Biochar as a filter media for removing lead and arsenic in water

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Terra Preta

A very dark, fertile manmade (anthropogenic) soil found in the Amazon Basin; “black earth” or “black land”

High OM and CEC -> fertile soil in terra preta today...

If this woody aboveground biomass were converted into biochar by means of simple kiln techniques and applied to soil, more than 50% of this C would be sequestered in a highly stable form.
Biochar

• A black carbon obtained from the thermochemical conversion of biomass in an oxygen-limited environment.

• Soil amendment and other environmental applications.
How biochar is made, and its potential applications

Biomass
- Manure
- Organic wastes
- Crop residues (forest and agriculture)

Pyrolysis
Biochar is produced through pyrolysis or gasification — processes that heat biomass in the absence of oxygen.

Biochar
- Returned to soil as Biochar
  - Boost crop yield
  - Reclaim mine sites
  - Sequester carbon
- growth media for greenhouse vegetables and horticultural crops
- Clean up of wastewater in the energy sector
Pristine Biochar

• Woody and grass materials
  – Wood and grass including invasive species
  – Forestry residues
  – Sawdust and lumber residues

• Agricultural wastes
  – Shells, hulls, etc
  – Manure
  – Citrus residuals

• Solid waste
  – Yard wastes
  – Municipal sludge
Engineered Biochar

- **Impregnations**
  - Nano metal oxyhydroxides (e.g., Magnetized biochar)
  - Graphene and carton nanotube

- **Surface activation**
  - Activated carbon
  - Oxidation
  - Coating
Heavy metal removal in water

- Membrane filtration
- Ion exchange resin
- Precipitation
- Adsorption

Study objectives

• To produce biochars using locally-sourced feedstock materials
• To evaluate the biochars for their efficacy in binding aqueous lead and arsenic.
• To investigate biochar performance affected by pyrolysis temperature and feedstock types.
Biochar Production in this study

Pyrolyzed each biomass at three different temperatures (300 °C, 450° C, and 600°C) for 1 hr.
Adsorption experiment

- **Single Point Adsorption**: used 10 ppm of Pb, 10 mg of biochar, and 4 ml of solution.
  - The single point adsorption studies were done to determine which biochar pyrolyzed at a different temperature was more effective in removing lead.
- **Effect of solution pH**: solutions were adjusted to a pH range of 2-6.
- **Adsorption isotherms**: the adsorption isotherm were conducted at varying concentrations of aqueous Pb (5, 10, 25, 50, 100, and 250 mg L\(^{-1}\)) in triplicates and their pH was adjusted to pH 6.
Pyrolysis temperature > 450 °C for corn stover biochar resulted in greater Pb binding while lower temperature did better for orange peel biochar.
Effect of solution pH on Pb binding onto the biochars

- Pb adsorption efficiency increases with the increase in pH
Pb adsorption isotherm fitted by Langmuir model

Max. Sorption Capacity ($S_{\text{max}}$) for CS600 = 25,000 mg kg\(^{-1}\)

$S_{\text{max}}$ for OP300 = 11,000 mg kg\(^{-1}\)

$S_{\text{max}}$ for PS600 = 2,500 mg kg\(^{-1}\)
## Biochar characterization

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Temperature (°C)</th>
<th>Yield (%)</th>
<th>pH</th>
<th>(^a)EC ((\mu)Scm(^{-1}))</th>
<th>(^b)SA (m(^2)/g)</th>
<th>Ash (%)</th>
<th>Moisture (%)</th>
<th>(C) (wt.%)</th>
<th>(O) (wt.%)</th>
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<tbody>
<tr>
<td>Orange Peel</td>
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</table>

Arsenic removal with orange peel biochar

- As (III) is more toxic (40-60 times) than As (V)

\[ H_3\text{AsO}_4 + 3\text{H}^+ + 2\text{e}^- \rightarrow H_3\text{AsO}_3 + \text{H}_2\text{O} \]

Arsenate, As (V) \hspace{2cm} Arsenite, As (III)

http://2the4.net/arsenicart.htm
Our preliminary data showed that As binding was poor with OP biochar.....

• Because arsenic stays as an oxyanion and biochar surface is mostly negatively charged.
Magnetized biochar

- Coated biochar surface with iron oxide -> magnetized biochar

FeCl₂

OP biochar + NaOH

Magnetized OP biochar
OP biochar before magnetization

OP biochar after magnetization
As (III) and As (V) adsorption study is in progress.

Applications of biochar for stormwater management

- Filtration media in new/existing treatment systems (e.g., filter socks, bioswale, permeable reactive barrier, etc.)
“Water is the driver of Nature.”
“We might say that the earth has the spirit of growth; that its flesh is the soil.”
- Leonardo da Vinci

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