Generating Novel Biochar Adsorbents from Landfill-Bound Waste Materials for Removal of Organic Contaminants in Landfill Leachate

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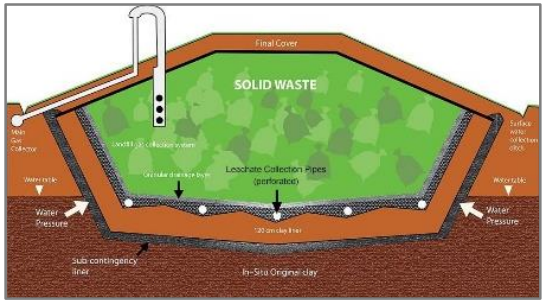
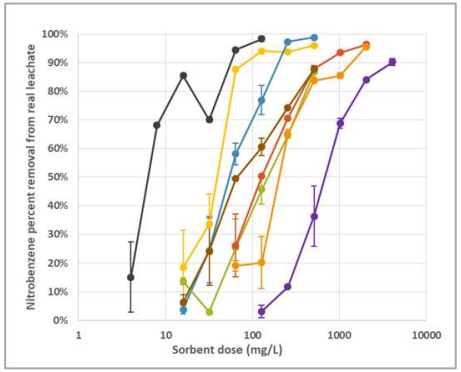
Biochars have the capability to remove organic pollutants from landfill leachate



Landfill leachate contains organic contaminants

Batch tests completed with biochar



Biochars analyzed

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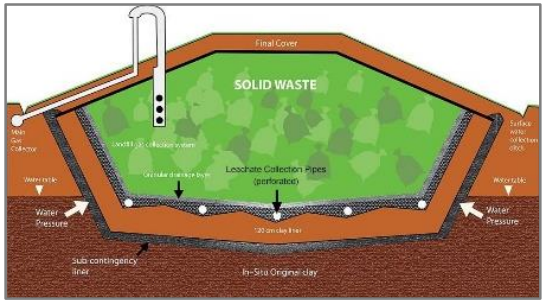

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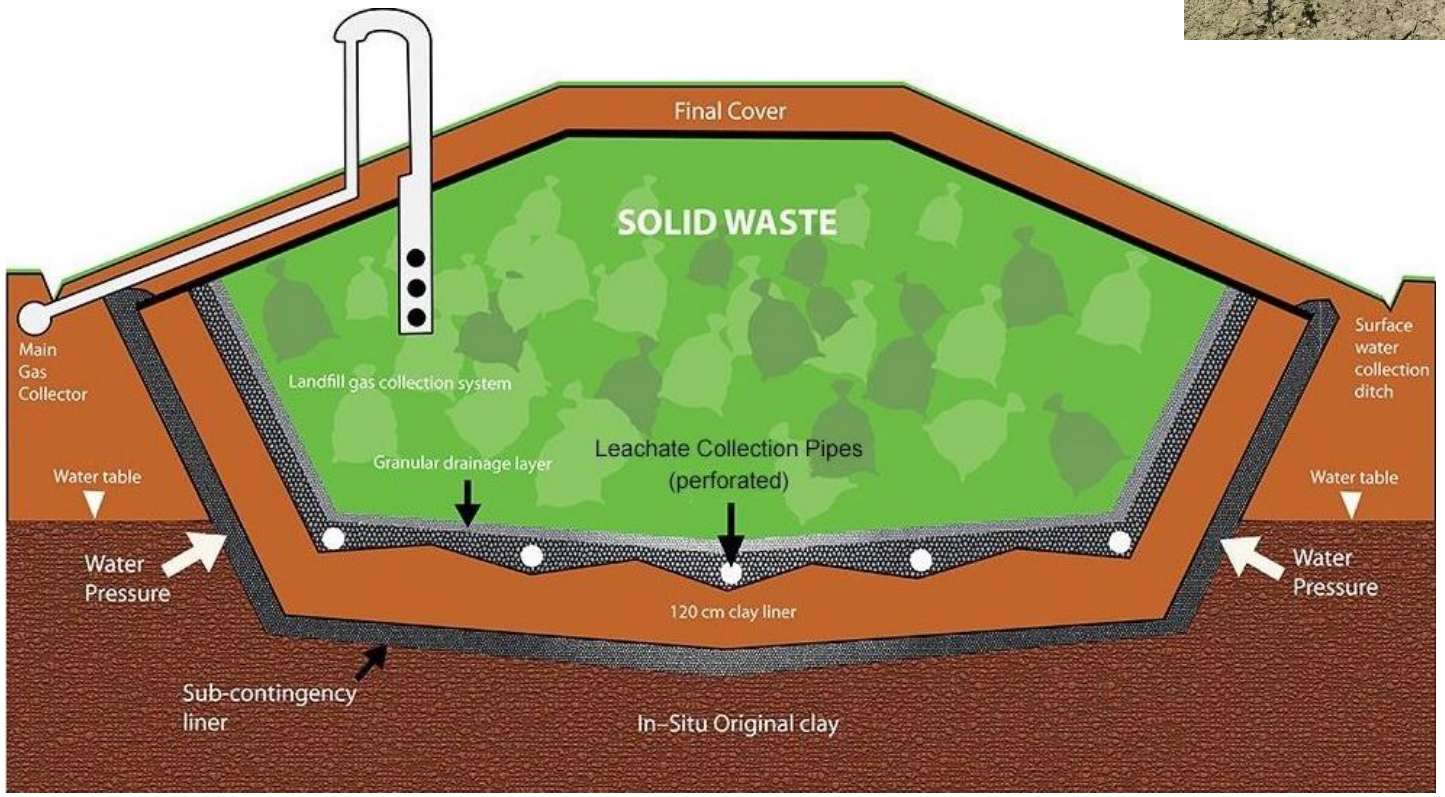
Significant quantities of landfill leachate are produced annually

2 billion tons MSW generated worldwide in 2016.

One landfill can produce 1,000 – 10,000 gal/day

There are over 2500 landfills in the US alone



(What a Waste 2.0, 2018; Ibrahim et al., 2016; EPA LMOP, 2019; Clean Way USA)

Activated carbon is effective but expensive, and biochar could be a viable alternative

Activated Carbon

- Works wells for sorption
- $400 - $2000 per ton
- Energy intensive (97 MJ/kg)

Biochar

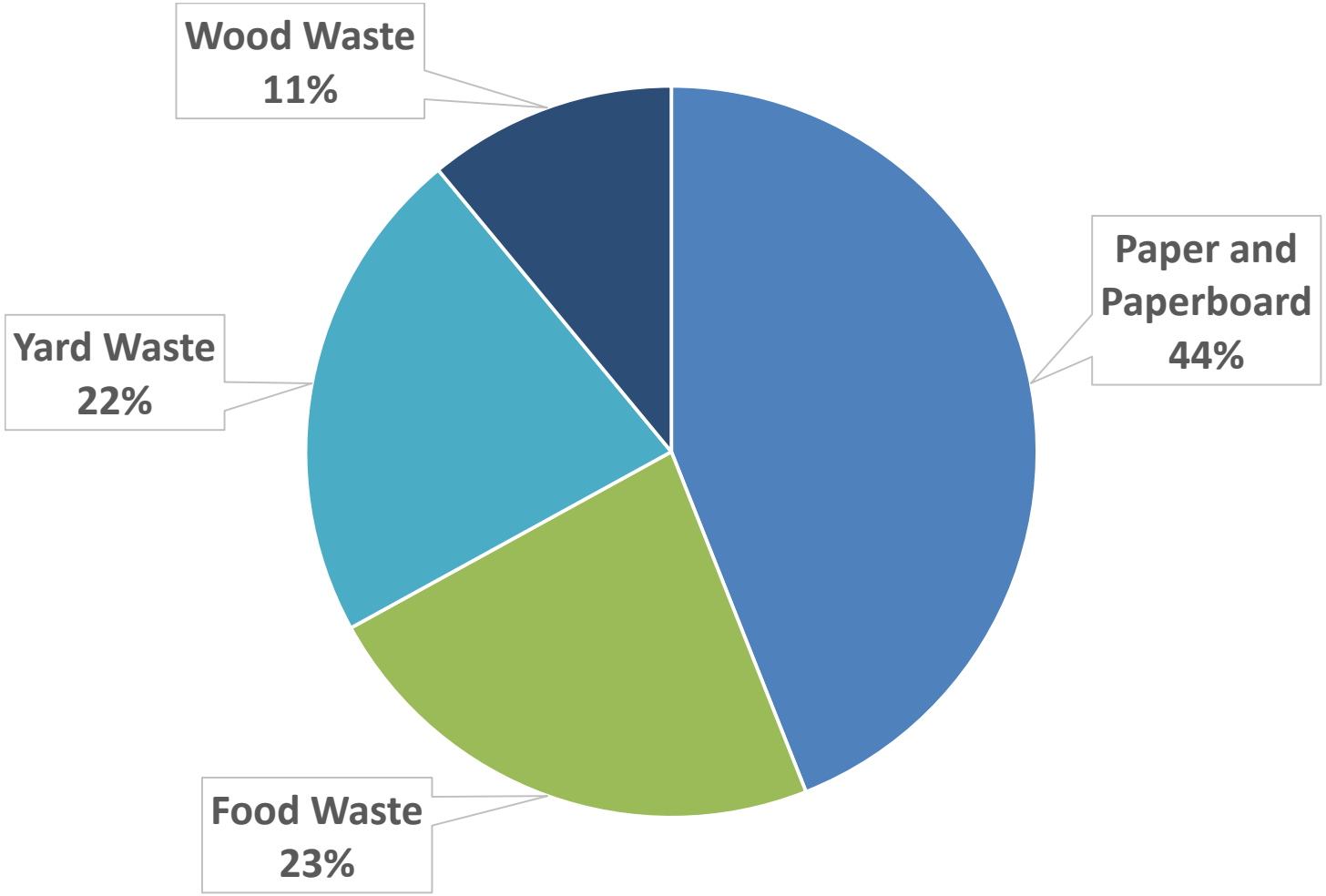
- Can be made from recycled materials
- $100 to $250 per ton from waste materials
- Energy cheap (6.1 MJ/kg)
- Could potentially reduce leachate contamination

Use waste materials as biochar → **Divert waste from landfill** → **Reduce contamination in leachate**

(Foo and Hameed, 2009; Chingombe et al., 2006; Roberts et al., 2010; Alhashimi and Aktas, 2017; Shackley et al., 2011)

Biochar could be produced using landfill-bound materials, 74% of which is organic.

