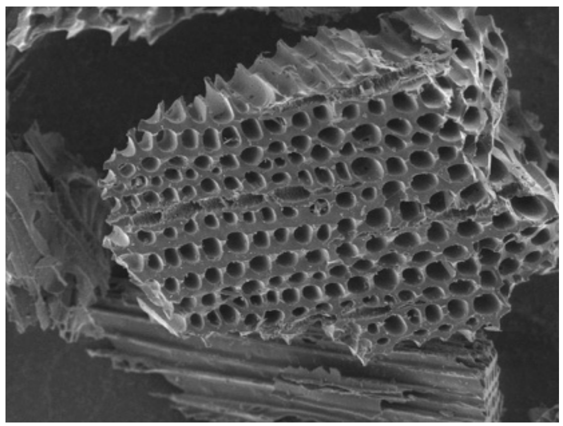
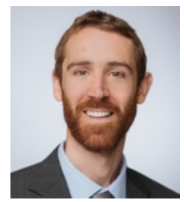
BIOCHAR IN STORMWATER MANAGEMENT
Applications for Filtration & Green Stormwater Infrastructure



Minnesota Stormwater
September 29, 2023



Myles Gray, P.E.
Program Director
US Biochar Initiative

USBI
Building the future from the ground up.™

ABOUT USBI

Established 2009

Fact Sheets

Online Producers Directory

Equipment & Technology Development

USBI is a not-for-profit organization promoting the sustainable production and use of biochar through research, policy, technology & doing it!

Activities:

North America Conferences, Workshops, Demos, Fact Sheets, Newsletter, Website, Provider Directory, Social Media, Biochar Advocacy, Referrals, Forestry Partner, Technical Advisory Team, Research, Outreach & Education, biochar.groups.io

In-field Workshops

Trade shows & Conferences

USFS Biochar Basics bit.ly/3NCtv78

Content Contributor

WHAT IS BIOCHAR?

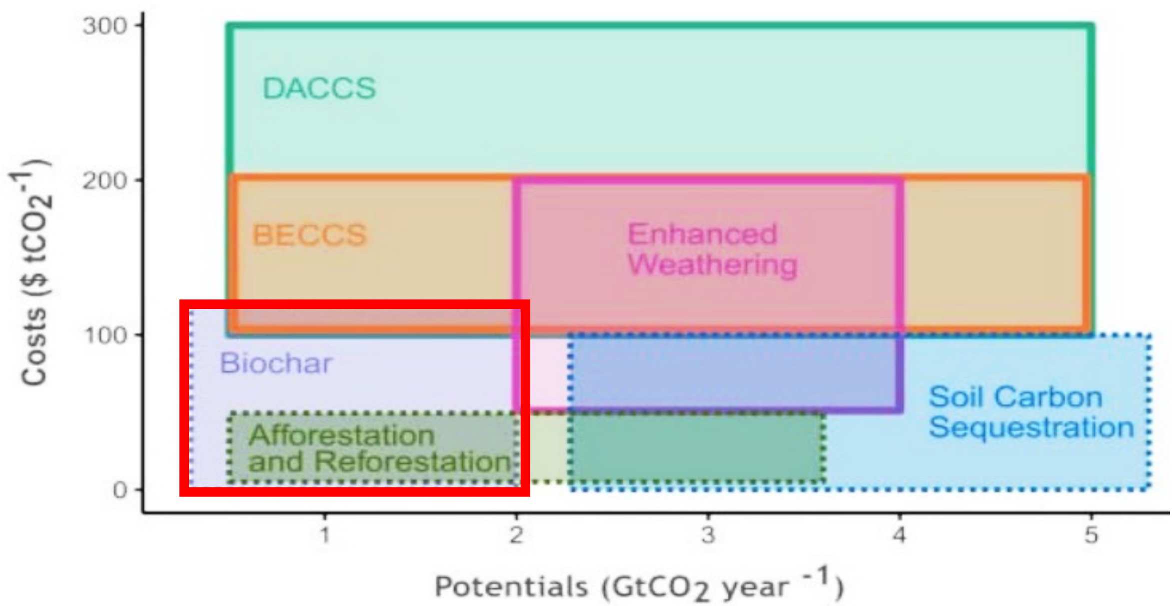
- Granular black carbon, like charcoal
- Produced via pyrolysis: heating without oxygen
- Resistant to decay for 100’s - 1,000’s years
- Multiple beneficial environment applications such as stormwater filtration
- When produced from waste biomass it can be part of an approach to:
    - Produce renewable biomass energy
    - Remove carbon from the atmosphere
    - Create valuable environmental and agriculture materials

WHY SHOULD WE CARE ABOUT BIOCHAR?
Scalable, verifiable carbon removal with co-benefits

