Biochar: A Promising Bioretention Amendment for Enhancing Removal of Contaminants from Stormwater

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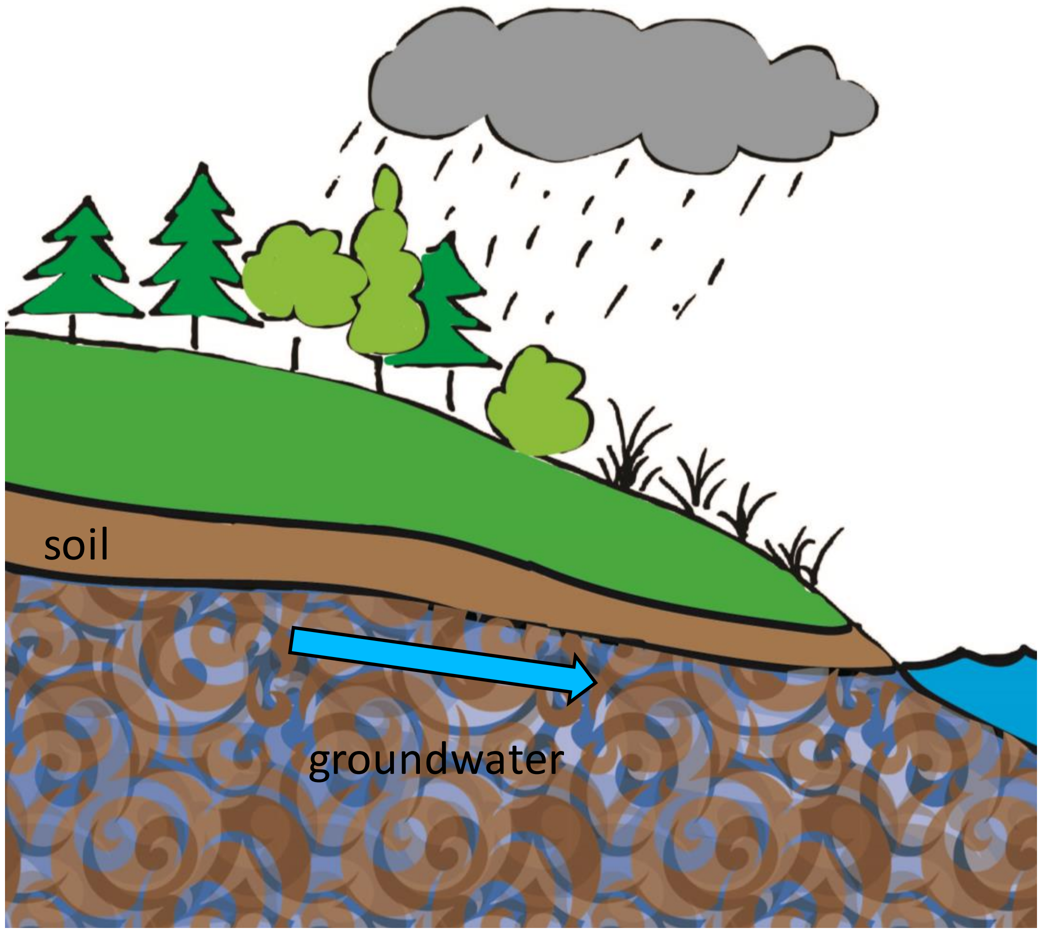
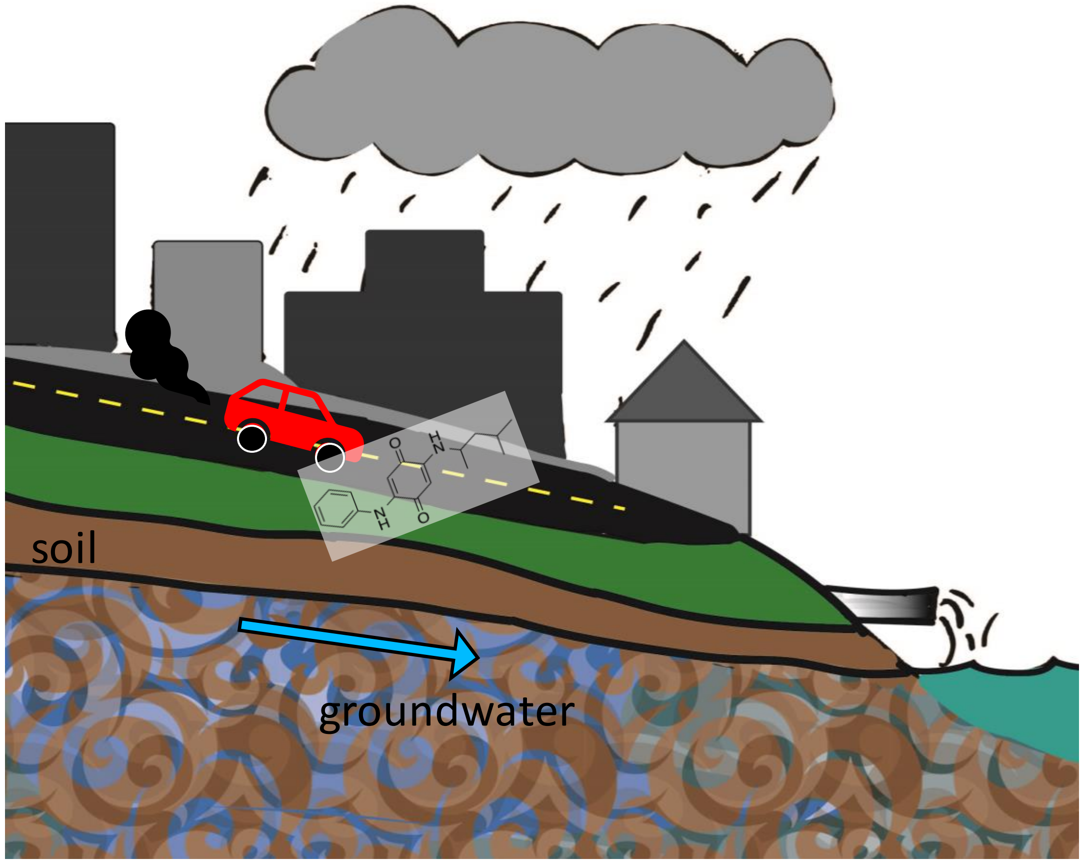
Overview

- Why is stormwater a problem?
- How do we manage stormwater?
- What is bioretention?
- Current challenges with bioretention
- Ways **biochar** might address these challenges
- **Research overview:** biochar as a bioretention amendment
- Challenges of incorporating biochar into bioretention

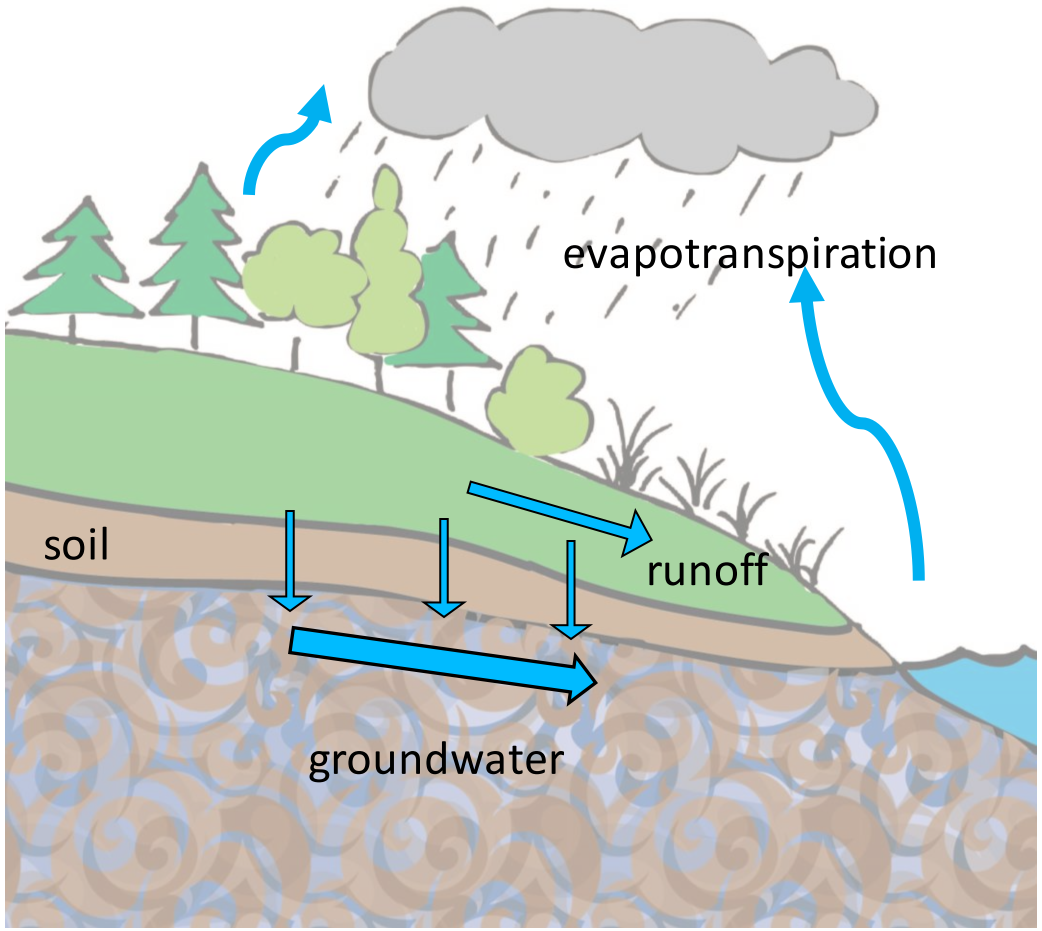
Natural landscape (pervious)

Developed landscape (impervious)

