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CLOSING THE LOOP ON LIGNOCELLULOSIC - BASED SOLID WASTE MANAGEMENT: PRODUCTION OF BIOCHAR FOR AGRICULTURAL LAND AND CONTAMINANT ADSORPTION APPLICATIONS AND FOR CLIMATE CHANGE

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Final Report
Harris Centre Solid Waste Management Applied Research Fund 2011-2012

Closing the Loop on Lignocellulosic -based Solid Waste Management: Production of Biochar for Agricultural Land and Contaminant Adsorption Applications and for Climate Change

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This research project is focused on examining the feasibility of converting lignocellulosic -based solid waste streams destined for landfill, into a valuable biochar product. Biochar has many applications including a soil amendment to improve soil fertility and in low-cost adsorption applications such as control of odorous sulphur pollutants in air emissions, and as an adsorption surface for toxic metals in industrial waste streams. We have completed an inventory of lignocellulosic –based waste from municipal sources (and expanded our study to include university, demolition and garden wastes), We have produced small amounts of biochar samples and chemically tested their properties for applications stated above.

This a long term project, however, through funding from the Harris Centre's applied research Fund we have been able to address some of the objectives outlined in the original proposal aimed at diverting a major solid waste stream from landfills to the production of a useful biochar product.

1. Inventory of lignocellulosic – based material from municipal, university, demolition and garden waste: (*note: dose not include waste diverted to recycling)*

Initially we were going to do an inventory of municipal garbage being received at the regional landfill in St. John's. Because of safety reasons at the landfill, we decided to perform an inventory of individual Household Garbage. This inventory represented weekly garbage from 20 households, taken twice one month apart. To represent institutional waste, we decided to take an inventory of garbage destined for landfill from Memorial University. This inventory was based on examining garbage from the Chemistry building each week for 4 weeks. Demolition Waste was collected from two demolition sites in the East end of St. John's. It was confirmed by the contractor that the waste was destined for landfill. Finally, representative Garden Waste was collected from neighours yard during the summer and fall seasons in the Churchill Sq. area.
The results of the inventory, relative abundances and % ash of each type of lignocellulosic waste stream are given in Table 1. The ash content of the feedstock is very important in the properties of the resulting biochar. Ten groups (i.e., paper towel) of lignocellulosic waste were selected from municipal, nine from university, three from demolition and five from garden waste.
A *supplemental inventory* for paper cups and tetrapaks was done later. These were not included to the primary inventory (Table 1) since they contained a significant amount of

wax/plastic and not deamed useful for biochar production. These two waste streams will be investigated later. The results of this supplemental inventory are:

Municipal:	Paper Cups (√)	Tetrapaks (√√)
University:	" " (√√)	" " (√)

Table 1. Most common lignocellulosic wastes, relative abundance and % ash content.

Type of sample		codes	% ash	abundance in garbage	Comments
Muncipal waste					This inventory was based on weekly garbage from **20 household's** collected twice,1 month apart.
Cereal box		A46	**11.7%**	√	
paper towel		A43	0.3%	√√√	
Coloured paper		A38	5.6%	√	
Paper towel roll		A2	5.4%	√	
Plain white paper		A18	9.2%	√√	
Brown paper bag		A13	4.5%	√√	
Corrugated cardboard		A3	4.2%	√√	
Newsprint		A4	9.0%	√√√	
White paper with ink		A36	10.0%	√√√	
Glossy paper		A7	20.0%	√√√	
University garbage					This inventory was based on examining garbage from Chemistry building **4 times**, once a week.
Corrugated cardboard-white		A31	1.5%	√	
Paper towel roll- laboratory		A40	4.5%	√	
Plain white paper		A5	9.0%	√	
Glossy paper		A6	22.2%	√√	
Journal article paper		A26	10.0%	√√√	
Laboratory paper towel		A42	0.3%	√√√	
Newsprint		A20	0.2%	√√	
Brown paper envelope		A9	8.0%	√	
Cardboard packing		A12	10.1%	√√	
Cardboard packing (*replicate*)		A19	9.9%	√√	
Demolition waste					This waste was collected from two demolition (house) sites in St. John's.
Particle board		A11	1.1%	ND	
Plywood		A29	0.8%	ND	
wood 2x4		A37	0.7%	ND	
garden waste					
Fresh spruce chips (dried)		A15b	0.3%	ND	This waste was collected around the Churchill Sq. area.
Twigs (softwood)		A17	1.2%	ND	
Maple Leaves (dried)		A22	5.7%	ND	
Freshly cut grass (dried)		A34	5.3%	ND	
cut grass (old)		A35	5.2%	ND	

