Skogssällskapet

# Slutrapport

**Projektrubrik:** BIO-REACT: Biochar reactors to purify forest runoff water in managed peatland forests – efficiency of novel biochar feedstocks

**Huvudsökande:** Eliza Hasselquist

**Projektets löptid:** 2021-04-01 – 2022-08-31

## Populärvetenskaplig sammanfattning

Fifteen million hectares of northern peatlands have been drained for forestry and nearly 50% of these are in Fennoscandia. Ditch cleaning (DC) is generally used to maintain drainage and timber productivity, especially after final felling when groundwater levels rise because mature trees no longer use the water. But, DC can increase the export of sediment and nutrients to downstream waterways, degrading water quality, leading to eutrophication and algae-blooms in lakes. To meet water quality targets set by the EU as well as meet forest biomass production and climate goals, we need new and innovative tools for reducing the impact of DC.

In our project, we tested a potential method of filtering ditch waters in the lab and field using new biochar source materials, or "feedstocks." Biochar is made by heating organic material at high temperatures and low oxygen conditions and can be produced from different organic feedstocks. The ability of biochar to act as a filter depends on, among other things, the dosage and feedstock. In the laboratory, we tested the nutrient adsorption rate and capacity of wood (a mix of 80% pine, 20% spruce and birch) and garden residue (shrubs and branches) biochars in high and low doses. High doses of biochar made from wood removed the most nitrogen (N) and carbon (C) from ditch waters in the lab. Phosphorus (PO4) was released by both types of biochar, but to a lesser extent by the wood-based biochar. Because the wood-based biochar removed more N and C, and minimally affected PO4, we selected this feedstock for testing in field conditions.

In September of 2021, one year after forest harvest and a few days after ditches were cleaned, we installed biochar reactors in four study catchments within the Trollberget Experimental Area (TEA, Figure 1). We filled jute sacks with wood-based biochar and placed them in the ditches. We sampled water ~20 times above and below these biochar reactors until November, when ditches began to freeze. We found that the biochar did remove N and C from the water by up to 7%. Although the percentage removal was statistically significant, it is unclear if this is ecologically significant. Given the relatively low percent removal in the water in addition to the effort to deploy and retrieve the biochar in the field, more work should be done to develop practical ways of building and maintaining biochar reactors. Furthermore, the results from the field study suggest that there is potential for wood-based biochar to be used as a soil amendment to recycle captured nutrients, thus increasing forest production and soil carbon stocks. But, further studies are needed to determine if the N would actually be released from the biochar and become available to trees and furthermore, if the N fertilization effect is worth the effort to deploy biochar reactors in ditches to only reduce N in ditch waters by 7%. At this time, we suggest avoiding ditch cleaning when possible to avoid damages to water quality.

# Resultat

Experiment 1: Biochar sorption potential in a controlled environment

The initial concentration of C, N and P in the two biochars made with different feedstocks were significantly different ($p<0.05$; Fig 2). The biochar made from garden residues (GR) had a higher concentration of N (0.5±0.01%) and P (1288.6±4.1 mg kg-1), but a lower concentration of C (73.2±2.4%) compared to the wood (W) - based biochar (0.09±0.003% of N, 55.5±11.5 mg kg-1 of P and 85.7±0.5% of C).

The high dose (12g) of W-biochar, decreased the concentration of Dissolved Organic Carbon (DOC) and Total Dissolved Nitrogen (TDN) in ditch water over time by 10%, but increased the concentration of phosphorous (PO4) by 40% ($p<0.05$; Fig 3a,b,c). However, using a low dose (3g) of W-biochar did not have an effect on PO4, TDN, nor DOC concentration in the ditch water ($p>0.05$, Fig 3a,b,c). The high dose of GR-biochar reduced the concentration of DOC in ditch water by 17% ($p<0.05$), while both lower and higher biochar doses did not change the concentration of TDN (Fig 3e&f). Both doses of GR-biochar had a greater effect on PO4 than W-biochar, and increased the concentration of PO4 in water by 300% ($p<0.05$; Fig 3d). Furthermore, the addition of both W- and GR-biochar increased ($p<0.05$) the pH of the water, for both high and low doses. Again, the GR-biochar had a larger effect, increasing pH from 5.0 up to 7.9, while the W-biochar increased pH just to 5.8.

