GREENHOOD
Nutrient management strategies for regional ecosystems across Europe
Deltares KWR Waterschap Aa en Maas WAGENINGEN UNIVERSITY & RESEARCH
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#175

Woodchip bioreactor as a site-specific approach to reduce nitrate loads from agriculture: demonstration in practice

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Introduction

- The WFD surface water targets for nitrogen are still out of reach.
- The bulk of this nitrogen is in the form of nitrate from diffuse sources such as agriculture.
- Woodchip bioreactors (WBR) can reduce nitrogen emissions from agricultural drainage.

Objectives:

- Determine the efficiency of nitrate removal
- Analyse the effect on total nitrogen
- Minimize side effects (e.g. sulphide production, ammonium production or incomplete denitrification)

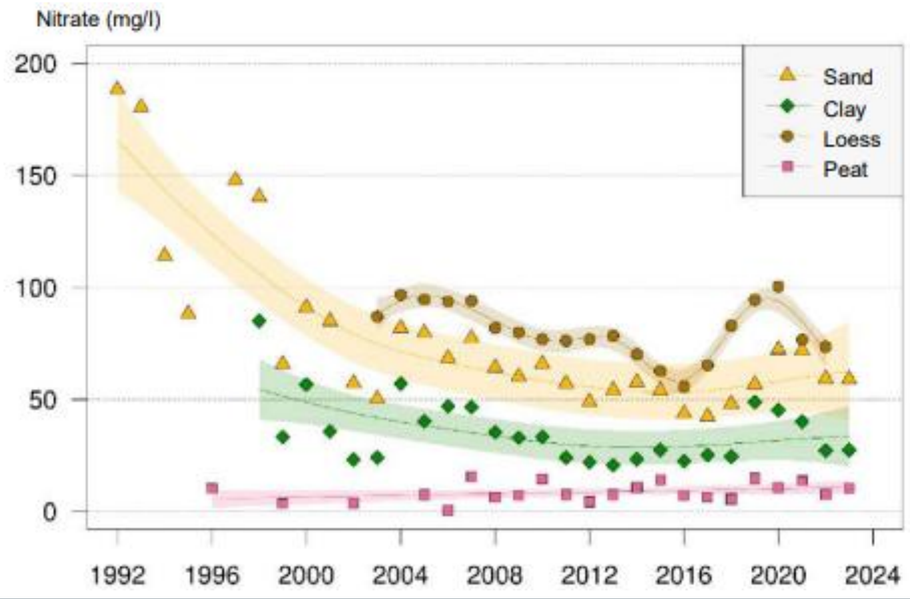

Figure 1: Nitrate concentrations (as NO3 in mg/l) in water leaching from the root zones of farms per region in the period 1992–2023. Annual average measured concentrations, weighted by acreage. The band represents the 95% confidence interval of the fitted trend line. (Source: RIVM, 2025)

Materials & methods

- Two drainage years (1-11-2023 / 18-6-2024 and 18-11-2024 / 7-4-2025)
- 60 m^3 of willow woodchips.
- Controlled discharge with an adjustable bypass and pumps at the inlet and outlet.

Continuous sensor measurements at inlet and outlet:
NO_3^-, pH, T and EGV
Biweekly grab sample measurements:
IC and ICP-MS

