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The role of wildfires and forest succession in stream biogeochemistry within the continuous permafrost zone of Central Siberia

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Wildfires transform boreal and subarctic forested landscapes leading to the changes in organic matter and inorganic nutrient turnover in terrestrial ecosystems. To get an insight to the fire effect on C fluxes and general hydrochemical characteristics of streams draining continuous permafrost terrains of Central Siberian Plateau (64o N 100o E), we have selected the chronosequence of basins (n = 17) which were severely affected by fires (>80% of basin area) in the time range from 1 to 116 years ago. Stream waters were sampled continuously during frost free seasons (May-September) of 2006-2015. Four streams have been equipped with water level, temperature and conductivity probes for continuous monitoring.
The strongest negative effect of wildfires on dissolved organic carbon (DOC) concentrations in streams has occurred right after a fire event, and minimum mean annual concentrations of DOC appeared between 15 and 20 years elapsed after a fire. The most pronounced decrease in DOC concentrations during an annual cycle found in freshet period (May-June) and summer-fall storm events: differences of DOC concentrations among “intact” (>100 years after fire) and recent fire basins (<6 years) reached as much as 2-fold. Less differentiation among basins appears under lowflow conditions, as DOC-depleted solutes from deeper soil layers become dominating in stream flow. Following the post-fire forest recovery, the seasonal mean DOC concentrations in streams demonstrated linear growth at the rate of ca. 0.11 mgC/l/a and approached the initial values already after ca. 60 years after fire disturbance.
An opposite trend (i.e. increasing load to streams after fire impact) was observed for dissolved inorganic carbon, major anions and cations. Sulfate was found to be a good tracer of fire affect as increased 200-fold in stream waters right after a fire and steady decreased at the rate [SO42-] = 3.65 x (year after fire)-0.75 as terrestrial ecosystems were recovering after a fire. For study area, Na+ and Cl- in streams appear to be good indicators of permafrost degradation as they reflect talik formation and connection of a stream to underlying evaporitic deposits. While evidence of permafrost degradation is currently not apparent in the region, we expect increasing concentrations of Na+ and Cl- in streams of Central Siberian Plateau as permafrost degrades due to decreased fire return interval and warming temperatures.
The generalized data of active layer thickness (ALT) within analyzed watersheds have demonstrated that fire-driven deepening of ALT results in increasing stream inorganic compounds concentrations. The inverse relationship found between DOC and ALT might be attributed to deeper infiltration of solutions, sorption of DOC on clay minerals, and an increasing rate of DOC microbiological mineralization to CO_2 due to increased soil temperatures. Post-fire forest recovery and, particularly, the accumulation of organic mater in the moss-lichen layer and soil organic horizon on watersheds accounted for increasing mean DOC concentrations in the streams. In opposite, increased insulation of soils by organic matter accumulating on the soil surface leads to steadily decreasing ALT and constrains an infiltration of solutes to subsoil. As a result, inorganic solute loading to stream channels is tended to decrease during post-fire forest succession in permafrost affected terrains.