Cumulative adsorption was calculated for each time step during the nine days of the lab experiment (Fig 4). For the W-biochar, the cumulative adsorption of DOC was higher when the lower dose is added (Fig 4e), while for the GR-biochar, the adsorption was higher when the high dose of biochar was added (Fig 4f). The cumulative adsorption of DOC by the W-biochar ranged between 0.1-0.7 mg C g biochar-1 with the high biochar dose, and between 0.6-1.3 mg C g biochar-1 for the low dose (Fig 4e). For the GR-biochar, the high dose adsorbed DOC at a similar rate as the high dose of the W-biochar, but the low dose had no adsorption (Fig 4f). Both W- and GR-based biochar adsorbed and desorbed (released) TDN at different points during the experiment (Fig 4c&d), and there was no significant relationship over time ($p>0.05$). Furthermore, the W- and GR-based biochar desorbed PO4 when a high concentration of biochar was added (Fig 4a&b), yet the W-biochar showed adsorption when the low biochar dose was added (Fig 4a).

Experiment 2: Biochar sorption potential in field conditions

Based on Experiment 1, the W-biochar was used to upscale the experiment to the catchment level in field conditions. The water collected at the outlet of the biochar reactor had a lower mean concentration ($p<0.05$, Table 1) compared to the inlet (Fig 4a,b) for DOC and TDN, being 2.1 mg l-1 and 0.08 mg l-1 lower, respectively. The mean percentage of removal over time ranged between 1-5% for DOC (0.4-8.0 mg C l-1), and between 1-7% for TDN (0.03-0.25 mg N l-1)(Fig 5). Furthermore, the efficiency of biochar to remove DOC and TDN was dependent on the initial concentration of the incoming water ($p<0.05$), this suggests that the higher the concentration of DOC and TDN in the inlet, the higher the removal. Finally, there was no statistical difference ($p>0.05$) between the inlet and outlet concentration for PO4 (Table 1).

Potential for biochar reactors to be used as a soil amendment
In the lab experiment, we were unable to analyze the final nutrient content of the biochar because it had disintegrated and there was no solid sample left to analyze. Instead, we used the initial concentrations of the biochar and the measurements of nutrient concentrations in the water to conclude that the GR-biochar had the potential to release PO4 and increase the pH and thus, was not a candidate for the field experiment. Given the relatively high N and P content of the GR-biochar, it could be a good soil amendment at poor nutrient sites, but this needs more research to determine if application to the soil exports PO4 to downstream waters or is used by plants.

We analyzed the nutrient content of the W-biochar at the end of the field experiment and found that the %N of the W-biochar had increased by 45%, from 0.096% (±0.013) before the biochar reactors were placed in ditches to 0.139% (±0.029) after it had been in ditches. The %C in the biochar decreased slightly after the biochar reactors had been in the ditches, starting at 86.6% (±0.84) and ending at 83.2% (±7.33). These results suggest that there is potential for W-biochar to be used as a soil amendment after being incubated in ditches, but further studies are needed to determine if the N in the biochar is available to trees and furthermore, if the N fertilization effect is worth the effort to deploy biochar reactors to only reduce N in ditch waters by 7%.

## Målbeskrivning

The primary goal of our project was to test a novel water protection method – Biochar Reactors. We fulfilled most of our goals set out in the initial grant application within the expected timeframe of the project. We tested the adsorption rate and capacity in the laboratory and field for two sources of biochar: 1) a standard and local, wood-based biochar (Vindelkol, Vindel, Västerbotten County) and 2) a new, garden residue-based biochar from a first-of-its-kind in Europe biochar plant (Batchpanna FPP 40, Earth Systems, Australia) from Södertälje, Stockholm County, that started producing in Spring 2021. Furthermore, we assessed how different amounts (doses) of biochar influence the adsorption rate and capacity for removing nutrients from ditch water. We did not include different particle sizes in the lab experiment due to a miscalculation in the proposal budget that did not allow for this many samples to be analyzed. Finally, we evaluated the nutrient content in the biochar itself after being used as a filter to determine its potential for being used as a soil amendment in the future.