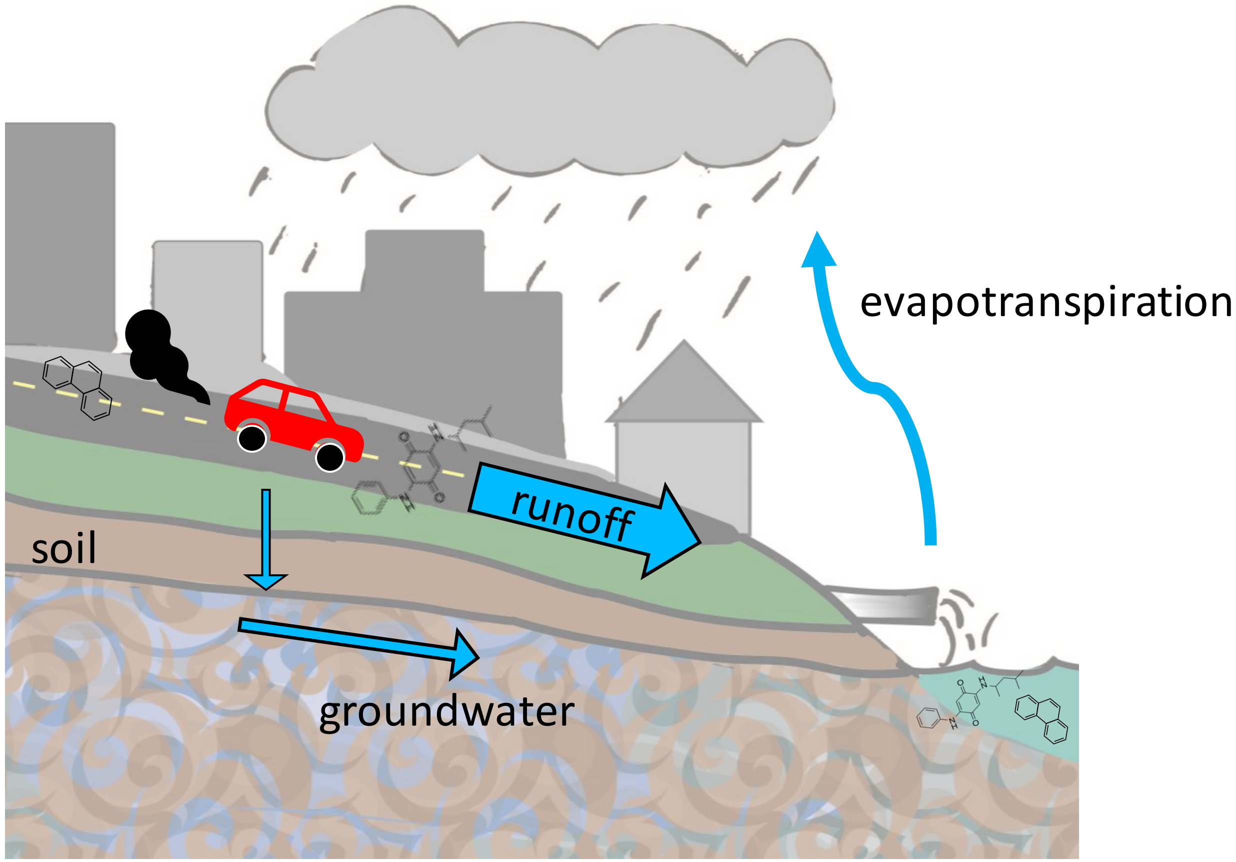




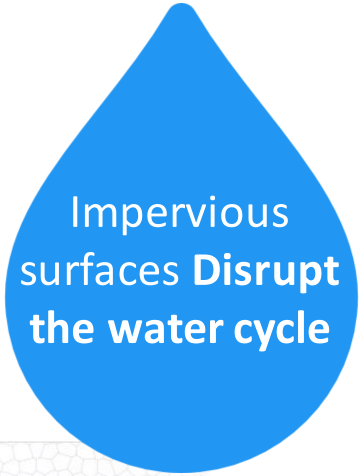
Natural landscape (pervious)



Developed landscape (impervious)



Why is stormwater a problem?



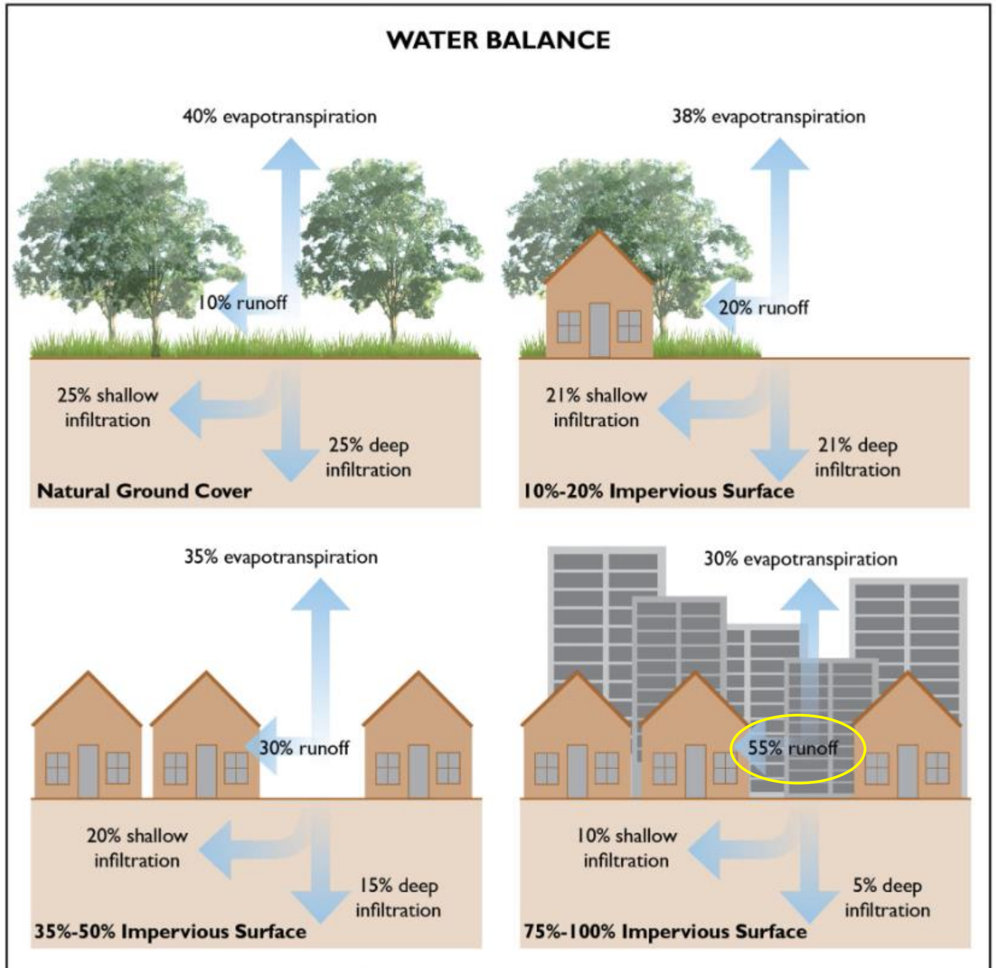
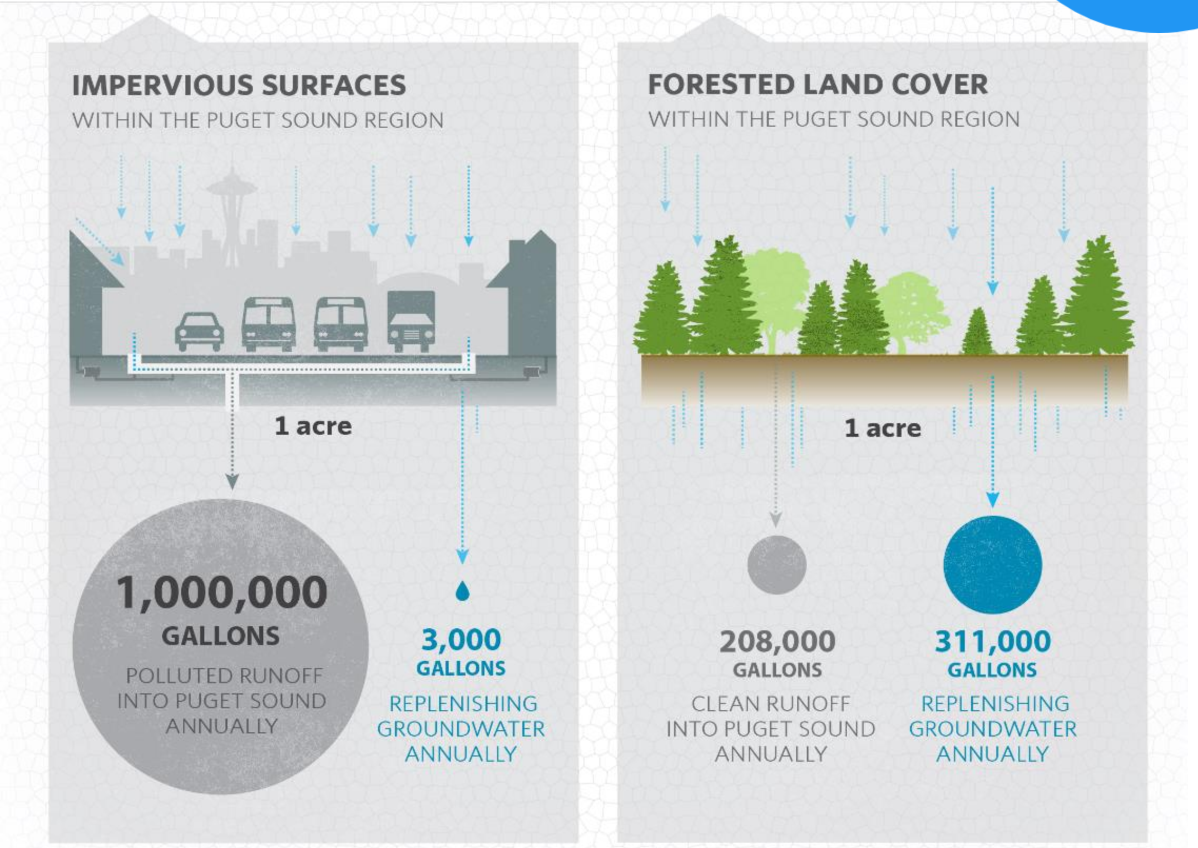
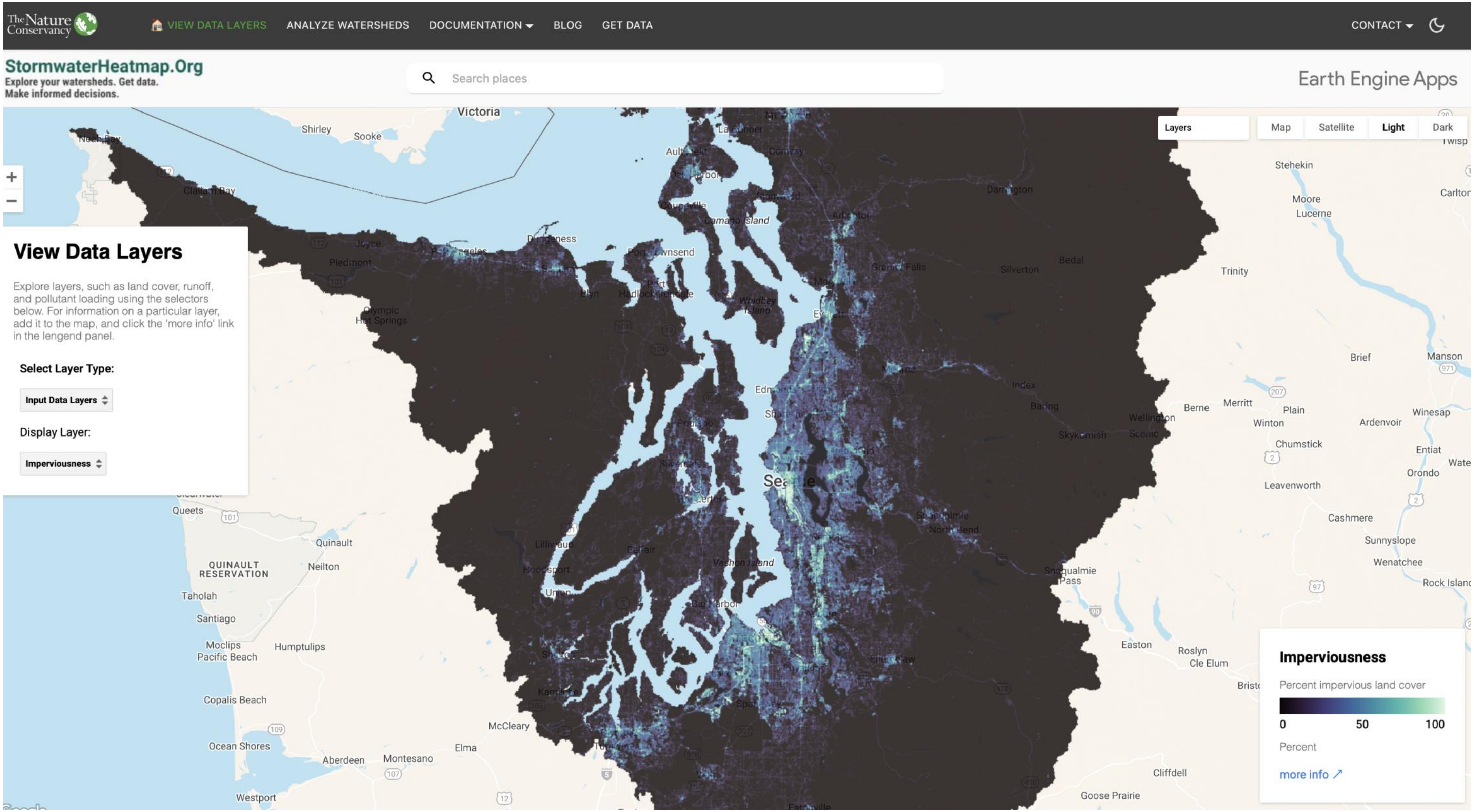


