Nitrate removal from waste rock drainage with denitrifying bioreactors at the Kiruna iron ore mine

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Nitrogen in mine waste

- Much of the nitrogen in mine drainage is derived from ammonium nitrate – based explosives used in the mine
- Undetonated ammonium nitrate dissolves in mine drainage and adsorbs to waste rock.
- On average 12 g N per ton waste rock at Kiruna mine.

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Risk for toxic effects from ammonia (NH_3) and nitrite as well as eutrophication in aquatic environments

Rainwater and snowmelt leach out nitrogen compounds from waste rock deposits.

Passive, low cost, low maintenance methods are needed to treated many small diffuse releases from waste rock deposits

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Nitrate removal through denitrification

- Nitrate (NO_3^-), the most common form of nitrogen in the mine drainage, is removed through the process of denitrification
- Denitrification is a microbial process requiring the presence of a community of denitrifying bacteria and organic carbon (CH_2O) for metabolic energy and cell growth

$$4NO_3^- + 5CH_2O \rightarrow 2N_2(g) + 4HCO_3^- + H_2CO_3 + 2H_2O$$

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

nitrate *nitrite* *nitric oxide* *nitrous oxide* *nitrogen gas*

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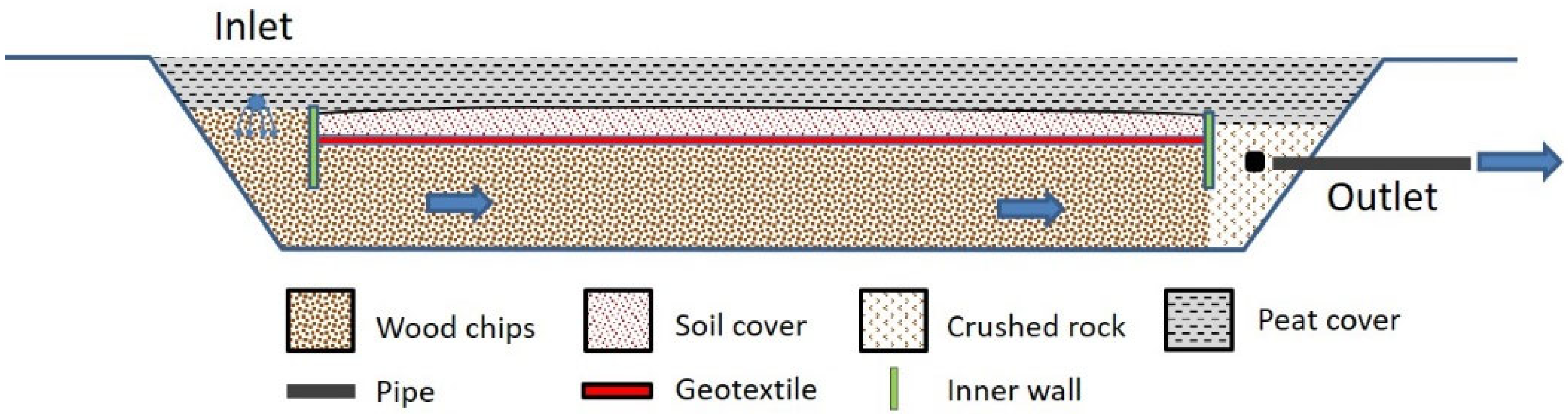
Denitrifying woodchip bioreactors

- Excavation lined with an impermeable geomembrane and filled with pine wood chips and a small amount of active sewage sludge.
- Organic material functions as a carbon and energy source for the denitrifying bacteria.
- Bioreactors are 44 m long, 7 m wide, and 2 m deep (excluding cover)



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Bioreactor placement

- Three bioreactors have been constructed so as to treat drainage from the ”Triangle area” waste rock deposit (0.56 km^2)
- Purpose is only to treat ~ 40% of the drainage
- Based on previous studies, optimal treatment is achieved at flows < 0.5 L/s per bioreactor