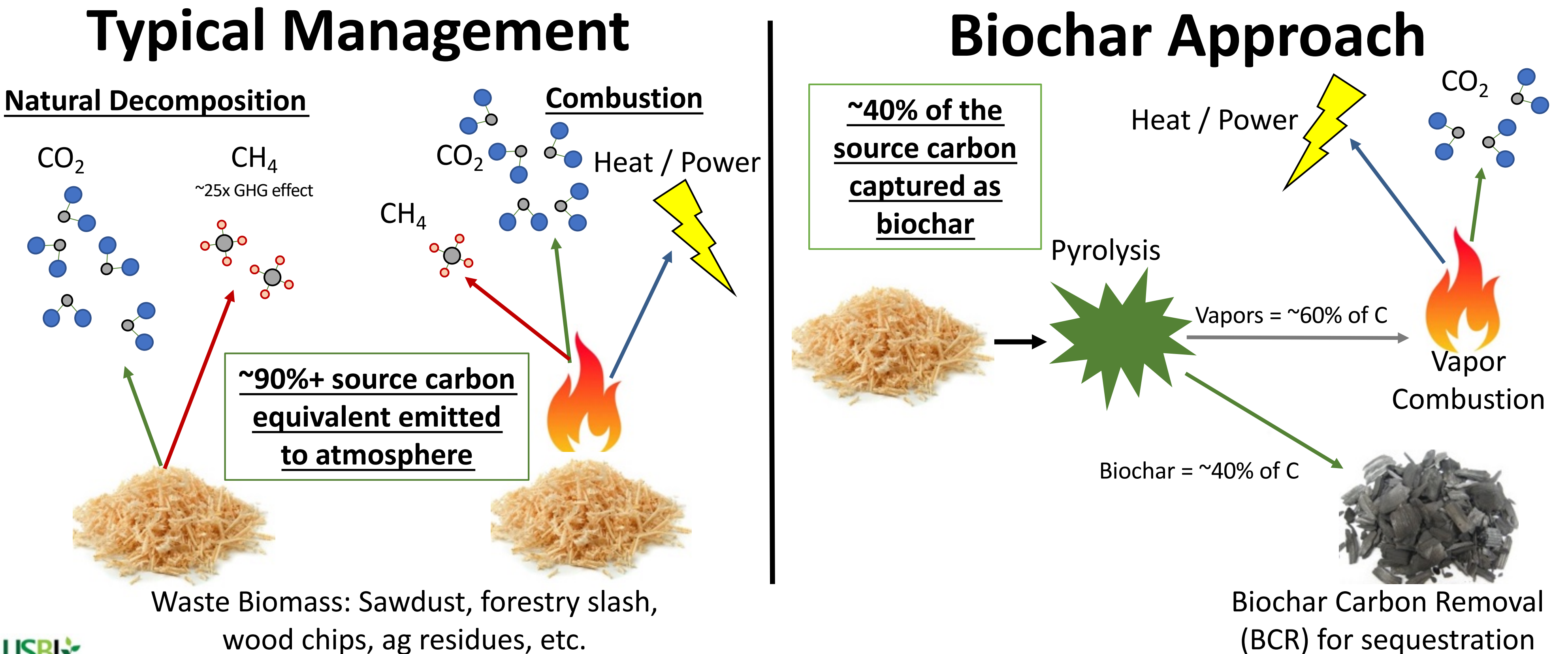
According to IPCC 6th Assessment:

- Limiting warming to 2 ºC requires decarbonization AND carbon removal
- Carbon removal to offset hard-to-abate emissions and to drawdown historic emissions
- Biochar among most viable and scalable options

Potentials by 2050



BIOCHAR CARBON REMOVAL (BCR)
Sequestration of waste biogenic carbon



BIOCHAR CHARACTERISTICS
Physical Properties

Highly porous; surface area up to 500 m^2/g

Three distinct pore types:

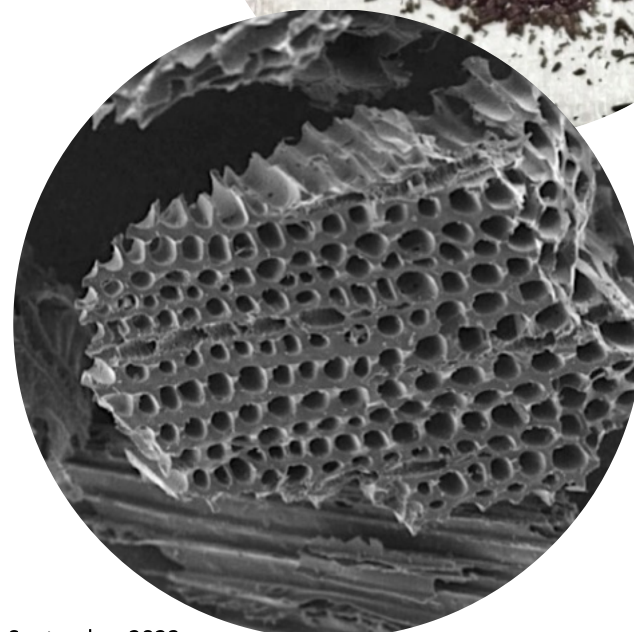
External pores: Dependent on particle size