√ = least abundant; √√= commonly present; √√√= abundant
% ash of the original (dried) waste
Codes: sample codes of categorized waste used in all tables and figures

2. Production of biochar, % yield and ash

A suitable (tube furnace) pyrolysis apparatus (10-20 g sample size) was constructed and tested. Biochar (~ 7 g) was produced at 550°C for each feedstock listed in Table 1. The yields and ash content were recorded and graphed for visual comparison as shown in Figure 1.

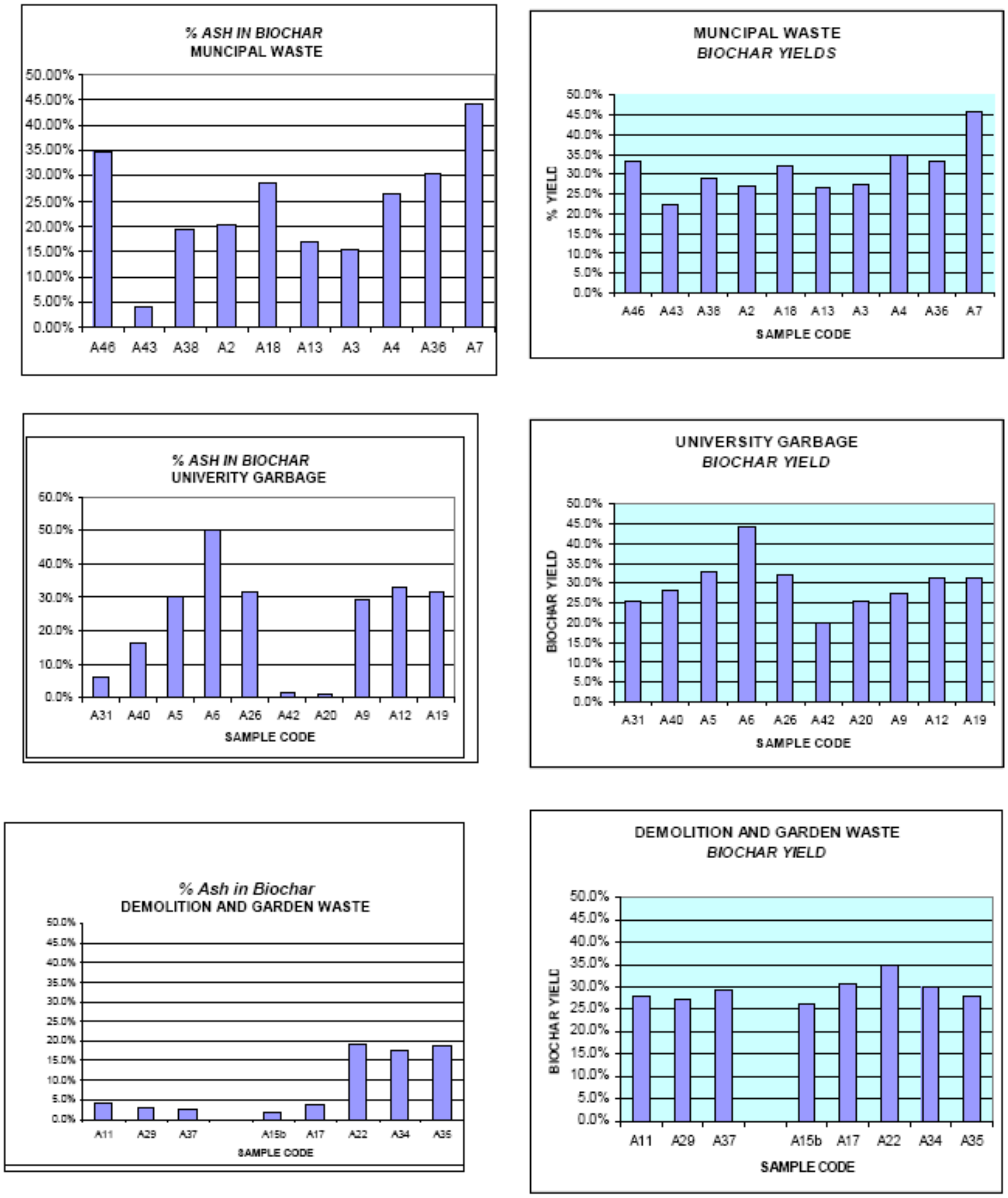

Figure 1. Graphs showing biochar yield **(right column)** and % ash in biochar **(left column)** from various wastes collected from municipal, university and other sites. Sample codes in Table 1.

It was observed that % yield of product correlated with % ash contented in the biochar products. Among the low ash –containing biochars, the samples which gave highest yields were the demolition (*plywood, wood*) and garden (*wood chips and twigs*) waste.
By far the highest yields (45-50%) of all feedstocks are from glossy paper samples (A6,A7).

3. Important properties of biochar for gas and contaminate adsorption use

It was been found that two suitable properties that biochar product should have are 1) gas adsorption capacity (GAP) and 2) high carbon/ oxygen ratio (C/O). Both these measurements were taken and the results graphed in Figure 2. Any value greater than 6 % GAP is a useful biocarbon (activated carbon as a GAP of 25%). Only products from newsprint, paper towels and brown envelopes showed good GAP. High C/O ratios were observed for paper towel, wood chips and demolition wood.

