Reducing Organic Waste and Improving Soil Systems with Biochar in Washington State
WA Biomass Inventory – 2013 update

<table>
<thead>
<tr>
<th>Sector</th>
<th>Mtbd/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Total</td>
<td>10.6</td>
</tr>
<tr>
<td>Field Residue</td>
<td>2.6</td>
</tr>
<tr>
<td>Animal Waste</td>
<td>0.8</td>
</tr>
<tr>
<td>Forestry</td>
<td>5.8</td>
</tr>
<tr>
<td>Food Packing</td>
<td>0.15</td>
</tr>
<tr>
<td>Food Processing</td>
<td>0.14</td>
</tr>
<tr>
<td>Animal Processing</td>
<td>0.05</td>
</tr>
<tr>
<td>Municipal</td>
<td>1.0</td>
</tr>
</tbody>
</table>

http://pacificbiomass.org
Biomass Methane Potential

Moody et al., 2011
Compost and Biosolids applications

12 sites monitored 2 to 18 years after application:

- Soil carbon and nitrogen remained above control soils
- Soil water holding capacity also above control soils

Brown et al., 2011

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What is Biochar

Biochar is a fine-grained, highly porous material created by the thermo-chemical transformation of wood (& straw ....) biomass.

Biochar helps soils retain nutrients and water due to its large surface area. The greater the surface area the better the biochar.

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Biochar is similar to activated carbon

Activated carbon properties

- High Surface area/gram
- High sorption capacity
- Can be designed for high cation and/or anion exchange
- High water holding capacity and increased aeration
Scanning Electron Micrograph: WSU

Douglas Fir Wood

Douglas Fir Bark

Hybrid Poplar wood

Suliman et al., 2016
Soil and added Biochar: Water Holding Capacity

Quincy Sand (QS)

- High water release
- Low soil water retention

Unoxidized biochar + QS

- Low water release
- High soil water retention

Oxidized biochar + QS

- Lower water release
- Higher soil water retention

Suliman et al., 2017
Biochar impact on Soils

- Significantly increase water holding capacity
- Improve fertilizer N use, & legume nodulation
- Biochar provides other macro/micro nutrients
- Biochar reduces $\text{N}_2\text{O}$ off-gassing & increases $\text{CH}_4$ uptake in soils
  - GHG impact of $\text{N}_2\text{O}$ & $\text{CH}_4$ - 296 and 23 times CO$_2$
How is biochar made?

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 Courtesy Kelpie Wilson
 http://www.greenyourhead.com
World’s smallest biochar reactor

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Biochar is made & used around the world

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Ag Energy Solutions finds unexpected market for biochar

Waste-to-power byproduct becomes company’s focus

By Mike McLean
September 14th, 2017

• Numerous crops and other uses being evaluated
• Marijuana produces well with AgEnergy biochar
• Expect to be profitable next year
Biochar Solutions Inc. Chips to Biochar
2 Dry tph chips - > 2 CY/hr biochar + MMBtuh thermal

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Organic matter in WA soils

SSURGO Weighted Average Organic Matter Content for the Upper 30 cm, Excluding Forest Organic Surface Litter

Legend
- OM 0-30 cm wt% avg.
  - < 1
  - > 1 - 2
  - > 2 - 3
  - > 3 - 4
  - > 4 - 5
  - > 5 - 6
  - > 6 - 7
  - > 7 - 8
  - > 8 - 9
  - > 9

Data Source: Soil Survey Geographic Database (SSURGO), 2013 (http://websoilsurvey.sc.egov.usda.gov)

Organic matter content is percent by weight in the los < 2 mm fraction. Blank areas indicate that SSURGO data is not available.

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Palouse silt loam - near Pullman, WA

- Soil organic carbon 4% to 5% (topsoil)
- Depth interval 4” (10 centimeters)
Terra Preta Soil of the Amazon Basin

Left - an oxisol poor in nutrients.
- typical soil of the hot/humid tropics

Right - fertile terra preta soil
- transformed by human activity
- Very high in stable carbon

Depth interval - 10 cm

Glaser, et al., 2001
African Dark Earth Soils

Left – Typical African soil
• Hot/humid Liberia and Ghana.