Organic biomass fraction of landfill materials:



(EPA, 2012)

However, biochar generally sorbs organics less effectively compared to activated carbon.

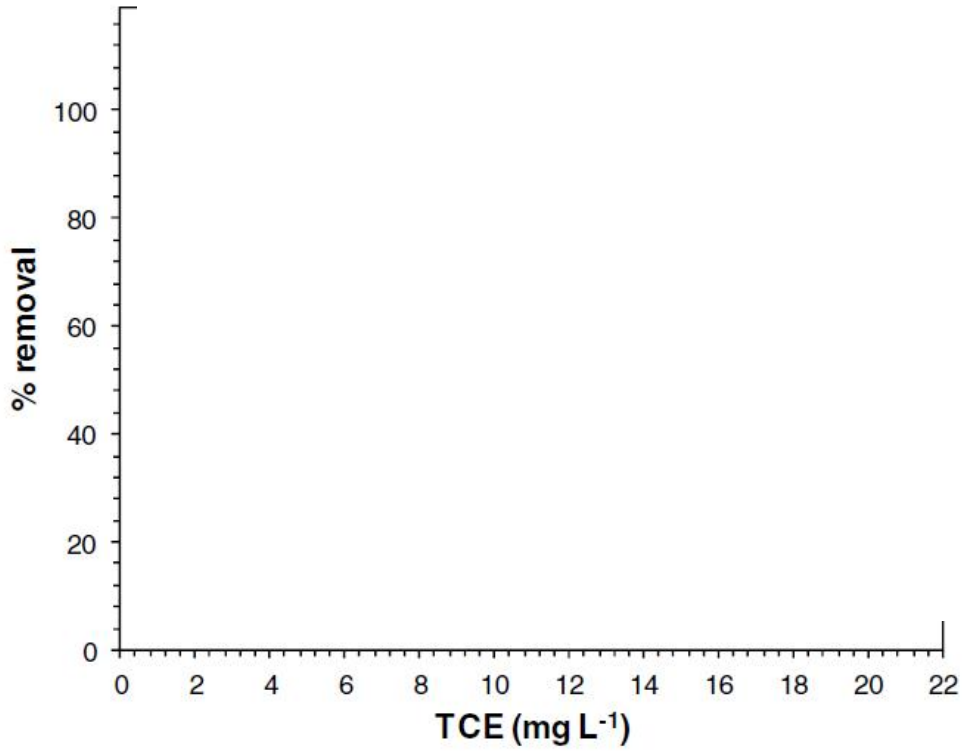
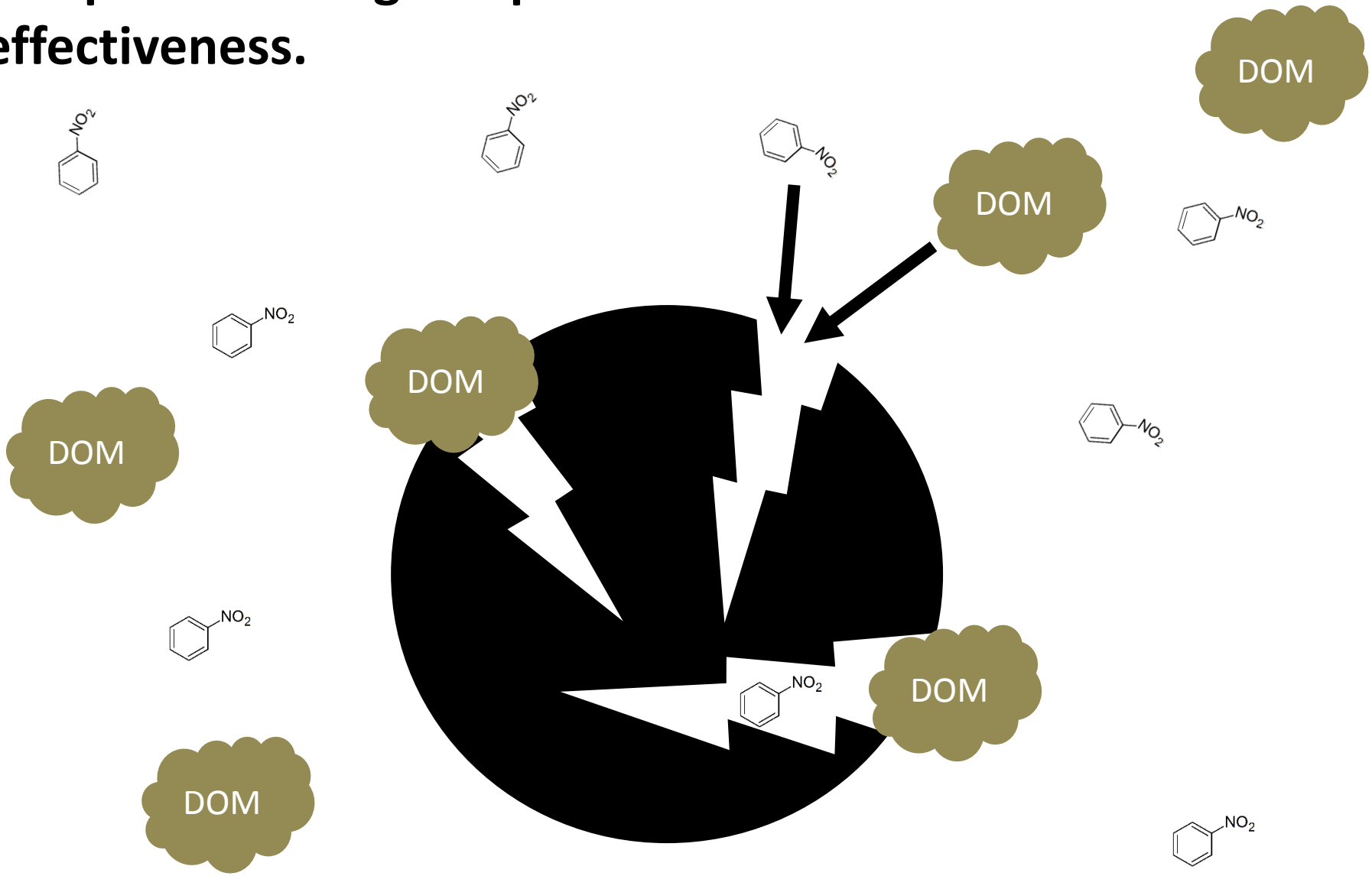


Fig. 2. Percentage removal of trichloroethylene (TCE) using biochars (BCs) and activated carbon (AC).

(Ahmad et al., 2012)

Dissolved organic matter (DOM) in landfill leachate could compete with organic pollutants and reduce sorbent effectiveness.



(Shimabuku et al., 2016; Quinlavin et al., 2005)

Biochars have the capability to remove organic pollutants from landfill leachate

Landfill leachate contains organic contaminants

Batch tests completed with biochar

Biochars analyzed

Seven MSW feedstocks collected for biochar production

Collected

Dried (105°C, 24 hr)

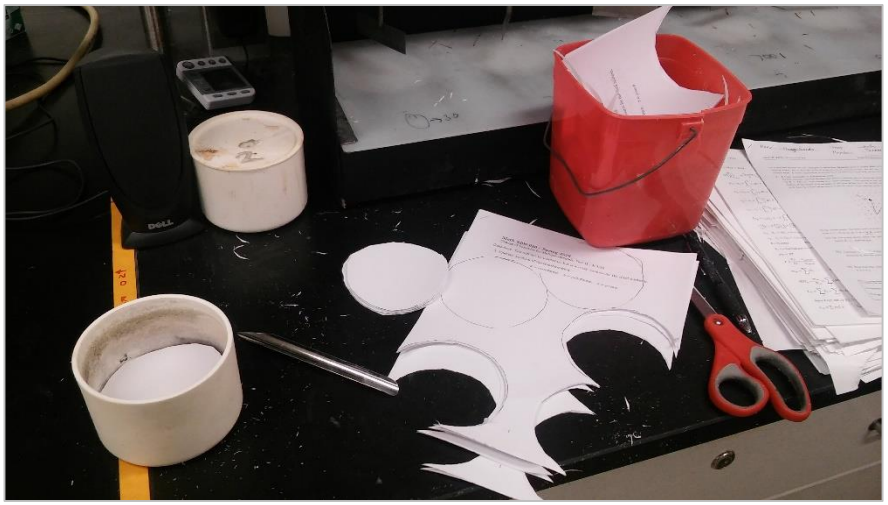
Cut/Pulverized

Paper Pine needles Grass Pine wood Peanut Orange Coffee

Powdered Activated Carbon (PAC) used to define baseline performance

Biochars pyrolyzed for sorbent consistency

- **Filled crucibles to limit air inside**



Biochars ground for sorbent consistency

- **Ground biochar (and PAC) using wet-grinding method to 35 – 75 µm particle size**

Treatments on biochar to aid sorption performance by improving pore structure

Ash-pretreatment

- Made wood ash (550°C, 6 hr)
- Mixed ash in DI water, filtered
- Soaked feedstock in ash solution
- Dried (105°C, 24 hr)
- Pyrolyzed as normal
- Ground as normal

Double-heating

- Pyrolyzed as normal
- Ground as normal
- Added to small crucibles with little air space
- Heat again at 600 °C for 2 hours

Wood, grass, paper, and orange treated to represent material types

Batch tests were done with real and synthetic landfill leachate

Real leachate

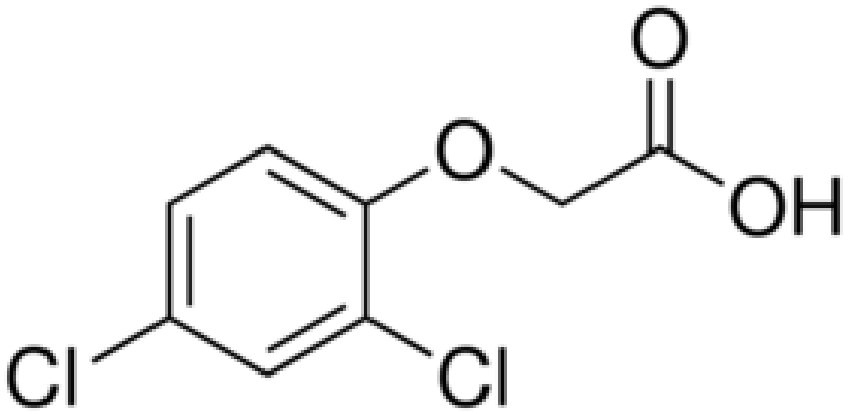
- **Collected from Front Range Landfill, Erie, CO**
- **Variable**
- **Full competition effect**

