weights %		
H-2-20-180	1	66.9	19.2	13.9
	2	75.1	24.9	-
	3	59.3	13.8	26.9
	4	67.4	21.6	11.0
	5	61.8	28.3	9.9

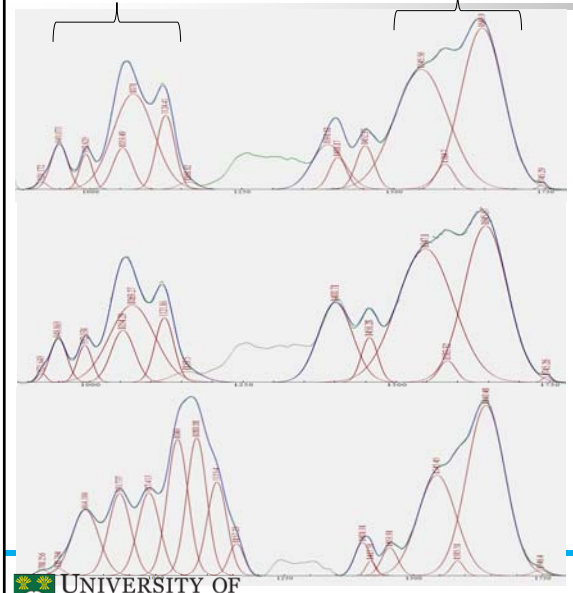
Sample ID	Sample Location	O	P	K
		Weights %		
H-4-30-210	1	65.2	20.1	14.7
	2	68.6	16.9	14.5
	3	70.4	19.9	9.7
	4	64.1	35.9	-
	5	68.9	20.0	11.2
	6	70.6	21.6	7.8
	7	71.8	19.1	9.0

INDUSTRY SOLUTIONS

9

P-O Stretching region

Carboxyl region

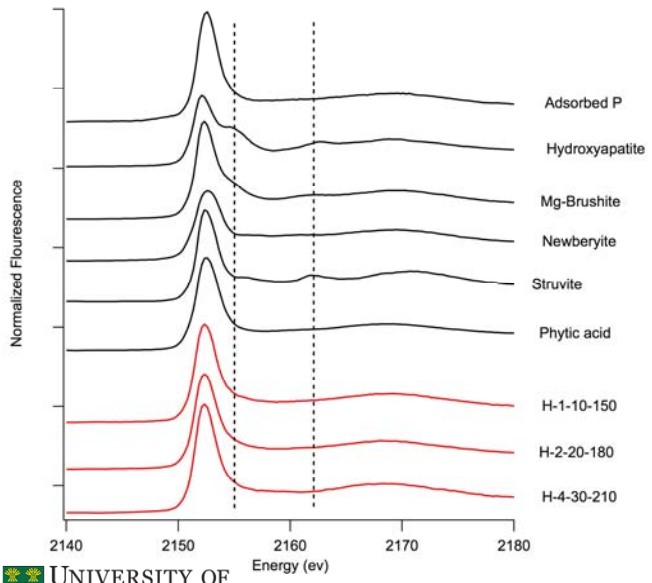


- **Highly proteinaceous substances**
- **Changes in vibrations in both the carboxyl and amides bands of proteins**
- **Changes in number and position P bands**
- **Multivariate stats suggest temp and % protein an effect but not time.**

UNIVERSITY OF SASKATCHEWAN

INDUSTRY SOLUTIONS

10



- **Mostly Organic P – Very similar to Phytic acid XANES spectra, similarly to adsorbed PO_4 reference**
- **A minor $CaHPO_4$ mineral component is also present.**
- **Unidentified structure around 2158eV in higher temperature samples (H-4-30-210)**

UNIVERSITY OF SASKATCHEWAN

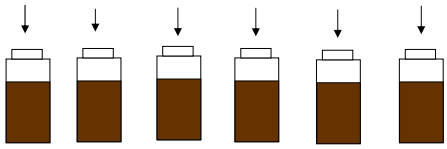
INDUSTRY SOLUTIONS

11

Benzene Isotherms

Varied: Initial reactant concentration
Fixed: Solid density, ionic strength, pH, temperature, V_0

C_0 = 0ppm 5ppm 10ppm 25ppm 50ppm 75ppm



Equilibrate, filter/centrifuge, and measure final solution concentration (C_f)