Macropores: Dependent on feedstock

- 10-100 µm range for wood biochars

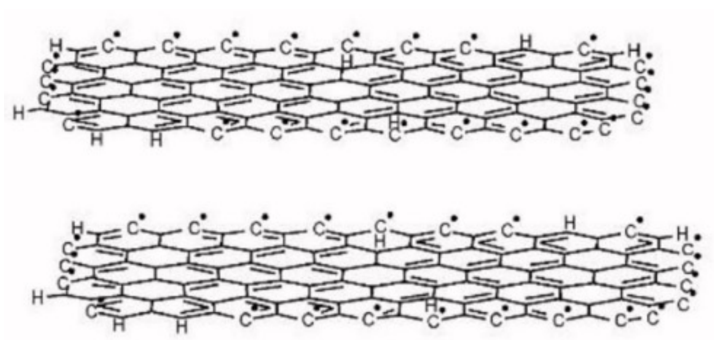
Micropores: Dependent on production

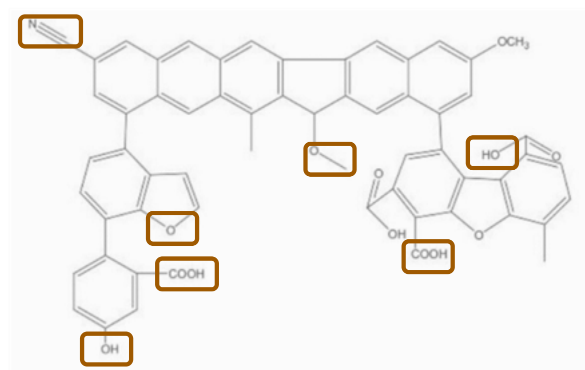
- 1-10 nm range = 10-100 water molecules!
- Majority of surface area with high potential sorption



BIOCHAR CHARACTERISTICS
Chemical Properties

- Biochars are primarily stable carbon rings that resist decay, especially those produced above 550 C.
  - Limited reactivity, but some sorption of hydrophobic compounds and metals
- Edges of sheets contain oxygen-containing regions
  - Increased reactivity of chemical sorption
  - Increases over time, increasing reactivity and sorption





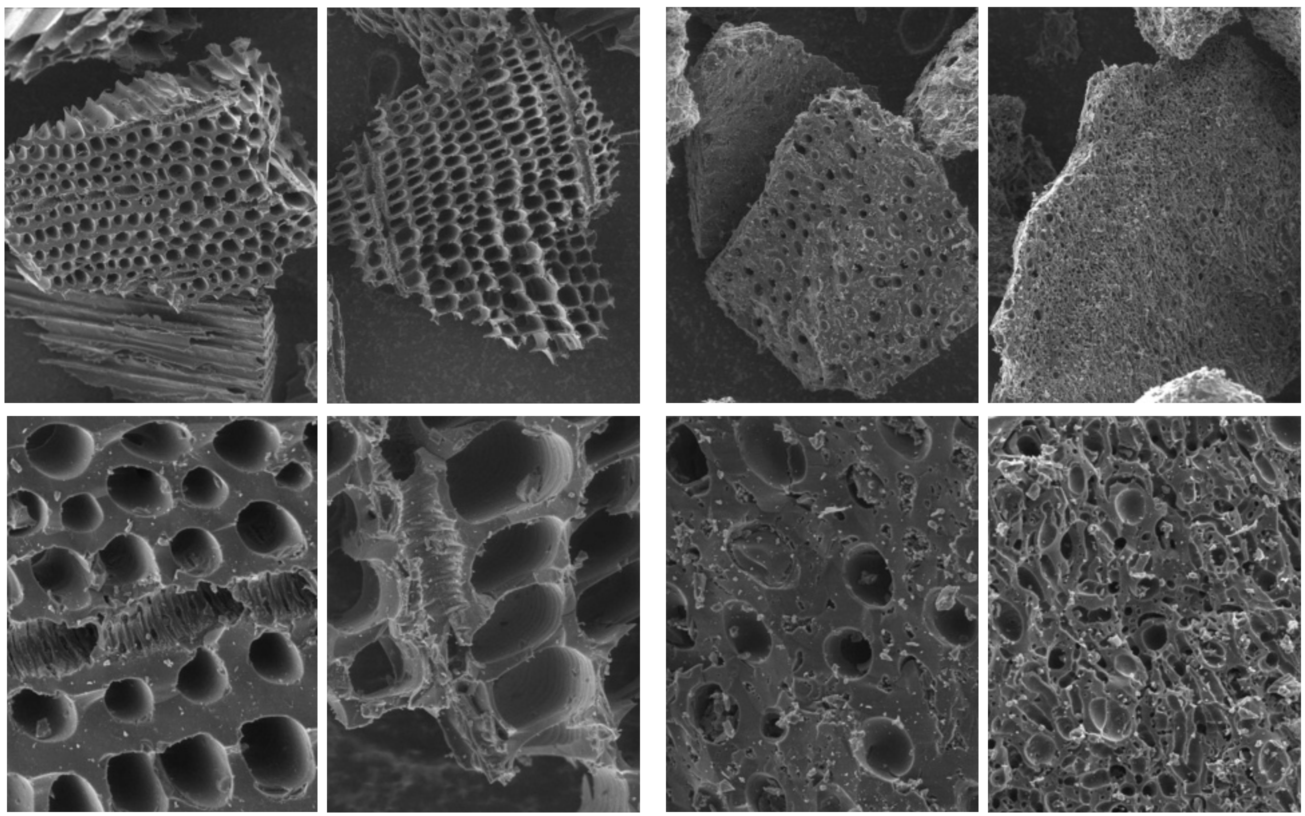
BIOCHAR IS NOT CREATED EQUAL

Properties depend on feedstock and production process

Douglas-fir 500 °C | Douglas-fir 650 °C | Hazelnut shells 500 °C | Hazelnut shells 650 °C

Top Row Scale
100 µm

Bottom Row Scale
20 µm



STORMWATER MANAGEMENT
What are the goals and drivers?

