When mobilized organic matter and glacial suspended sediment meet: effects of adsorption, photo-and biodegradation

Marloes Groeneveld[1], Elizabeth Jakobsson[1], Jeffrey Hawkes[2], Jörg Tittel[3], Dolly Kothawala[1] and Lars Tranvik[1]

Background

Thawing of permafrost is leading to increased export of organic matter (OM) that was previously stored within frozen peatland soils into aquatic ecosystems[1].

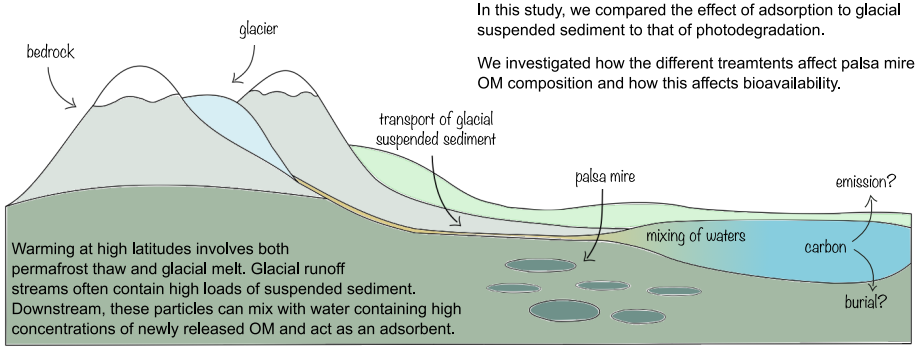
This OM has been found to be reactive to microbial and photo-chemical processes[2,3,4], so that permafrost thaw is expected to lead to an increased production of greenhouse gases[5].

Being able to predict the fate of these increased loads of terrestrial organic carbon in aquatic systems is therefore important from a carbon cycle and climate change perspective.

In a previous study[6] we suggest that terrestrial organic compounds susceptible to photodegradation are also prone to adsorb to mineral particles.

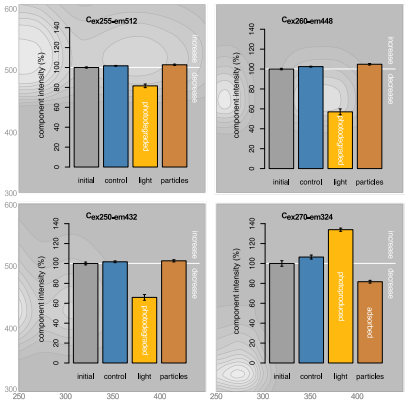
In this study, we compared the effect of adsorption to glacial suspended sediment to that of photodegradation.

We investigated how the different treamtents affect palsa mire OM composition and how this affects bioavailability.



Warming at high latitudes involves both permafrost thaw and glacial melt. Glacial runoff streams often contain high loads of suspended sediment. Downstream, these particles can mix with water containing high concentrations of newly released OM and act as an adsorbent.

Which DOM compounds are adsorbed, photodegraded or photoproduced?



Intensity of PARAFAC components for the treatments relative to the initial sample

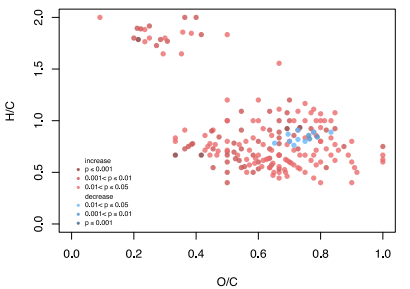
DOC decreased from 16.3 mgl^{-1} with 1.1 mgl^{-1} (6.6%) by adsorption and with 0.8 mgl^{-1} (4.8%) by photomineralisation

Fluorescence spectroscopy

- 'Humic-like' DOM (C_{em512}, C_{em448} and C_{em432}) are photodegraded
- 'Protein-like' DOM (C_{em324}) is photoproduced
- 'Protein-like' DOM (C_{em324}) is adsorbed