Diagram inspired by a graphic produced by the Federal Interagency Stream Restoration Working Group (FISRWG)

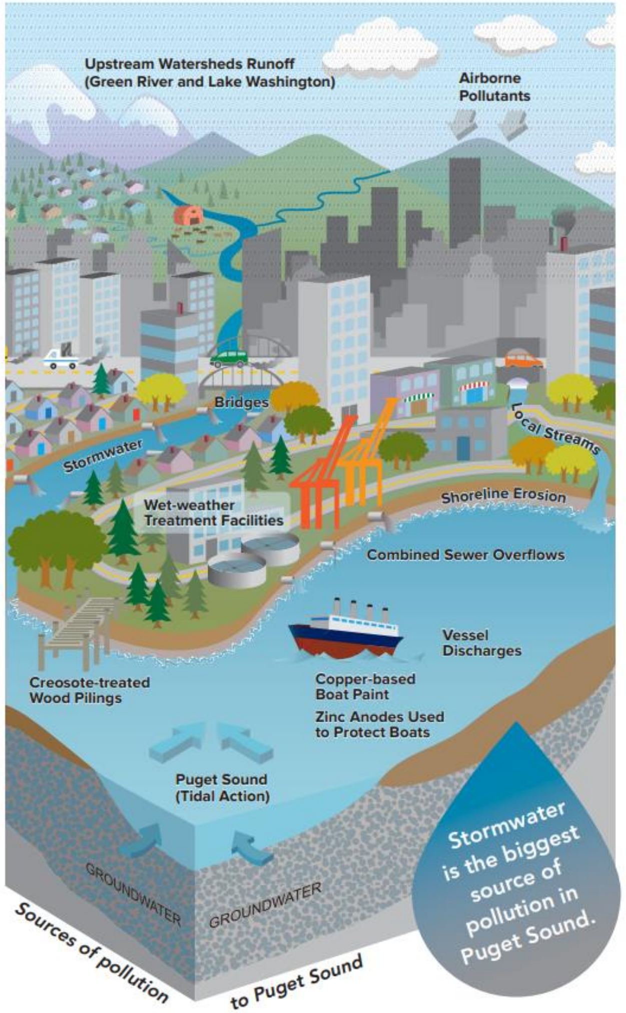


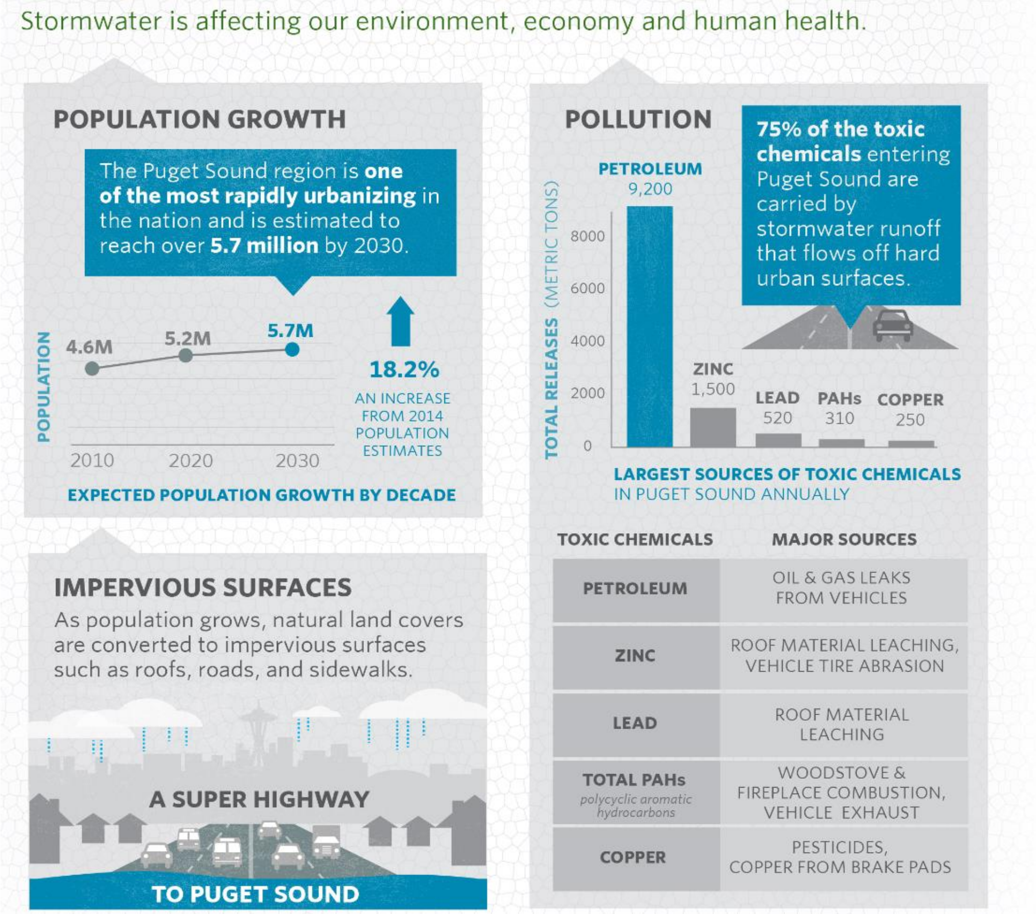
Data Sources: Puget Sound Fact Book - Parametrix (2010) Puget Sound Stormwater Retrofit Cost Estimate Appendix A, USGS Summary of Land Cover Trends Puget Lowland Ecoregion, WSDOT Hydraulics Manual - Runoff Coefficients for the Rational Method 10-year Frequency. All stormwater runoff volumes shown are estimates. Infographic © TNC\Erica Simek Sloniker

Impervious cover – Puget Sound



Why is stormwater a problem?

