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Controlling factors of mercury accumulation in lake sediments during the past 17,000 years – A case study from Southern Patagonia

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The coupling of mercury and organic matter has been considered as an important factor controlling the transport of mercury in and between terrestrial and aquatic systems. If coupled to the evaluation of climatic and paleo-environmental proxies, lake sediments provide reliable archives to investigate factors controlling past mercury cycling at least on a regional scale. While some studies suggest that accumulation of mercury in lake sediments is mainly controlled by varying fluxes of organic matter bound mercury from the catchment soils, other propose changes in aquatic productivity and related scavenging by algea as a major process. Although suggesting different "carriers" of mercury into lakes and sediments, both processes are to a vast extent controlled by climatic conditions. To understand the future influence of a changing climate on the environmental cycling of mercury, information about the influence of climate is essential to predict future risks. However, long term records of mercury accumulation in lake sediments encompassing different climatic conditions have been rarely investigated. Here we present a 17,000 year old high resolution record of mercury accumulation in a remote lake in southern Patagonia, Chile. Continuous sedimentation started after glacier retreat, which offers to study the interrelation between mercury and carbon dynamics in the lake and its catchment under changing environmental and climatic conditions. Besides mercury accumulation, we investigated the sedimentary history of the lake expressed by the sedimentation of organic (e.g. organic carbon) and lithogenic components (e.g. zirconium), respectively. Sources of organic matter were examined (aquatic versus terrestrial) based on C/N ratios. Local rocks and soils, as well as terrestrial and fresh aquatic organic material were analyzed for mercury content to account for the contribution of different mercury sources.
Sedimentation of terrestrial and aquatic organic matter as well as lithogenic elements reveals profound environmental and climatic changes throughout the past 17,000 years. In contrast, long term mercury accumulation remained nearly constant (median 29 μg m-2 yr-1) suggesting that atmospheric fluxes have been similar throughout this period. However, short term, mainly climatically driven changes in mercury accumulation vary in a wide range between 10 to 157 μg m-2 yr-1 (factor 16) even exceeding the anthropogenic forcing of modern atmospheric mercury fluxes (factor 3-5). Mercury accumulation shows a striking covariance with other organically bound elements in soils such as copper or yttrium, but only a small influence of bulk organic matter. Statistical data evaluation based on Principal Component Analyses reveals, that the dominant driver controlling changes in mercury accumulation rates is leaching of soluble organic complexes from soils, which is strongly determined by precipitation rates. Moreover, our data indicates that scavenging by algal derived organic matter may enforce mercury accumulation also, especially during times of higher aquatic productivity, which is also influenced by climate factors such as temperature and nutrient fluxes. The observed climatic components in the mercury cycle and the vast amounts of anthropogenic mercury stored in modern top soils suggest that recent climate change may rise terrestrial mercury fluxes into adjacent aquatic systems drastically. We assume that leaching of mercury from soils due to increasing fluxes of dissolved organic matter will be the dominant factor in this process.