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Geochemical and Hydrological limitation of carbon sequestration and methane release in anoxic peat soil from the Luther Marsh, Canada

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In deep peat layers, anaerobic respiration showed a slow-down due to the lack of solute transport which causes an accumulation of metabolic end products (i.e. DIC and CH_4). This accumulation can lower the Gibbs free energy levels available to the terminal respiration processes, potentially leading to an inhibition in the decomposition. In particular, this state can affect the methanogenesis, acetogenesis and fermentation processes which occur near thermodynamic minimum energy levels. We conducted a column experiments with an ombrothrophic bog peat over a period of 300 days at 20°C, to test the hypothesis that alteration in solute and gas transport rates can remove this biogeochemical inactivation of DIC and methane turnover rates. To this end, we tested a i) control treatment with no gas and solute transport, ii) advective flow treatment with a flow water of 10 mm d^{-1}, iii) ebullition treatment with methane removal by conduit transport as surrogate for bubbling, and iv) an O_2-free atmosphere treatment to test the effect of remote transport of electron on anaerobic decomposition, in absence of oxygen compared to the other treatment. We determined detailed concentration depth profiles of dissolved inorganic carbon (DIC), methane (CH_4) and relevant decomposition intermediates (i.e. H_2, Fe, nitrate, acetate, formiate and propionate), every 15 days at the beginning and every ca. 2 months after 75 days. CO_2 and CH_4 fluxes were measured using a static chamber approach. Net turnover of DIC and CH_4 in depth layers was calculated for individual depth intervals from mass balance approach based on diffusive mass fluxes between adjacent depth layers and change in storage over time. Thermodynamic energy levels of relevant electron accepting processes were calculated over time. In the initial phase of the experiments, DIC and CH_4 concentrations increased mostly below the water table level at 10 cm depth and over time in all treatments. After 45 days of incubation, CH_4 concentrations strongly increased in the advective flow treatment, peaked at 70 cm depth with 700 μmol L^{-1}, and in the O_2-free treatment, peaked at 20 cm depth with ca. 600 μmol L^{-1}. DIC concentrations after 45 days showed similar pattern in term of levels between the different treatments, showed an increase from ca. 3000 μmol L^{-1} near the water table to about 5000-6000 μmol L^{-1}at 70-75 cm depth. Furthermore, DIC and methane concentrations in the ebullition treatment showed a decline over time, probably due to the export of gases through the formation of bubbles. At the end of the experiment, we expect that a negative feedback on decomposition will mostly occur in deeper layers in the control treatments due to the slowness of transport and where the accumulation of CO_2 and CH4 will be eased, in line with the results presented in previous studies.

Keywords: Peatlands; Anaerobic decomposition; Methanogenesis; Net turnover rates; Gas fluxes; Advection; Ebullition.