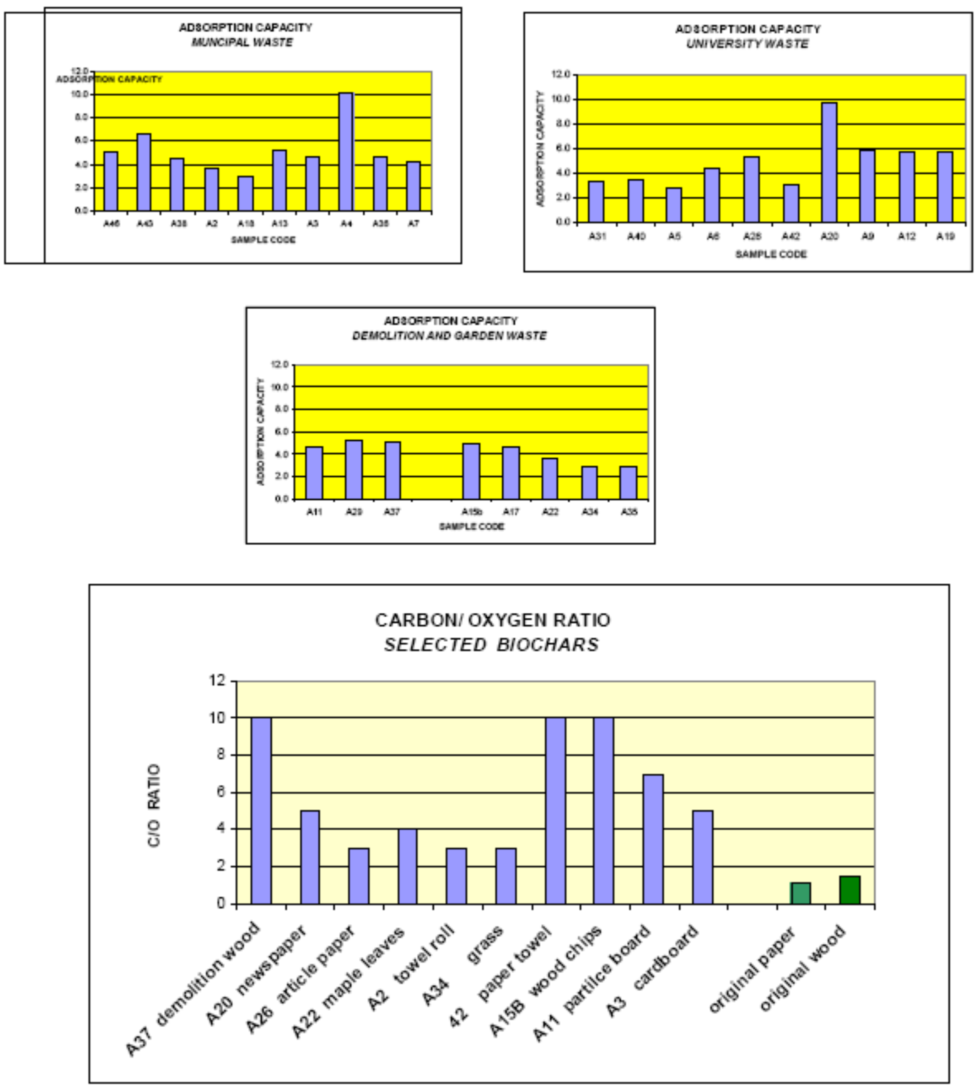

Figure 2. Graphs showing adsorption capacity (**top 3 graphs**) of biochar produced and calculated carbon/oxygen ratio (**bottom graph**) of most promising waste-derived biochars. Sample codes in Table 1.

4. Important properties of biochar for soil amendment use

Biochar has been successfully used as a soil amendment to improve crop yields. Two important parameter of a suitable biochar are (a) volatile carbon (VC; the lower the better) (b) ion exchange capacity (IEC). These measurements are shown in Figure 3. Good commercial biochars have VC < 10% and IEC of > 125 mmolNa/kg. The biochars with the worst VC values are the grass and leave wastes and all cardboard feedstocks. The highest IEC properties were shown from cereal boxes, brown corrugated cardboard, leaves and cut grass. After combining the best of each, the only feedstock to show good overall soil amending properties is the cereal box. However, other wastes with IEC and low VC less than 125 mmol Na/kg should be considered in future soil trials.