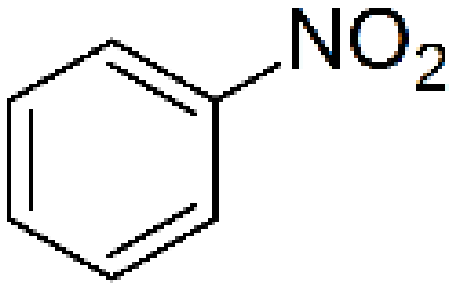
Synthetic leachate

- **Recipe modified from Hrapovic, 2002**
- **Controlled**
- **Comparable batch tests**

(Hrapovic, 2002; Champagne and Li, 2009)

2,4D and nitrobenzene chosen as representative compounds for pesticides and aromatic hydrocarbons





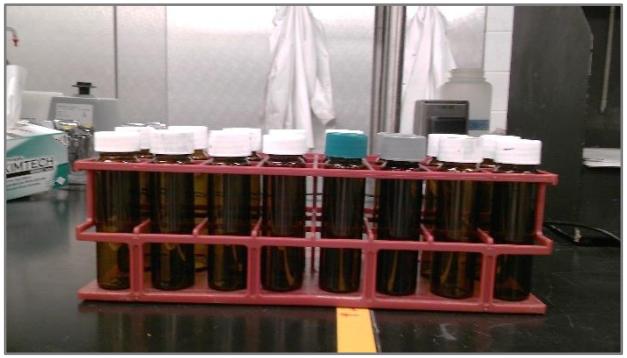
2,4-Dichlorophenoxyacetic acid (2,4D) **Nitrobenzene**

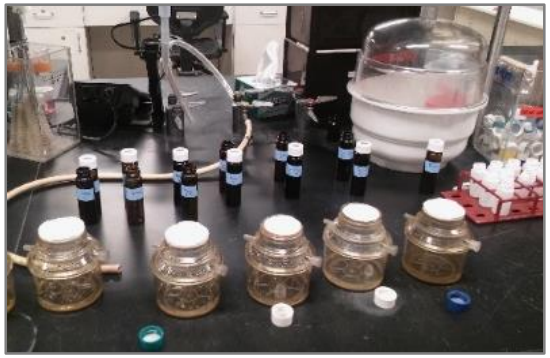
***2,4D and nitrobenzene are not removed well → conservative estimate**

***30 µg/L of each compound added → environmentally relevant concentration**

Batch tests completed for organic contaminant removal

- 40 mL batch test vials
- 6 biochar doses (8 mg/L, 16 mg/L, etc)
- Duplicates
- 3 hour batch test based on kinetics
- Filter vials (1.2 µm)
- Test on Liquid Scintillation Counter (LSC)





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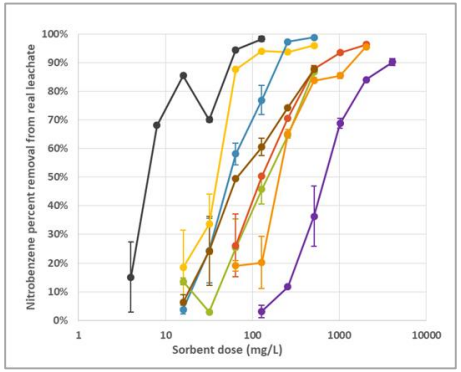
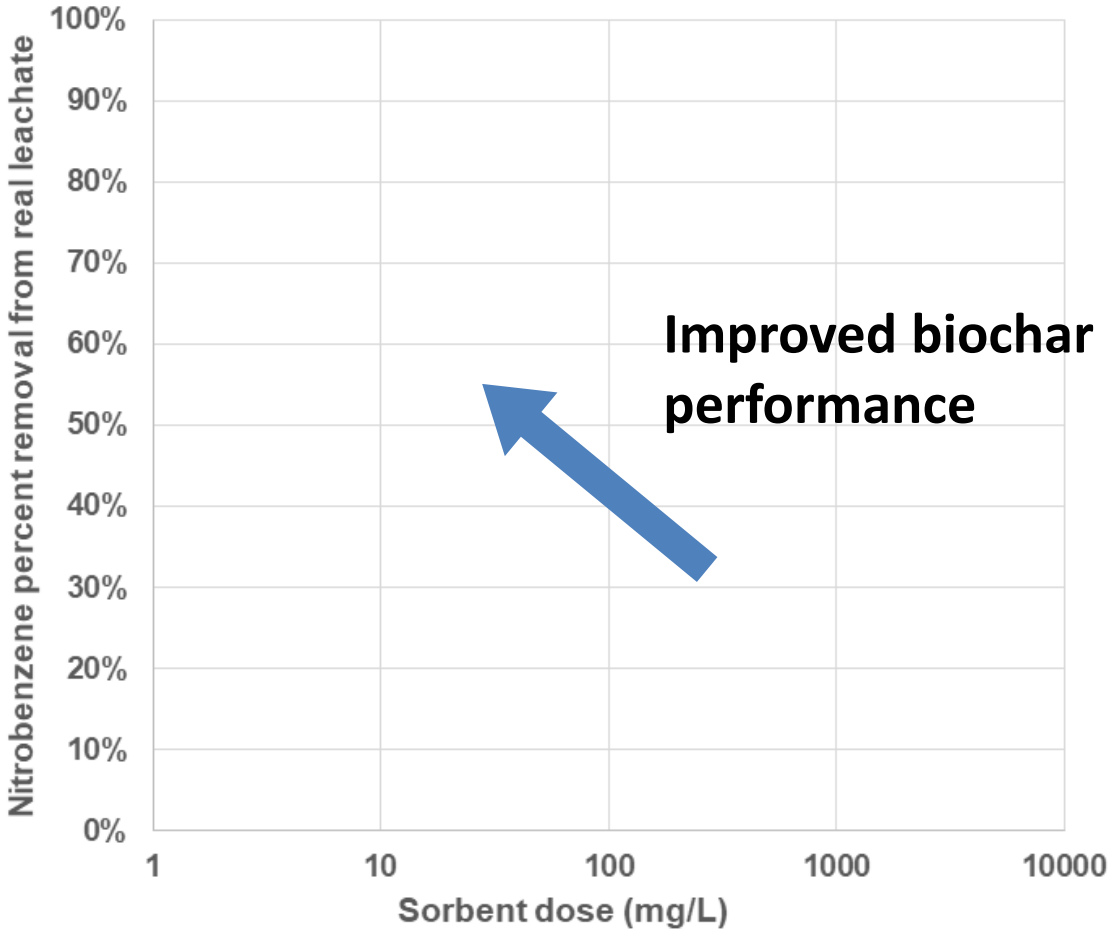


