Impacts of acid deposition and lake browning on organic carbon storage in Canadian northern forest lakes

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Lake sediments are an important carbon (C) sink as they can accumulate C over very long time periods (centuries to millennia), and thus remove C from the short-term C cycle. Yet little is known about the sensitivity of this sink to anthropogenic disturbances. During the 20th century, atmospheric acid deposition disrupted terrestrial-aquatic C cycling by drastically lowering dissolved organic carbon (DOC) loads in many lakes across NE North America and northern Europe. Recovery from acid deposition has, in turn, led to widespread DOC increases (i.e., lake browning). To date, it remains unclear how acid deposition and lake browning have altered the role of lakes as long-term C sinks. We present organic carbon accumulation rates (OCAR) over the past ~150 years, and other supporting infrared spectroscopic, isotopic and elemental geochemical proxies, for eight lakes in and around Sudbury, Ontario, Canada – an area heavily affected by acid deposition from smelting activities in the late-19th and 20th centuries. Sediment-inferred trends in lake-water DOC showed a strong response to the effects of acid deposition during the past century, which is corroborated by increasing observed lake-water DOC concentrations since the 1980s. Despite these changes in DOC, as well as changes in water acidity, only lakes with direct physical watershed disturbances (i.e., vegetation loss and soil erosion following acidification and metal contamination) showed short-lived increases in OCAR, whereas OCAR changed little in remote Sudbury region lakes with minimal direct human disturbances (mean OCAR: 14.3±8.7 g/m^2/yr). This is in stark contrast to many other northern forest lakes with minimal direct catchment disturbances that experienced significant increases in OCAR during the 20th century. It has been suggested that lake browning may increase C burial by promoting the flocculation and sedimentation of additional DOC. Our results caution that lake browning alone may not be a dominant driver behind the recent widespread increase in organic C burial in northern lakes, and that additional DOC is instead mostly exported downstream or mineralized and released as greenhouse gases to the atmosphere.