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The size matters: aerobic methane oxidation in thermokarst lake sediments in Western Siberia

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Thermokarst lakes of permafrost peatlands in Western Siberia are among the most important sources of greenhouse gases (GHG) such as CO_2 and CH_4 because of current permafrost thawing due to climate change. Field measurements demonstrated the increase of dissolved GHG concentrations with the decreasing lake size due to higher concentration of coastal-derived organic C in water of small lakes. However, the size-dependent mechanisms of the GHG production and consumption (e.g. CH_4 oxidation) in the sediments of these lakes remain poorly known. We estimated aerobic CO_2 production and CH_4 oxidation potentials based on natural ^{13}C abundance and ^{13}C labeling in two layers of upper 20 cm sediments of three thermokarst lakes: small (~ 300 m^2), medium (~ 3000 m^2) and large (~ 1 km^2). We hypothesized that i) specific CO_2 production (per gram of sediment) decreases with increasing lake size, but CH_4 oxidation increases, and ii) both processes are more intensive in the upper 10 cm of sediments than in deeper 10–20 cm, due to naturally occurring O_2 gradients and the available C. As expected, CO_2 production in the upper layer was 1.4–3.5 times higher than in the deeper layer and the rate of production increased from large (170 nmol CO_2 g^{-1} d.w. h^{-1}) to medium (182) and small (234) lakes. In contrast to CO_2, CH_4 oxidation in the uppermost sediment layer was similar between lakes, while the deeper layer in the large lakes had 12- and 73-fold higher oxidation rates (5.1 nmol CH_4-derived CO_2 g^{-1} d.w. h^{-1}) than in small and medium lakes, respectively. This was attributed to the fact that the O_2 concentration in the water of large lakes is higher than in smaller lakes due to the intense turbulence caused by wind and waves. Due to the ongoing and future thawing of permafrost, smaller lakes will increase in size, so that a large part of the CH_4 produced in the sediments will be oxidized. However, this process can be (over)compensated by the increased formation of new small lakes. From an ecological perspective, the sediments of shallow

thermokarst lakes in the discontinuous permafrost zone of Western Siberia could oxidize up to 0.48 Tg C as CH_4 in the summer period, with the largest contribution coming from the large lakes. This confirms the key role of the thermokarst lake ecosystems as a global hotspot of GHG turnover.

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