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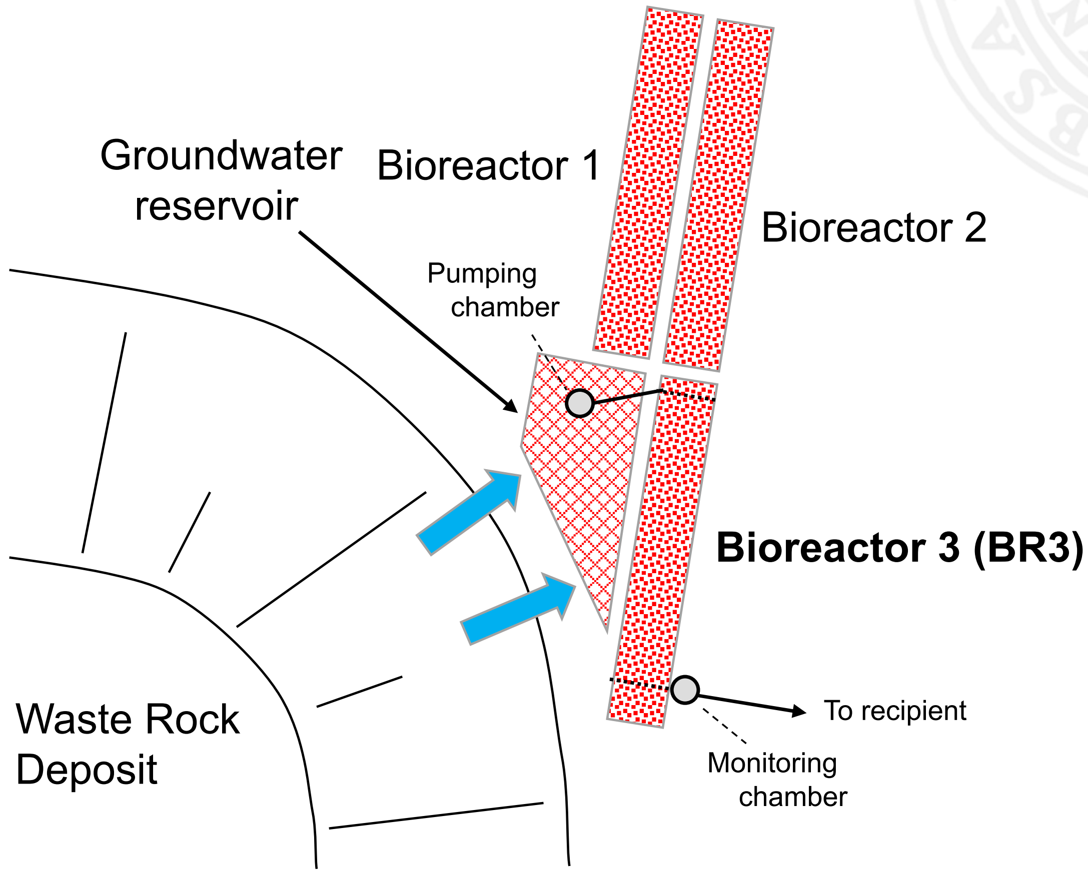
System design

- Groundwater reservoir collects groundwater seepage, which consists almost exclusively of leachate from waste rock dump
- Water pumped from a pumping chamber through gate valves to the bioreactors.
- Water discharges from each bioreactor through a monitoring chamber and further to a drainage ditch.



