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Research Results

Soil Amendment Guidance for Infiltration and Stormwater Treatment

This task investigates the properties of various soil amendments to maximize the stormwater treatment performance of soils mixtures used in the California Department of Transportation (Caltrans) right of way (ROW) and clear recovery zone (CRZ).

Environmental

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Project Title: Soil Amendment Guidance for Infiltration and Stormwater Treatment

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WHAT WAS THE NEED?

Pollutants from roadway runoff are the leading cause of surface water impairments. Thus, treatment of road runoff by building roadside stormwater best management practices (BMPs) could prevent pollution. However, limited infiltration in compacted roadside soil poses a significant challenge to designing roadside BMPs. The Caltrans Office of Stormwater Program Development developed guidance to comply with new National Pollutant Discharge Elimination System (NPDES) permit requirements for post-construction stormwater treatment controls. The permit requires Caltrans not only to prioritize soil-based BMPs but also to give first consideration to installing BMPs that can drain the amount of water from an 85th percentile 24-hour storm event. These permit conditions must be implemented where feasible, based on other Caltrans safety and design requirements. Installing soil amendments adjacent to roadsides is a challenge because of vehicle traversability issues. Caltrans Standard Specifications require 90% relative-compaction within the CRZ. For amended soils less than 90% compaction is preferred to enhance infiltration/ retention of stormwater runoff. This project developed the information needed for estimating stormwater runoff infiltration volumes and flow rates that enable Caltrans practitioners design, install, and maintain soil amendments (e.g. compost and biochar) in the CRZ when viable, while meeting the NPDES permit requirements. Prior to this study, NCHRP and several DOTs evaluated biochar in limited laboratory settings

WHAT WAS OUR GOAL?

The goal of this task was to evaluate the stormwater treatment performance of various soil amendments.

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WHAT DID WE DO?

This study investigated the properties of various soil amendments to maximize the stormwater treatment performance of soil mixtures used in the Caltrans ROW and CRZ across the four hydrologic soil groups (HSGs) A, B, C, and D. To improve their infiltration capacity, four types of bulking agents were tested: coarse sand, vermiculite, perlite, and expanding shale clay silt aggregate (ESCS). Under normal compaction rates, all soils demonstrated poor water infiltration capacity and contained low organic carbon, which also limited their ability to filter pollutants. Consequently, the research team tested new soil mixtures including a mixture of ESCS, sand, and biochar. Biochar is a charcoal-like material derived from various biomass sources. This study exclusively used biochar generated from woody biomass. The second phase of the study focused on field testing these soil mixtures' real-world stormwater management performance along Caltrans ROW and CRZ. Road runoff was routed into separate stormwater biofilter areas for each experimental soil mixture, including the biochar-ESCS formula as well as Caltrans standard soil blend for right of way areas. The standard soil is comprised of sand, compost and soil, but does not have any supplemental biochar. The research team conducted infiltration, filtration, and sequestration tests to compare with the results from the laboratory experiments.

WHAT WAS THE OUTCOME?

The results reveal that sand and ESCS could achieve a minimum infiltration capacity (6 in h-1) under compaction, whereas vermiculite and perlite failed to meet the infiltration criteria because they became compressed and restricted the free flow of stormwater. The biochar-ESCS amended soils demonstrated both significantly improved infiltration and filtration performance. In addition, the best biochar type was determined, as well as the optimal amendment rates per hydrologic soil group. A pilot-scale field study was then conducted to evaluate the performance of an engineered filter media composed of ESCS, biochar, and topsoil, relative to a standard sand–compost–soil blend. The engineered media demonstrated a 3.3-fold higher infiltration or drainage capacity (5.9 cm h^{-1} vs. 1.8 cm h^{-1}) compared to the conventional system. During initial monitoring effort without appropriate conditioning of media, conventional media amendment with compost and sand showed net leaching of metals (negative removal), whereas the engineered media (biochar and ESCS) showed a net removal for heavy metals, including Pb (55%), Co (47%), Ni (59%), Cu (61%), and Cd (54%), and Zn (27%). These improvements are attributed to the high porosity, chemical reactivity, and structural stability of ESCS and biochar under compaction, which together maintain permeability and enhance pollutant retention. In contrast, the compost-rich media exhibited low capacity for infiltration after being compacted and potential for initial metal leaching. A long-term monitoring of effluent could provide realistic removal rates for both media. These findings affirm the potential of biochar–ESCS-amended media as a viable, field-validated alternative to conventional amendments for curbside infiltration and treatment of road runoff.

WHAT IS THE BENEFIT?

The results of this study provided Caltrans' Stormwater Program, as well as its Divisions of Design, Construction, and Maintenance a potentially better approach for improving stormwater management and meeting NPDES permitting requirements. The study demonstrates that the biochar-ESCS mixture is a high-performing soil amendment that could significantly improve stormwater management in the State Highway System. In addition, this study finds that biochar could also significantly improve water quality through the removal of heavy metals and potentially other emerging pollutants of concern. The most significant benefit is biochar's deployment potential and sustainability as biochar can be sourced as an inexpensive and renewable byproduct of biofuel energy production and burned forests from wildfire events.

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IMAGES

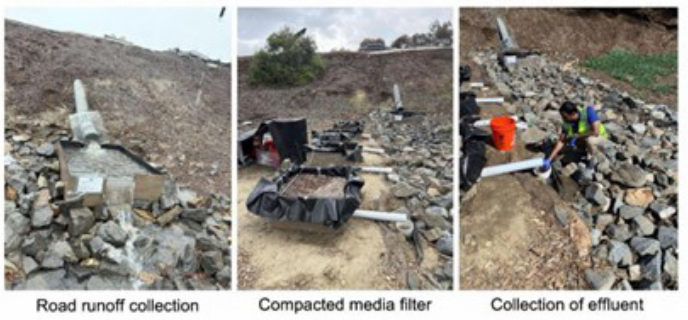

Image 1: Road Runoff Treatment Using Compacted Engineered Media (Courtesy: Dr. Sanjay Mohanty)