Urbanization creates **water quality** and **hydrology** problems

Stormwater management aims to **mitigate impacts** for existing and new development and for industry

Mechanisms built into development and pollution prevention **regulation**

- Industrial Stormwater Permits
- Municipal Development Permits

STORMWATER QUALITY
Pollutants are Ubiquitous in the Urban Environment

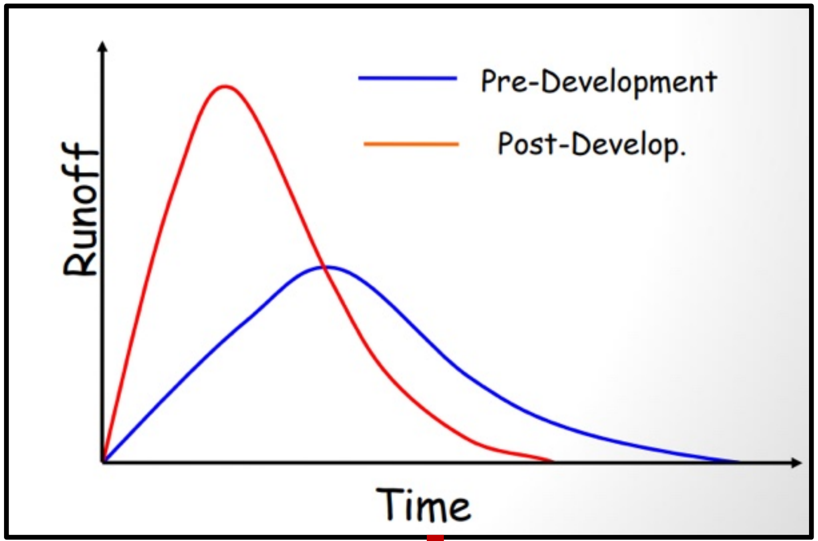
Pollutants	Sources	Impacts
Total Suspended Solids (TSS)	Car brakes and tires, construction sites, industry, dust	Reduced water clarity, settling on bottom of water bodies
Nitrogen and Phosphorus	Car exhaust, fertilizers, pets, exposed soil	Eutrophication and dead zones
Heavy Metals: Copper & Zinc	Car brakes, tires, galvanized metal, herbicides	Direct toxicity to aquatic organisms
Human Pathogens: E. coli	Pets, birds, misconnected sewers, landfills	Direct toxicity to humans
Oils and Grease	Car oil and gasoline leaks, industry, restaurants	Direct toxicity to aquatic organisms
Trace Organics: PCBs, PAHs, PFAS	Car exhaust, industrial solvents, consumer products, legacy contaminants	Toxicity to aquatic organisms and humans, carcinogens, bioaccumulants

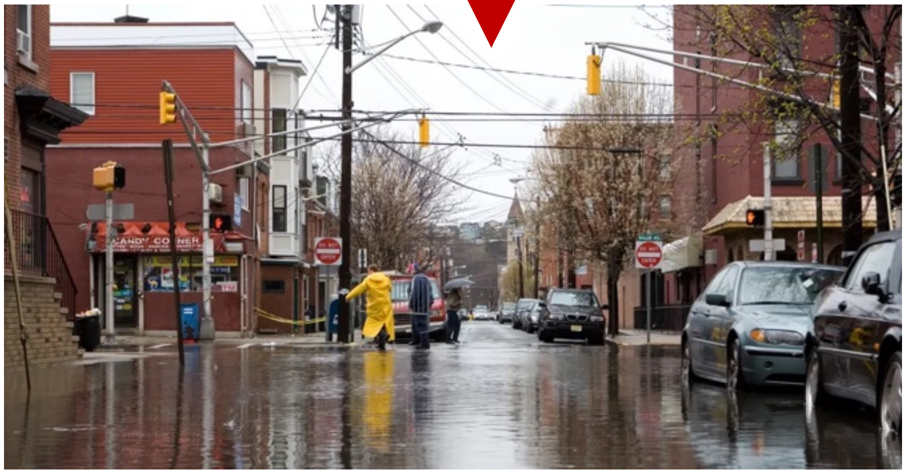
STORMWATER HYDROLOGY
Urban Hydromodification

Conversion of pervious surfaces into impervious surfaces leads to:

- Increased peak runoff flow rates
- Increased total runoff volume
- Reduced soil infiltration

- Increased urban flooding
- Hydromodification of streams
- Reduced groundwater recharge



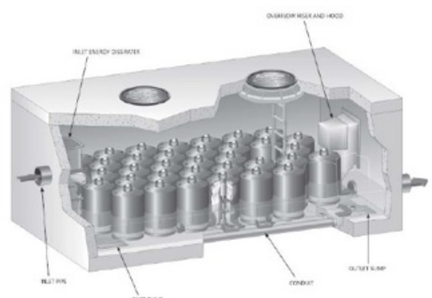


STORMWATER MANAGEMENT SYSTEMS
“Best Management Practices” (BMP)