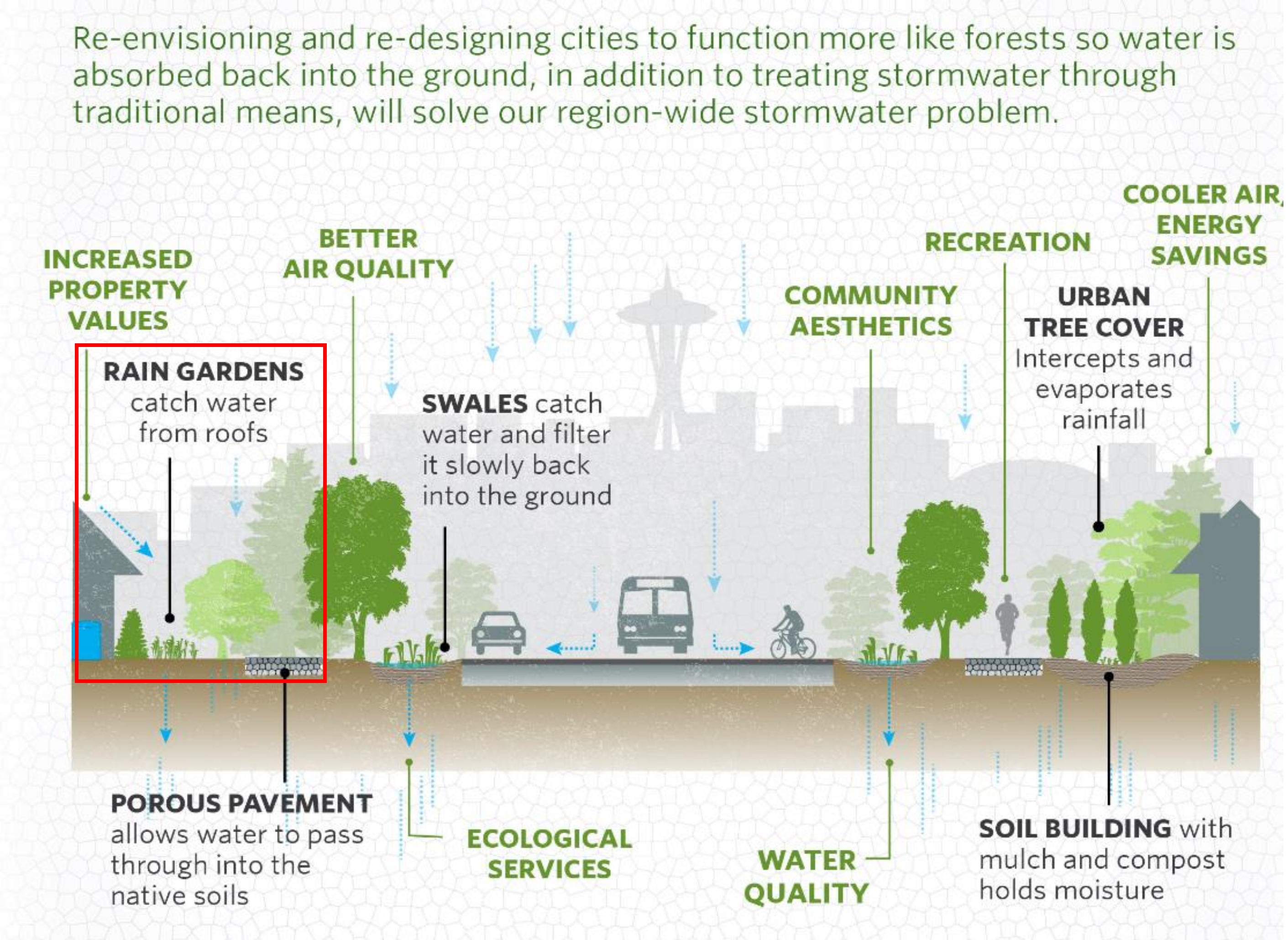




Stormwater runoff **transports pollutants**

How do we manage stormwater?

Goal: protect ecosystems, wildlife, human water uses



Credit: The Nature Conservancy

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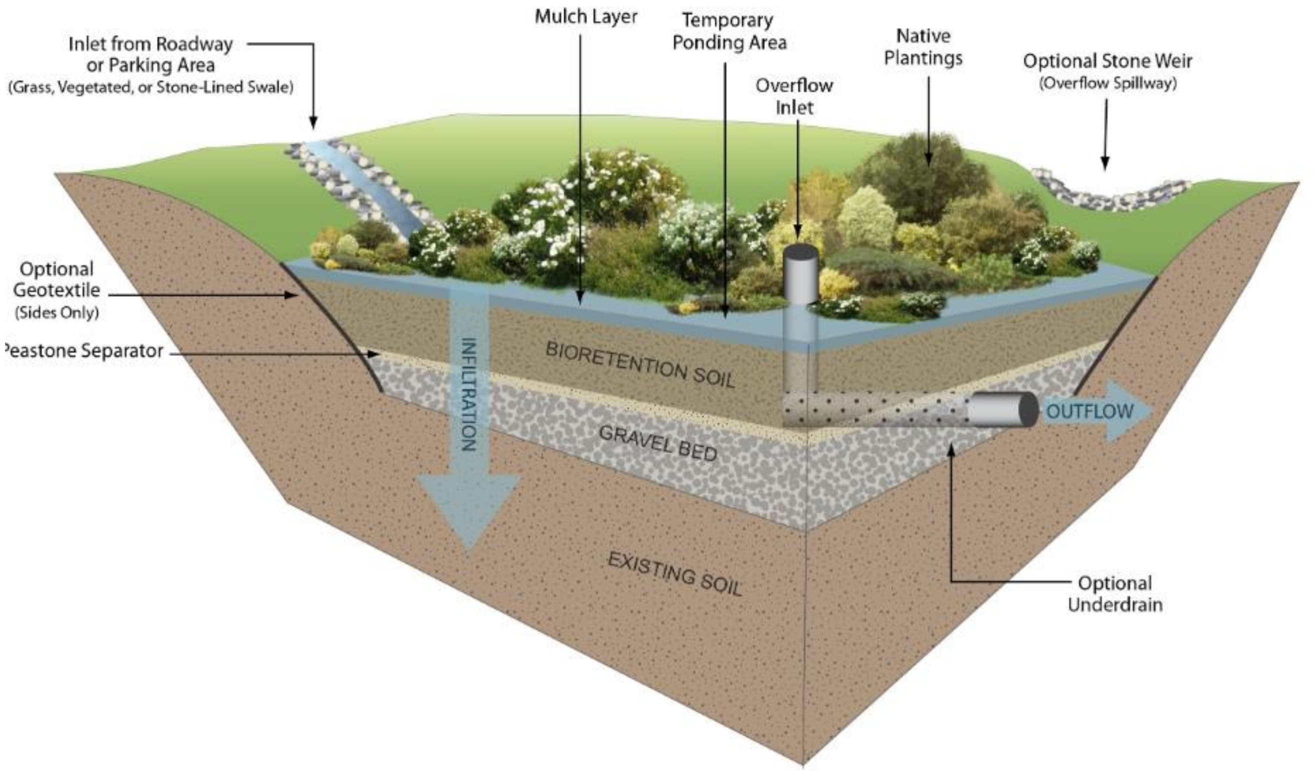
Credit: Puget Sound Partnership

What is bioretention?



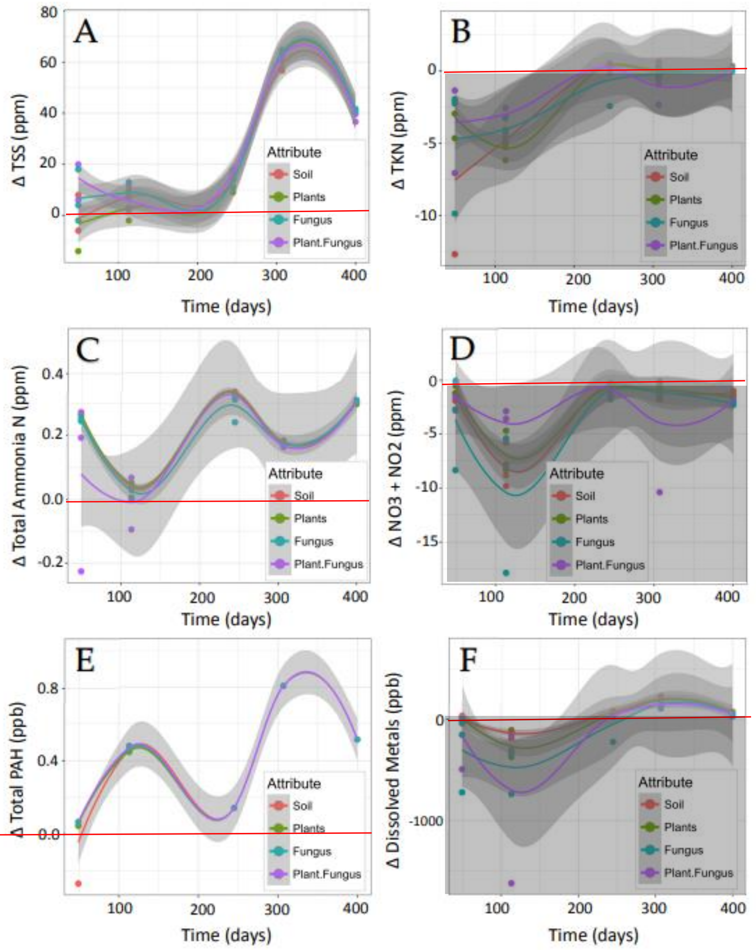
Bioretention areas are similar to rain gardens, but are more highly engineered to include an underdrain, overflow inlet, gravel bed, and engineered soils to promote infiltration.

