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Black Carbon characterization in Quebec black spruce forests

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Black carbon (BC), the solid carbonaceous residue of incomplete combustion, is a major by-product of wildfires in Quebec black spruce forests. Because of its estimated recalcitrance, it is considered a valuable pool in the global carbon cycle. However, BC characteristics, and more specifically its resistance to degradation depend on its conditions of formation. The objective of this study was to characterize BC chemical and physical properties under varying fire severities in order to assess its potential for recalcitrance as a passive carbon pool. Fresh BC samples from the forest floor were collected in 2010 from Quebec black spruce forests stands that had burnt 3-5 years prior. Fire severity was assessed at each sampling location and a total of 33 samples were selected to cover the range of severity encountered in these burnt forests. Samples were further analyzed for aromaticity and porosity using elemental and proximate analyses, solid-state 13C nuclear magnetic resonance (NMR) spectroscopy, scanning electron microscopy (SEM) and surface area (SA) analysis. They were then compared to BC samples produced under controlled conditions in the laboratory (lab-BC). The 13C NMR spectra of the BC collected on low fire severity sites showed a distribution of total intensity between the different spectral regions very similar to those of unburnt fuels. They were generally dominated by a peak at 74 ppm indicative of cellulose. On the other hand, 13C NMR spectra obtained for BC from high fire severity sites were dominated by peaks from aromatic carbons. When compared to the lab-BC NMR spectra, we concluded that the temperature of formation for the 33 analyzed samples ranged between 75°C and 250°C and that pyrolysis conditions prevailed, which points towards BC formation by a smouldering fire. Atomic ratio values (H/C = [1.36-0.77]; O/C = [0.75-0.30]) decreased with increasing fire severity and were in agreement with the results from 13C NMR spectroscopy. Finally, the analyzed samples exhibited very low SA (1.1 to 2.3 m^2/g) but those results have to be tempered by a possible reduction of the initial porosity by adsorption of various compounds.
Fresh BC produced by wildfires in Quebec black spruce forests appeared to be mostly composed of transition and amorphous chars. Fire severity is related to the fresh BC chemical properties; an increasing fire severity inducing an increase in condensation. Nevertheless the aromaticity of the fresh BC we collected was not very high when compared to the whole BC continuum.