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Bioreactor 3 construction

Sampling positions

12 Jun 2019

Pumping chamber

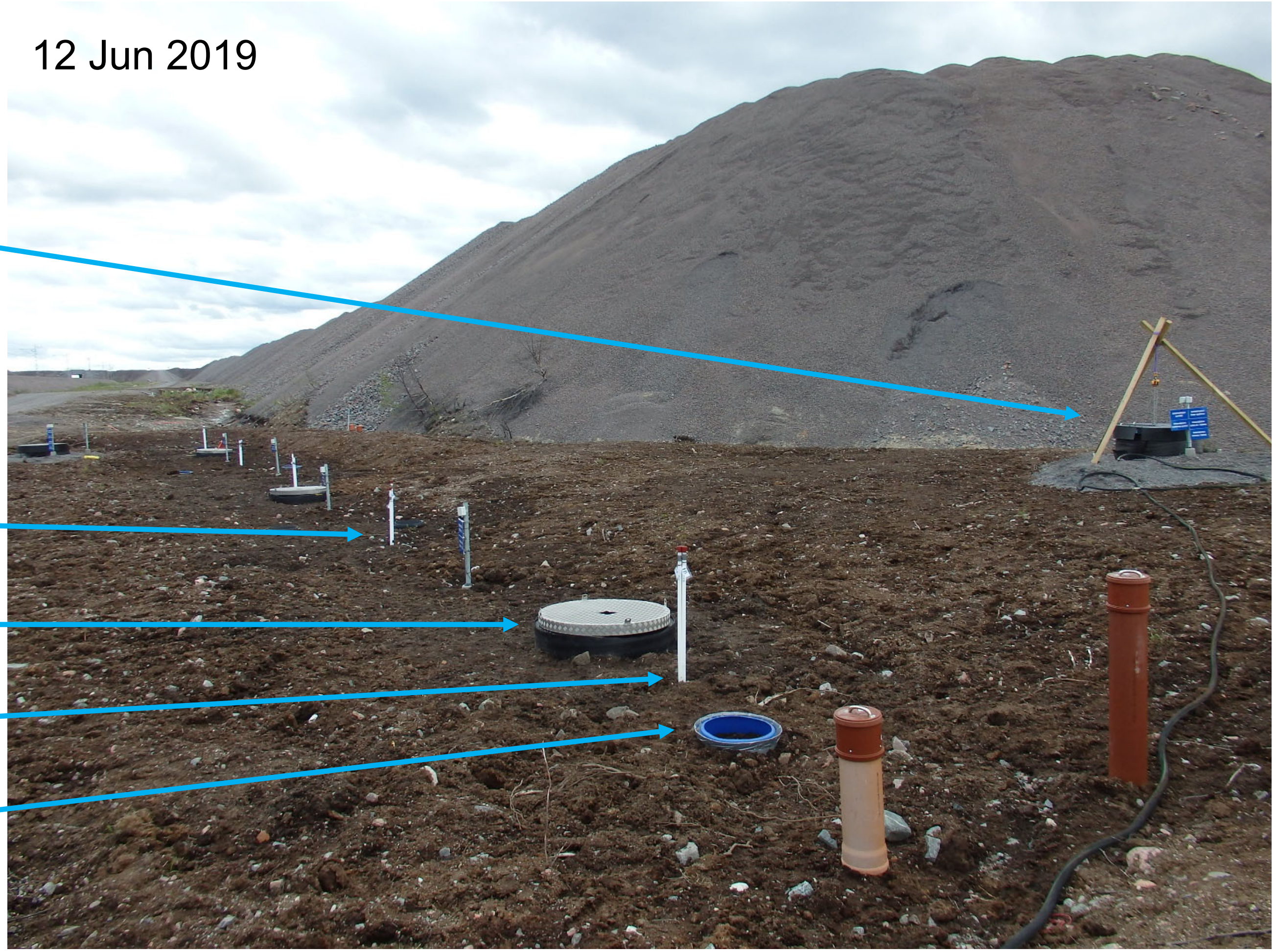
Water sampling from monitoring chamber at outlet