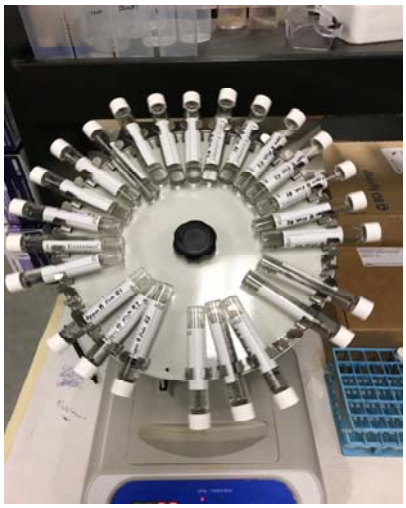
C_0-C_f = C_{sorbed}
V_0C_0-V_fC_f/mass sorbent = q (amount sorbed per unit mass soil)
q vs. C_f = adsorption isotherm!

UNIVERSITY OF SASKATCHEWAN

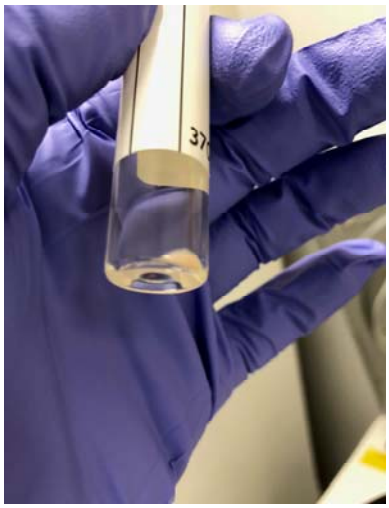
INDUSTRY SOLUTIONS

12

Isotherms



Reaction Vessel

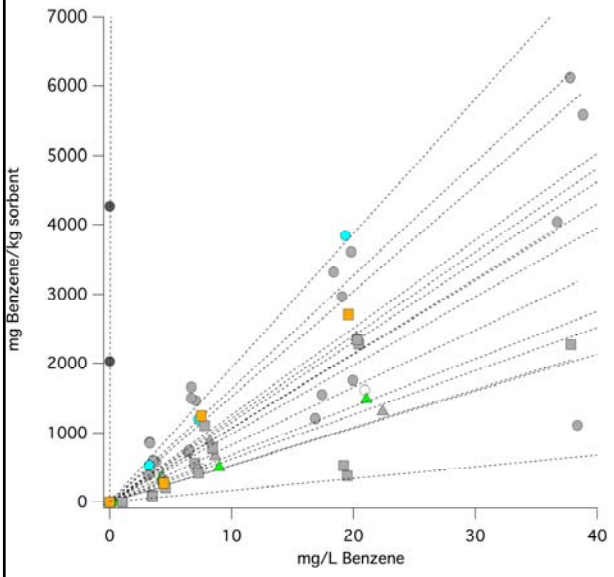


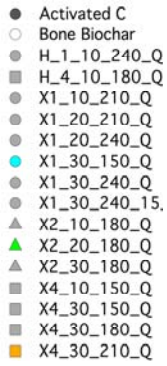
Benzene Measurement

UNIVERSITY OF SASKATCHEWAN

INDUSTRY SOLUTIONS

13





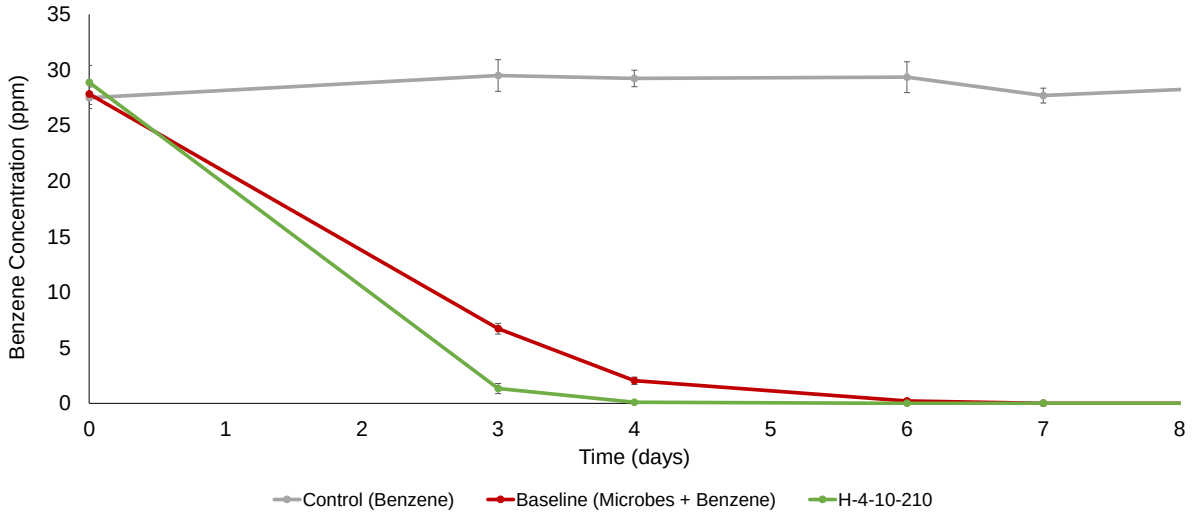
- Lower time in reactor correlated to increased adsorption of Benzene
- Hydrochars generally adsorb more benzene then traditional fish and bone meal biochars but less then activated carbon
- Best hydrochar candidate has least reaction time and lowest surface area

UNIVERSITY OF SASKATCHEWAN

INDUSTRY SOLUTIONS

14

Biodegradation of Benzene



INDUSTRY SOLUTIONS

15

- **Hydrochars have more adsorption capabilities then traditional biochars on a mass basis**
- **Isotherms for benzene on hydrochars are essentially linear until high benzene concentrations**
- **All hydrochars thus far are highly hydrophilic making them excellent candidates for bioremediation**
- **Hydrochars stimulate benzene degradation in model systems**

INDUSTRY SOLUTIONS

16

INDUSTRY SOLUTIONS

17

INDUSTRY SOLUTIONS

18

- **It is feasible to scale up hydrochars to produce a field scale amendment**
