Characterization of Gas and Particle Emissions from Laboratory Burns of Peat

Robert Black, Johanna Aurell, **Amara Holder**,

Ingrid George, Brian Gullett, Michael Hays, Chris

Geron, Dennis Tabor

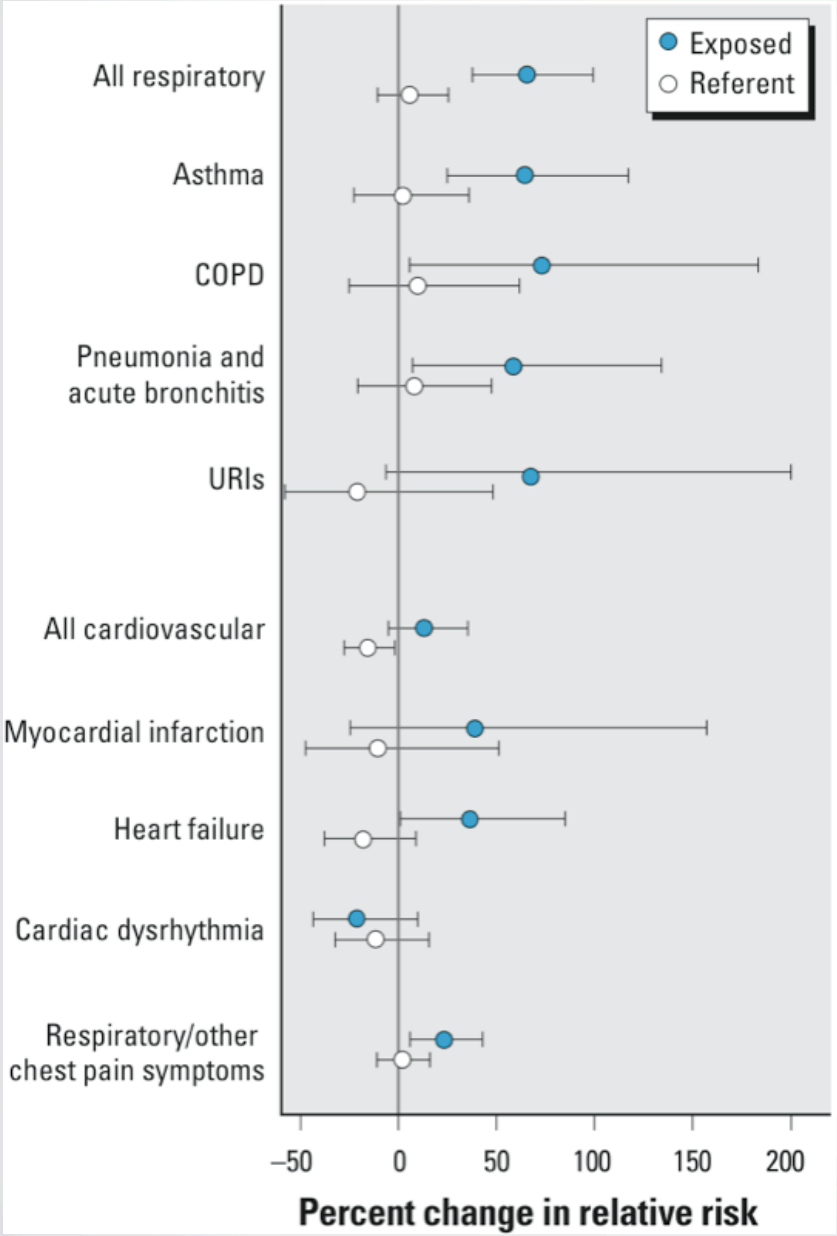
Peat fires can be a major source of air pollution

U.S. Fish & Wildlife Service https://www.fws.gov/fire/news/nc/evans_road.shtml

- Peat is an organic soil formed in wetlands
- Can burn for months to years through smoldering combustion in the underground layers
- Smoldering combustion has been less studied compared to other biomass burning
- Peat fires have been linked to adverse respiratory and cardiovascular effects

Study Objective:
Characterize underreported emissions from laboratory combustion of peat