Two 2” groundwater tubes at five positions

Three woodchip sampling wells

Four temperature sensors

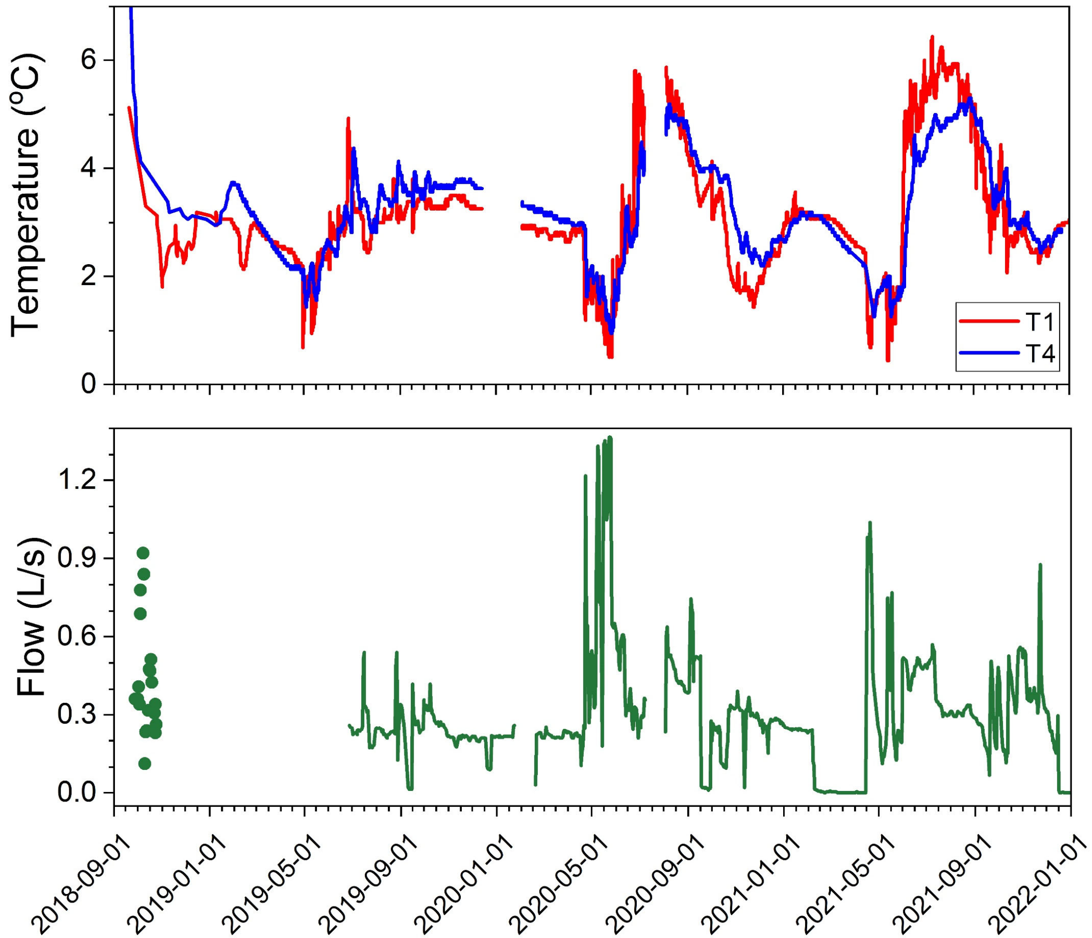
Six gas sampling collars



Sensors:

Flow determined from water depth
with ultrasound sensor over a H-flume in monitoring chamber