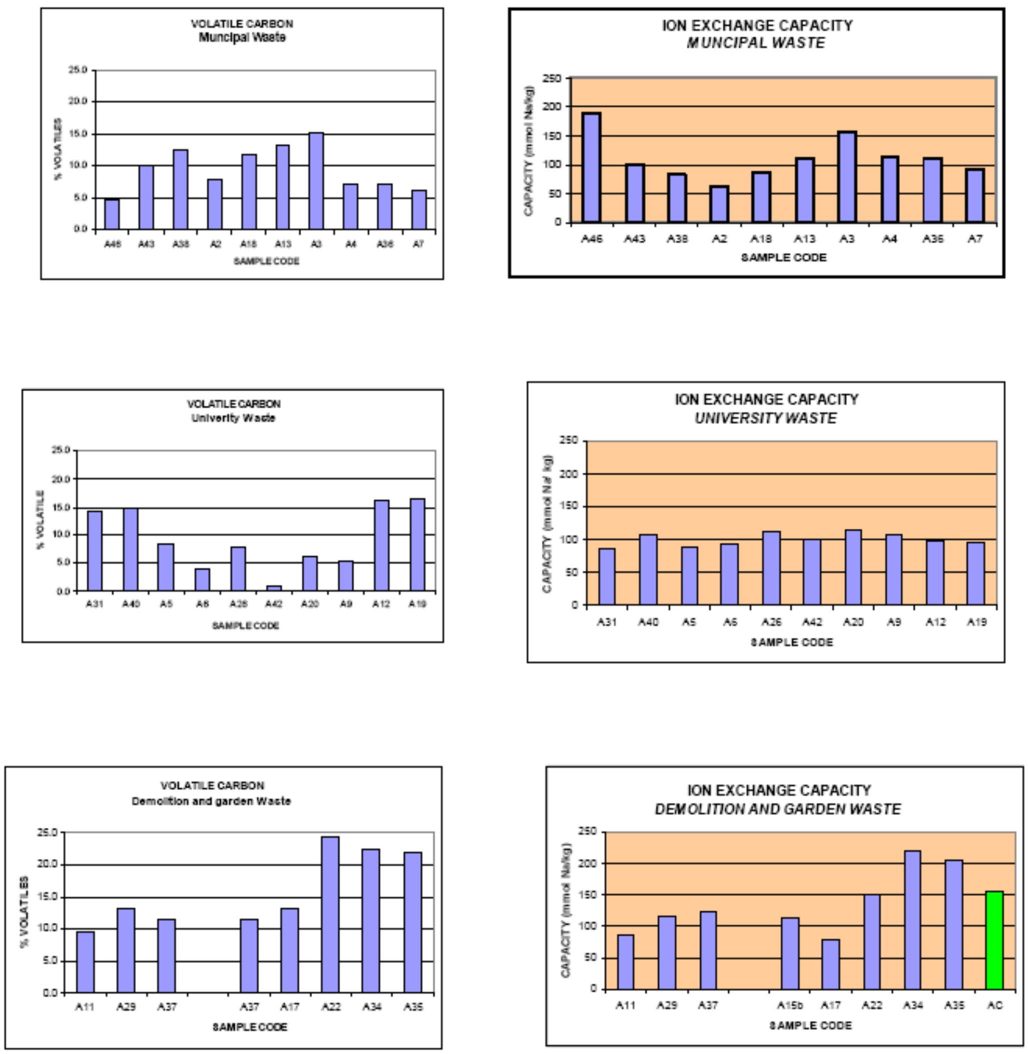

Figure 3. Graphs depicting the differences in % volatile carbon **(left column)** and ion-exchange capacity (**right column**) of biochars derived from various wastes. Sample codes in Table 1.

Student Training

The PI was responsible to completing the inventory of waste for all four sources, household garbage, university waste and demolition and garden waste. The two students, Mr. Dalley and Mitchell worked together to perform (with no assistance from staff) the following measurements *(specialized equipment)*: % ash, % volatile carbon (TGA instrument), ion exchange capacity (Flame AA) and gas adsorption capacity. Mr. Dalley designed and built the tube furnace pyrolyzer assembly with precision measured quartz sample boats.

They learned to work and plan out the experiments together. The students interacted with researchers and chemists from other parts of the world who work in biochar science.

Summary and Deliverables

In summary we have delivered the first inventory of lignocellulosic-derived streams present in St. John's municipal waste. We have further extended this inventory to institutional waste (Memorial U.) and examined both demolition and garden waste as potential biochar feedstock. A total of 27 individual feedstocks were collected and characterized for their ash content. Small amounts of biochar were produced from a home-made pyrolysis unit, % yields recorded and important chemical and physical properties measured; for commercial use in soil amendment, ion exchange capacity (IEC) and volatile carbon (VC); for commercial use as gas and contaminant adsorbent, gas adsorption capacity (GAP) and C/O ratio.

1) The samples (lowest ash) which gave highest yields were the demolition (plywood, wood) and garden (wood chips and twigs) waste.
