Electronic Supplementary Information
for
Evaluating landfill leachate treatment by organic municipal solid waste-derived biochar
Table S1. Measurements of each dry feedstock’s elemental composition, which includes carbon (C), hydrogen (H), nitrogen (N), and ash; each of these was used to calculate oxygen (O) and the hydrogen to carbon (H/C), oxygen to carbon (O/C), and oxygen plus nitrogen to carbon (O+N/C) ratios. All are percent by mass. Note: * denotes that lignin and cellulose composition were based on typical feedstock compositions as found in the referenced literature.

<table>
<thead>
<tr>
<th></th>
<th>C %</th>
<th>H %</th>
<th>N %</th>
<th>Ash %</th>
<th>O %</th>
<th>H/C %</th>
<th>O/C %</th>
<th>O+N/C %</th>
<th>Lignin* %</th>
<th>Cellulose* %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>54</td>
<td>7.5</td>
<td>0.5</td>
<td>18</td>
<td>21</td>
<td>166</td>
<td>29</td>
<td>29</td>
<td>0 to 15 %</td>
<td>62 to 99 %</td>
</tr>
<tr>
<td>Pine needles</td>
<td>49</td>
<td>7.0</td>
<td>1.5</td>
<td>3.8</td>
<td>39</td>
<td>170</td>
<td>59</td>
<td>62</td>
<td>20 to 33 %</td>
<td>30 to 39 %</td>
</tr>
<tr>
<td>Grass</td>
<td>44</td>
<td>5.5</td>
<td>1.0</td>
<td>11</td>
<td>38</td>
<td>149</td>
<td>65</td>
<td>67</td>
<td>4.0 to 30 %</td>
<td>25 to 50 %</td>
</tr>
<tr>
<td>Wood</td>
<td>49</td>
<td>6.0</td>
<td>1.0</td>
<td>0.25</td>
<td>43</td>
<td>143</td>
<td>64</td>
<td>66</td>
<td>29 to 35 %</td>
<td>38 to 44 %</td>
</tr>
<tr>
<td>Peanut</td>
<td>48</td>
<td>5.4</td>
<td>1.7</td>
<td>28</td>
<td>17</td>
<td>134</td>
<td>27</td>
<td>30</td>
<td>30 to 40 %</td>
<td>25 to 45 %</td>
</tr>
<tr>
<td>Orange</td>
<td>50</td>
<td>6.4</td>
<td>0.9</td>
<td>3.2</td>
<td>40</td>
<td>153</td>
<td>60</td>
<td>62</td>
<td>0.6 to 6.9 %</td>
<td>13 to 34 %</td>
</tr>
<tr>
<td>Coffee</td>
<td>57</td>
<td>7.6</td>
<td>2.1</td>
<td>2.0</td>
<td>31</td>
<td>159</td>
<td>41</td>
<td>44</td>
<td>18 to 26 %</td>
<td>12 to 23 %</td>
</tr>
</tbody>
</table>
**Table S2.** Synthetic leachate recipe.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Chemical formula</th>
<th>Units</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VOCs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>C₆H₅NO₂</td>
<td>mg/L</td>
<td>0.03</td>
</tr>
<tr>
<td>2,4 Dichlorophenoxyacetic acid</td>
<td>C₈H₆Cl₂O₃</td>
<td>mg/L</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>VFAs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic acid</td>
<td>CH₃COOH</td>
<td>mL/L</td>
<td>2.4</td>
</tr>
<tr>
<td>Propionic acid</td>
<td>C₃H₆O₂</td>
<td>mL/L</td>
<td>1.714</td>
</tr>
<tr>
<td>Butyric acid</td>
<td>C₄H₈O₂</td>
<td>mL/L</td>
<td>0.343</td>
</tr>
<tr>
<td><strong>Inorganic compounds</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium bicarbonate</td>
<td>NH₄HCO₃</td>
<td>mg/L</td>
<td>2440</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>CaCl₂*2H₂O</td>
<td>mg/L</td>
<td>3350</td>
</tr>
<tr>
<td>Dipotassium phosphate</td>
<td>K₂HPO₄</td>
<td>mg/L</td>
<td>30</td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td>MgCl₂*6H₂O</td>
<td>mg/L</td>
<td>3115</td>
</tr>
<tr>
<td>Magnesium sulfate</td>
<td>MgSO₄</td>
<td>mg/L</td>
<td>156.3</td>
</tr>
<tr>
<td>Potassium bicarbonate</td>
<td>KHCO₃</td>
<td>mg/L</td>
<td>312</td>
</tr>
<tr>
<td>Potassium carbonate</td>
<td>K₂CO₃</td>
<td>mg/L</td>
<td>325</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>NaHCO₃</td>
<td>mg/L</td>
<td>3015</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>NaNO₃</td>
<td>mg/L</td>
<td>50</td>
</tr>
<tr>
<td>Urea</td>
<td>CO(NH₂)₂</td>
<td>mg/L</td>
<td>695</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum sulfate</td>
<td>Al₂(SO₄)₃*16H₂O</td>
<td>µg/L</td>
<td>30</td>
</tr>
<tr>
<td>Ammonium molybdate hydrated</td>
<td>(NH₄)₆Mo₇O₂₄*4H₂O</td>
<td>µg/L</td>
<td>50</td>
</tr>
<tr>
<td>Boric acid</td>
<td>H₃BO₃</td>
<td>µg/L</td>
<td>50</td>
</tr>
<tr>
<td>Cobalt sulfate</td>
<td>CoSO₄*7H₂O</td>
<td>µg/L</td>
<td>150</td>
</tr>
<tr>
<td>Copper sulfate hydrated</td>
<td>CuSO₄*5H₂O</td>
<td>µg/L</td>
<td>40</td>
</tr>
<tr>
<td>Ferrous sulfate hydrated</td>
<td>FeSO₄*7H₂O</td>
<td>µg/L</td>
<td>3659</td>
</tr>
<tr>
<td>Manganese sulfate</td>
<td>MnSO₄*H₂O</td>
<td>µg/L</td>
<td>305</td>
</tr>
<tr>
<td>Nickel sulfate</td>
<td>NiSO₄*6H₂O</td>
<td>µg/L</td>
<td>500</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>96% H₂SO₄</td>
<td>µL/L</td>
<td>1</td>
</tr>
<tr>
<td>Zinc sulfate</td>
<td>ZnSO₄*7H₂O</td>
<td>µg/L</td>
<td>50</td>
</tr>
</tbody>
</table>
Figure S1. Measured biochar micropore (plus sign) and non-micropore (star) surface areas as a function of feedstock A) cellulose and B) lignin contents for each biochar (color based on feedstock). The lignin and cellulose content’s error bars represent the range found in literature (Table S1), and the marker is the midpoint of that range. Despite that future research has found that lignin and cellulose can contribute to biochar structure,\textsuperscript{65,66} there were no correlations with the estimated lignin contents (possibly due to the large ranges of possible values for each feedstock) and only weak correlations with the estimated cellulose contents.

