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## Implementing biochar and compost as organic amendments for improved pollutant removal in bioswales

Utilisation de biochar et de compost comme amendements organiques pour améliorer l'élimination des polluants dans les baissières d'infiltration végétalisées.

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### RÉSUMÉ

Les bassins d'infiltration végétalisés sont de plus en plus utilisés dans les régions urbaines pour le drainage et le traitement des eaux pluviales en raison de leur capacité à fournir divers services écosystémiques. Bien que ces systèmes soient connus pour éliminer efficacement les sédiments et les polluants liés aux particules, ils peuvent ne pas réussir à éliminer les polluants dissous de manière fiable au cours de leur cycle de vie. Ce projet de recherche vise à résoudre ce problème en étudiant l'utilisation d'amendements organiques du sol, à savoir le biochar et le compost issu de déchets verts. L'objectif du projet est de maintenir la sécurité du drainage et d'améliorer l'efficacité et la rétention à long terme des polluants dissous (métaux lourds et composés organiques traces) tout en améliorant la compréhension des mécanismes d'élimination des polluants dans les bioswales. Le projet vise à produire des connaissances transférables et adaptables pour améliorer les services environnementaux des bioswales urbaines avec une approche interdisciplinaire.

### ABSTRACT

Vegetated infiltration swales are increasingly being implemented in urban areas for dewatering and stormwater runoff treatment due to their potential for providing various ecosystem services. While these systems are known for effectively removing sediments and particulate-bound pollutants, they can fail to remove dissolved pollutants in a reliable manner over their lifecycle. This research project intends to address this issue through investigating the use of organic soil amendments, namely biochar and green-waste-derived compost. The focus of the project lies in the maintenance of drainage security and the enhancement of the efficiency and long-term retention of dissolved pollutants (heavy metals and trace organic compounds) while enhancing the understanding on the mechanisms of pollutant removal in bioswales. The project is intended to provide transferrable and scalable knowledge for improving the environmental services of urban bioswales with an interdisciplinary approach.

### KEYWORDS

Dissolved pollutants, Green Infrastructure, Organic soil amendments, Vegetated infiltration swales, Stormwater management.

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## 1 INTRODUCTION AND OBJECTIVES

The implementation of green infrastructure is an increasingly popular strategy for stormwater management in cities, as it can provide several ecosystem services beyond runoff drainage and pollution control (Prudencio & Null, 2018; Taguchi et al., 2020). This is the case of bioswales, which are underground depressions where different mixtures of geomedia and vegetation serve as passive stormwater treatment systems (Boehm et al., 2020). While bioswales are known for effectively removing sediments and particulate-bound pollutants, they can fail to remove dissolved pollutants in a reliable manner over their lifecycle (Boehm et al., 2020; Bork et al., 2021; Gavrić et al., 2019; LeFevre et al., 2015). For instance, the removal of dissolved heavy metals like copper and zinc has been mostly linked to the retention of total suspended solids (TSS) (Gavrić et al., 2019); and hydrophilic, polar trace organic compounds (TOCs) are removed to different and sometimes insufficient extents, depending on their physicochemical properties (LeFevre et al., 2015; Spahr et al., 2020). Furthermore, the changing soil saturation properties or the development of preferential flow pathways can also impact pollutant breakthrough (Bork et al., 2021). Thus, an improved pollutant retention in bioswales is crucial for fully harnessing the benefits of green infrastructure for stormwater management.

While the use of several organic and inorganic soil amendments in bioswales has been studied, the implementation of carbonaceous media has gained special attention due to some characteristics that can promote the removal of dissolved TOCs and heavy metals, such as its high organic matter content, high porosity, hydrophobicity and the surface presence of reactive functional groups (Burch, 2018; Mohanty et al., 2018). Within these type of amendments, biochar is an attractive material as it can be easily available, has relatively low production costs and can potentially remove a wide range of contaminants while supporting favorable conditions for long term operation of bioswales and fostering a circular resource use (Mohanty et al., 2018). However, the use of biochar in bioretention systems has some challenges to overcome. Although various studies have provided important insights on the efficiency and removal mechanisms of dissolved pollutants in biochar-amended swales, most of the experiments have been done at laboratory scale in conditions that do not resemble relevant hydrological and environmental conditions in bioswales (Biswal et al., 2022; Boehm et al., 2020; Mohanty et al., 2018). More studies with real - or more representative - stormwater and multiple-pollutant matrices are needed for a better appraisal of the effect of Natural Organic Matter, nutrients and TSS in pollutant transport (Biswal et al., 2022). The effect of seasonal environmental characteristics that represent the changes in saturation, pH and ionic strength (caused, for example, from the use of deicing salts) also need to be addressed in biochar-amended bioswales; as well as the effect of combining different types of biochars and other organic amendments (e.g., compost) in the overall pollutant retention (Biswal et al., 2022). Lastly, while biochar has been linked to improvements in the soil water retention capacity, the nutrient provision for plant uptake and the maintenance of favorable conditions for microbiota development in bioswales (Mohanty et al., 2018), there is little information on how these factors improve the long-term pollutant removal (Biswal et al., 2022; Gavrić et al., 2019).

