RESEARCH SUMMARY

DEPARTMENT OF TRANSPORTATION

LOCAL ROAD RESEARCH BOARD

AUGUST 2025

Developing Biochar Specifications for Stormwater Management

Effective stormwater management helps keep roadway contaminants from entering Minnesota's lakes and streams. Management practices include soil and vegetation in roadside bioretention systems that filter heavy metals and hydrocarbons created by vehicles. Based on other studies, retention and transformation of roadside pollutants should be improved by biochar application to existing or engineered soils. Abundant sources of biomass can be used to produce biochar, a soil amendment with numerous benefits. MnDOT and local agencies identified biochar specifications for effective use in stormwater treatment to support the next phase of testing and development of biochar design guidance.

What Was the Need?

Managing stormwater runoff from roads can involve infiltration systems to mitigate pollutant discharge from Minnesota's ponds, streams and lakes. Biochar created from biomass waste can filter heavy metals, excess nutrients and organic contaminants before they reach bodies of water. When mixed with other materials like compost, peat, topsoil or sand, biochar can be used in roadside bioretention systems.

Biochar is produced from many different feedstocks, and processing methods can vary significantly. Although some counties have been using biochar in roadside applications, its performance in stormwater runoff mitigation and as a soil amendment is not well understood, especially for multiple pollutant types and waste load reduction such as tires, metals, microorganisms, nutrients, volatile organic compounds (VOCs), fuels and PFAS.

MnDOT and local agencies needed product standards and material specifications to ensure biochar products have the necessary physical and performance properties for stormwater contaminant removal and other desired purposes. In this first of a two-phase project, the

"From this project phase alone, we likely have enough information to develop standard specifications for using biochar for stormwater management. Field tests will illustrate its multiple benefits even more."

—DWAYNE STENLUND, EROSION CONTROL SPECIALIST, MnDOT OFFICE OF ENVIRONMENTAL STEWARDSHIP

agencies sought to explore biochar production, characterize its properties and understand its performance in filtering stormwater runoff.

What Did We Do?

Ash trees were chosen as the biochar feedstock due to the abundance of these trees infested with the emerald ash borer. Researchers used a biochar production kiln that allowed for rigorously tight control of temperatures during pyrolysis, a heating process that thermally degrades organic waste into reusable biochar and combustible gases. Ten highest thermal treatment (HTT) temperatures were used during pyrolysis to create biochar products with different physical properties and contaminant-filtering performance.

Testing in the lab measured the biochar's physiochemical properties and analyzed its elemental composition, including carbon, hydrogen, nitrogen and sulfur. Since biochar retains the vascular network present in the feedstock wood, researchers also explored the biochar's water-holding capacity and porosity through assessing pore size distribution.

An analysis of contaminated stormwater mixed with biochar samples illustrated the product's sorption performance and its ability to absorb or adsorb contaminants. Researchers observed the amount of heavy metals, including copper, nickel, zinc and lead, and hydrocarbons from vehicles that were retained in the stormwater samples containing biochar.

What Did We Learn?

Production and testing of biochar samples identified the material properties that are conducive to filtering contaminants from stormwater runoff and methods to accurately test for the desired properties. Researchers recommended an important production parameter and material property to ensure high sorption performance from biochar:

- **Pyrolysis temperatures.** Heavy metals are most effectively filtered in biochar produced at temperatures equal to or greater than 600 degrees Centigrade (C). Hydrocarbons require an HTT equal to or greater than 675 degrees C.

- **Vascular porosity.** A pore volume equal to or greater than 0.40 mL/g and a vascular pore diameter range from 500 to 80,000 nm are recommended for high water retention and aerated, noncompacted soils.

They also recommended a minimally expensive test to ensure VOCs do not remain in the produced biochar and later released into the soil and watersheds. Recommended tests can generally be performed at analytical service labs.

What's Next?

The second phase of this project—to field-test biochar products identified in the initial phase—is underway. Soil hydrology and stormwater treatment efficiency testing on biochar combined with various other media, including compost, peat, topsoil and sand, will support the development of construction design guidance for using biochar in bioretention systems.

Amending roadside soil with biochar holds significant promise for increasing soil health and preventing compaction, improving vegetation growth and filtering contaminants from stormwater runoff. The process of biochar production is self-propagating, as the gases created by pyrolysis are reused to heat the kiln, requiring little additional energy. Finally, the graphite-like biochar captures carbon, preventing release into the atmosphere and potentially creating carbon credits.

About This Project

REPORT 2025-36
"Development of Biochar Specification Criteria as Soil Amendment for Slopes, Conveyances and Stormwater Treatment Systems (Phase I)."
Find it at mdl.mndot.gov.

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PROJECT COST
$231,476

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