Water temperature and flow



T1: near inlet
T4: near outlet

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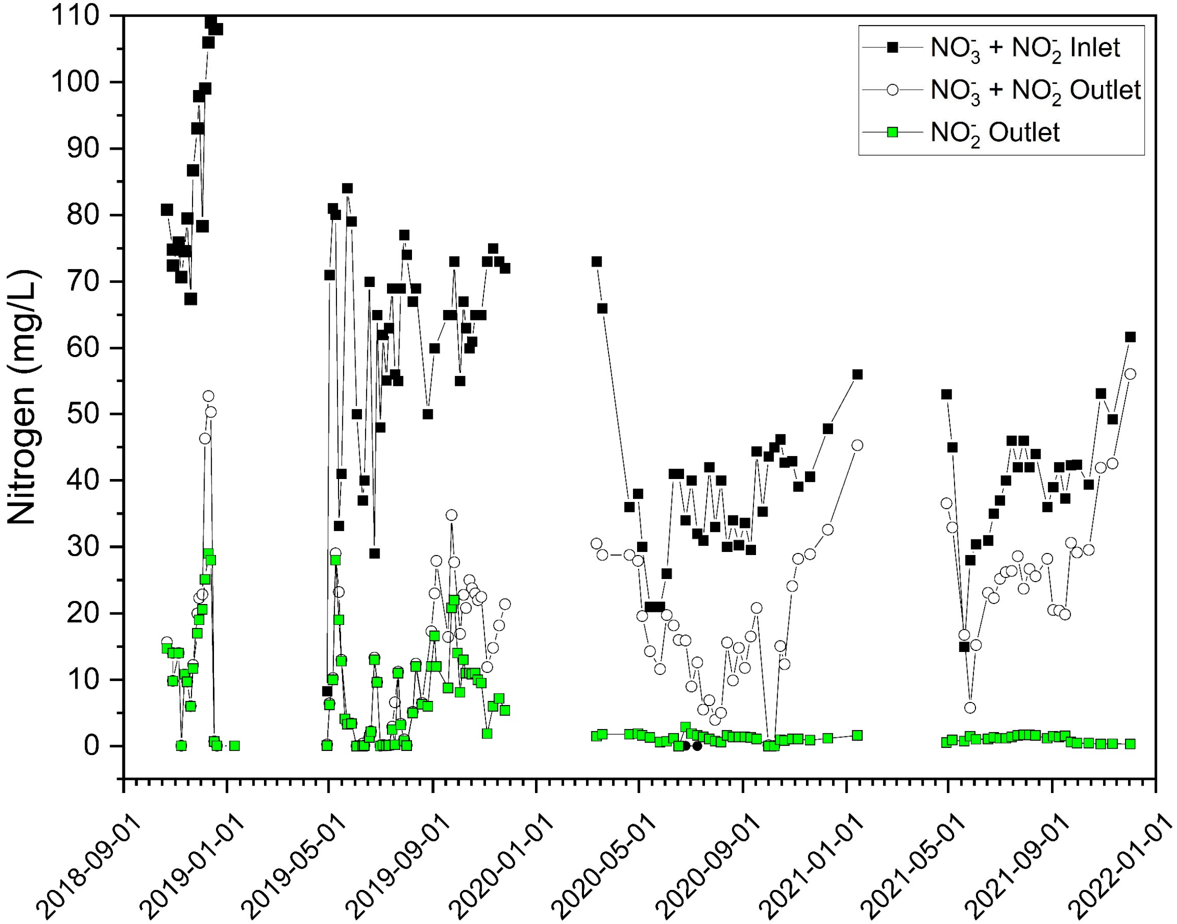
Nitrogen removal in bioreactor



