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Fire derived carbon in boreal forests - current knowledge and uncertainties

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Fire strongly influence the carbon (C) cycle in boreal regions. Fire converts biomass and detrital C mainly to gaseous forms (CO_2 and smaller proportions of CO and CH_4), and some 1-7% of mass to pyrogenic C (PyC). PyC is mainly produced as solid charred residues, including visually-defined charcoal, and a black carbon (BC) fraction chemically defined by its resistance to laboratory oxidation, plus much lower proportions of volatile soot and polycyclic aromatic hydrocarbons (PAHs). All PyC is characterized by fused aromatic rings, but varying in cluster sizes, and presence of other elements (N, O) and functional groups.

There are several reasons for current interest in defining more precisely the role of PyC in the C cycle of boreal regions. First, PyC is resistant to decomposition, and therefore contributes to very stable C pools in soils and sediments. Second, it influences soil processes, mainly through its sorption properties and cation exchange capacity, and third, soot aerosols absorb solar radiation and may contribute to global warming. However, there are large gaps in the basic information needed to address these topics. While charcoal is commonly defined by visual criteria, analytical methods for BC are mainly based on various measures of oxidation resistance, or on yield of benzenepolycarboxylic acids. These methods are still being developed, and capture different fractions of the PyC "continuum". There are few quantitative reports of PyC production and stocks in boreal forests (essentially none for boreal peatlands), and results are difficult to compare due to varying experimental goals and methods, as well as inconsistent terminology. There are almost no direct field measurements of BC aerosol production from boreal wildfires, and little direct information on rates

and mechanisms for PyC loss. Structural characterization of charred biomass and forest floor from wildfires generally indicates a low level of thermal alteration, with the bulk of the material having H/C ratios still $>$0.2, and small aromatic cluster sizes. For the more chemically-recalcitrant BC fraction, a variety of circumstantial evidence suggests very slow decomposition, with turnover on a millennium timescale (5,000-10,000 years), depending on environmental conditions and PyC properties, but the main limitation to PyC storage in soil is likely consumption by subsequent fires. Degraded, functionalized PyC is also incorporated into humified soil organic matter, and is transported to sediments in dissolved and particulate form. We estimate boreal production of PyC production as 8 Tg PyC, of which perhaps one-third could be defined as the more-resistant BC fraction. Primary research needs to include basic field data on production and stocks of PyC in boreal forests and peatlands, development of standardized analytical methods and of approaches to assess the chemical recalcitrance of typical chars from boreal wildfires; to accomplish these effectively, however, there must also be much greater focus on development of interdisciplinary approaches.