WATERPRO

Good Practices
Pilot sites: Luleå University of Technology

Nitrogen removal in cold-climate mine ponds, northern Sweden


Clarification pond, Kiruna iron mine


Clarification pond, Aitik copper mine

Summary: A mesocosm study and computer modelling were conducted to investigate if P fertilization of mine ponds can be used to increase N removal through denitrification. Denitrification did increase both in the mesocosm test and in a computer model of the Kiruna mine pond. The method needs further testing before full-scale implementation. Work was conducted in cooperation with Swedish University of Agricultural Sciences, Uppsala.

Operation and applicability: The method was only tested in pilot-scale mesocosms, where increased algal growth and denitrification were observed during a three-month summer period. Applicability is mainly limited by unknown potential eutrophication effects.

Efficiency of method: Nitrate concentration in mesocosms decreased by 5 mg/L during 86 days. Computer modelling showed 5% decrease of nitrate concentrations.

Background

- Ammonium nitrate based explosives are a major nitrogen source in the mining industry. At many mines, undetonated explosives are the main source for nitrogen leaching into mine waters.
- Nitrogen release, mainly as nitrate, should be reduced to minimize eutrophication of receiving waters.
- Active treatment of large water volumes from mines is expensive and difficult to achieve.
- A project was conducted at two Swedish mine sites to investigate the usefulness of passive / semi-passive nitrogen removal methods.
- Three methods were studied: 1) actively increasing denitrification in mine ponds, 2) denitrification in constructed bioreactors, and 3) phytoremediation and denitrification in wetland systems.

Increased denitrification in mine ponds

- Typical levels of nitrate and ammonium in the Kiruna pond are around 20-25 mg/L NO_3-N and 0.05 mg/L NH_4-N, respectively.
- Denitrification in the anaerobic pond sediment is carbon-limited, and can be increased by adding a suitable carbon source driving denitrification.
- Laboratory experiments showed that addition of algae to the sediment increased denitrification by a factor of about 5.
- The hypothesis of the study was that algal growth could be increased by fertilizing pond water with phosphorus, and in turn increase denitrification.
- Expected disadvantages of the method are: 1) denitrification is low in cold-climate, 2) adding phosphorus will increase the risk of eutrophication of receiving waters.

Advantages and drawbacks: Microbially mediated denitrification occurs normally in mine pond sediments. The method was investigated as an innovative, passive / semi-passive nitrogen removal method utilising existing ponds that often cover large areas at mine sites. A disadvantage in cold climates is the reduced denitrification rate during winter. Applicability is limited by potential eutrophication effects in receiving waters, although added P may to some extent be trapped in pond sediments. With algae as a carbon source, release of the greenhouse gases methane and dinitrogen oxide (N_2O) was observed.

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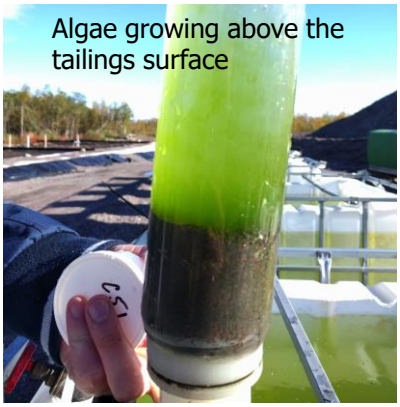
Experimental mesocosms at the Kiruna mine site

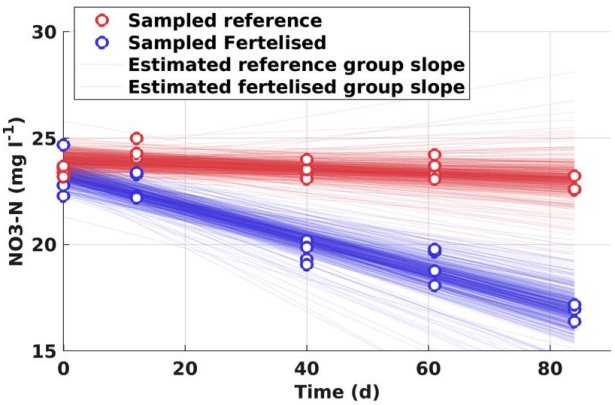
Experimental mesocosms at Kiruna filled with tailings and pond water



Algae growing above the tailings surface

Methods

- Denitrification and nitrogen transformations were studied in a mesocosm experiment and computer modelled (mesocosms and mine ponds).
- Carbon addition for enhancing denitrification was studied in a laboratory experiment.
- Algal growth and nitrate concentrations were measured in mesocosms with and without phosphorus added during two summer seasons.
- Potential denitrification capacity was measured in pond sediments and mesocosm tailings.
- A biogeochemical computer model was developed and tested in the ponds at the Kiruna and Aitik mines, as well as in the experimental mesocosms.
- The nitrogen isotopic composition of nitrate and ammonium in mesocosms confirmed the validity of the computer model.



Measured (circles) and statistically calculated (lines) decrease in nitrate concentrations in fertilized (blue) and non-fertilized (red) mesocosms during 86 days.

Results

- The amount of algae increased by a factor of 50 in the phosphorus-fertilized mesocosms.
- Nitrate concentrations decreased by about 5 mg/L after 86 days of the mesocosm study.
- Compared to the amount of P added o the mesocosms, the increase in bioavailable P was relatively minor (10-20 µg/L). Added P to a large extent was transferred to the sediment.
- Computer modelling of phosphorus fertlization of the Kiruna mine pond showed Chlorophyll-a concentrations of 25 µg/L the day after the first P addition.
- Areal extent and rate of modelled dentrification agreed well with potential denitrification activity measured in the pond sediment.
- Addition of 27 kg of bioavailable P in the model resulted in a 5% decrease of the nitrate concentration in the pond water.
- The actual nitrate removal can be expected to exceed 5% due to recycling of pond water back to the mine
- Limitations of method: 1) Risk of eutrophication of receiving waters must be further evaluated, 2) low rate of denitrification during winter, 3) release of ammonium, methane and dinitrogen oxide (N_2O) when algae is used as carbon source.

MORE INFORMATION
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