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Air emissions from organic soil burning on the coastal plain of North Carolina

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HIGHLIGHTS

► $PM_{2.5}$ EFs were at least a factor of 2 greater than those from above-ground fuels.
► CO EFs (250–300 g kg^{-1} fuel dry weight) are at the high end of the range of previously published EFs.
► Levoglucosan was found to compose 1–3 percent of $PM_{2.5}$ from the organic soil fires.
► $PM_{2.5}$ emissions may account for 10–20% of the total U.S. $PM_{2.5}$ air emission inventory.

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ABSTRACT

Emissions of trace gases and particles ≤2.5 microns aerodynamic diameter ($PM_{2.5}$) from fires during 2008–2011 on the North Carolina coastal plain were collected and analyzed. Carbon mass balance techniques were used to quantify emission factors (EFs). $PM_{2.5}$ EFs were at least a factor of 2 greater than those from forest burning of above-ground fuels because of extended smoldering combustion of organic soil layers and peat fuels. This is consistent with CO_2 EFs at the low end of previously reported ranges for biomass fuels, indicating less efficient combustion and enhanced emissions of products of incomplete combustion (PICs). CO EFs are at the high end of the range of previously published EFs for smoldering fuels. The biomass burning tracer levoglucosan was found to compose 1–3 percent of $PM_{2.5}$ from the organic soil fires, similar to fractions measured in smoke from above-ground fine fuels reported in previous studies. Organic soil fuel loads and consumption are very difficult to estimate, but are potentially as high as thousands of tonnes ha^{-1}. Combined with higher emission factors, this can result in emission fluxes hundreds of times higher than from prescribed fires in above-ground fuels in the southeastern US. Organic soil fuel represents a source of particles and gases that is difficult to control and can persist for days to months, jeopardizing human health and incurring considerable costs to monitor and manage. Extended fires in organic soils can contribute substantially to $PM_{2.5}$ on CO emission inventories and may not be adequately accounted for in current estimates.

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1. Introduction

The United States Environmental Protection Agency (EPA) has recently revised the National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$. Primary $PM_{2.5}$ standards are set at 15 μg m^{-3}, annual mean, and 35 μg m^{-3}, 24-h average, to provide increased protection against a wide range of PM-related health effects. These health effects include premature mortality, increased hospital admissions and emergency room visits, increased respiratory symptoms and disease, decreased lung function, and alterations in lung tissue and structure and in respiratory tract defense mechanisms (Fowler, 2003). Through emission of $PM_{2.5}$ and ozone precursor gases, fire also reduces visibility. Hence, natural area and agricultural land management, nationwide, may come under increased scrutiny as regulators seek reductions in pollutant emissions which contribute to NAAQS violations. Current guidelines allow flexibility in application of prescribed burning in smoke-sensitive areas if burn prescriptions are adhered to. Biomass burning in North America can also be a potentially significant source of radiatively active trace gases (Vose et al., 1997; Wiedinmyer et al., 2006). Areas burned in North and Central America can exceed 10 million hectares per year, resulting in trace gas and PM emissions that range from 10 to 40% of total emissions from all sources (Hoezelmann et al., 2004; Wiedinmyer et al., 2006).

Residual smoldering combustion (RSC) has been found to produce elevated $PM_{2.5}$ (McMahon et al., 1980) and (non-CO_2) trace gas emissions relative to flaming combustion (Bertschi et al., 2003). The largest potential pool of carbon vulnerable to RSC in many areas

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is organic soils (McMahon et al., 1980; See et al., 2007). On the coastal plain of the eastern U.S., wildland fires that burn into organic soils can smolder for weeks or even months, emitting tons of air pollutants and posing health, safety, and ecological hazards to local communities. Although above-ground fuel loads and emission factors have received considerable attention in the laboratory and field, much less data are available for below-ground fuel components. Here we investigate CO_2, CO, and $PM_{2.5}$ emission factors (EFs) from smoldering organic soils in North Carolina, USA.

2. Site description and burn conditions

2.1. Pocosin Lakes National Wildlife Refuge (PLNWR)

The tracts burned at this site (see Plate 1) were occupied primarily by pond pine (*Pinus serotina*) pocosins with a heavy understory of loblolly-bay (*Gordonia lasianthus* L.), red bay (*Persea borbonia* L.), gallberry holly (*Ilex coriacea* (Pursh) Chapm.), fetterbush (*Lyonia lucida* Lam. K. Koch) and wax myrtle (*Myrica cerifera* L.). A prescribed fire was ignited at 12 PM on February 16, 2008 with fine fuel moisture ranging between 9 and 10% and relative humidity at 50%. Fuels burned vigorously with flame lengths often exceeding 15 m. Pre-fire fuel loads in the pocosin ecosystem were highly variable. In the fetterbush/gallberry shrub patches, shrub density in these species was quite high prior to burning (~9 tons $acre^{-1}$ or 20 tonnes ha^{-1}, Mickler et al., submitted for publication). Pine and broadleaf litter and shrub comprised about 90% of the fuels consumed (11.2 tons $acre^{-1}$ or 25 tonnes ha^{-1}), consistent with North Carolina Division of Forest Resources (North Carolina Smoke Management Program, 2008), which estimates fuel loads of 11–22 tonnes ha^{-1} for medium density tall brush (>1.3 m) composed of red bay, loblolly-bay, gallberry, and wax myrtle. Fuel consumption efficiency was high at 70 and 80% (6.2 tons $acre^{-1}$, or 14 tonnes ha^{-1}) of the shrub and litter fuel, respectively. Approximately 10% of the total fuels consumed were woody. Fuel loads and consumption in wax myrtle woodlands at PLNWR were lower than in the Fetterbush/gallberry stands. Only 1.2 tons $acre^{-1}$ (2.7 tonnes ha^{-1}) was consumed in wax myrtle litter and woody fuel classes (Mickler et al., submitted for publication).

Following the prescribed burn, small pockets of smoldering combustion as deep as 1 m into the organic peat layers was observed. We collected smoke samples from these sites on February 17, 2008, and also removed over 60 kg of organic soil (peat) layers intact in cores 30 cm in diameter and 40–50 cm in length. These cores were collected fully intact and within a meter of areas where soil had burned to a depth of 50–100 cm. The cores were used to determine organic soil and elemental composition and to perform laboratory combustion tests.

Plate 1. Image of eastern North Carolina showing fire locations for this study. Inset shows burn scars from 2008 PLNWR and 2011 ARNWR wildfires within white rectangles. Imagery courtesy of Google Earth.

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