Innovative Stormwater Quality Control: Application of Biochar

Kyle Shimabuku
EPA STAR Fellow/ Graduate Research Assistant
kyle.shimabuku@colorado.edu

University of Colorado Boulder

NKRI: Drought Vulnerability and Tools for Improving Water Resilience Workshop
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OUTLINE

Background
- Stormwater reuse
- Stormwater contaminants → Organic pollutants
- Biochar

Research
- Optimizing biochar performance
- Regeneration
- Environmental impact

Applications
- Full scale biochar production and stormwater treatment
Stormwater reuse: future potential

Benefits

- Decrease dependence on imported water
- Meet stormwater regulations
- Flood protection
- Enhance community health and safety (Kuo, 2001)

Legislation

California Senate Bill No. 985

“... authorize one or more public agencies to develop a stormwater resource plan.”

“...one of the most cost-effective sources of new water supplies, ...using significantly less energy than other sources of new water supplies.”

Proven

Swiss Water Pollution Control Law, 1992, Article 7

“Non-polluted waste water must be discharged by infiltration according to the instructions of the cantonal authority.”
Stormwater reuse: challenge of water quality

(Grebel et al., 2013)
# Stormwater reuse: challenge of water quality

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<td>2,4-D</td>
<td>&lt;67</td>
<td>70</td>
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“Stormwater infiltration for aquifer recharge is commonly practiced, but designs and regulations in the United States may not be adequately protective.” (NAS, 2015) (Grebel et al., 2013)
Stormwater reuse: challenge of water quality

- Monitored for 75 pesticides in 51 sites

- % with 1 or more pesticides with conc. exceeding aquatic life benchmarks

(Gilliom, 2007)

- cyp1a proteins correspond to cardiotoxicity

(McIntyre et al., 2016)
Stormwater treatment systems

- Unable to remove many organic contaminants without reactive media
  - Zhang et al. (2014) observed <50-20% removal of atrazine and simazine in biofilters
- Many widely used sorbents (e.g., activated carbon) are too expensive to apply in stormwater treatment systems (Pit, 1999)
- Need for a low-cost sorbent
Biochar

- Material produced from the pyrolysis or “charing” of biomass
  - Byproduct of energy production from biomass
- Soil amendment
  - Bind and slow release nutrients
  - Water holding capacity
- Biochar is an alternative sorbent to activated carbon
  - Can have comparable sorption capacity for organic contaminants (Shimabuku et al. 2016)
  - 2-30% cost of activated carbon (Kearns et al., 2014)
  - Has shown better removal for metals than activated carbon (Cao et al., 2009)
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Biochar

**Feedstock**
- Biomass

**Pyrolysis conditions**
- 400-900 °C
- n/a

**Activation**
- <500 m²/g
- Can be positive
- negative

**Surface area**
- Energy balance
- Carbon balance

**Activated carbon**

- Mostly coal, some biomass
- > 500 °C, N₂
- Thermal >850 °C: Steam, CO₂
- Chemical: KOH, ZnCl₂, H₃PO₄
- <2,000 m²/g
- Usually negative
- Usually positive
Biochar: Bacteria removal

Intermittent Rainfall

Sand

Enhance Detachment

More Bacteria

Biochar

Prevent Detachment

Less Bacteria

1-3 log more removal with laboratory and commercial biochars

(Mohanty et al., 2014)
Background

Applications

Biochar: Metals and nutrients

- Filtered stormwater with commercial biochar

- Observed removal of metals and nutrients even after desorption phase

(Reddy et al., 2014)
Biochar: Organic contaminant - Atrazine

For a 100 m² drainage basin for a 3 acre catchment
- Receiving 16 in precipitation/year
- Commercial biochar exhibited ~10X less capacity than commercial activated carbon in batch

(Ulrich et al., 2015)
Research topics

- Most biochars are optimized to be soil amendments
- My overall research objective is to determine if we can optimize biochars for organic contaminant removal
  - Elucidate how production conditions determine the physicochemical properties and organic contaminant sorption behavior of biochar
  - Regeneration
  - Sustainability

![Diagram showing the research topics and their relationships]

- Peak Temp.
- Duration
- Gaseous conditions
- Pyrolysis
- Biochar
- Sorption behavior
- Characterization
- Sorption/desorption
- Competition
- Kinetics
Biochar: environmental impact

- Functional unit: 75% removal of sulfamethoxazole from 12.5 mgd wastewater effluent over 40 years.

-Low-impact PAC: Coal-based powdered activated carbon produced in California

(Thompson et al., 2016)
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-Low capacity biochar: Commercial biochar

(Thompson et al., 2016)
Biochar: environmental impact

- Functional unit: 75% removal of sulfamethoxazole from 12.5 mgd wastewater effluent over 40 years.

-Low-impact PAC: Coal-based powdered activated carbon produced in California
-High-impact PAC: Coal-based powdered activated carbon produced in Kentucky
-Low capacity biochar: Commercial biochar
-Moderate capacity biochar: optimized using laboratory furnace

(Thompson et al., 2016)
Biochar: applications

Port of Port Townsend Pilot Test

Port of Tacoma Log Yard Bioinfiltration system

(Gray et al., 2015) 

(Fichthorn et al., 2014)
Biochar: applications

- Targets Street Runoff & Building Sites Affluents
- Removal Rates for CODs etc. in 99% Range
- Attracts & Sorbs Petro-Products
- Sorbs 8-9x its Weight in Contaminate Runoff
- Ideal Size for Retention & L.I.D. Systems

*Sold in Bulk, Waddles & Socks
Biochar: production
Pilot test: Port of Port Townsend

Paper mill produces biochar byproduct ~10,000 gallons of treatment

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<tr>
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<th>Mean Effluent</th>
<th>Benchmark</th>
<th>Mean Removal</th>
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<tbody>
<tr>
<td>Total Copper</td>
<td>46.5</td>
<td>2.52</td>
<td>17</td>
<td>93.5%</td>
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<tr>
<td>Total Zinc</td>
<td>4925</td>
<td>7.46</td>
<td>120</td>
<td>99.8%</td>
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(Gray et al., 2015)
Summary

- A wide array of contaminants may need to be removed from stormwater for its reuse
  - Use of biochar can contribute to the removal of these contaminants

- Biochar is already being used to treat stormwater

- Biochar can be produced with the same organic contaminant sorption capacity as activated carbon
  - Not all biochars are the same
  - Production conditions need to be tailored to produce efficient sorbents

- Biochar holds promise for thermal regeneration

- Biochar can be more environmentally beneficial than activated carbon
**PhD Advisor:** Professor Scott Summers

**Master’s students:**
- Ben Greinger
- Luisa Vargas

**Undergraduate students:**
- Marisol Luna
- Julian Paige
- Connor Brosart

**Funding:**
- USEPA STAR Fellowship
- NWRI Fellowship
- AWWA American Water Scholarship
### References