Source Control

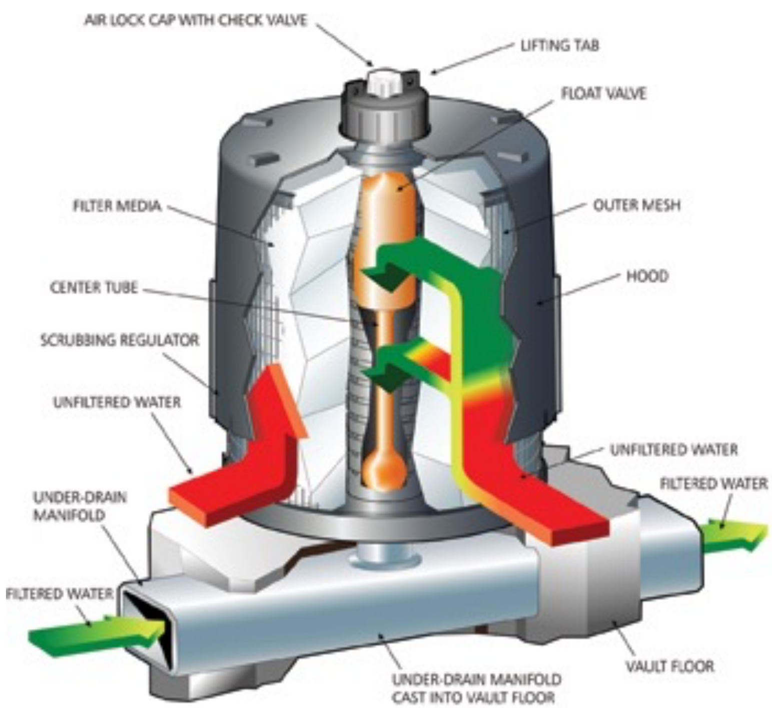
Structural

Filtration



Green Infrastructure

FILTRATION BMPs
Pollutant Removal in a Small Footprint



Filtration media contains:

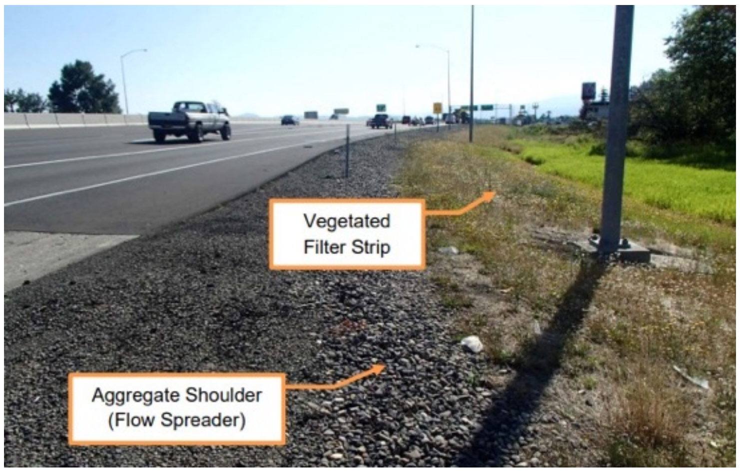
- Sand and/or Perlite to remove solids (i.e., TSS)
- Activated carbon to remove organic pollutants
- Granular ferric oxide to remove metals
- All high carbon accounting materials

Filtration media particle size carefully controlled to achieve high treatment flow rates

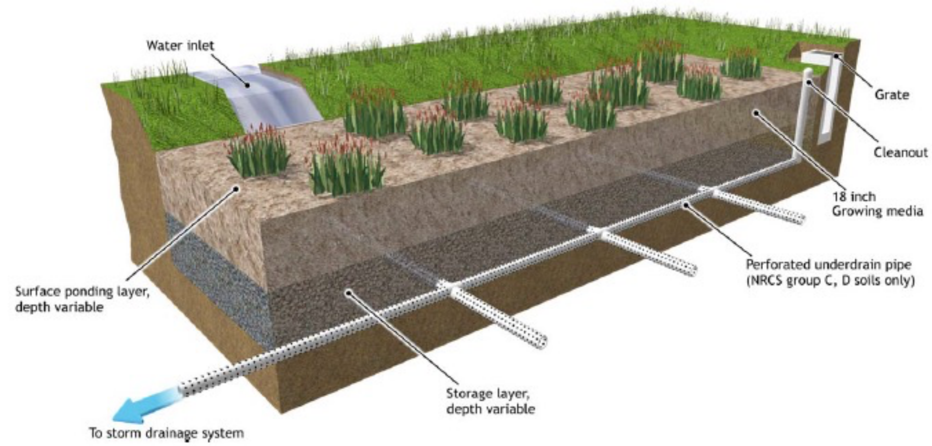
PROS	CONS
Good pollutant removal	High-cost, proprietary, filtration media
Small footprint	Filtration media clogging
High quality designs	No co-benefits
Can be low cost	No effect on hydromodification

GREEN INFRASTRUCTURE
Hydrology, Pollutant Removal, & Co-Benefits

Vegetated Filter Strip



Bioretention

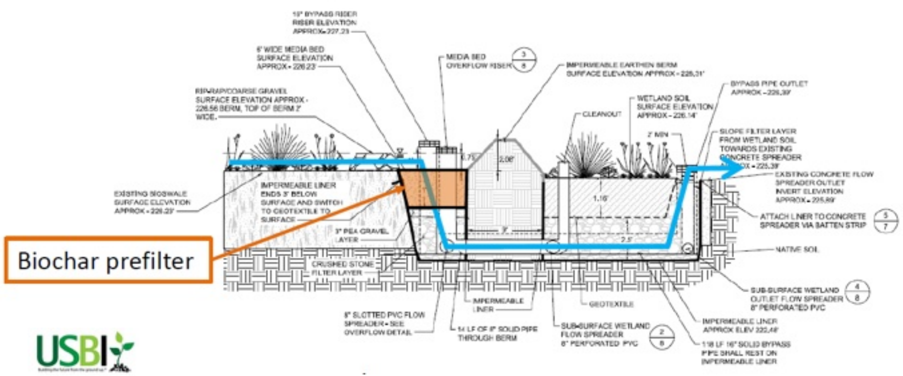


Green Infrastructure BMPs are vegetated treatment systems that harness plants and sandy soil to manage hydrology and remove pollutants