Adverse health effects from peat fires



Rappold et al. 2011 EHP 119, 1415-1420

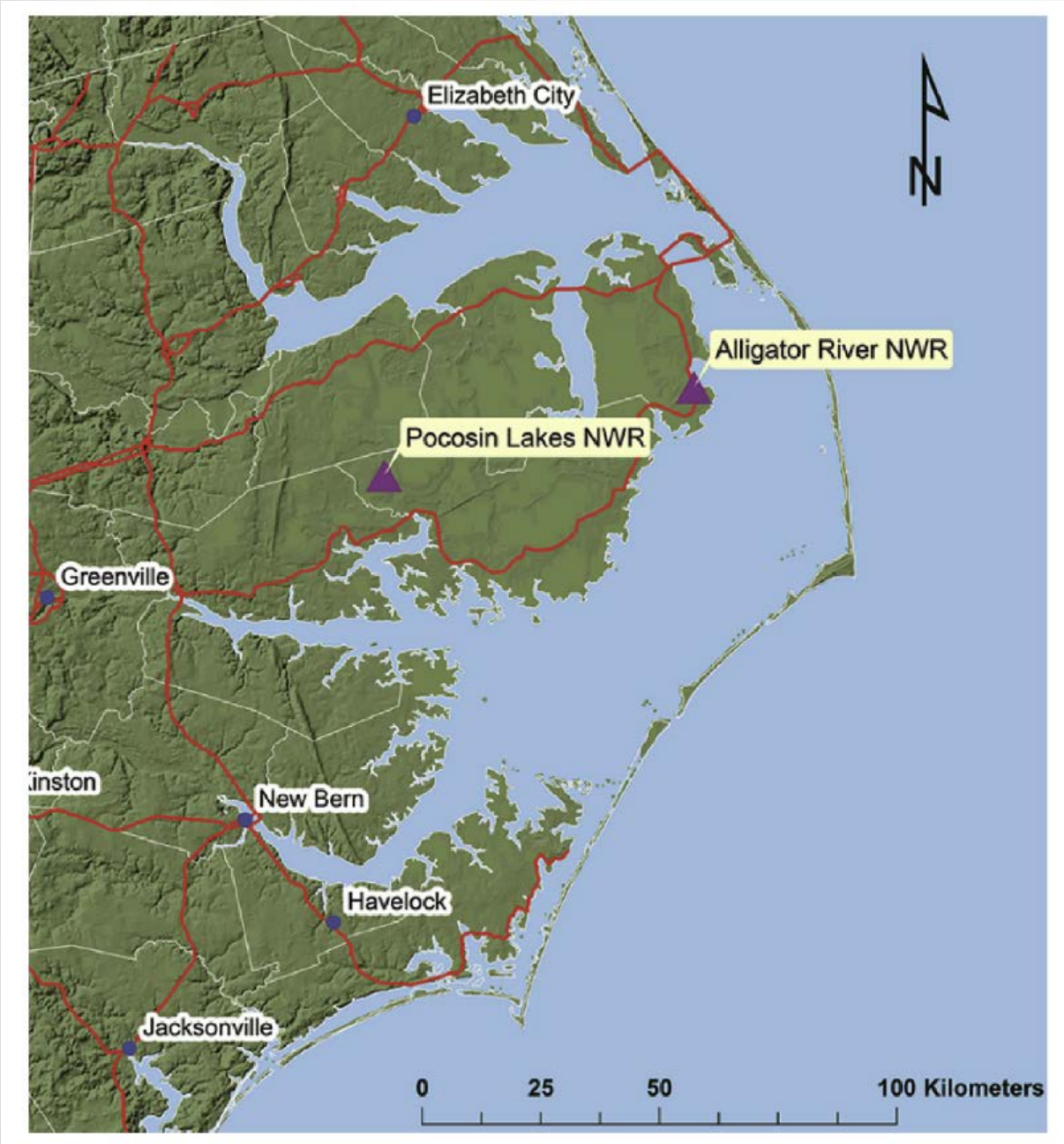
Exposure to peat fire emissions in North Carolina were linked with elevated adverse effects (Rappold et al. 2011)

On smoke impacted days emergency room visits were elevated for:

- Asthma
- COPD
- Pneumonia, bronchitis
- Cardiopulmonary symptoms

PM from the fire were shown to have pro-inflammatory effects in mice (Kim et al. 2014)

Experimental – Peat Source



Collected peat cores (150mm diameter, 200 – 250 mm deep) from two locations along the North Carolina coast:

- Alligator River National Wildlife Refuge (AR)
- Pocosin Lakes National Wildlife Refuge (PL)

Site of extensive wildfires in the last 10 years, consuming over 40,000 acres at each location, emitting 0.44 Tg $PM_{2.5}$ (~10% of the annual US $PM_{2.5}$ emissions)

Experimental – Laboratory burns

Cores were contained in a galvanized stove pipe and were dried 24 – 36 hr at 110 C before burning

Self-sustaining fires were ignited with a propane torch, 2 cases needed to be reignited