Biochars analyzed

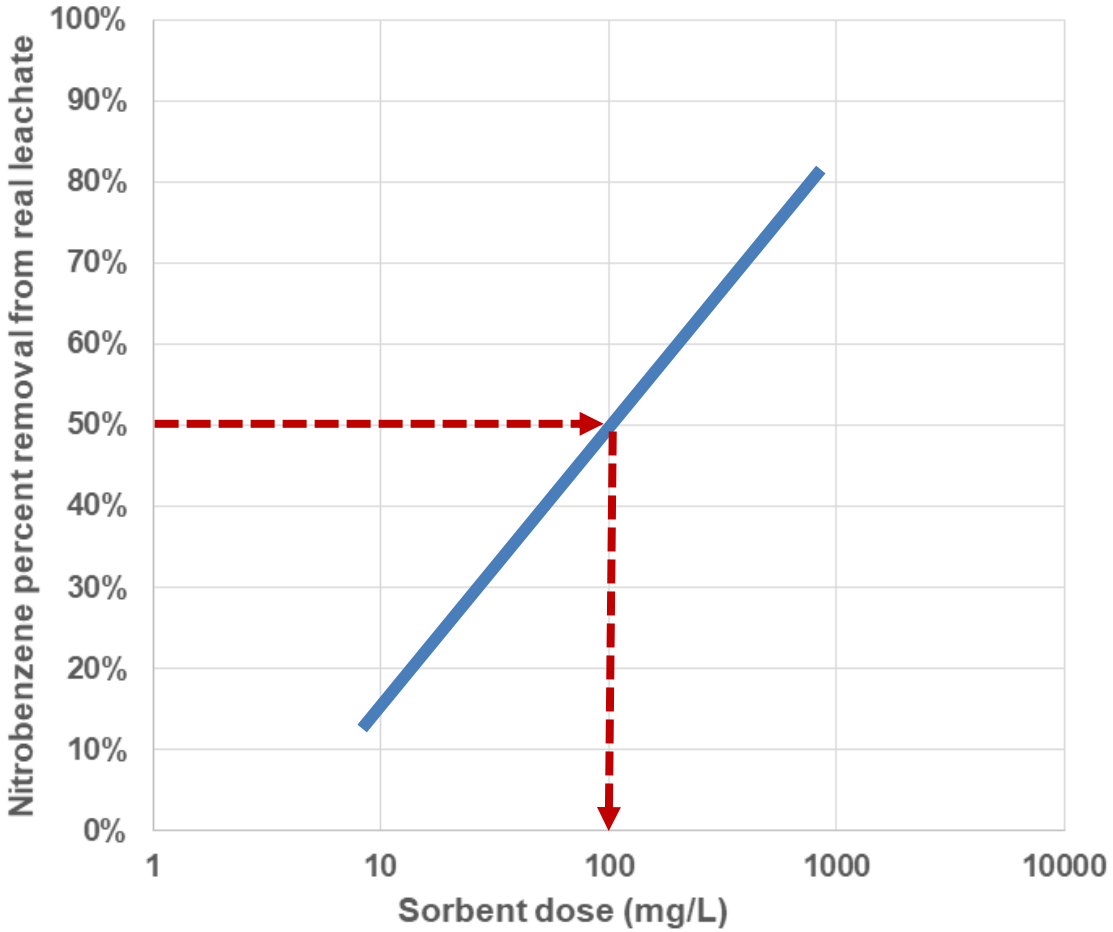
Reading Sorption Dose Response Curves



*Log scale

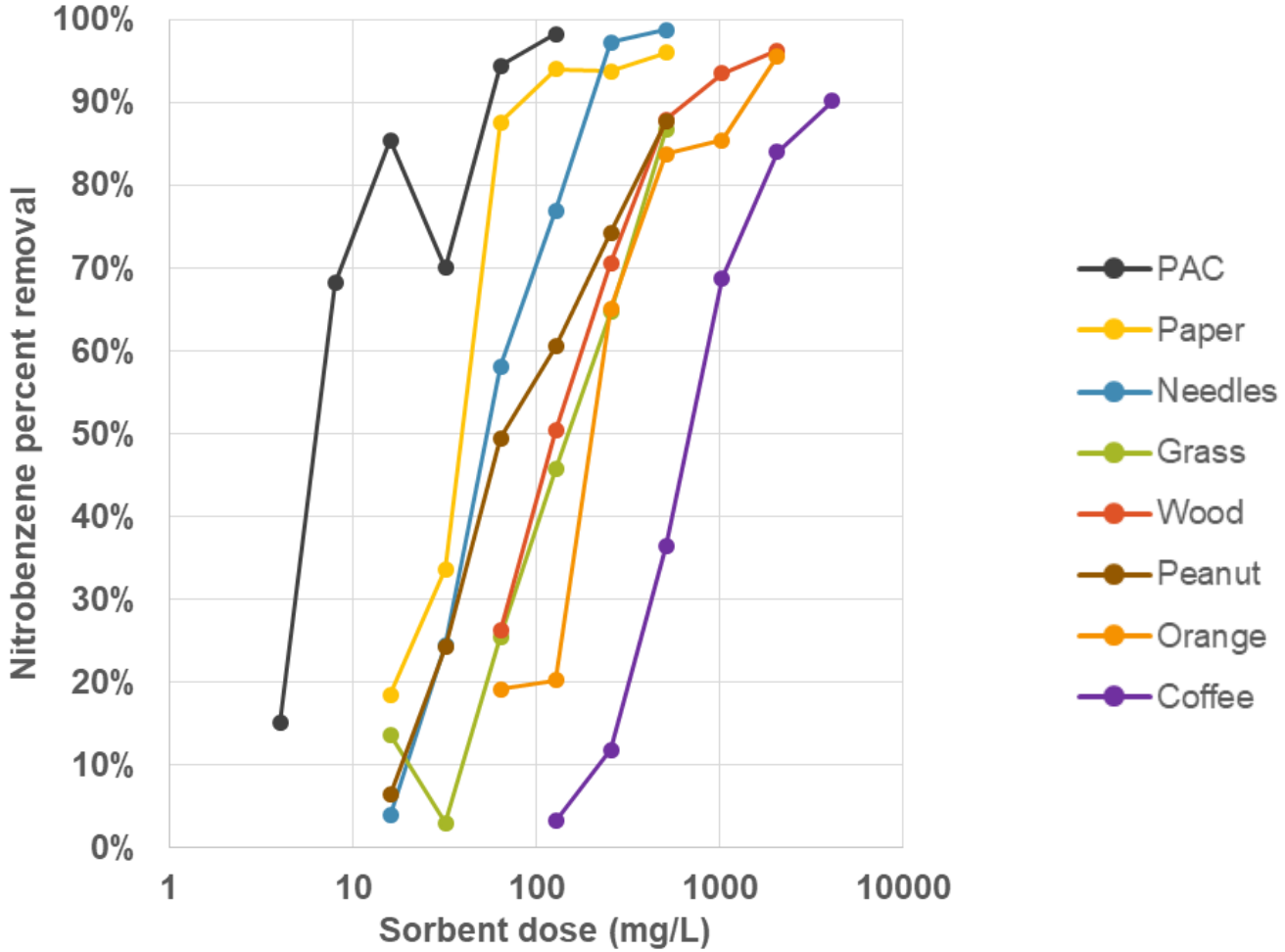
Reading Sorption Dose Response Curves – Removal doses

50% removal



≈100 mg/L

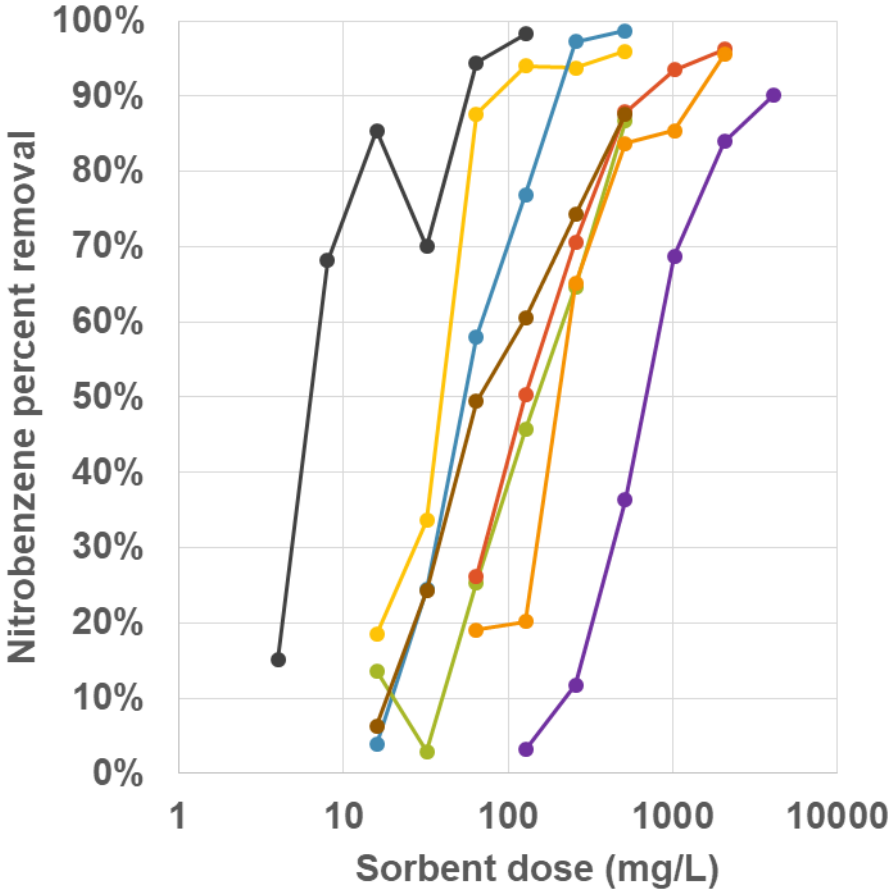
Paper and pine needles biochar performed well for nitrobenzene removal in real leachate