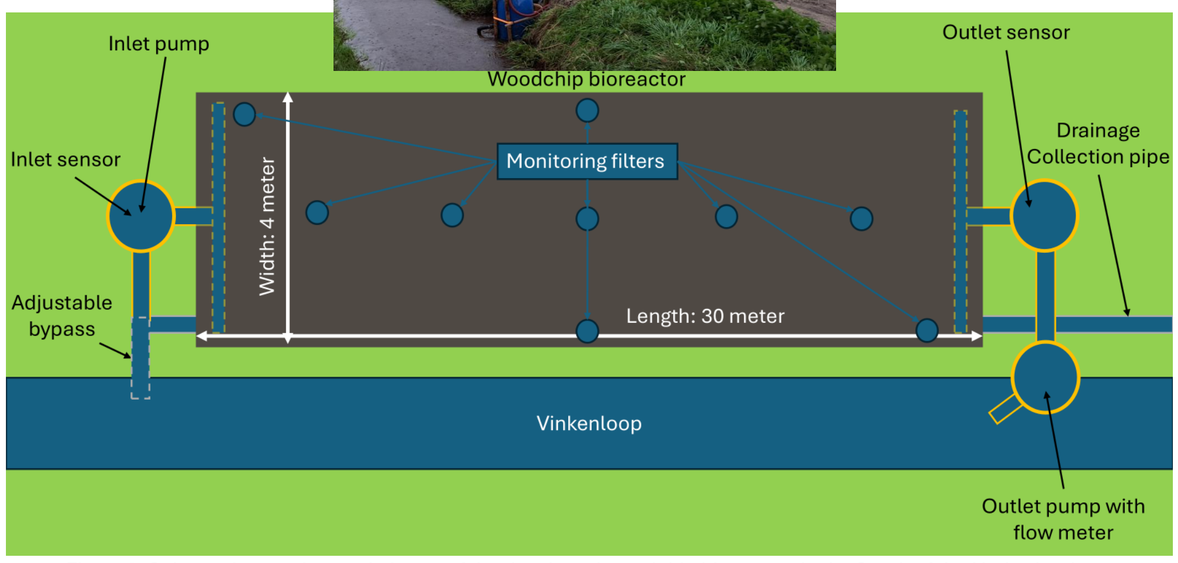

Figure 2: Schematic overview and picture of the developed woodchip bioreactor in the South of the Netherlands.

Efficiency in nitrate removal

- Overall removal efficiency of the WBR is ~80%.
- First year almost 100% removal.
- The removal efficiency decreases in periods when the filter operates (sub)optimal, temperature is <10 ^{0}C, and inflow concentrations are >12 mg N/l.
- Mismatch between near zero grab sample concentrations and sensor data → Likely caused by the leaching of organic matter.

Table 1: The average discharge (in m^3/day) during different filter operational phases. As phases of proper functioning were alternated by clogging problems and pump malfunctioning.

Filter operation	Discharge (m^3/day)
Start-up (1-11-2023 / 1-12-2023)	Unknown
Filter operates suboptimal (1-12-2023 / 15-12-2023	~ 10
Clogging problems (15-12-2023 / 1-4-2024)	~ 1
Filter operates properly (1-4-2024 / 18-6-2024)	~ 30
Start 2nd drainage season (18-11-2024 / 22-12-2024)	~ 20
Malfunctioning of pumps (22-12-2024 / 8-1-2025)	0
Filter operates properly (8-1-2025 / 1-4-2025)	~ 20