Right - fertile African Dark Earth soil
• transformed by human activity
• Very high in stable carbon

Depth interval - 10 cm

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Solomon et al., 2016
Terra Preta

8 g C/kg = 15 tons/ac-ft

oxisol – low black carbon

terra preta – high black carbon

from Glaser, et al., 2001

African Dark Earth

Solomon et al., 2016
Soils of the Illinois Plain

Drummer Silty Clay Loam
- State Soil of Illinois
- Depth interval – inches
- Deep, well mixed, extremely fertile organic rich soils

Illinois State Soil, NRCS - USDA

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Four main strategies to reduce compost odor:

- Enhance emissions control infrastructure (more air quality control equipment),
- Biological optimization of compost piles (changes in windrow size, aeration, etc.),
- Add anaerobic pre-processing for the highly biodegradable wastes (high solids anaerobic digestion), and
- Amending compost materials with high-carbon products (biochar).

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### Typical Odor Causing compounds from Composting

<table>
<thead>
<tr>
<th>Compound Name</th>
<th>Chemical Formula</th>
<th>Primary Odor Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>CH$_3$CHO</td>
<td>Pungent</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH$_3$</td>
<td>Urine, pungent</td>
</tr>
<tr>
<td>Butyric acid</td>
<td>CH$_3$CH$_2$CH$_2$COOH</td>
<td>Rancid, sour</td>
</tr>
<tr>
<td>Diethyl sulfide</td>
<td>C$_2$H$_5$C$_2$H$_5$S</td>
<td>Garlic</td>
</tr>
<tr>
<td>Dimethyl amine</td>
<td>CH$_3$CH$_3$NH</td>
<td>Fishy</td>
</tr>
<tr>
<td>Dimethyl sulfide</td>
<td>CH$_3$CH$_3$S</td>
<td>Foul, decayed</td>
</tr>
<tr>
<td>Ethyl mercaptan</td>
<td>C$_2$H$_5$SH</td>
<td>Decayed cabbage</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>HCHO</td>
<td>Pungent</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>H$_2$S</td>
<td>Rotten eggs</td>
</tr>
<tr>
<td>Indole</td>
<td></td>
<td>Fecal</td>
</tr>
<tr>
<td>Methyl mercaptan</td>
<td>CH$_3$SH</td>
<td>Foul, decayed</td>
</tr>
<tr>
<td>Phenol</td>
<td>C$_6$H$_5$OH</td>
<td>Medicinal</td>
</tr>
<tr>
<td>Propyl mercaptan</td>
<td>C$_3$H$_7$SH</td>
<td>Unpleasant</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>SO$_2$</td>
<td>Pungent</td>
</tr>
<tr>
<td>Trimethyl amine</td>
<td>CH$_3$CH$_3$CH$_3$N</td>
<td>Fishy, ammonical</td>
</tr>
<tr>
<td>Valeric acid</td>
<td>CH$_3$CH$_2$CH$_2$COOH</td>
<td>Body odor</td>
</tr>
</tbody>
</table>
Compost Emissions from control, 5% ash, and 5% biochar mixtures in the first 2 weeks

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Cumulative CO$_2$, CH$_4$, & N$_2$O during compost & biochar blended compost
Evolution of CO$_2$, CH$_4$, NH$_3$, N$_2$O, extractable NH$_3$ & TKN during composting

DFSS – De-watered fresh biosolids
WS – Wheat Straw
L – Lime
B – Biochar

Awasthi et al, 2016
June 4, 2014 – Dryland Winter Wheat Field Plots
Amended Lime & Gasified Biochar—Gady Farm, Rockford, WA

S.M. Griffith, G.M. Banowetz, D. Gady
USDA-ARS-FSCRIU, Corvallis, OR in cooperation with Synthigen Inc.
Biochar co-compost, Basil greenhouse study at WSU

A

Eleanora Basil

B

TSQ Basil

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Biochar co-compost, Basil greenhouse study at WSU

![Bar chart showing fresh weight comparison for Mint, TSQ, and SW treatments with different compost and ash + compost treatments.](chart.png)

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Greenhouse gas analysis for 70,000 cows, 20% v/v food waste

<table>
<thead>
<tr>
<th>AD w/ Nutrient Recovery</th>
<th>Atmospheric Carbon offset in MMT CO2e/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD methane capture</td>
<td>0.342</td>
</tr>
<tr>
<td>Co-digestion methane capture</td>
<td>0.611</td>
</tr>
<tr>
<td>Electrical Offset</td>
<td>0.114</td>
</tr>
<tr>
<td>Peat replacement (separated fiber)</td>
<td>0.019</td>
</tr>
<tr>
<td>Bio-Phosphorous (P recovered from digester solids)</td>
<td>0.003</td>
</tr>
<tr>
<td>Bio-Nitrogen (from NH₃ stripping)</td>
<td>0.014</td>
</tr>
<tr>
<td>Total</td>
<td>1.103</td>
</tr>
</tbody>
</table>

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