PROS	CONS
Good pollutant removal	Larger footprint
Infiltration to mitigate hydromodification	Can initially export pollutants
Co-benefits	Often high maintenance cost

BIOCHAR IN STORMWATER MANAGEMENT

A transformative material



BIOCHAR FOR POLLUTANT REMOVAL

A Potential Lower Cost, Green Alternative for Filtration

Property	Biochar	Activated Carbon
Feedstock	Mostly wood for filtration	Coconut shell, coal
Carbon Balance	*Carbon negative*	Carbon intensive
Surface Area	Up to ~400 m^2/g	Up to 1,600 m^2/g
Pollutant Removal	Good	Excellent*
Treatment Flow Rate	Depends on particle size distribution	
Cost	~$50-300/CY	~$1,000/CY

* Stormwater filtration media frequently clogs prior to sorption exhaustion, so added pollutant removal not always valuable.

Key stormwater question: Can biochar be used in common stormwater filtration devices as a drop-in replacement for other treatment media?

BIOCHAR TO MITIGATE HYDROMODIFICATION

Improving Water Holding & Infiltration

Bioretention soil media is sandy soil with limited water holding and can become clogged by particulates

In soil research, biochar amendment:

- Increases plant available water, especially in sandy soil (e.g., bioretention soil)
- Sometimes increases infiltration rates
  - Less impact in sandy soils, at least initially
  - May have longer-term impact in bioretention soil as plant growth counteracts clogging

Key stormwater question: Does biochar provide long-term improvements in water holding and infiltration rate that provide meaningful improvements to Green Infrastructure effectiveness?

BIOCHAR TO IMPROVE PLANT HEALTH
Improve Performance & Reduce Costs

Plant health in bioretention is a significant problem:
- Healthy plants maintain infiltration rates while unhealthy or dead plants require replanting

In agriculture research, biochar amendment improves plant growth and health, especially in sandy soils
- Range of mechanisms involved, but results are robust

Key stormwater questions:
- Does biochar improve plant health enough to provide meaningful improvements?
- Does this improvement offset added costs of biochar, compared to ~$50/CY average for typical bioretention media

BIOCHAR SPECIFICATIONS
General Guidance for Stormwater Systems

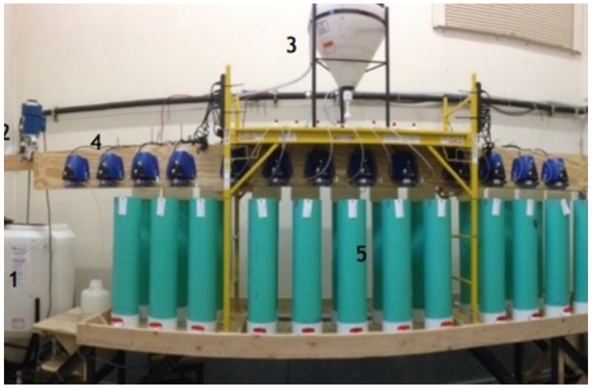
Parameter	Recommendation	Comments
Feedstock	Wood or nut shells	Avoid friable biochar derived from feedstocks like grass and high-nutrient feedstocks like manure
Production temperature	> 500 ºC	Lower temperature materials can contain impurities and have lower surface area.
Ash content	< 20%	Ash can contain impurities and pollutants
pH	< 10	Stormwater runoff is typically slightly basic (pH ~7.5) so overly alkaline biochar is not recommended
Percent passing #8	90-100	Overly coarse biochar particles provide limited pollutant removal in media. Biochar fines can migrate through media and cause clogging.
Percent passing #40	0 – 20	
Percent passing #100	0 – 2	
Impurities and pollutants (e.g., PAHs, dioxins)	Variable	Limits may depend on jurisdiction and on treatment goals

CASDE STUDY: BIORETENTION APPLIED RESERACH
Reducing Phosphorus Export in Washington