2) Commercial use as adsorbent or carbon material: Biochar from newsprint, paper towels and brown envelopes showed very good GAP properties. For high carbon-content (measured as C/O ratio) applications (i.e., metallurgy, batteries) biochar from paper towel, wood chips and demolition wood were the best.
3) Commercial use as soil amendment: The only biochar feedstock with good VC and IEC was the lone cereal box. However the abundance of this type of waste is low in waste. Other wastes with reasonable IEC and low VC should be considered in future soil trials.

Specific deliverables:

Presentations and demonstrations:

- Mr. Dalley presented his research proposal seminar to the MUN's Environmental Science Programme.
- St. John's Safer Soil Project: successful biochar demonstration (2010-2012) at the Safer Soil Demonstration Garden, first of its kind to take place in Newfoundland.

Proposals submitted to extend this research:

> A 5 year, multi-university, NSERC Strategic Network application lead by Dr. Berruti (U. of Western) "NSERC STRATEGIC NETWORK FOR CANADIAN BIO-CARBON RESEARCH AND APPLICATION (Bio-C Net)" submitted March 2012.

Future Deliverables

MES thesis and publication by Travis Dalley.

We anticipate securing funds ($3,000) to design and build a pilot-scale pyrolysis unit using a simple design and 50 gal barrels (barrel-pyr). The 10 kg-quantities of biochar product (from feedstock chosen from the present study) will be used in demonstration garden plots. It is also hoped that small farms and rural communities will adopt the use of the barrel-pyr as a way of diverting solid wastes.
Helleur will apply for additional funds to examine the biochar products from disposable paper cups and tetrapacks. Additional experiments will also be conducted to produce unique biochar from waste mixtures (i.e., grass + leaves+ twigs).


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