- Depression in the landscape with engineered media
- Designed to **capture and infiltrate** stormwater runoff
- Primary use – **hydrological control**
- Secondary use – **water quality treatment**
- Relatively low cost
- Decentralized treatment/management

https://megamanual.geosyntec.com/npsmanual/bioretentionareasandraingardens.aspx

Current challenges with bioretention media

- WA standard – 60% sand, **40% compost**
- Contaminant leaching/export
- Nutrients
- Metals
- Example from Taylor et al. 2018



Nitrogen export

Metals export

Positive value = concentration removed

Negative values = concentration exported

Taylor, A., Wetzel, J., Mudrock, E., King, K., Cameron, J., Davis, J. and McIntyre, J., 2018. Engineering analysis of plant and fungal contributions to bioretention performance. *Water*, *10*(9), p.1226.

Why use biochar in bioretention?

S.K. Mohanty et al. / Science of the Total Environment 625 (2018) 1644–1658

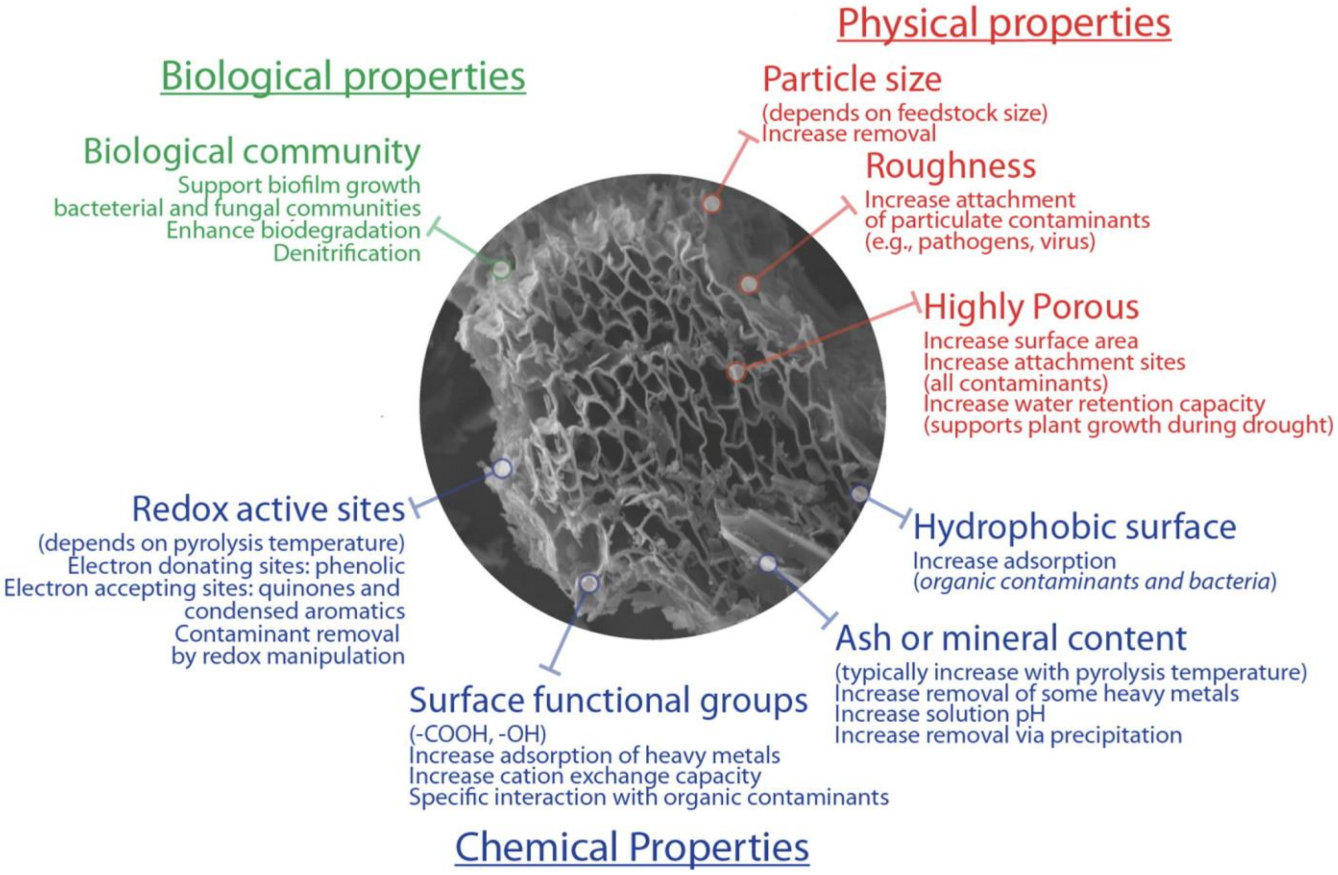
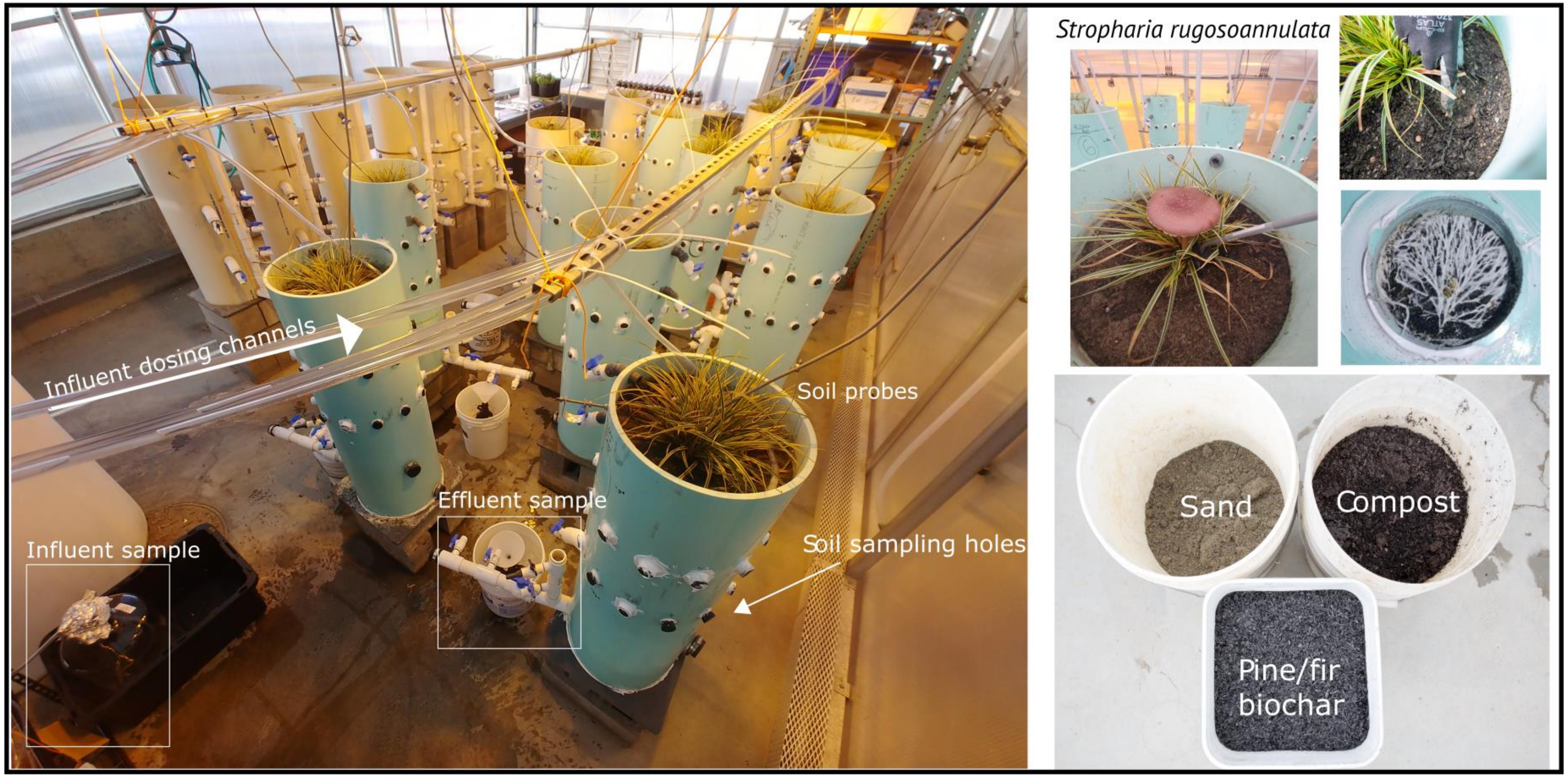


Fig. 1. Physical, chemical, and biological properties of biochar for removal of contaminants from stormwater.

- Highly porous
- High surface area
- Lots of places for contaminants to stick to
- High water holding capacity
- **Less likely to leach nutrients and metals than compost**

Mohanty, S.K., Valenca, R., Berger, A.W., Iris, K.M., Xiong, X., Saunders, T.M. and Tsang, D.C., 2018. Plenty of room for carbon on the ground: Potential applications of biochar for stormwater treatment. *Science of the total environment*, *625*, pp.1644-1658.