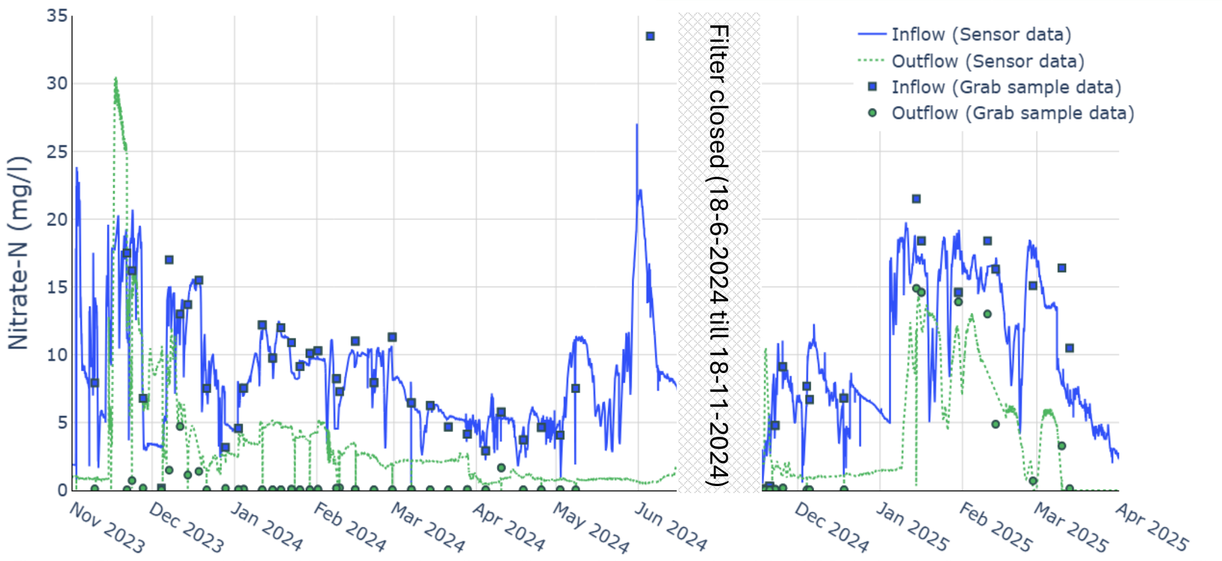

Figure 3: The measured nitrate-N concentrations (in mg/l) at the inlet and outlet of the WBR during the first two drainage seasons. The concentrations were measured with a UV spectral sensor (lines) and with lab analysed grab samples (dots).

Changes in nitrogen species

- The **total nitrogen** is on average reduced by 60%.
- The amount of **organic nitrogen** and **nitrite** in the outflow is increased compared to the inflow.
- **Nitrite** outflow shows a peak of 1.1 mg N/l in the first half of December 2023.
- In the second drainage year **nitrite** is elevated to ~0.3 mg N/l in the outflow, except for the period of pump malfunctioning.
- In the beginning of 2025 **ammonium** concentrations in the outflow are higher than the inflow concentrations.

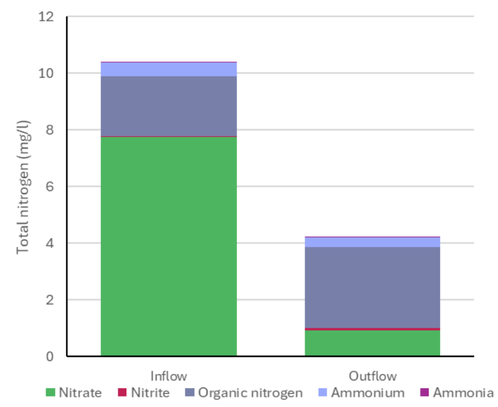

Figure 4: The average concentration of nitrogen compounds (in mg/l) of the lab analysed grab samples of the inflow and outflow of the WBR during the two drainage seasons.