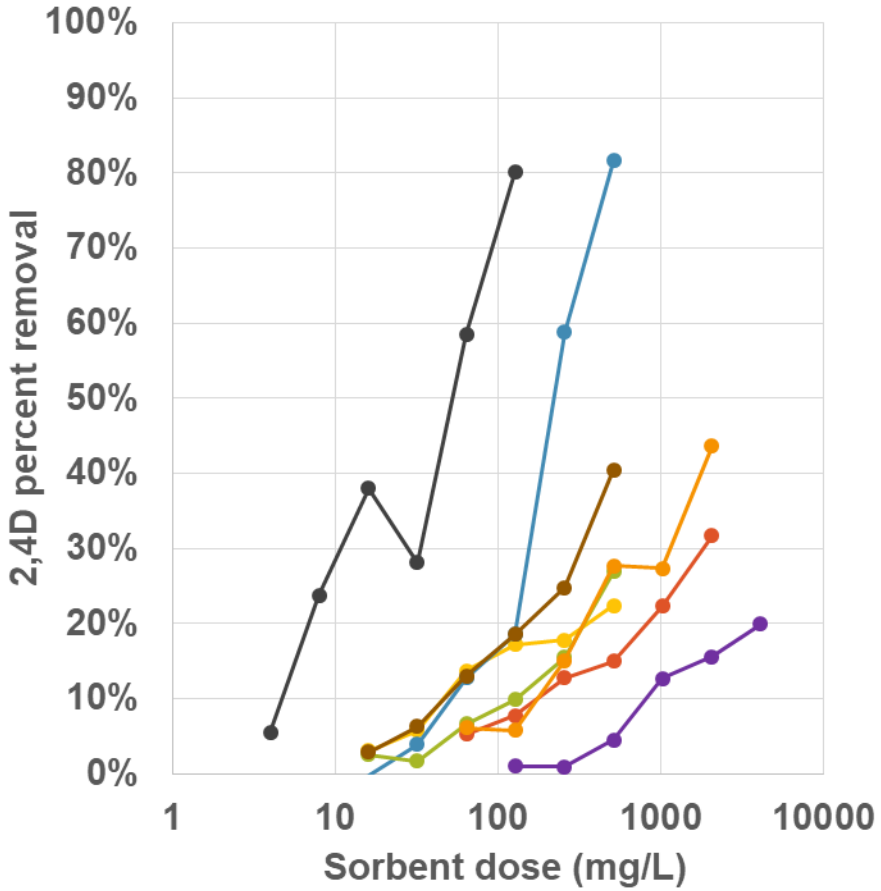


3 hours in real leachate

***Average standard deviation was about 5-10% across sorbents**

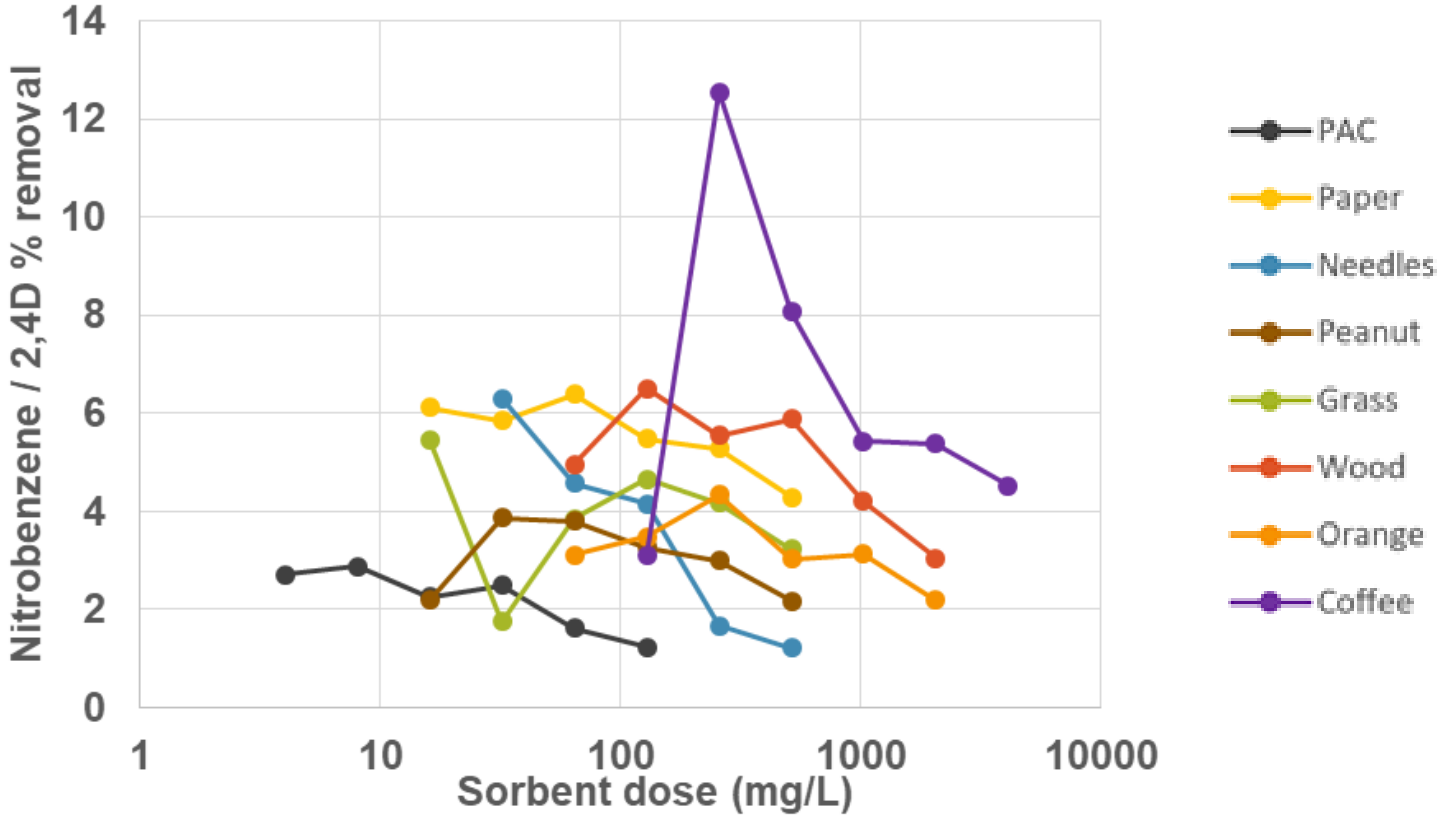
Nitrobenzene was removed significantly more than 2,4D at the same biochar doses





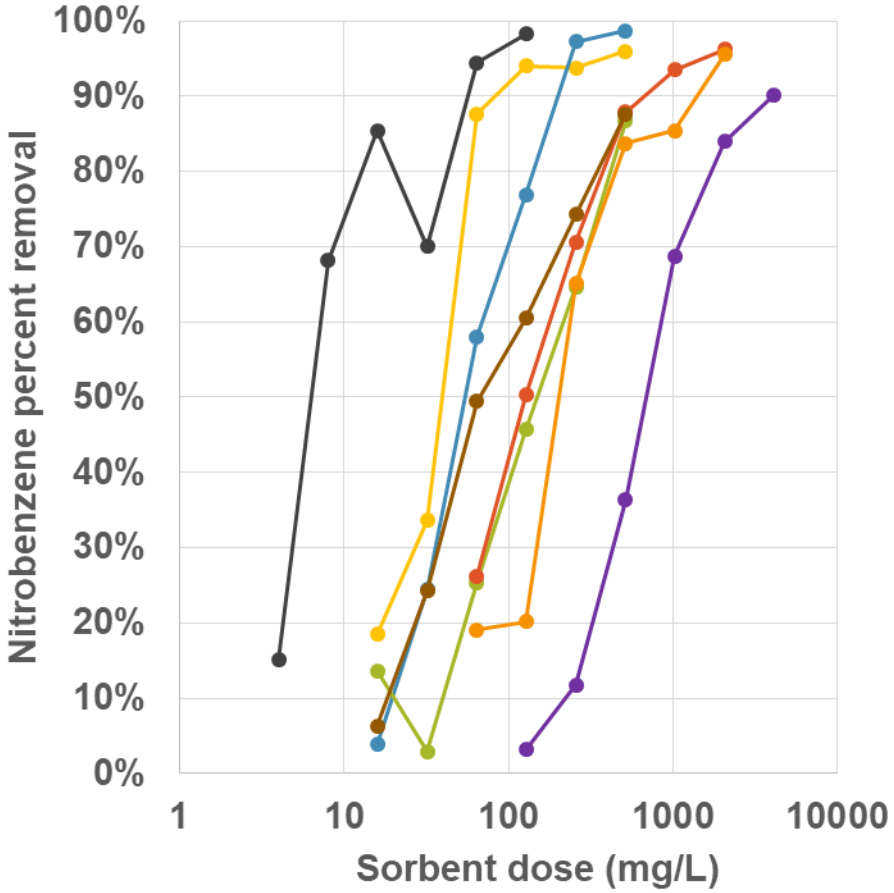
3 hours in real leachate

Certain sorbents (paper, wood, coffee) had a greater difference in removal between 2,4D and nitrobenzene than others (PAC, grass, pine needles, peanut)

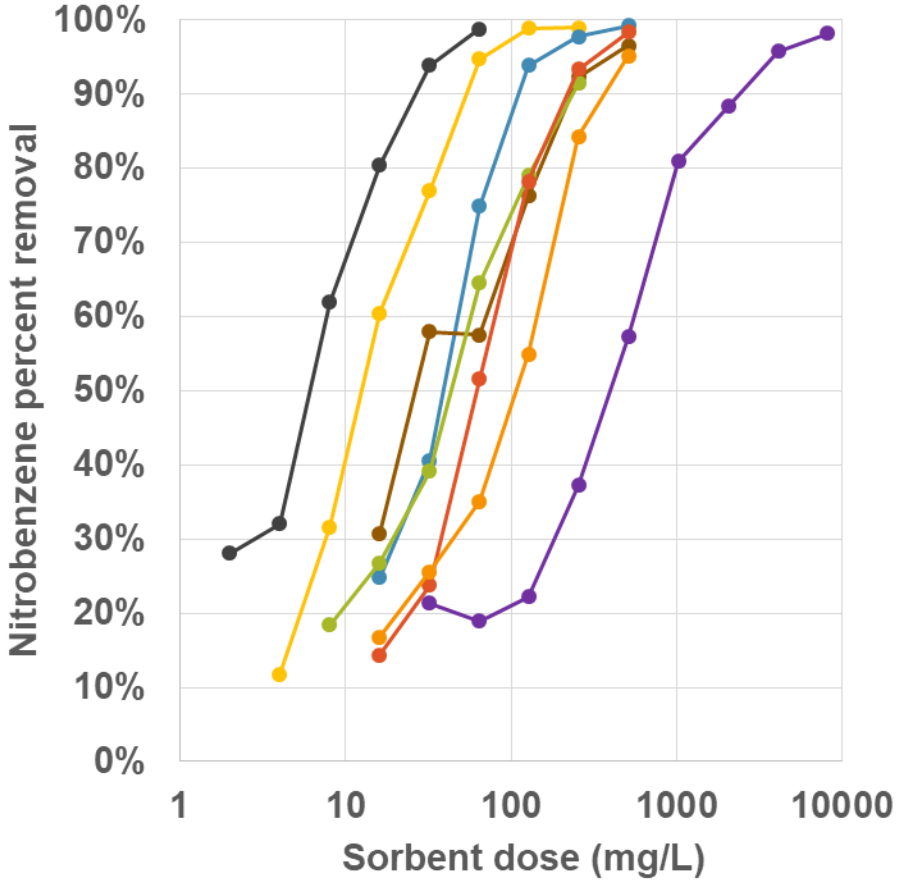


3 hours in real leachate

In general, the ranking of biochars was consistent in both real and synthetic leachate.