Waste rock drainage is a Ca-SO_4-rich water with neutral in pH

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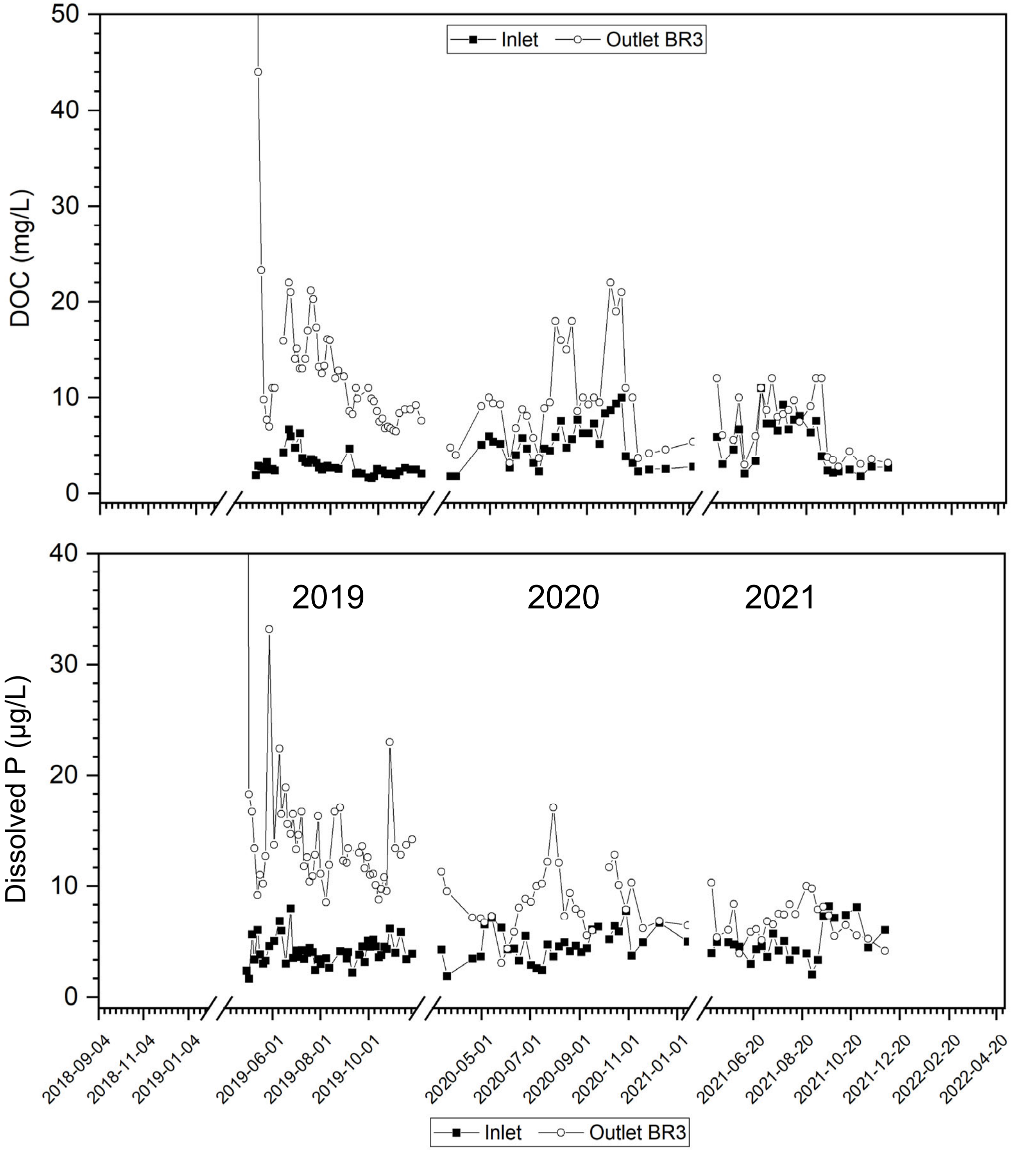

DOC and phosphorus

- DOC and dissolved P concentrations increase through bioreactors
- Release of DOC and P decreases from 2019 to 2021