1-3 m flaming period was followed by ~5-7 h smoldering period

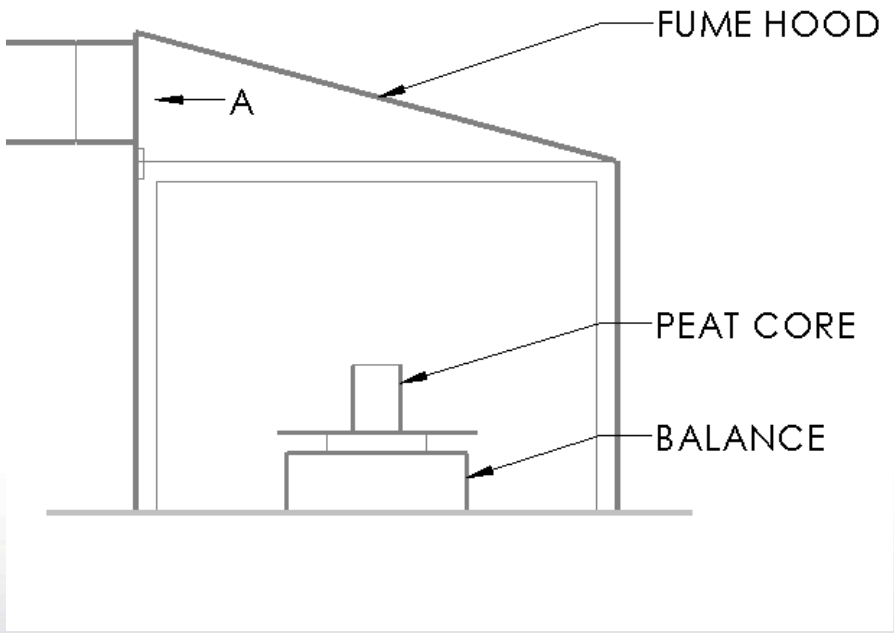
2 sampling periods:

0-3 h = Initial sampling period

3-7 h = Final sampling period

Burns carried out in ventilated burn test facility

A hood was used to collect concentrated emissions



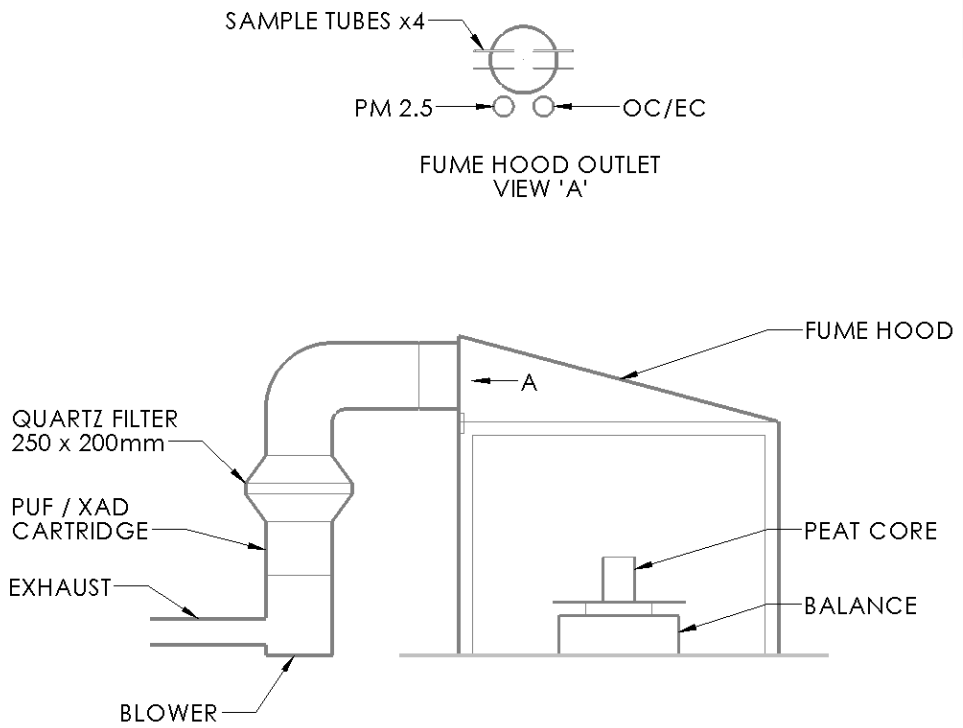
Experimental – Emissions Sampling

Emissions were sampled in the duct from the fume hood

Species	Instrument
CO and CO_2	Horiba, VIA510
SO_2	API, 100AH SO_2
NO_x	Teledyne, 200E
O_2	Rosemont, 755
THC, CH_4	CAI, 300-HFID
BC, UVPM	Aethlabs, AE52