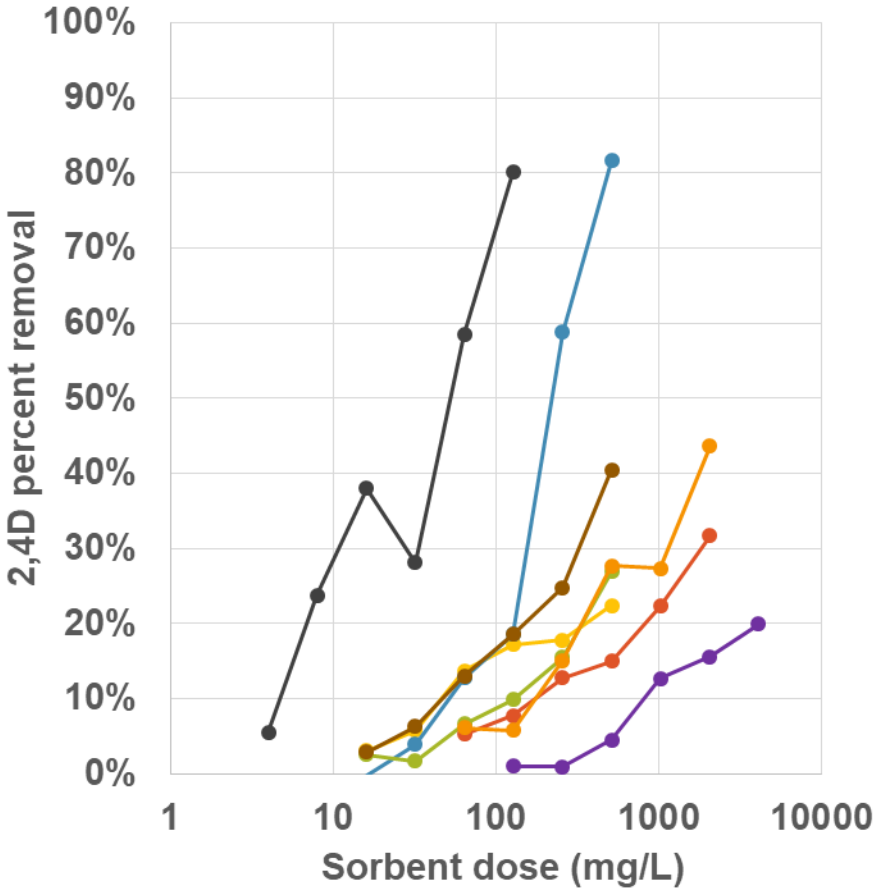


3 hours in
real leachate

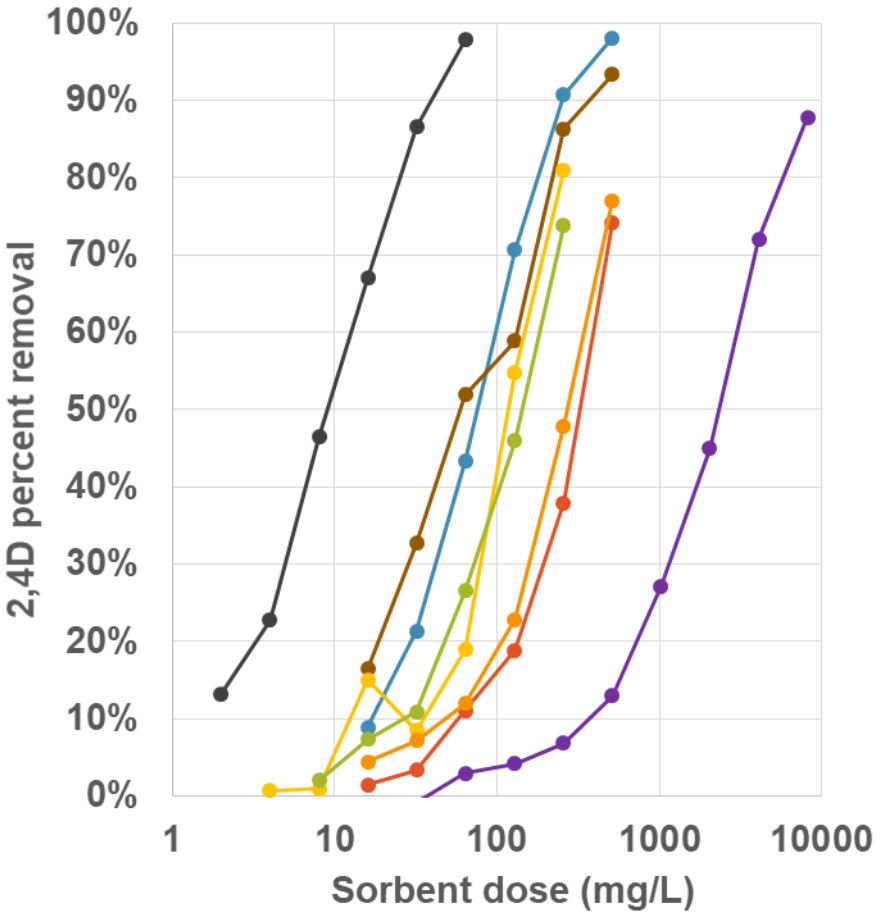


3 hours in
synthetic leachate

In general, the same trend was true for 2,4D removal.

