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Molecular analysis of lake-sediment organic matter:

Long-term dynamics and environmental implications in boreal lakes

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Akademisk avhandling

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Abstract

Lake sediment organic matter is material composed of residues from plants, algae, animals, fungi and bacteria. Its molecular composition is dependent on the sources as well as secondary biotic and abiotic transformations, which combined generates a highly complex matrix. Considering that organic matter plays a key role in carbon and nitrogen cycle, and its composition affects many different biogeochemical reactions, paleolimnologic studies have payed proportionately little attention to the organic matter composition compared with the other sediment fractions, even though organic matter makes up 20–60 % of the dry sediment mass in boreal and subarctic lakes. This thesis therefore primarily aims to explore and evaluate two methods; pyrolysis-gas chromatography/mass spectrometry (Pyrolysis-GC/MS) and diffuse reflectance Fourier-transform infrared spectroscopy (DRIFTS) for characterisation of bulk organic matter at the molecular level, both which have been extensively used for soils and peat and which balances the need for cost and time-effective analysis and for analytical detail.

With pyrolysis-GC/MS the organic matter composition and long-term dynamics in two neighbouring boreal lakes is explored and compared with the conventional bulk carbon and nitrogen contents and their stable isotopes. Both pyrolysis data and conventional data capture the timing of organic matter compositional changes, but only pyrolysis provides detailed information on how the composition changes, which allows for a deeper understanding of the processes behind the changes. The same two lakes are also analysed with DRIFTS and with this approach information on the major organic compound groups aromatics, lignin, aliphatics, proteins and polysaccharides is extracted. In combination with the rapid analysis time and low cost, DRIFTS emerges as a very useful tool for rapid yet informative organic matter analysis. DRIFTS is then evaluated as a stand-alone tool for sediment characterisation in four mountain lakes. The four lakes all have different sediment composition and as a result of the multi-fraction information obtained with DRIFTS compositional differences can be related and explained in terms of their individual lake and landscape settings. The importance of landscape setting is further highlighted in the synthesis of the long-term dynamics of lake-water quality in seven lakes where development trajectories and responses to different types of disturbances are connected to the extent of peatlands within the lake catchments. This thesis demonstrates the advantages of two different approaches for more detailed lake sediment organic matter characterisation and advances our understanding of the molecular organic matter composition in boreal lakes over the Holocene, and how landscape setting affects both the organic matter composition and the sensitivity of lakes to disturbance.

Keywords
Mid-infrared spectroscopy, DRIFTS, visible-near infrared spectroscopy, pyrolysis-GC/MS, organic matter, lake sediment, lake-water TOC, pollen, land use, alpine, boreal

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