Figure S2. Dose to 50\% nitrobenzene removal in real leachate as a function of the reciprocal of biochar micropore surface area. All biochars were included except peanut biochar because it did not have micropore surface area. Micropore surface area had a potential correlation with nitrobenzene removal.
Figure S3. Doses to 50% nitrobenzene (NB) and to 25% 2,4-D removal in real leachate versus synthetic leachate; both removal trendline slopes are greater than one, suggesting that the real leachate had more competitive effects than the synthetic leachate.

Figure S4. Doses to 50% nitrobenzene (NB) and to 20% 2,4-D removal in synthetic leachate versus deionized (DI) water; the largest, common 2,4-D removal dose in DI water was 20%. Biochar doses in synthetic leachate were similar to those in water without any DOM (i.e., DI water).
Figure S5. Factor change in dose to 25% 2,4-D and to 50% nitrobenzene (NB) removal required from synthetic to real leachate background matrices as a function of non-micropore surface area for each biochar. No trend exists for either OMP, suggesting that non-VFA DOM is not being accommodated by increasing non-micropore surface area.

Figure S6. Factor change in dose to 25% 2,4-D and to 50% nitrobenzene (NB) removal in real leachate as impacted by the ash-pretreatment enhancement; dose change is graphed as a function of A) factor change in biochar ash content (enhanced biochar ash content relative to the untreated biochar of the same feedstock), and B) feedstock ash content. Biochar performance generally improved if the biochar ash content increased after the enhancement, but that improvement was not correlated with the feedstock ash content.
References