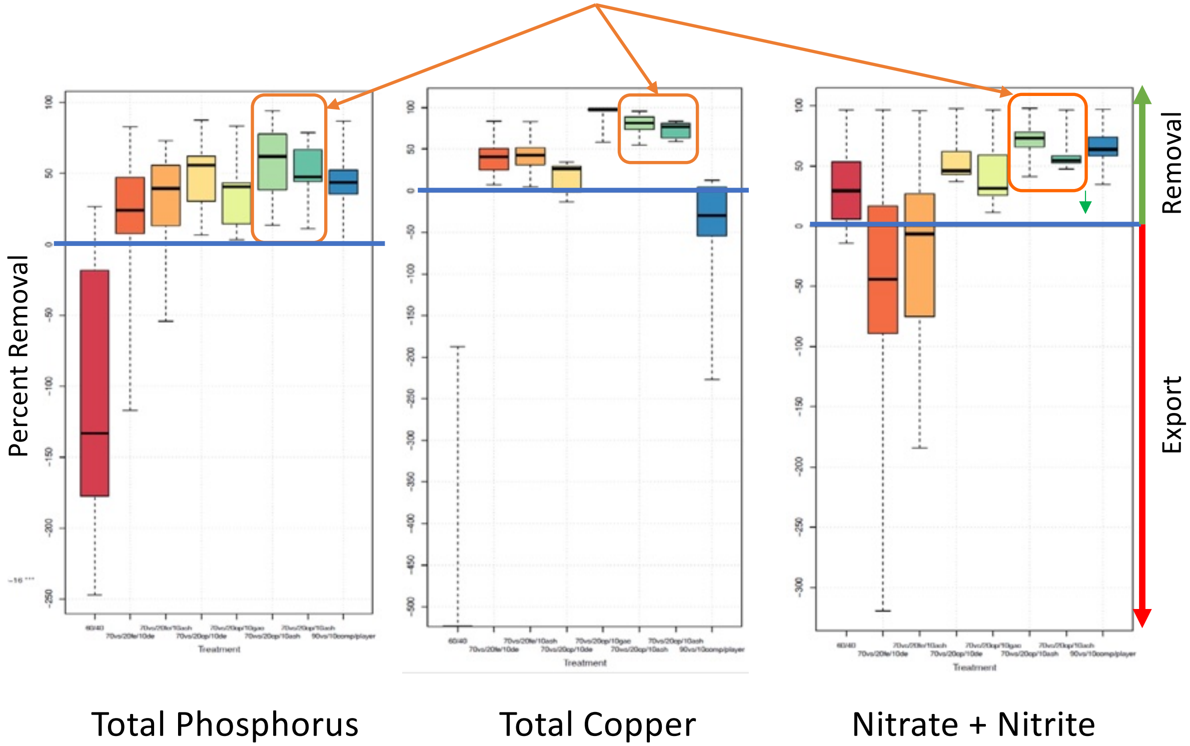
Objective: Develop alternative bioretention media specification to reduce nutrient export

- Current specification is 40% compost and exports nutrients to streams

Testing Approach:
- Started with laboratory leaching tests
- Followed by laboratory dosing tests
- Testing led by Herrera Consultants, Inc.



2 Biochar blends: 70% sand (2 types), 20% coconut coir, 10% wood biochar



CASDE STUDY: BIORETENTION APPLIED RESERACH
Follow up Bioretention Soil Media Research

Objectives:
- Validate results in field test using real stormwater over a long duration to assess real-world performance.
- Assess hydrologic and water quality performance for full suite of typical stormwater pollutants

Approach:
- Used state-of-the-art mesocosm research facility at Washington State University (WSU) Puyallup
- Routed real stormwater through mesocosm for 2 years
- Continuously collected precipitation and flow data
- Collected stormwater samples for laboratory analysis during six storms
- Project led by WSU researchers and Geosyntec Consultants (me, while at Geosyntec)

CASE STUDY: BIORETENTION APPLIED RESEARCH

Project Results & Impacts

Pollutant	Mean Removal Efficiency (% removal)	
	Media with Biochar	Standard Media
Total Suspended Solids	90%	80%
Total Copper	82%	59%
Dissolved Copper	47%	-41%
Total Zinc	96%	94%
Dissolved Zinc	94%	93%
Total Nitrogen	28%	-171%
Nitrate + Nitrite	42%	-7%
Total Phosphorus	65%	-32%
Dissolved Phosphorus	52%	-78%

Research Takeaways

- Media with biochar more effectively removed all pollutants
- Both media types effectively removed TSS and zinc
- Standard media exported nutrients and copper, but media with biochar did not

Project Impact:

- Alternative bioretention media specification includes biochar as an ingredient. This media specification is required in areas in Western Washington in watersheds with known lake eutrophication problems.
- Momentum to include this specification for use more broadly in all areas of Western Washington.

INDUSTRIAL GREEN INFRASTRUCTURE

Engineered Solutions to Remove Specific Pollutants




INDUSTRIAL GREEN INFRASTRUCTURE

Engineered Solutions to Remove Specific Pollutants

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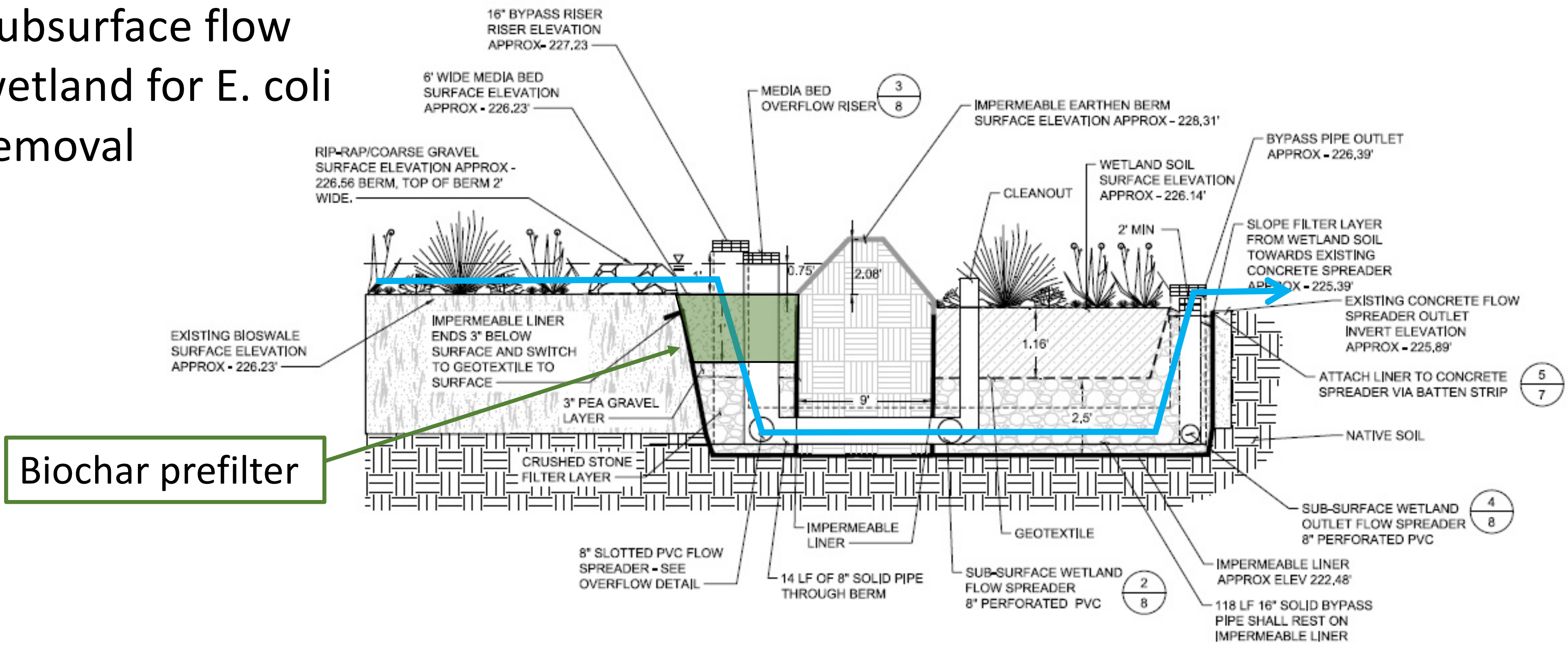
INDUSTRIAL TREATMENT SYSTEM