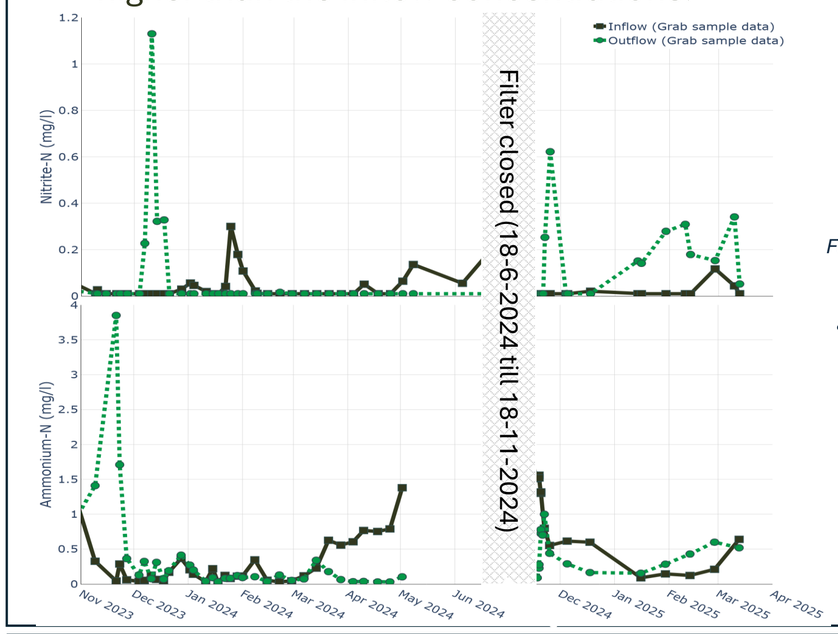

Figure 5: The lab analysed grab sample nitrite-N and ammonium-N concentrations (in mg/l) at the inlet and outlet of the WBR during the first two drainage seasons.

Sulphate reduction and sulphide production

- Decreased **sulphate** levels coincide with increased **sulphide** levels within the outflow.
- After the start-up late 2023, the outflow **sulphate** concentrations are almost continuously below detection in 2024.
- The production of **sulphide** is increased after the clogging problems were resolved in April 2024.
- The **sulphide** pattern is the inverse of the **nitrite** pattern.
- **Sulphate** reduction and **sulphide** production are low when the **nitrate** removal is low.

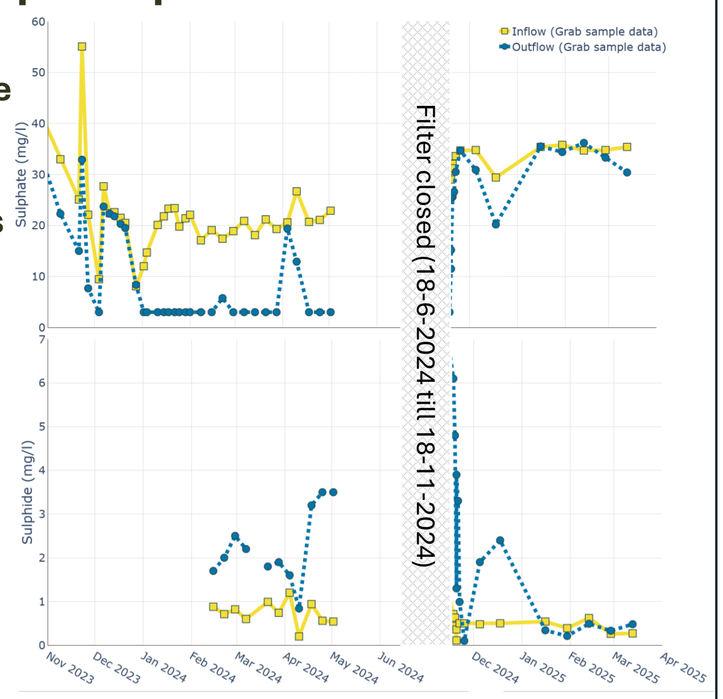

Figure 6: The lab analysed grab sample sulphate and sulphide concentrations (in mg/l) at the inlet and outlet of the WBR during the first two drainage seasons.

Conclusions

- The woodchip bioreactor works and continuously removes **nitrate** from the drainage water with the largest efficiency during low discharge and at the end of the first and start of the second drainage year. **Total nitrogen** is on average reduced by 60%, whereas **nitrite** and **organic nitrogen** concentrations increase on average.
- The minimization of one side effect could increase the other. The complete removal of **nitrate** coincides with **sulphate** reduction and **sulphide** production, whilst the incomplete removal of **nitrate** results in elevated **nitrite** concentrations. The latter could indicate the production of nitrous oxide, a strong greenhouse gas.

Future research

- Correlating the discharge and temperature to nitrate removal rate.
- Combining a land management model to a model of the WBR.

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