- **Hydrochars have good flow properties, high nutrient levels, and sorb benzene. This makes them ideal for microbial stimulation**
- **HTC synthesis allows for tailoring of hydrochar amendment**

INDUSTRY SOLUTIONS

19

Second Study: Plant Mediated Tailings Dewatering

Current inventory of oil sands tailings ~ 1.21Bm^3

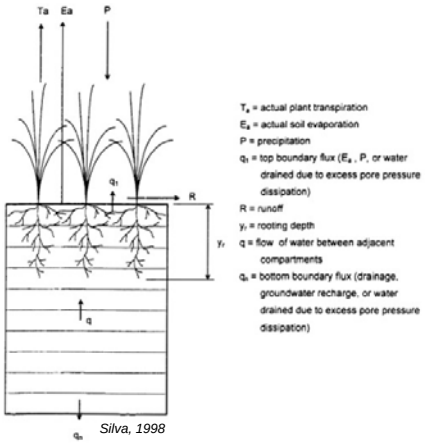
Several studies have suggested that certain plant species may be able to grow in tailings

- Tailings pond bank stabilization
- Tailings dewatering

Negative growth conditions

- Saline conditions
- Limited nutrients
- Hydrocarbons

www.cbc.ca/news/canada/edmonton/oilsands-tailings-ponds-to-be-limited-by-new-rules-alberta-says-1.2993923



Silva, 1998

INDUSTRY SOLUTIONS

20

Ongoing and Future Work

- Assessing the plant growth promoting potential of hydrochar from various feedstocks on fluid tailings for dewatering and process water for naphthenic acid degradation
- Evaluating hydrochar for promoting the growth of agricultural species in saline soil and phytoremediation of salts
- Formulating hydrochar from lignin feedstock for benzene biodegradation

INDUSTRY SOLUTIONS

21

Industry Partners
Federated Co-operative Limited
United Farmers of Alberta

NSERC, Alberta Innovates

NAIT
Arantxa Pino Persico
Victoria Collins

University of Saskatchewan
Drs. Peak, Siciliano
David Bulmer

CO-OP UFA ALBERTA INNOVATES NSERC CRSNG

INDUSTRY SOLUTIONS

22