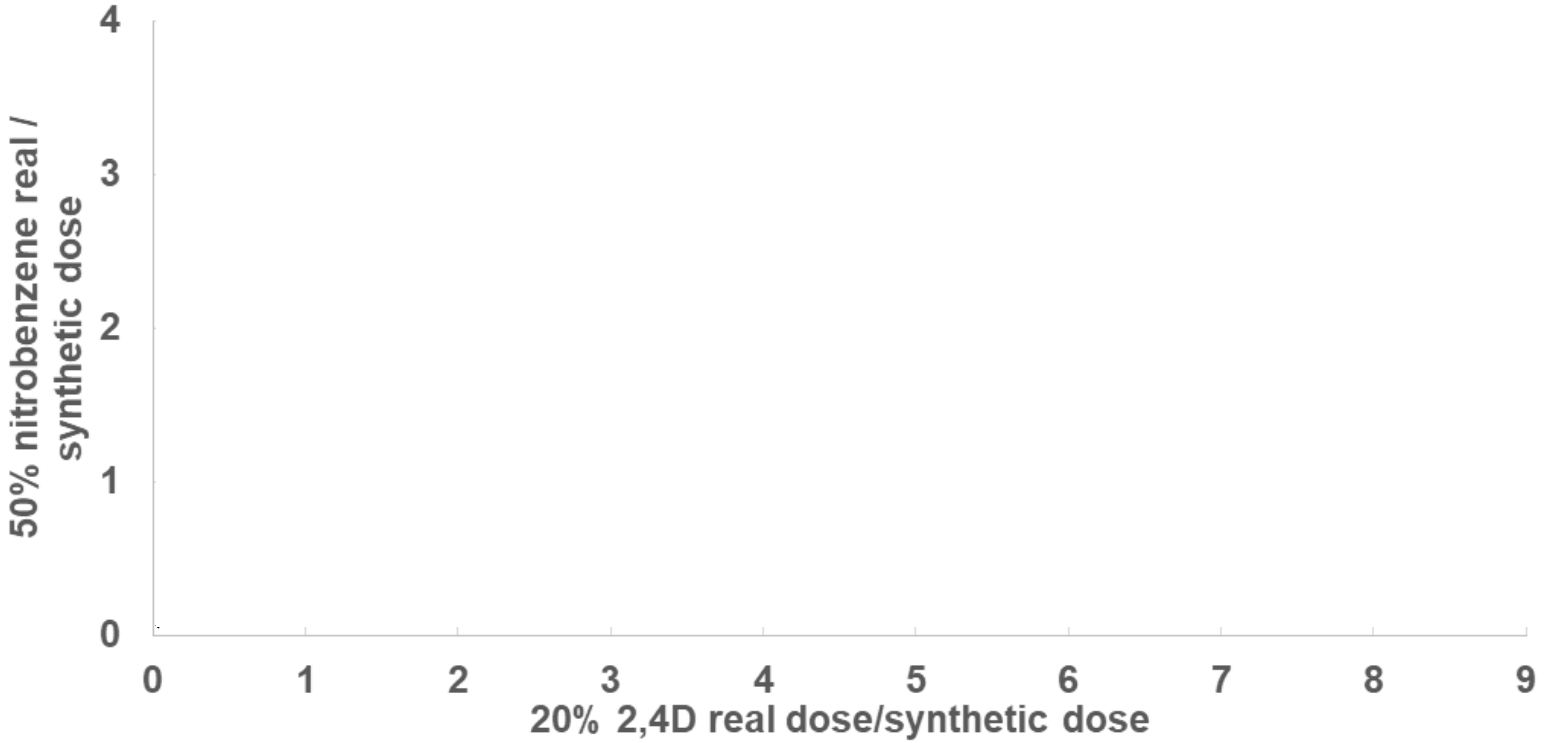


3 hours in
real leachate

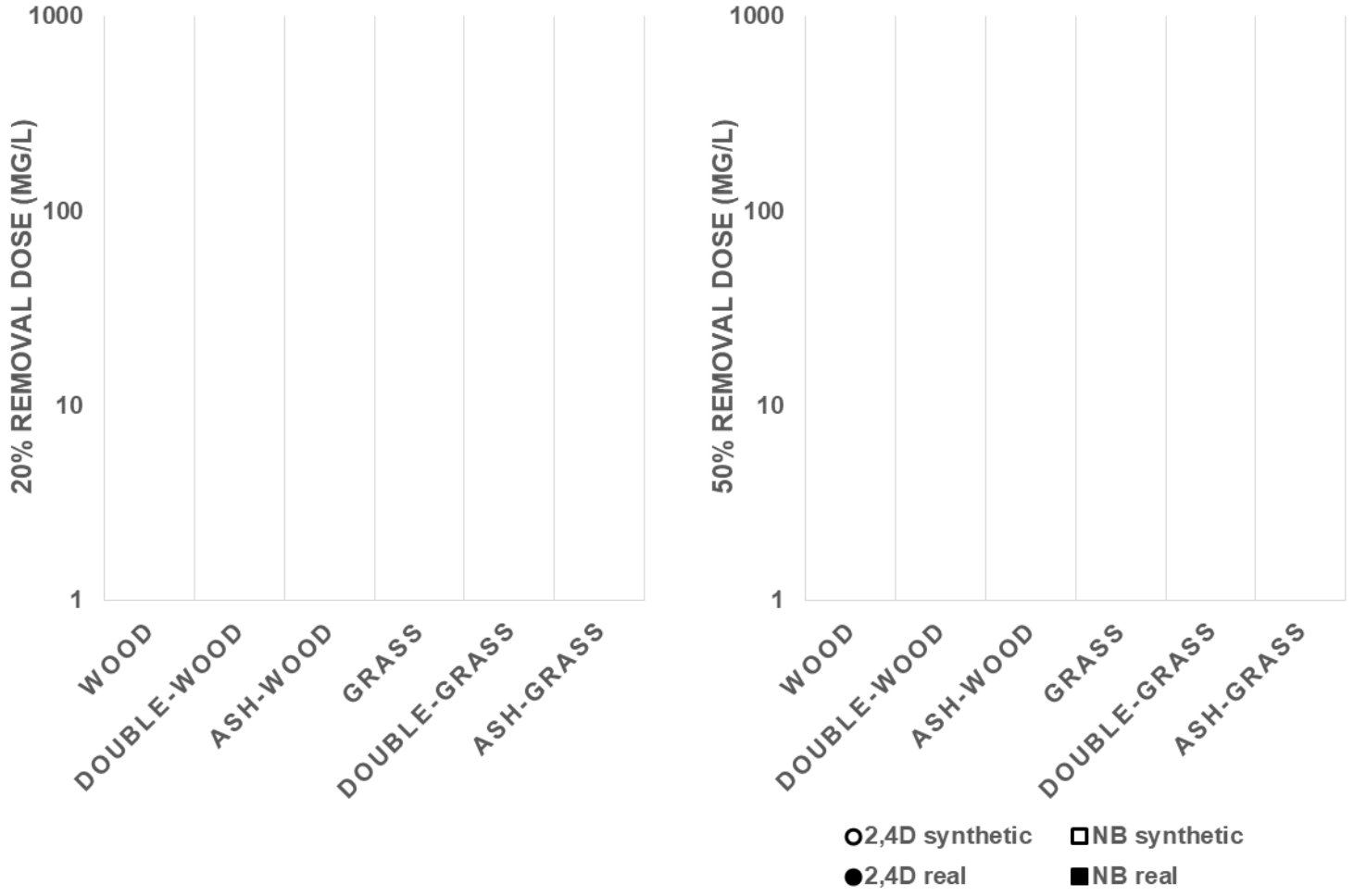


3 hours in
synthetic leachate

Competition had a greater impact on the sorption of 2,4D than nitrobenzene



Treated biochars generally performed better than the untreated biochars



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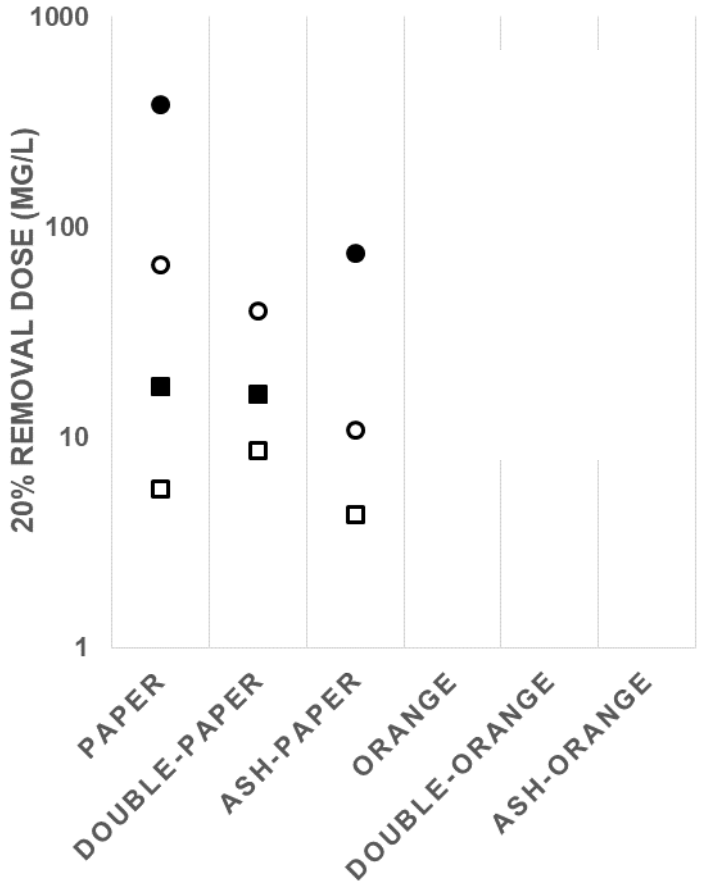
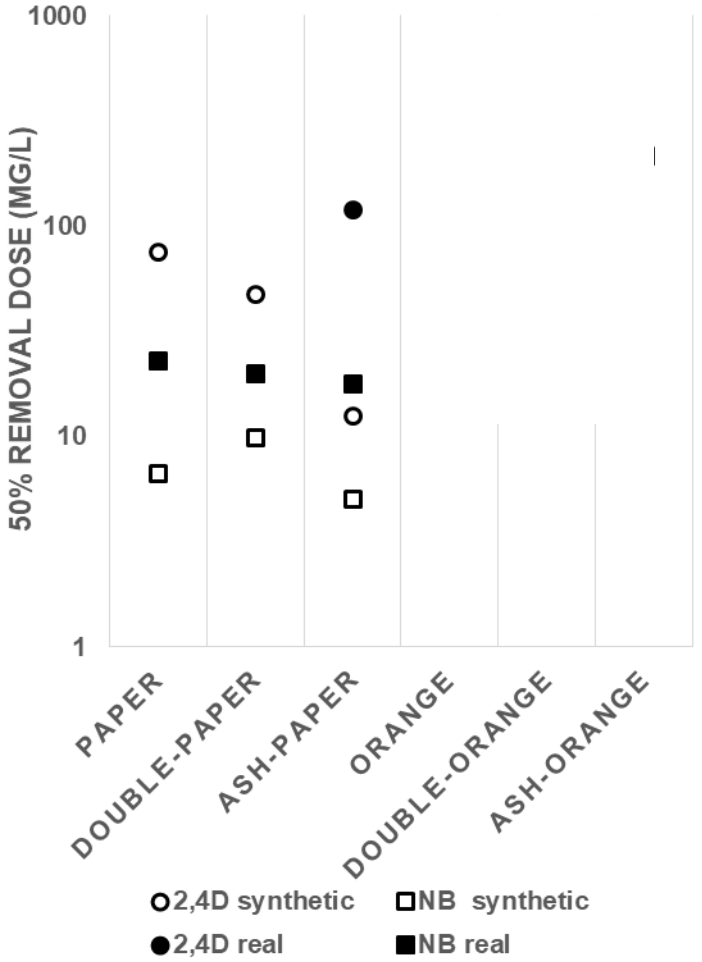
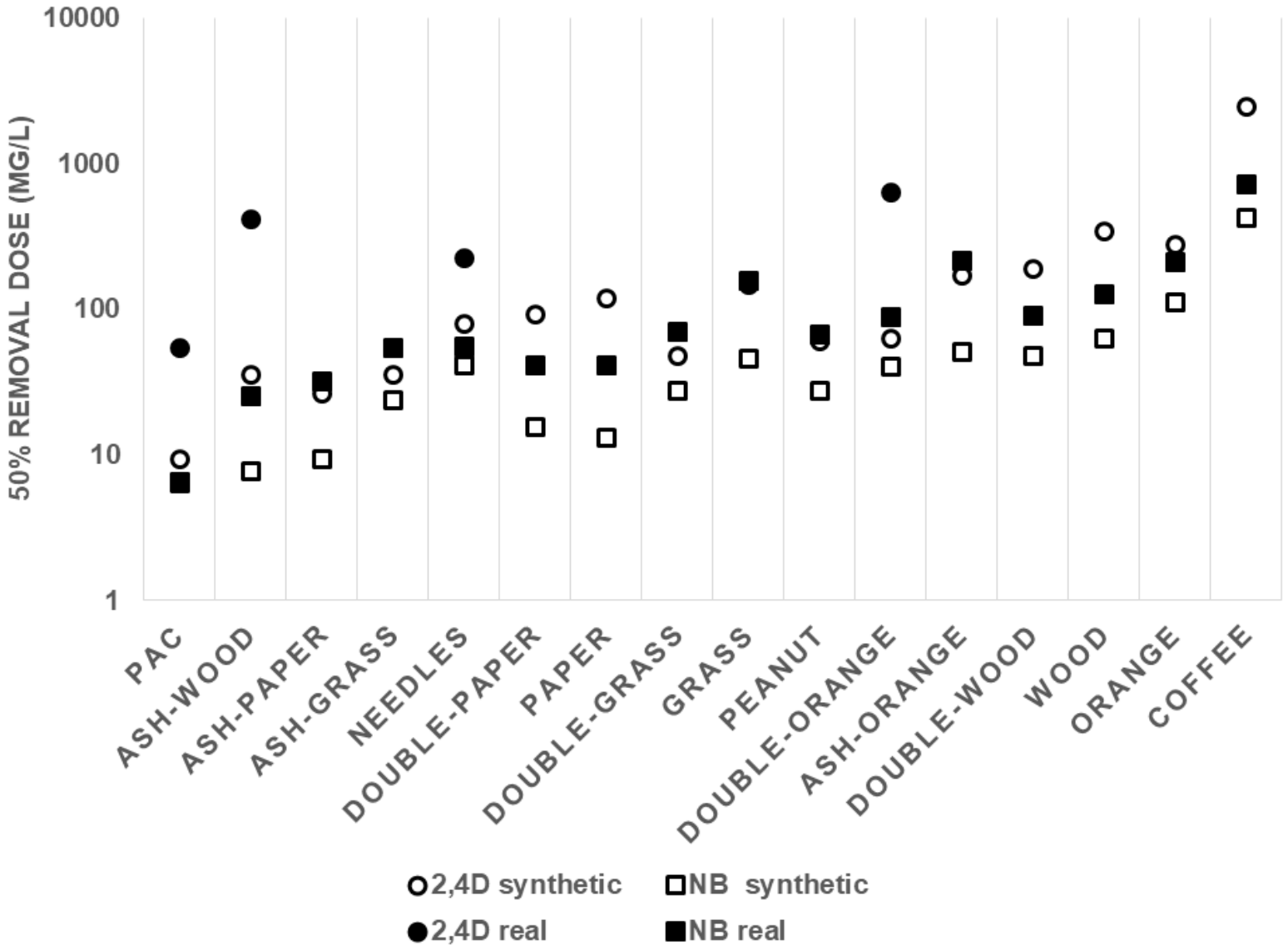