This research project intends to address some of these limitations for a better understanding of the impact of using biochar and green-waste-derived compost in the efficiency and mechanisms of pollutant removal in bioswales. The focus of the project lies in the maintenance of drainage security and the enhancement of the removal efficiency and long-term retention of dissolved pollutants. This project is part of the Research Training Group in Urban Green Infrastructure of the Technical University of Munich (TUM), which investigates the use of green infrastructure for stormwater management by studying the improvement of the multifunctionality of infiltration swales from an interdisciplinary perspective. Thus, the effects of using organic amendments in microbiological functionality, plant support and their potential for enhancing the carbon storage capacity of the soil substrates will also be investigated in collaboration with other institutes and PhD students at TUM.

## 2 MATERIALS AND METHODS

This PhD project will investigate different combinations of organic amendments in bioswales based on their physical, chemical and biological properties. Specifically, various mixtures of green-waste derived compost and biochars from different feedstocks and pyrolysis temperatures will be studied in terms of their physical and/or chemical pollutant removal efficiency. The project will also involve experiments with the chosen organic amendments in mixtures with with inorganic soil constituents currently used in conventional bioswales in Munich, Germany. The research will be conducted in laboratory- and meso-scale experiments, focusing on resembling real functioning conditions in bioswales. These include simulating dry/wet cycles and seasonal changes in ionic strength, using typical pollutant loads (focusing on the heavy metals copper and zinc; and the TOCs terbutryn and mecoprop) and a representative water matrix (particularly regarding the pH and the natural

organic matter content). The research work will be executed in four main stages as presented in Figure 1.

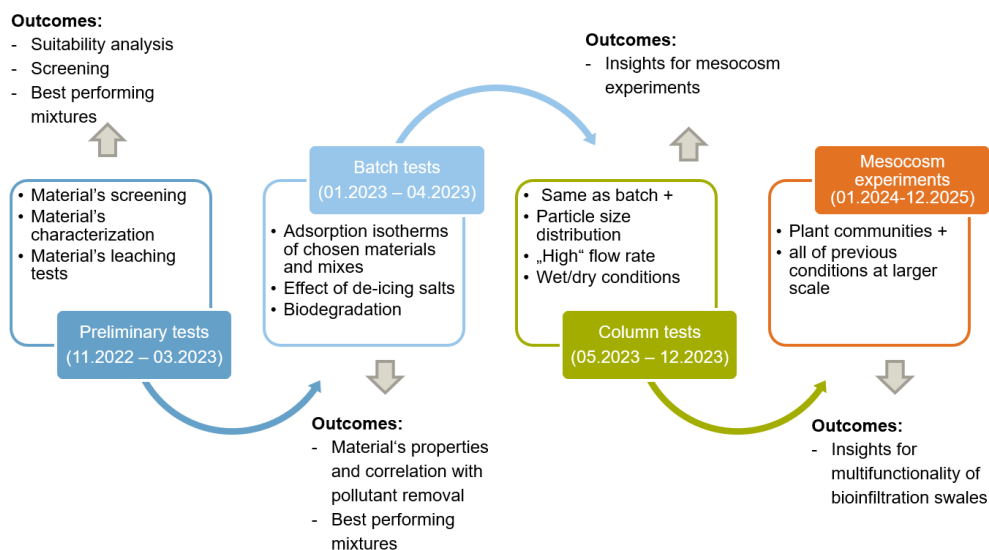


Figure 1. Overview of the project's methods and timeline

### 3 EXPECTED OUTCOMES

One key outcome of the project is to find an optimum type, proportion in mixture and particle size of biochar that can be added to the soil substrate of bioswales in combination with compost that has an improved dissolved pollutant removal while not compromising the hydraulic conductivity of the system. Furthermore, the effect of using different combinations of biochars derived from different feedstocks and pyrolysis production temperatures will also be investigated, where an enhanced and more robust pollutant retention is expected compared to conventional substrate media and benchmark amendments like activated carbon. The effect of an enhanced microbial activity stemming from the use of organic amendments and its effect on potentially increased biodegradation rates will be studied, as well as their impact in other overarching improvements in other ecosystem services of bioswales (e.g., the provision of favorable conditions for plant survival and the enhancement of the carbon storage potential). The project is intended to provide transferrable and scalable knowledge for improving the environmental services of urban bioswales, in particular for the enhancement of the removal efficiency and long-term retention of dissolved pollutants (heavy metals and TORCs) while maintaining their dewatering capacity.

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