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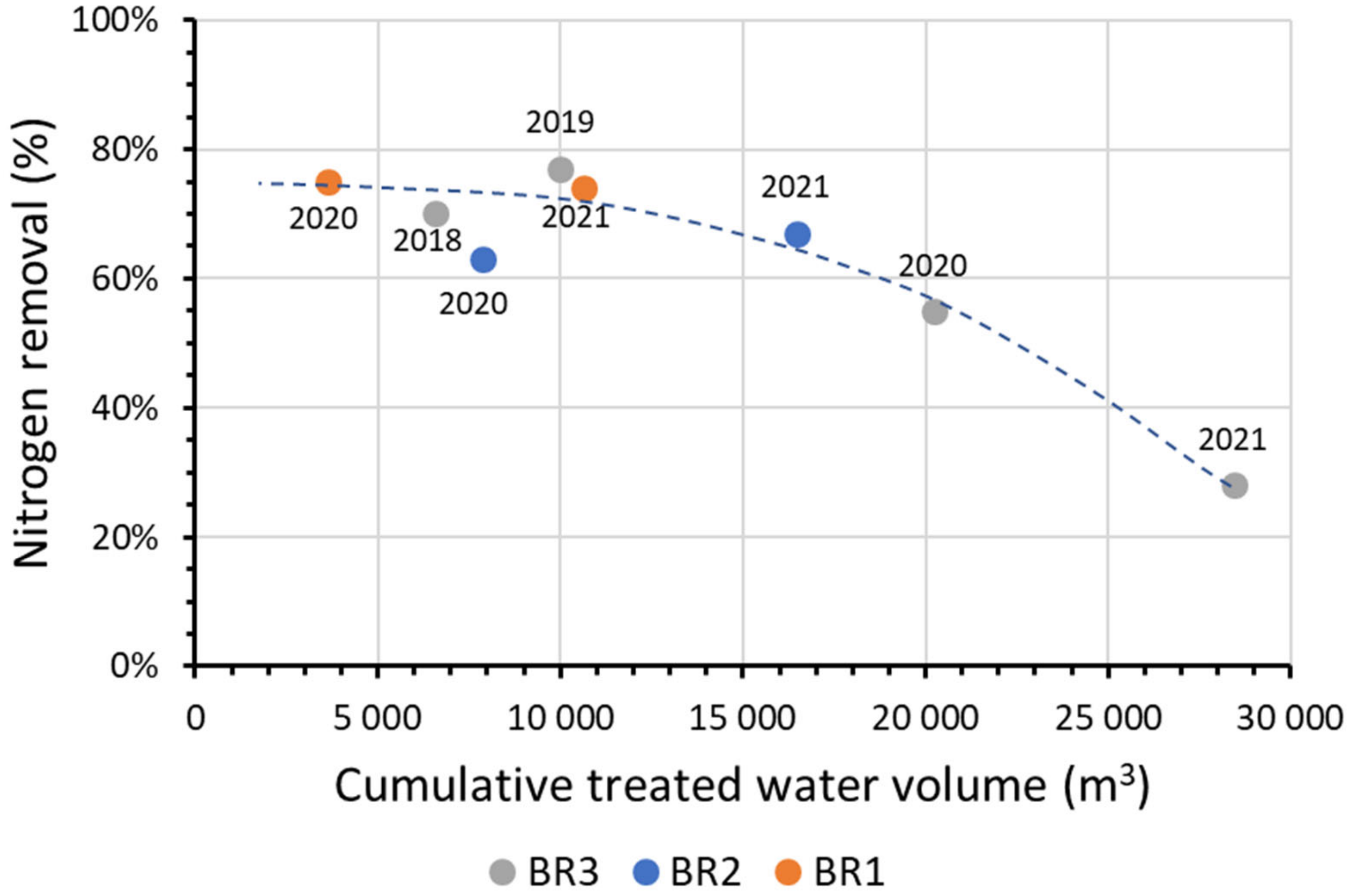
Decrease in nitrate removal efficiency



Challenges

- Decreasing woodchip reactivity with time
- Low temperature in groundwater
- Hydrogen sulfide production
- Microbial community needs time to establish itself
- Preferential flowpaths

Thanks for listening! Questions?

Published work to-date:

Hellman et al. (2024) Microbial succession and denitrifying woodchip bioreactor performance at low water temperatures, DOI: 10.1016/j.jenvman.2024.120607

Wang et al. (2023) Multirate mass transfer simulation of denitrification in a woodchip bioreactor, DOI: 10.1016/j.jhydrol.2023.129863

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