Some unexpected challenges did lead to some changes in the project plan; finding novel biochar sources, biochar stability, and handling of the biochar all posed challenges. Identifying a source for a 'sludge-based' biochar was difficult and further research suggested that sludge may contain residues of pharmaceuticals and heavy metals that would likely reduce, not improve water quality. We finally found Telge Återvinning (https://nya.telge.se/foretag/atervinning/produkter-tjanster/biokol/) and their brand new, first-of-its-kind in Europe biochar plant that is making biochar from garden residue (shrubs and branches, or "ris och grenar" in Swedish). Thus, our lab experiment was delayed, but we were still able to get the results in time to evaluate the biochars and decide on a biochar feedstock for the field experiment. Additionally, in the lab experiment, both biochar feedstocks slowly disintegrated over time - especially the garden-residue biochar - leaving no solid sample to analyze. This brings up questions about how much biochar disintegrates and could be exported downstream in field conditions. Finally, making the biochar reactors was difficult and dirty. We used jute sacks because they are an inexpensive and natural fiber, but they are very heavy when wet and quite porous.

This made transporting them, especially when the field experiment was done, laborious and sometimes the bags broke. Thus, some more research into the practicalities around getting the biochars and handling them in the lab and field was an unexpected challenge.

## Kommunikation och nyttiggörande av resultat

Our communication plan included various target groups (TGs), including scientists, policy-makers, practitioners, biochar producers, and direct local beneficiaries.

TG1: Scientists: We are in the process of drafting a manuscript to send out for peer-review at an international scientific journal. Moreover, EMH and/or VM will present the project findings at the annual Krycklan Symposium, which is held locally in Umeå, but attracts over 100 scientists, environmental managers, policy makers and the general public.

TG2: Policy makers: Knowledge that will help society balance the impact of DC on water quality with the positive effect on tree production is essential to be able to formulate solid strategies and policies aimed at improving the long-term sustainability of the forest industry. We have not yet written a policy brief to disseminate findings among policy and decision makers because we are still in the process of determining if the reduction in nutrients by biochar reactors in the field is ecologically relevant and worth the expense.

TG3: Practitioners: We are drafting a popular science summary due to be published this fall in SLU’s Skog & Framtid (distribution: 225,000 copies), as well as the Finnish Metsälehti, Maaseudun tulevaisuus. EMH has already included results from this project in her teaching at SLU within the Sustainable Boreal Forestry Masters course as well as with Bachelor’s level Forestry Students within the “Sveriges Resor Norr'' course. Thus, these research findings have been included in these university programs and shared with the newest generation of forest managers.

TG4: Direct local beneficiaries: If a significant proportion of the nutrients exported from cleaned ditches are filtered out in biochar reactors, then this will benefit all of Sweden and Finland, and likely most countries in the Baltic Sea region by reducing the water quality footprint of forestry. We have shared our results with Telge Återvinning, the County Board of Administrators, the Swedish Forest Agency and Holmön Skog (the landowner of TEA). Furthermore, the location of our field site will be a demonstration site for best practices for DC as part of the EU GRIP on LIFE Integrated Project, and we are developing permanent information boards with the Swedish Forest Agency that will stand at the site and report our results.

We hope to continue this work by using the biochar that has been incubated in ditches in a greenhouse experiment with tree seedlings. The goal of a greenhouse experiment would be to determine if the N would actually be desorbed from the biochar and become available to trees and furthermore, if the N fertilization effect is worth the effort to deploy biochar reactors to only reduce N in ditch waters by 7%. Furthermore, a portion of the biochar reactors are still in the ditches at TEA and we will test the biochar at later dates to determine if more nutrients are adsorbed over longer incubation times.