Orbitrap mass spectrometry

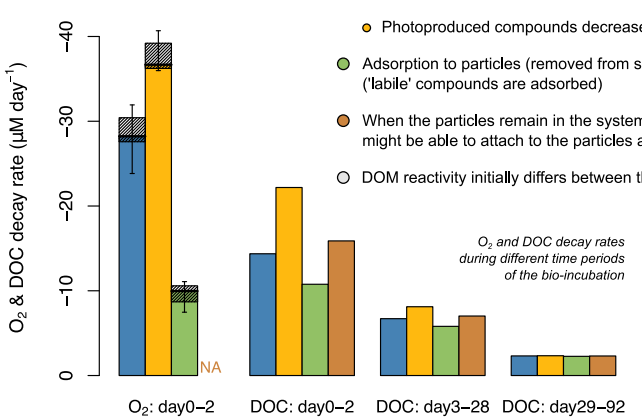
- Photodegradation of large, colored compounds is not detected with this Orbitrap-MS method
- Low H/C, high O/C compounds are photoproduced
- Compounds that are adsorbed are not detected with this Orbitrap-MS method



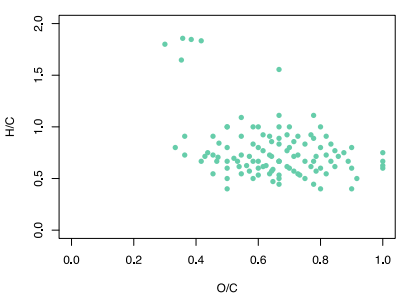
Changes in compound intensity between initial sample and after light exposure (paired t-test) in van Krevelen space (O/C vs H/C ratio of each compound)

How do phototransformations and adsorption affect bioavailability?

- Light exposure initially increases bioavailability ('recalcitrant' compounds are converted into more 'labile' ones)
  - Photoproduced compounds decrease during the bio-incubation
- Adsorption to particles (removed from solution) decreases bioavailability ('labile' compounds are adsorbed)
- When the particles remain in the system, bioavailability is little affected: microbes might be able to attach to the particles and consume the associated DOM
- DOM reactivity initially differs between the treatments, but converges over time



O_2 and DOC decay rates during different time periods of the bio-incubation



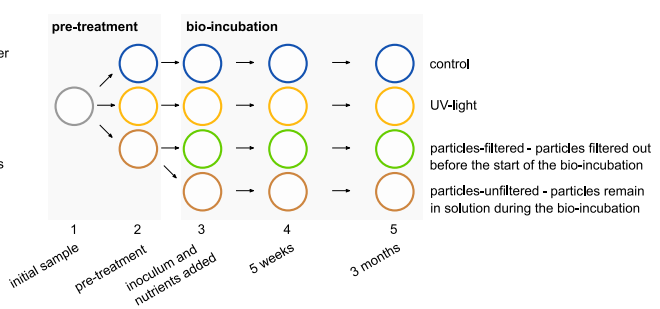
Overlap between compounds that increase as a result of light exposure and decrease during the bio-incubation

Methods

Set-up: pre-treatment of palsa mire dissolved organic matter (DOM) by light and particles followed by a 3-month bio-incubation on a roller table at 20°C in the dark

Light: 22-h exposure to UV-light

Particles: 22-h exposure to suspended sediment collected from a glacial stream, added as a freeze-dried powder (2 gl^{-1})



DOC: 4 replicates during 'event' 1-4, single measurements throughout the bio-incubation (18 or 19 in total)

Absorbance (250-600 nm) and **fluorescence spectrometry** (excitation 250-445 nm, emission 300-600 nm): 4 replicates

Size distribution: size exclusion chromatography – diode array detection (optical) and charged aerosol detection (abundance), 3 replicates

Orbitrap mass spectrometry: electrospray ionisation, m/z 200-800, 3 replicates

Oxygen concentrations (optical) during the first days of the bio-incubation, 7 replicates

Conclusions

Contrary to the expectation, photodegradation and adsorption to glacial suspended sediment removed different DOM compounds in a palsa mire surface water

The different processes also had opposing effects on DOM bioavailability

Adsorption and phototransformations affect palsa mire DOM reactivity short term

Affiliations: [1]Department of Ecology and Genetics, Limnology, Uppsala University, Uppsala, Sweden, [2]Department of Chemistry-BMC, Analytical Chemistry, Uppsala University, Uppsala, Sweden, [3]Department Lake Research , Helmholtz Centre for Environmental Research - UFZ, Magdeburg, Germany

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References: [1]Wauthy et al., 2018. L&O Letters, 3(3), 186–198. [2]Abbott et al., 2014. J Geophys Res Biogeosci, 119(10), 2049–2063. [3]Cory et al., 2013. PNAS, 110(9), 3429–3434. [4]Panneer Selvam et al., 2017. Sci Rep, 7, 45811. [5]Laurion et al., 2010. L&O, 55(1), 115–133. [6]Groeneveld et al., 2020. J Geophys Res Biogeosci, 125(3), e2019JG005236.