Nitrogen removal efficiency and wintertime hydraulics in mine peatlands

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Abstract Increased N load on recipient water bodies often deteriorate water quality and highlight the importance of efficient N removal. In this study, constructed wetlands as an N removal step in mine wastewater were studied with the focus of winter purification efficiencies and hydraulic wetland designing. The results showed lower N removal efficiency during winters than in frost-free periods although some N removal happened also at low temperatures. Temperature was not the only factor controlling N removal but also oxygen availability were important while snow/ice cover restrict oxygen transportation. The results increase the understanding of N removal processes in winter condition.

Key words Passive treatment, peatland, nitrogen, snow, frost

Introduction

Management and mitigation of harmful substances such as nickel, antimony, lead and sulphate contained in mine waters have received considerable attention in the last few decades (Nordstrom 2011, Kauppila et al. 2011, Räisänen 2009), but less attention has been paid to nitrogen (N) loads from mining activities (Chlot 2011). However, use of explosive, certain mineral processing activities, including pH regulation, use of cyanide in gold extraction and use of ammonia as lixiviant, generate nitrogenous load to the environment. The effect of increased N load on recipient water bodies can be remarkable, especially if N is the limiting nutrient in an aquatic ecosystem such as in many oceanic and coastal waters, but also some rivers in Finland. The high N concentration can also be toxic to ecosystems. A sustainable mining industry requires efficient N removal methods, but this has not been achieved yet.

At mines, N removal is mainly based on passive water treatment by recycling water via tailings ponds, or in constructed wetlands, where the water flow is delayed and a large filtration network is available with many adsorptive surfaces on plant roots or soil particles (Younger et al. 2002). Due to the high and temporally variable amount of mine water produced and variable mine water quality, efficient N removal is difficult in Nordic climate. It is well-known that winter conditions are extremely challenging to N removal processes, and wetland hydraulics is one of the crucial factors determining N removal efficiency.

The aim of this study was to understand changes in N removal efficiency that occur throughout the year and the role of winter conditions in the performance of treatment peatlands at a mine site.

Material and Methods

Winter conditions (soil and air temperature, snow depth, snow water equivalent, precipitation, frost depth) were studied in two constructed wetlands treating mine waters from October 2015 to the beginning of 2017. From September 2016 onwards, soil gas measurements have been conducted at different depths and at different points to demonstrate possible accumulation of N_2O in the soil during the winter time. Water quality monitoring data required in the environmental permit were used to study purification efficiencies of the wetlands. The inflow and outflow of the wetlands were sampled at least once or twice a month, but the number of inflow samples collected exceeded 30 in some months. Purification efficiencies of the wetlands were calculated based on inflow and outflow concentrations. The wintertime performance of the wetlands was compared to their performance during frost-free period.

Preliminary results

First results showed that N removal is clearly lower during winter time than during frost-free period although N removal processes still occurred at low temperatures in the wetlands (Fig. 1). Ammonium (NH_4-N) was removed clearly better than NO_3-N. The part of low NO_3-N removal could due to efficient anaerobic ammonia oxidation but uncompleted denitrification process resulting increase in NO_3^- concentration. It seems that temperature is not the only factor controlling N removal processes, but that also oxygen availability is important, as snow and ice cover restrict oxygen transport into the wetland soil. The results of this study increase our understanding of N removal processes in winter conditions and can be used in the design of constructed wetlands for mine waters.

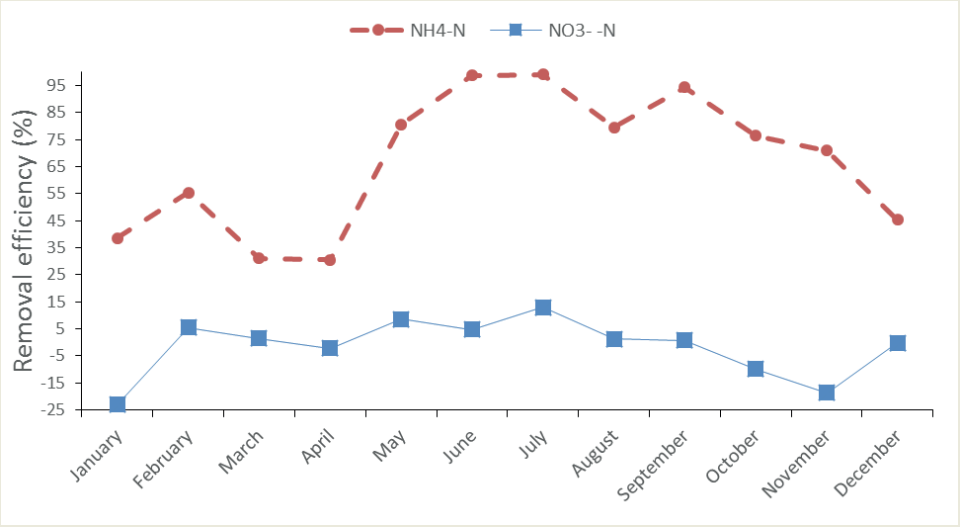

Figure 1 *The mean removal efficiencies of Ammonium (NH_4^+) and nitrate (NO_3^-) nitrogen in different months at a constructed wetland treating mine waters.*

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References

Chlot, S, (2011) Nitrogen effluents from mine sites in northern Sweden: nitrogen transformations and limiting nutrient in receiving waters. Licentiate thesis, Luleå tekniska universitet, Luleå. Licentiate thesis / Luleå University of Technology.

Kauppila P, Räisänen ML, Myllyoja S, (eds.) (2011) Best Environmental Practices in Metal Ore Mining. Finnish Environment 29en/2011. Finnish Environment Institute.

Nordstrom DK (2011) Hydrogeochemical processes governing the origin: transport and fate of major and trace elements from mine wastes and mineralized rock to surface waters. Appl. Geochem. 26: 1777–1791.

Räisänen ML (2009) Capability of natural and constructed wetlands to mitigate acidic leakage from closed mine waste facilities – cases in Eastern Finland. Conference Proceedings Securing the future, Mining, metals and society in a sustainable society and 8th ICARD International Conference on acid rock drainage Skellefteå, Sweden June 22 – June 26 2009. Electronic publication, 10 p.

Younger PL, Banwart SA, Hedin RS (2002) Mine Water, Hydrology, Pollution, Remediation. Kluwer Academic Publishers, Dordrecht, 464 pp