Bioretention columns study



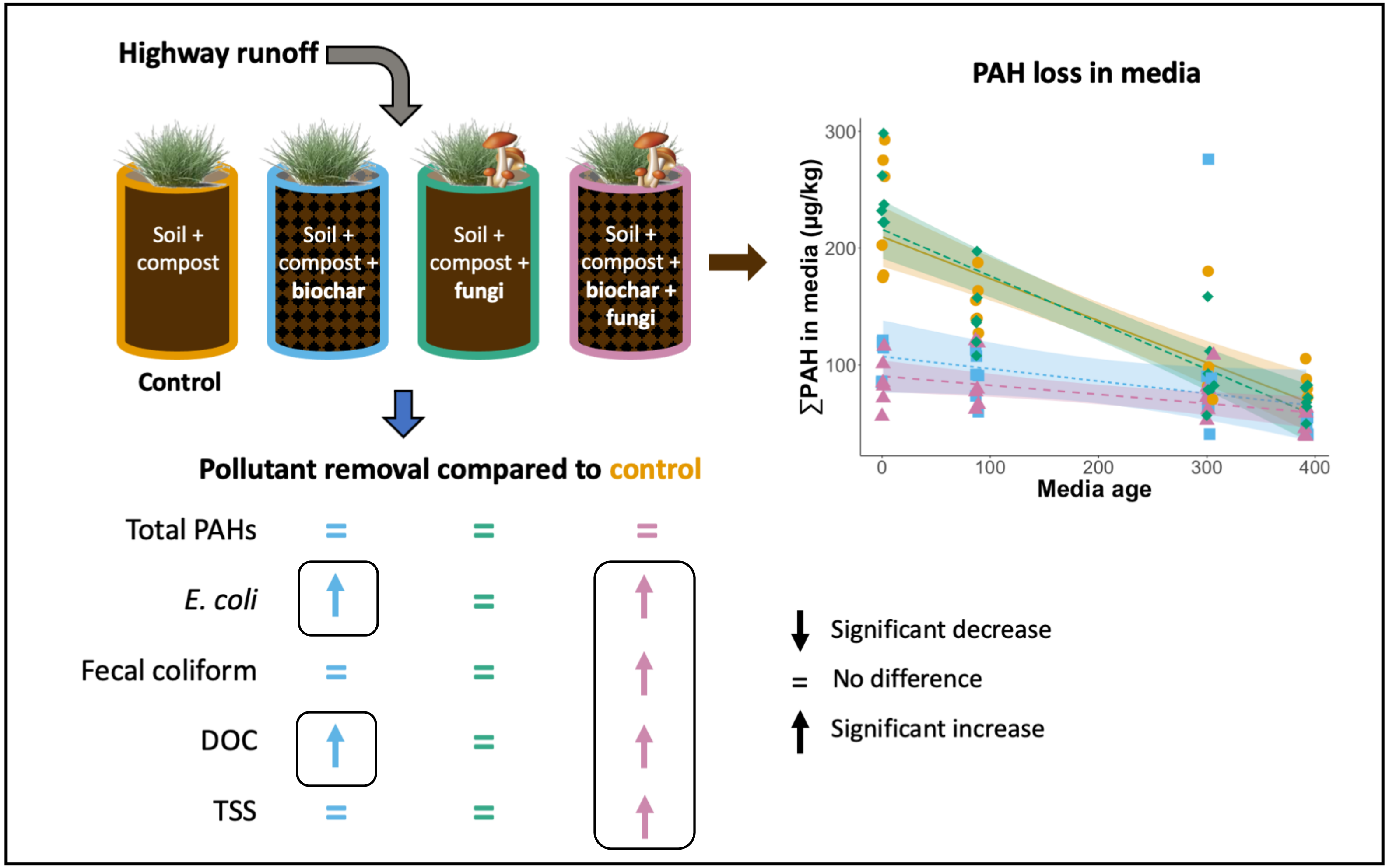
Amended 60:40 bioretention media with fungi inoculation, 20% replacement of compost with biochar, or both

- Polycyclic aromatic hydrocarbons (PAHs)
- *E. coli*
- Fecal coliform
- Dissolved organic carbon (DOC)
- Total suspended solids (TSS)

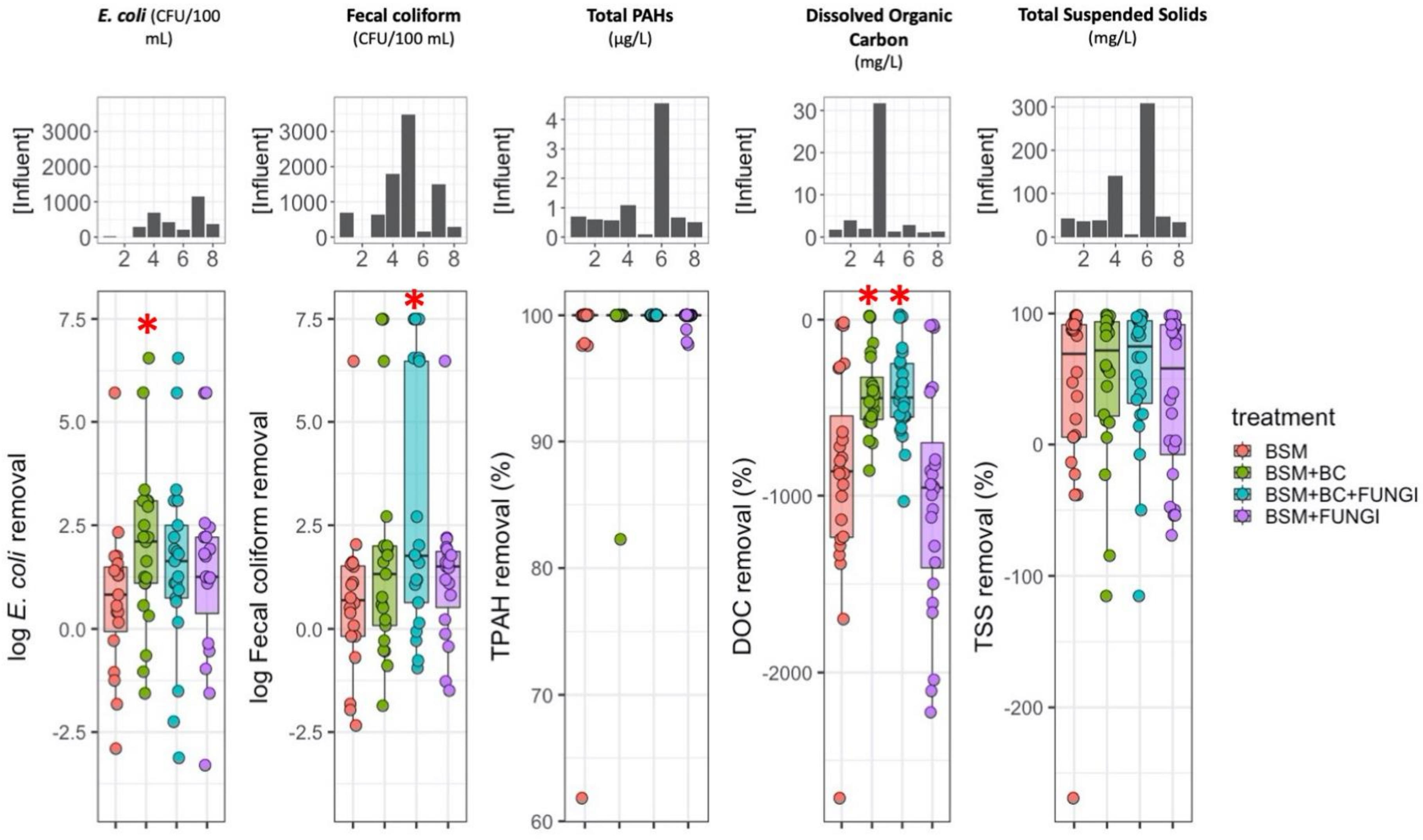
Research article

Biochar and fungi as bioretention amendments for bacteria and PAH removal from stormwater

Chelsea J. Mitchell, Anand D. Jayakaran *, Jenifer K. McIntyre

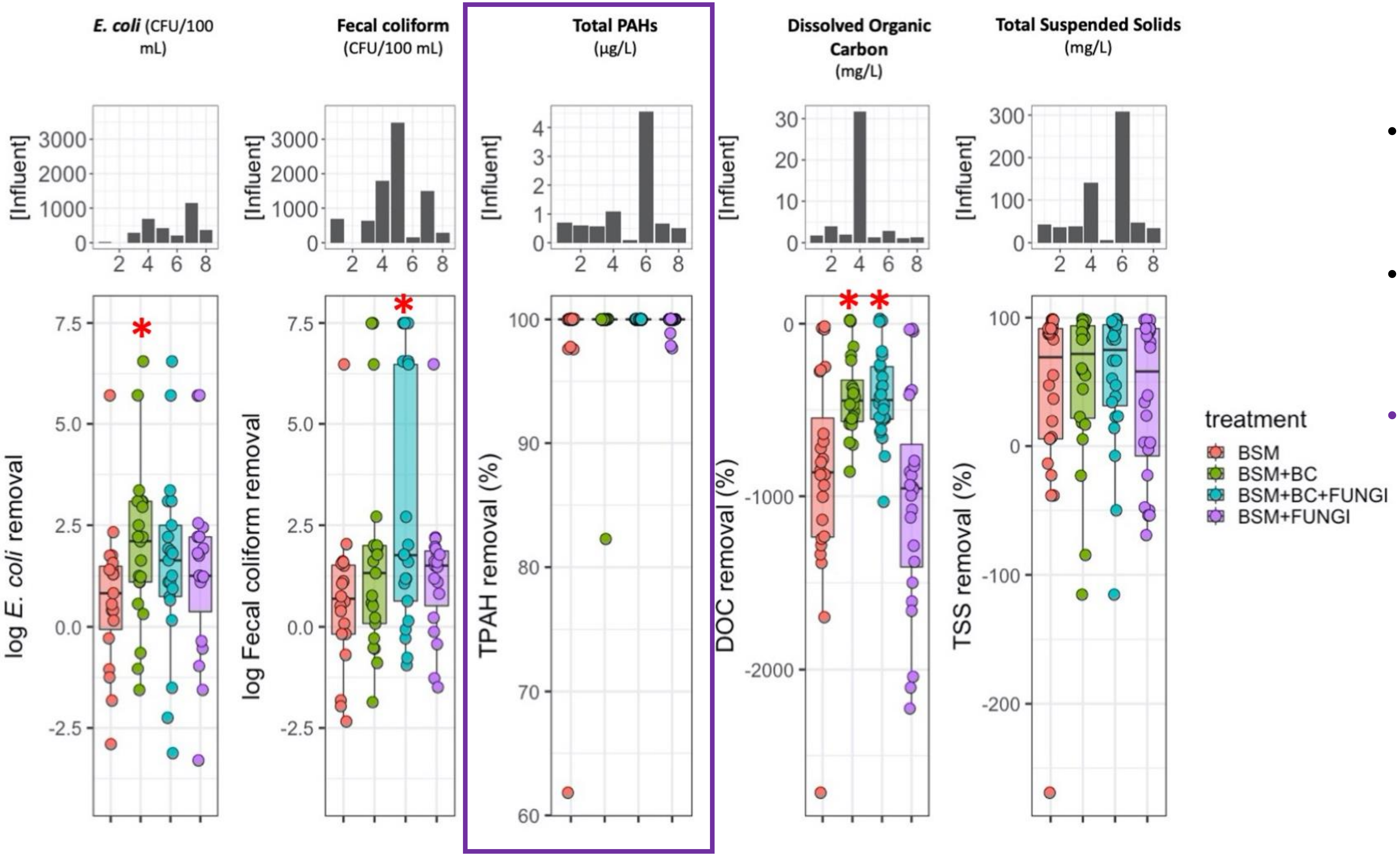


Results



* Removal is significantly higher than the BSM control – analysis by linear mixed effects model with dosing event as a random intercept