Subsurface flow wetland for E. coli removal



- Prefilter is 50/50 mix of coarse sand and coarse biochar
- 12 CY biochar sourced from local supplier
- Subsurface gravel wetland based on UNH design guidance

INDUSTRIAL FILTRATION DEVICES
Custom-Designed Filters Using Biochar

Biochar Feasibility Study at Port of Port Townsend, WA

Treatability Testing → Pilot Testing → Full Site Implementation
Media Development → Device Testing → Installation and Monitoring

Project Approach:

- Project site had excessive zinc in stormwater runoff
- Lab testing to develop high flow rate filtration media using biochar
- Biochar for pilot testing and full implementation sourced from Port Townsend Paper Company mill
- Custom upflow filter design developed for roof downspout filters
- Pilot test of one filter for four storms

	Mean Influent (µg/L)	Mean Effluent (µg/L)	Benchmark (µg/L)	Mean Removal (%)
Total Copper	46.5	2.52	17	93.5%
Total Zinc	4925	7.46	120	99.8%

- Full project implementation of 18 filters for rooftops at site
- Project led by Oregon State University (i.e., me), Olympic Biochar, and Biological Carbon

INDUSTRIAL FILTRATION DEVICES
Custom-Designed Filters Using Biochar

Project Results and Impacts:

- Final filtration media design used 20% biochar:
  - Other media included sand and peat
  - Biochar sieving and rinsing was critical to achieve flow rates
- Filters removed copper and zinc to achieve site permit limits
- Upflow filtration removed pollutants at high flow rates
  - Design was adapted by two stormwater treatment vendors*

Full project monitoring results

	Mean Influent (ug/L)	Mean Effluent (ug/L)	Mean Removal (%)
Total Copper	54.2	7.88	71.1%
Total Zinc	1018	39.0	92.6%

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* Stormwater Biochar (www.stormwaterbiochar.com) and Gullywasher (www.gullywasher.com)

BIOCHAR FOR STORMWATER MANAGEMENT
Where We Are Today

- Robust laboratory research on biochar as a material to remove pollutants from water and from stormwater. Ongoing research will continue to improve data and understanding
- Full-scale treatment projects have been successfully implemented at multiple sites:
  - Industrial, municipal, highways
- Biochar is effective for filtration and Green Infrastructure, but monitoring is needed to:
  - Understand longevity of effectiveness in real-world projects
  - Determine pollutant removal for emerging contaminants (e.g., PFAS, 6-PPDQ)
  - Assess long-term impacts on plant health and infiltration rates in Green Infrastructure
- Some specifications have been developed for biochar in stormwater have been developed, but not widely known or used
- Biochar material quality and consistency are improving, and costs are declining, especially when sourced from larger producers
- Most stormwater professionals have limited familiarity with biochar

BIOCHAR FOR STORMWATER MANAGEMENT
Future Needs for Stormwater Management

Focus on addressing needs of end-users to increase usage:

	Municipal	Industrial
Primary System Type	Green Infrastructure	Filtration
Site Applicability	New and Re-Development	All Industrial Sites
Key Metrics	Compliance with Stormwater Manuals	Pollutant Concentrations
Key Biochar Attributes	Biochar cost, O&M burden	Pollutant removal, O&M burden
Secondary Biochar Attributes	Pollutant removal, soil infiltration rate, climate impact	Biochar cost

- For Industrial sites, well-documented pollutant removal is key path forward
- For Municipal sites, low-cost biochar and clear specifications is best path forward
  - Target pricing for quality biochar = ~$50/yd^3 (carbon credits sold separately)
- Pilot and field research should be prioritized over lab research

Thank you!

Minnesota Stormwater
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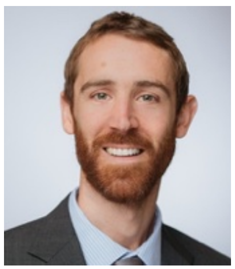

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