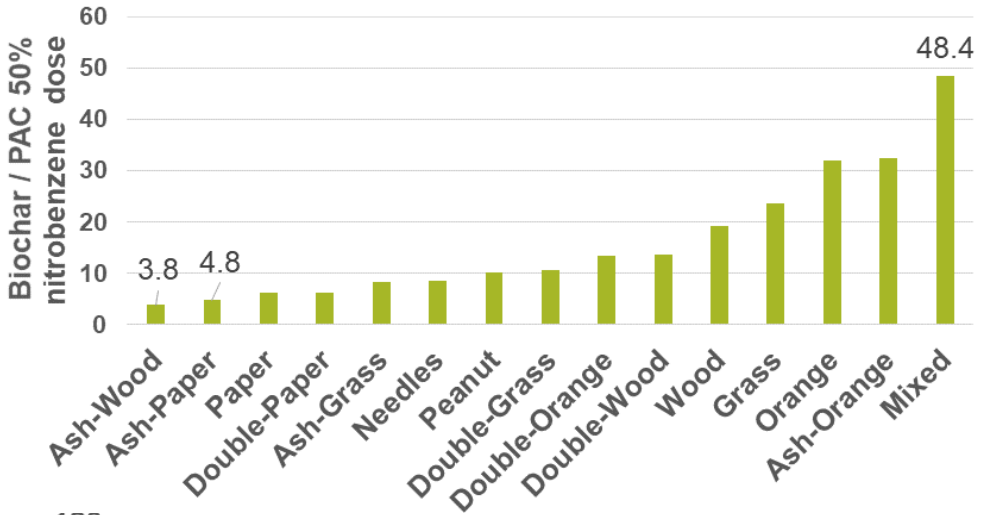


Ash-wood and ash-paper performed the best overall

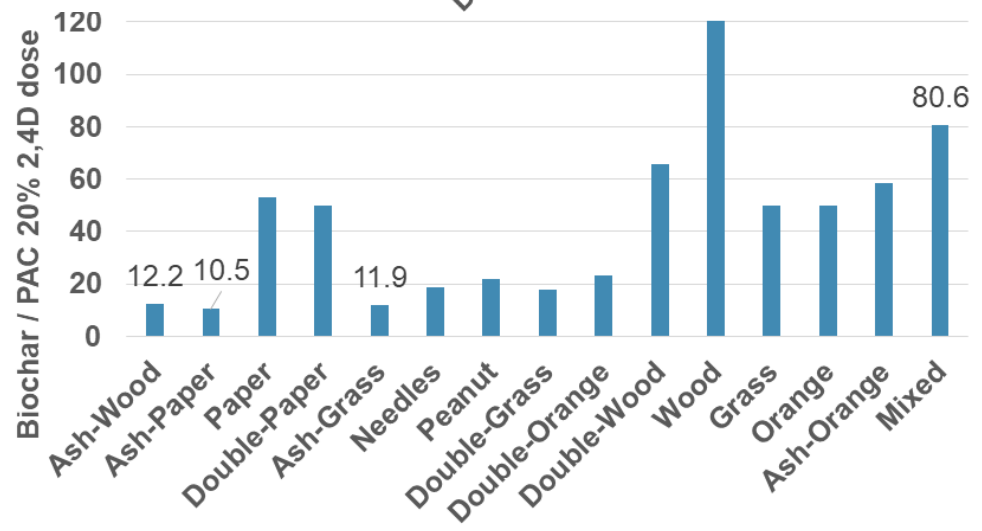


Biochar has the potential to be cheaper and more sustainable than activated carbon for the same level of leachate treatment

NB



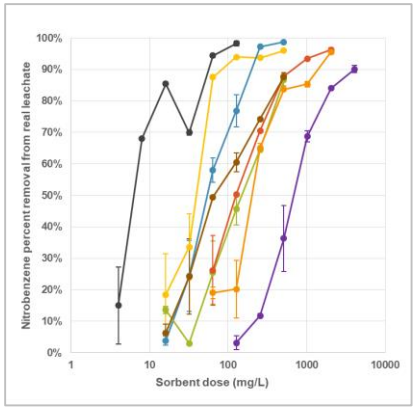
2,4D



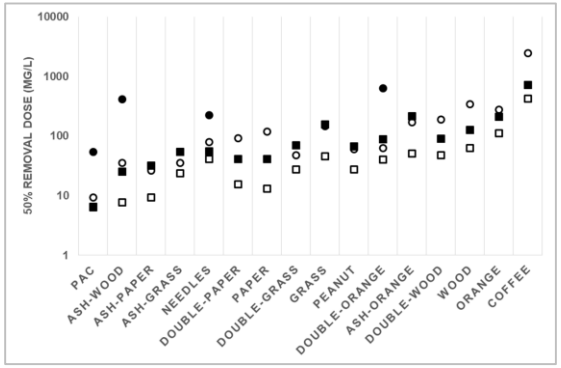
The best performing biochars required 4 – 10 times the amount of PAC for the same level of removal

(Foo and Hameed, 2009; Chingombe et al., 2006; Roberts et al., 2010; Alhashimi and Aktas, 2017; Shackley et al., 2011)

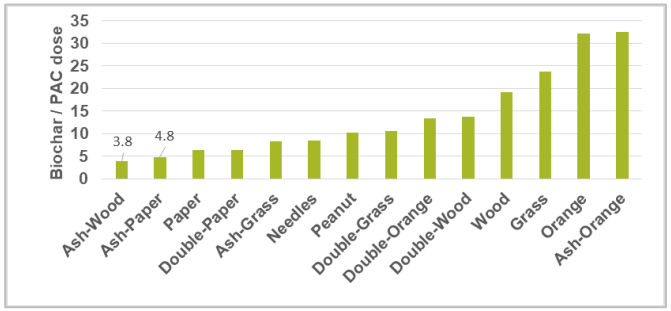
Biochar is a promising treatment solution for organic micropollutants in landfill leachate



Pine needles and paper showed promise as viable biochar feedstocks, but sorption differed between compounds and background matrices.



Treatments improved sorption performance, which was supported by the slight positive trend with ash content.



Biochar could be a more sustainable and cost-effective solution compared to activated carbon on a compounds-treated basis.

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University of Colorado **Boulder**

NSF

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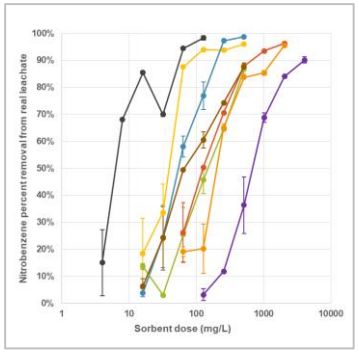

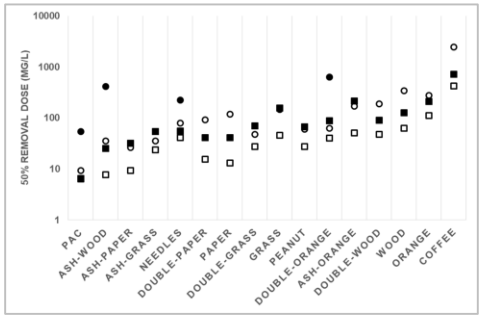

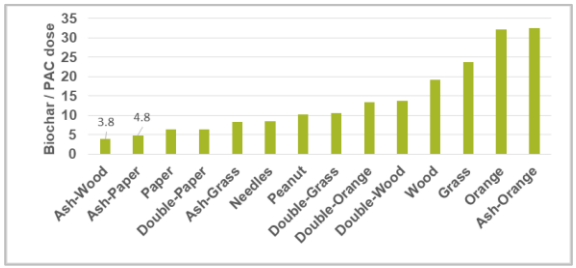

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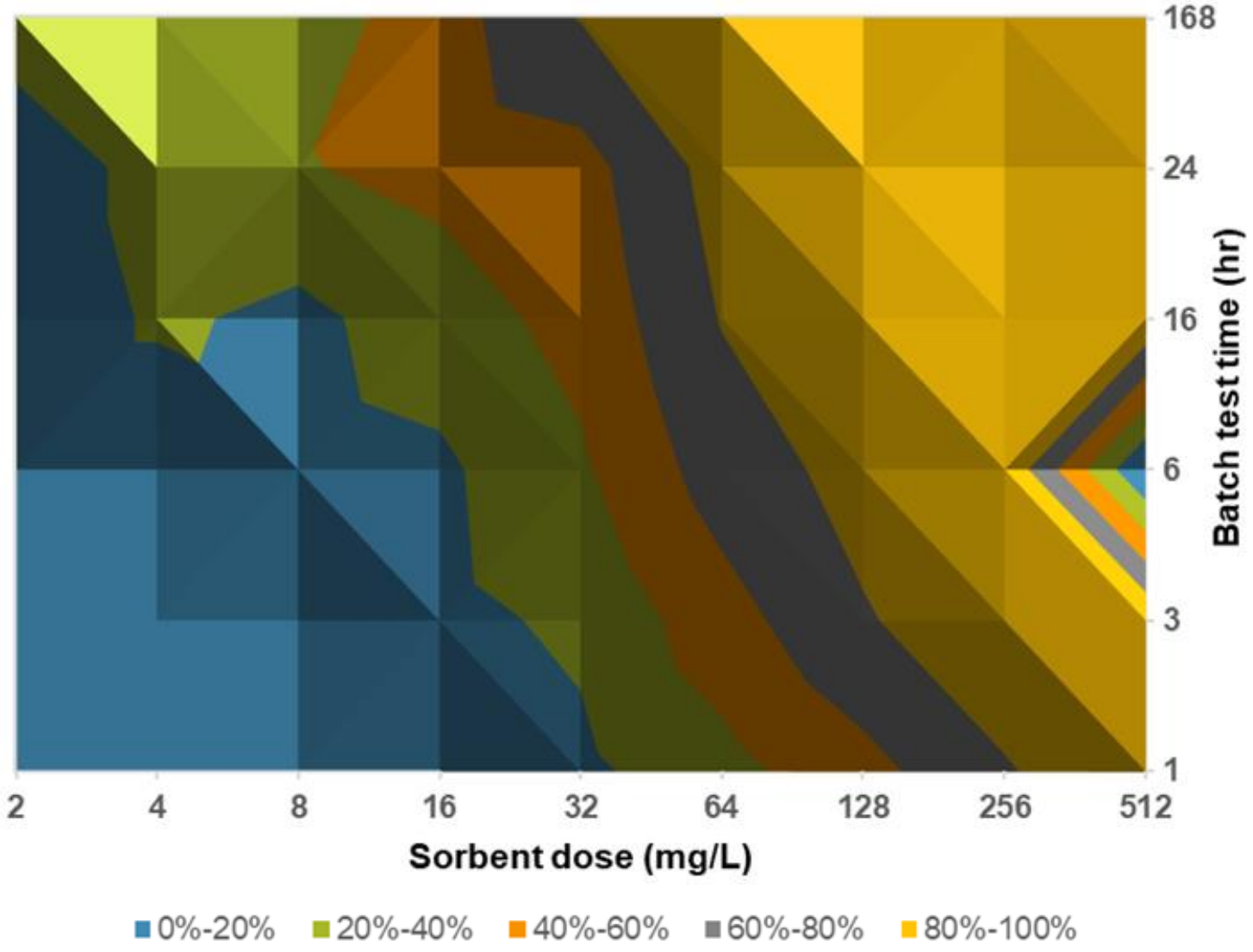
Questions?

Nitrobenzene removal kinetics in pine wood biochar



2,4D removal kinetics in pine wood biochar