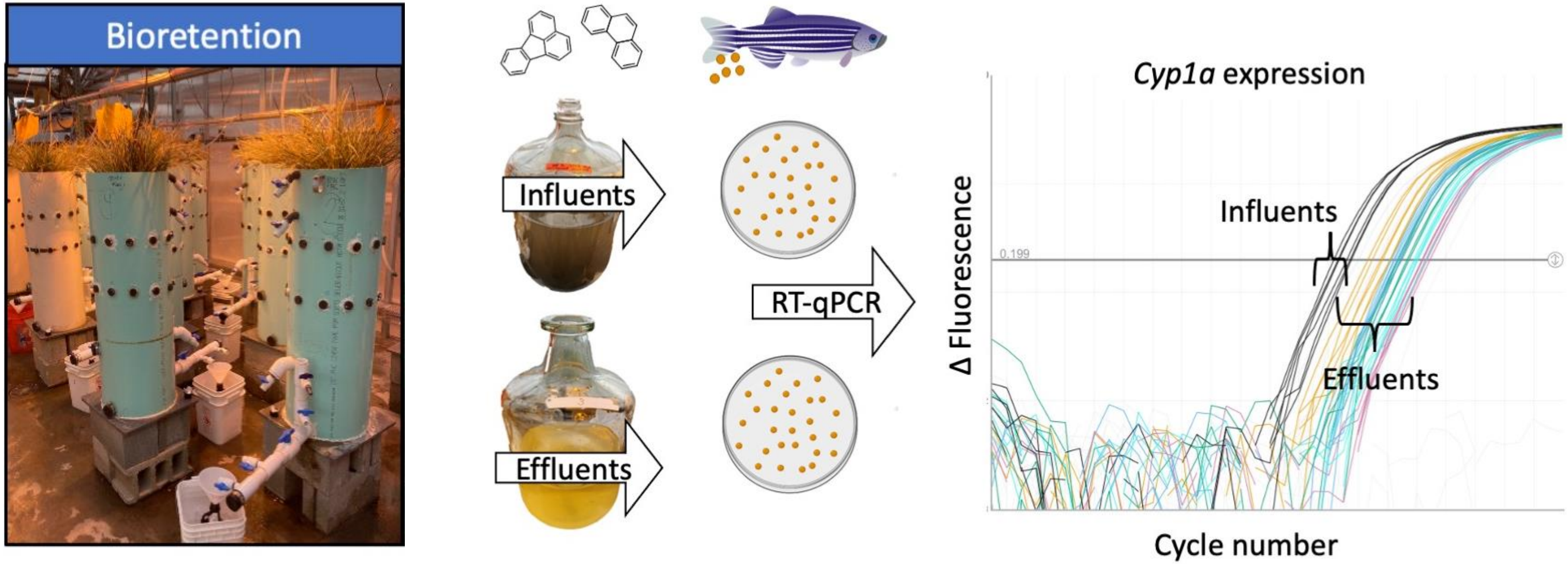
Results



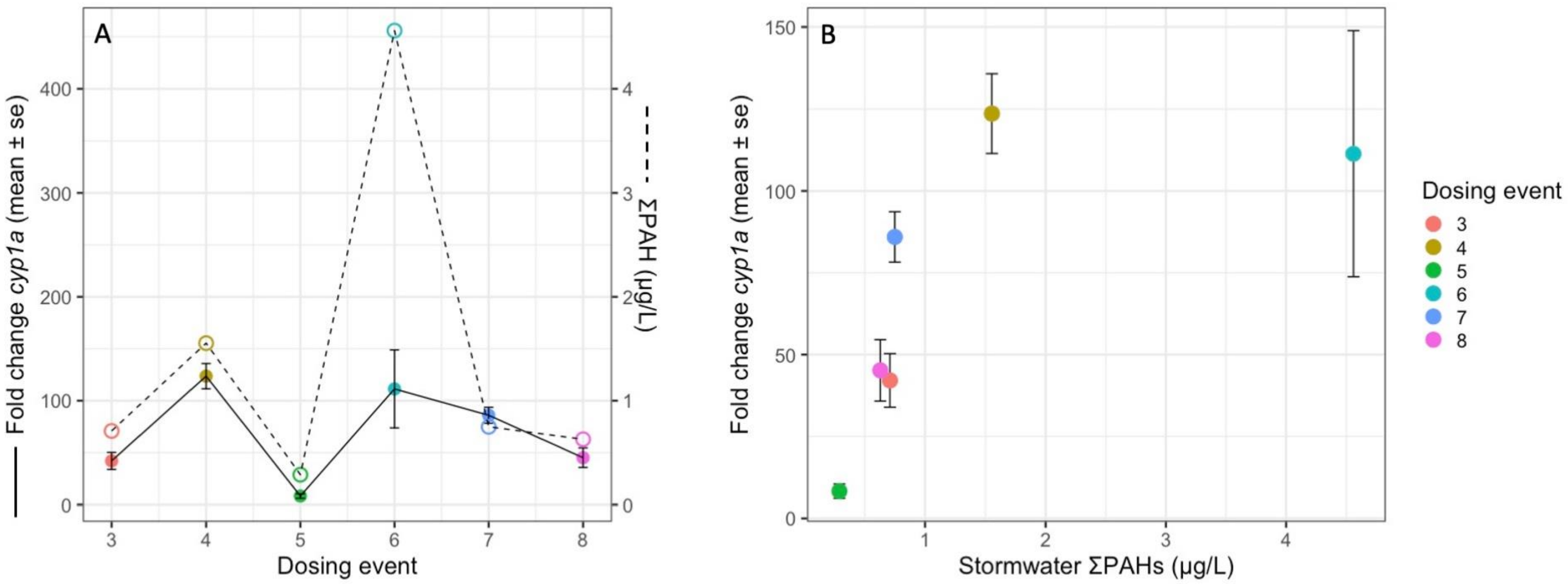
- *E. coli* removal was significantly higher in biochar-amended columns than BSM control
- Fecal coliform removal was significantly higher in biochar+fungi amended columns
- Biochar-amended columns had lower DOC export than the BSM control
- **Nearly all effluent PAH concentrations were below the detection level – couldn't distinguish between treatments.**

* Removal is significantly higher than the BSM control – analysis by linear mixed effects model with dosing event as a random intercept

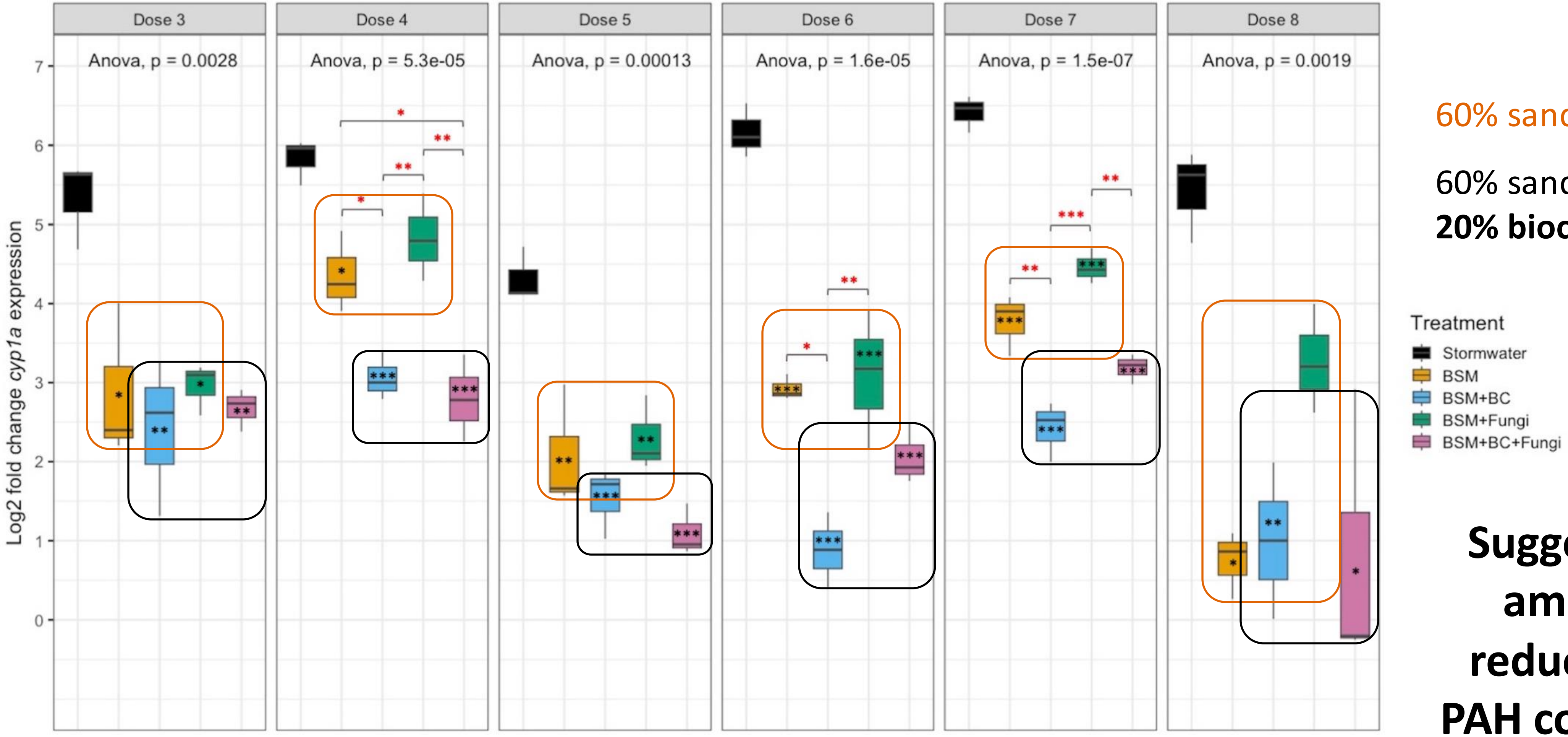
Evaluating biological effectiveness of stormwater bioretention using molecular tools



