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Impact of mine wastewaters on greenhouse gas emissions from northern peatlands used for mine water treatment

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The amount of wastewaters generated during mining operations is increasing along with the increasing number of operation mines, which poses great challenges for mine water management and purification. Mine wastewaters contain high concentrations of nitrogen compounds such as nitrate (NO_3^-) and ammonium (NH_4^+) originating from remnant explosives as well as sulfate (SO_4^{2-}) originating from the oxidation of sulfidic ores. At a mine site in Finnish Lapland, two natural peatlands have been used for cost-effective passive wastewater treatment. One peatland have been used for the treatment of drainage waters (TP 1), while the other has been used for the treatment of process-based wastewaters (TP 4).

In this study, the impact of mine water derived nitrogen compounds as well as SO_4^{2-} on the emission of the potent greenhouse gases methane (CH_4) and nitrous oxide (N_2O) from those treatment peatlands was investigated. Contaminant concentrations in the input and output waters of the treatment peatlands were monitored which allowed for the calculation of contaminant-specific retention efficiencies. Treatment peatlands showed generally good retention efficiencies for metals and metalloids (e.g. nickel, arsenic, antimony, up to 98% reduction in concentration) with rather low input-concentrations (i.e., in the μg/l-range). On the other hand, retention of contaminants with high input-concentrations (i.e., in mg/l-range) such as NO_3^-, NH_4^+ and SO_4^{2-} was much lower (4-41%, 30-60% and -42-30%, respectively), indicating the limited capability of the treatment peatlands to cope with such high input concentrations.

NO_3^- and NH_4^+ concentrations were determined in surface and pore water from TP 4 in July 2013 as well as in surface water from TP 1 and TP 4 in October 2013. Up to 720 μM NO_3^- and up to 600 μM NH_4^+ were detected in surface water of TP 4 in July 2013. NO_3^- and NH_4^+ concentrations in surface waters were highest near the mine wastewater distribution ditch and decreased with increasing distances from the ditch. NO_3^- concentrations were lower in pore water than in surface water, and the peak in NO_3^- concentration shifted further away from the distribution ditch with increasing depth. On the contrary, NH_4^+ concentrations were generally higher in pore water than in surface water, and peak concentrations increased with increasing depth. Highest NH_4^+ concentrations were detected in 30 to 60 cm depth near the outlet at the south end of TP 4.

Fluxes of the greenhouse gases CH_4 and N_2O from 4 sampling points (2 from TP 4, 1 from TP 1, 1 from reference area) were measured on 7 different occasions 2013 and 2014. CH_4 emissions were in the same range as measured in other northern pristine peatlands in the reference area, which is not influenced by mine wastewaters. Treatment peatlands showed only very minor CH_4 emissions or even CH_4 uptake. On the other hand, treatment peatlands showed high N_2O emissions, which were in the same range as N_2O emissions observed from northern peat soils used for agriculture. Highest emissions were generally observed near the wastewater distribution ditch of TP 4. N_2O emissions from the reference area were negligible or even negative. NO_3^-, NH_4^+ and SO_4^{2-} concentrations were determined from surface waters from each sampling point and sampling occasion. N_2O emissions were positively correlated with NO_3^- concentrations, indicating denitrification-derived N_2O production in treatment peatlands. On the other hand, CH_4 emissions were negatively correlated with SO_4^{2-} and NO_3^- concentrations, indicating that the presence of alternative electron acceptors in large amounts suppresses CH_4 production in treatment peatlands.

In conclusion, the study revealed that (i) treatment peatlands receive high loads of NO_3^-, NH_4^+ and SO_4^{2-} which are not well retained in the peatlands, (ii) mine wastewaters positively and negatively affect N_2O and CH_4 emissions, respectively, (iii) N_2O emissions are positively correlated with NO_3- concentrations, and (iv) CH_4 emissions are negatively correlated with NO_3^- and SO_4^{2-} concentrations. This study thus illustrates the pronounced impacts of mine wastewaters on processes involved in greenhouse gas turnover in peatlands ecosystems.