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Effect of permafrost thawing on the organic carbon and metal speciation

Oleg Pokrovsky (1), Liudmila Shirokova (2,1), Sergey Kirpotin (3), and Bernard Dupre (1)

(1) CNRS, LMTG, Toulouse, France (oleg@lmtg.obs-mip.fr), (2) Institute of Ecological Problems, Russian Academy of Science, Arkhangelsk, Russia, (3) Tomsk State Institute, Tomsk, Russia

Ongoing processes of the permafrost thawing in Western Siberia are likely to increase the surface of water reservoirs via forming so-called thermokarst (thaw) lakes, mobilizing the organic carbon from the soil pool to the rivers and, finally, to the ocean, and also modifying the fluxes of methane and CO2 to the atmosphere. In order to better understand the mechanisms of carbon mobilization and organic matter biodegradation during permafrost thawing and to establish the link between the organic carbon, microbial activity and geochemistry of major and trace elements in forming thermokarstic lakes, we performed a comparative multidisciplinary study on the biogeochemistry of organic carbon and bacterioplankton in lakes located in the northern part of Western Siberia. Towards this goal, fifteen lakes and three surface streams draining neogenic deposits on continuous permafrost ground of the Urengoy region. There is a sequence of ecosystem stages during evolution from peat thawing in depressions and palsa degradation due to permafrost subsidence in small ponds to large, km – size lakes subject to drainage and, finally, the khasyrei formation (remaining central parts of drained lakes). In the chronosequence of lake formation, there is a clear decrease of the relative proportion of < 1 kDa (1 kDa is close to 1 nm) organic carbon concentration along with concentration of total dissolved (< 0.45 μm) organic carbon. Other dissolved components such as major cations and Fe also decrease their concentration in the chronosequence of ecosystem evolution. Independent on the state of ecosystem development and organic carbon concentration, there is significant proportion of insoluble metals (Fe, Al, Ti, Ga, Y, REEs, Th, Zr, Hf), from 80 to 99%, in the colloidal form (1 kDa – 0.45 μm) present as organic (humic and fulvic) complexes. There is a systematic decrease of these element concentrations concomitant with OC concentration decrease in consecutive filtrates (5 micron – 0.45 micron) and dialysates (10 kDa – 1 kDa). In addition, concentration of heterotrophic eutrophic bacteria also decreases with decrease of OC from the initial stage of lake formation to mature, khasurey (drained lake) stage. Overall, our observations suggest that dissolved organic matter mineralization by aquatic heterotrophic bacterioplankton is the main process controlling the chemical composition of thaw lakes. We also show that, regardless of the stage of the thaw lake evolution, from small forming pond to large lake subjected to draining, there is always significant degradation of dissolved organic matter accompanied by permanent CO2 flux to the atmosphere. Since all lakes on the permafrost ground have thermokarst origin and thus similar to those studied in this work, one calculate the minimal flux of the CO2 to the atmosphere from 792,000 km^2 of all permafrost lake area, given that 65.5% of lakes to the north of the Arctic Circle occur in Russia. The annual input of CO2 from the earth surface to the atmosphere due to thermokarst lakes of Northern Siberia thus achieve 0.066 Gt C/y which is significantly higher than the total riverine flux of dissolved and suspended organic carbon from Russia territory to the Arctic ocean.