Zebrafish *cyp1*a expression as proxy for PAHs



Lower *cyp1a* expression in zebrafish exposed to biochar-amended media effluents



60% sand, 40% compost

60% sand, 20% compost, **20% biochar**

Suggests biochar amendments reduced effluent PAH concentrations

Challenges with using biochar in bioretention

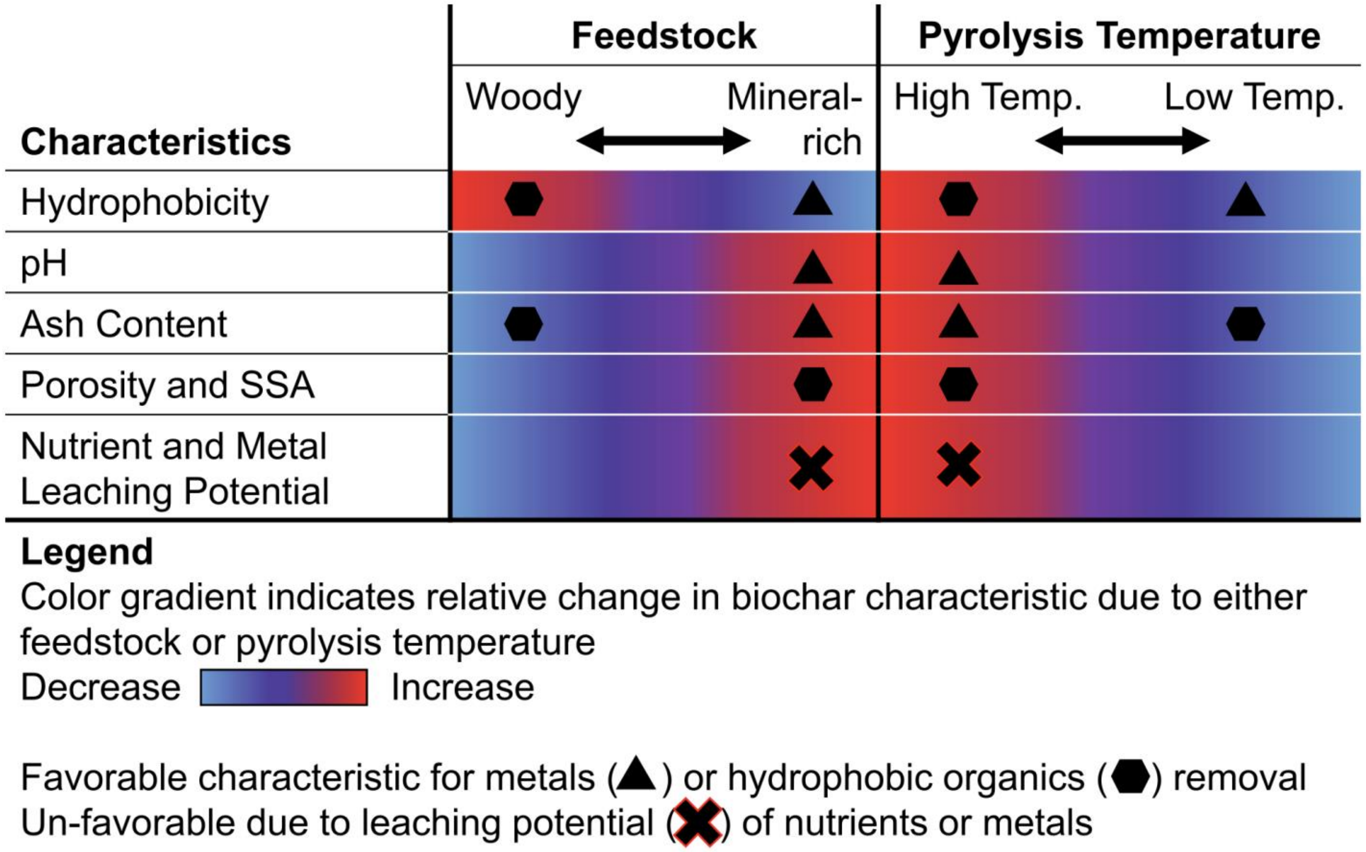


Fig. 2. Initial screening process for selection of biochar. Effect of feedstock and pyrolysis temperature on important characteristics for adsorption of metals and hydrophobic organics.

Biochar properties impacted by feedstock and pyrolysis temperature

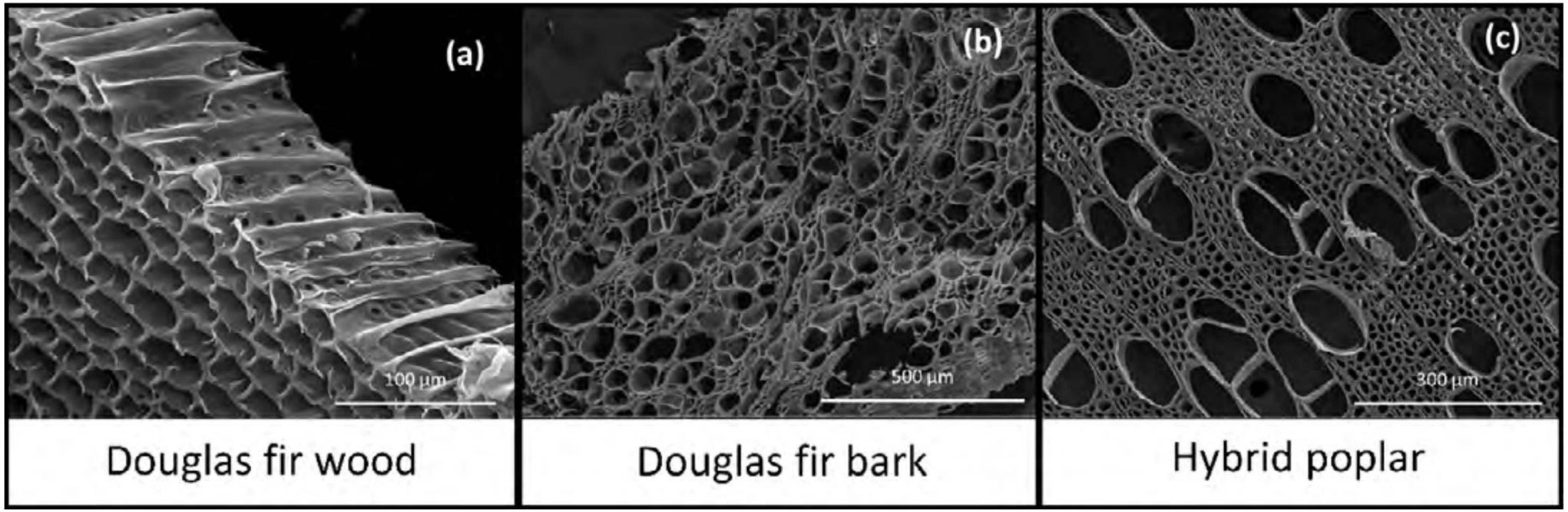
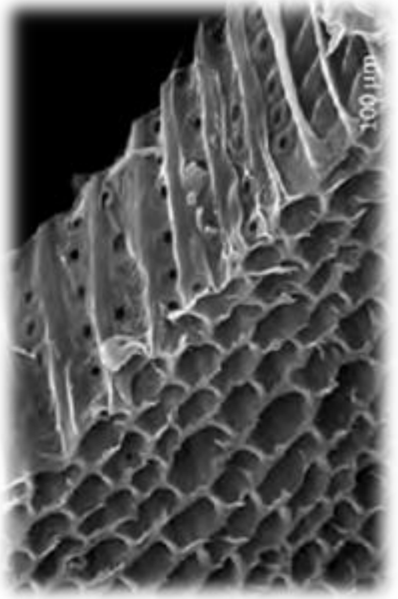


Figure 2.4. *Micropores in biochar vary based on feedstock type and pyrolysis temperature. Shown are electron microscopy images of biochar made from some typical feedstocks: Douglas fir wood, Douglas fir bark, and hybrid poplar. Reprinted from Biomass and Bioenergy, Vol 84, Suliman et al., Influence of feedstock source and pyrolysis temperature on biochar bulk and surface properties. Pages 37-48., Copyright 2016, with permission from Elsevier.*

Biomass to Biochar: *https://s3.us-west-2.amazonaws.com/wp2.cahnrs.wsu.edu/wp-content/uploads/sites/32/2022/01/Biomass2Biochar-Maximizing-the-Carbon-Value1.1.pdf*

Take home points



- Biochar has the potential to be an effective replacement for bioretention, though some compost may be needed to support plants
    - High water holding capacity
    - Reduced nutrients and metals leaching
    - Bonus: carbon sequestration
- Our research found that a 20% replacement of compost with biochar:
    - Increased *E.coli* removal
    - Reduced DOC export
    - Played a role in improving fecal coliform removal.
- Biochar has its own challenges – requires careful selection
    - Properties vary widely depending on feedstock and pyrolysis temperature
    - Not all biochars are alike

Thank you!

Contact: chemitchell@kingcounty.gov

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Carly Thompson
Andrew Flury

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