Filter samples were taken for the initial and final periods

Analyte	Method
PCDD/PCDF	Method 23
PAH	TO-9A
PM2.5	Teflon filter, gravimetric
Elements	X-Ray Fluorescence
EC/OC	Thermal-optical analysis (NIOSH)



Black et al. 2016 Characterization of gas and particle emissions from laboratory burns of peat, Atmospheric Environment **132**:49-57

George et al. 2016 Volatile and semivolatile organic compounds in laboratory peat fire emissions, Atmospheric Environment **132**:163-170

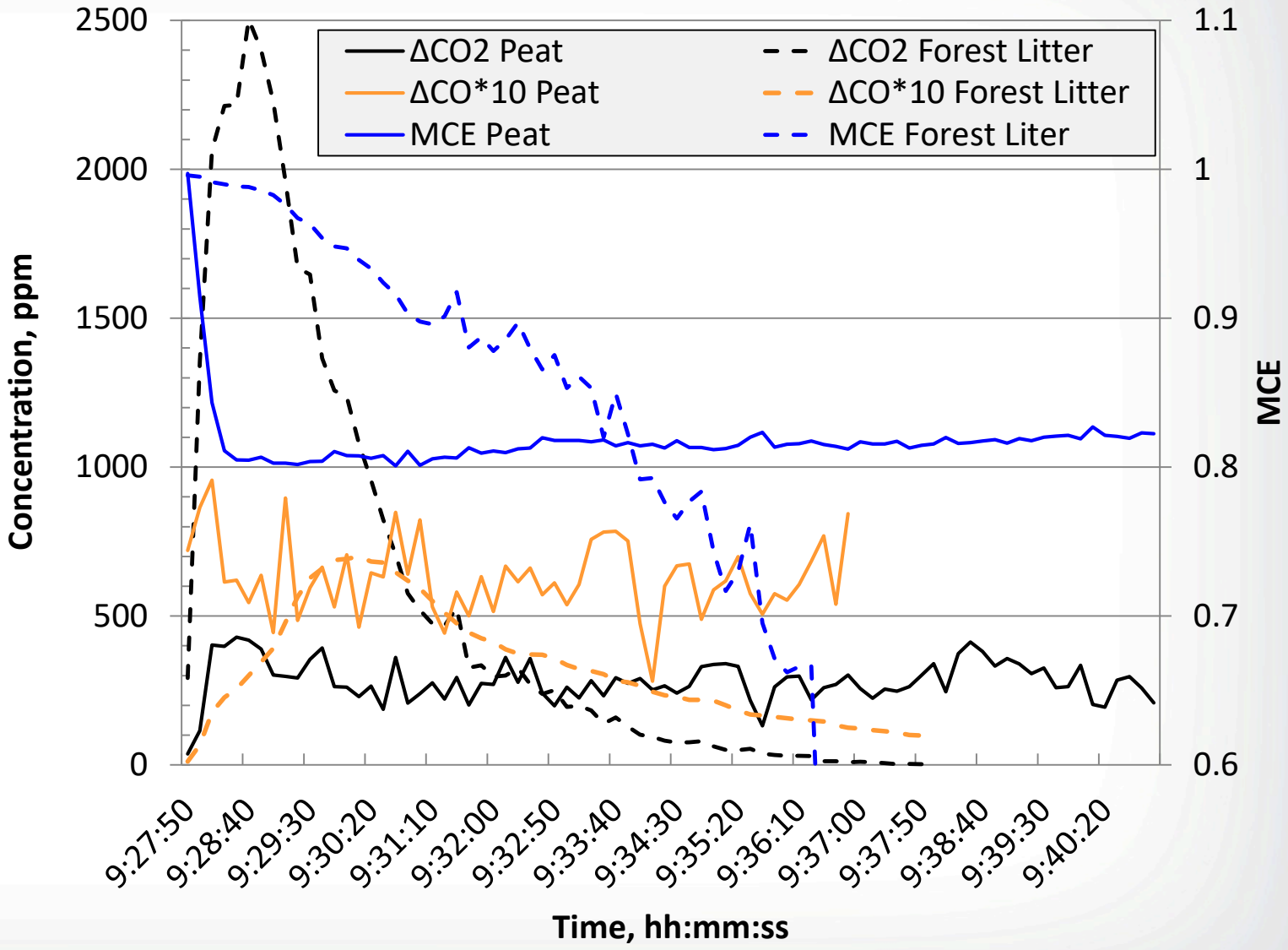
Results – Combustion Characteristics

Distinct differences in peat combustion compared to other biomass types

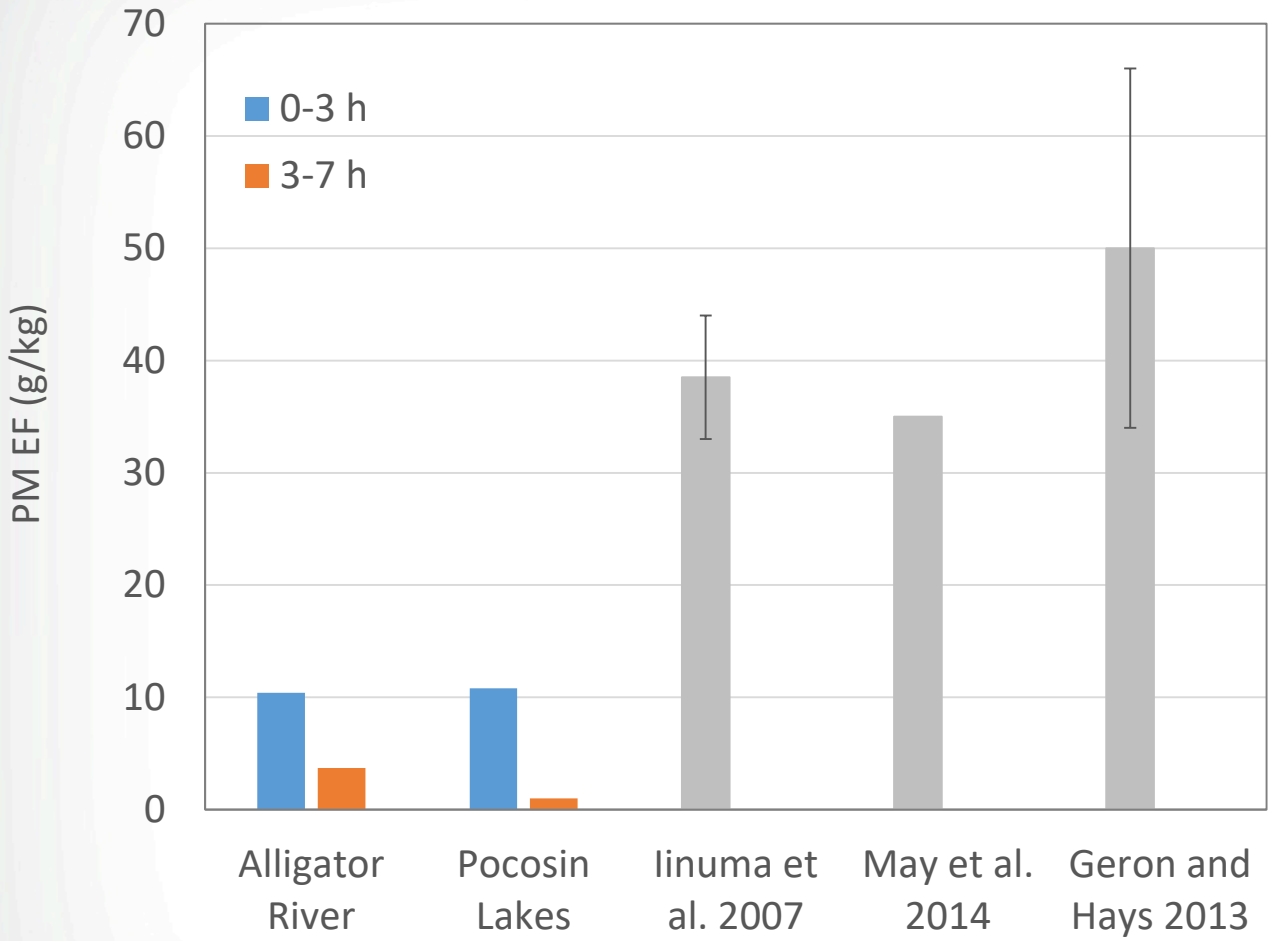
7 – 10% mass loss over the burn, 11-19% carbon consumed

Modified combustion efficiency was nearly constant over the burns at 0.8-0.88

Nearly constant ΔCO_2 and ΔCO concentrations after the initial flaming period (~60 s)



Results – PM Emission Factors



PM emission factors were much lower than literature values

Important distinctions from previous work:

- Lower fuel carbon content in fuel (28-30%) as compared to previous studies (54-60%)
- Much longer sampling times (7 h) as compared to previous studies (57 min)
- Longer sampling times lead to lower PM EFs
- PM sampling issues, i.e. partitioning, may have impacted EFs
- Field measurements were of aged PM, likely included SOA

Results – PM Composition

PM is almost entirely composed of organic carbon

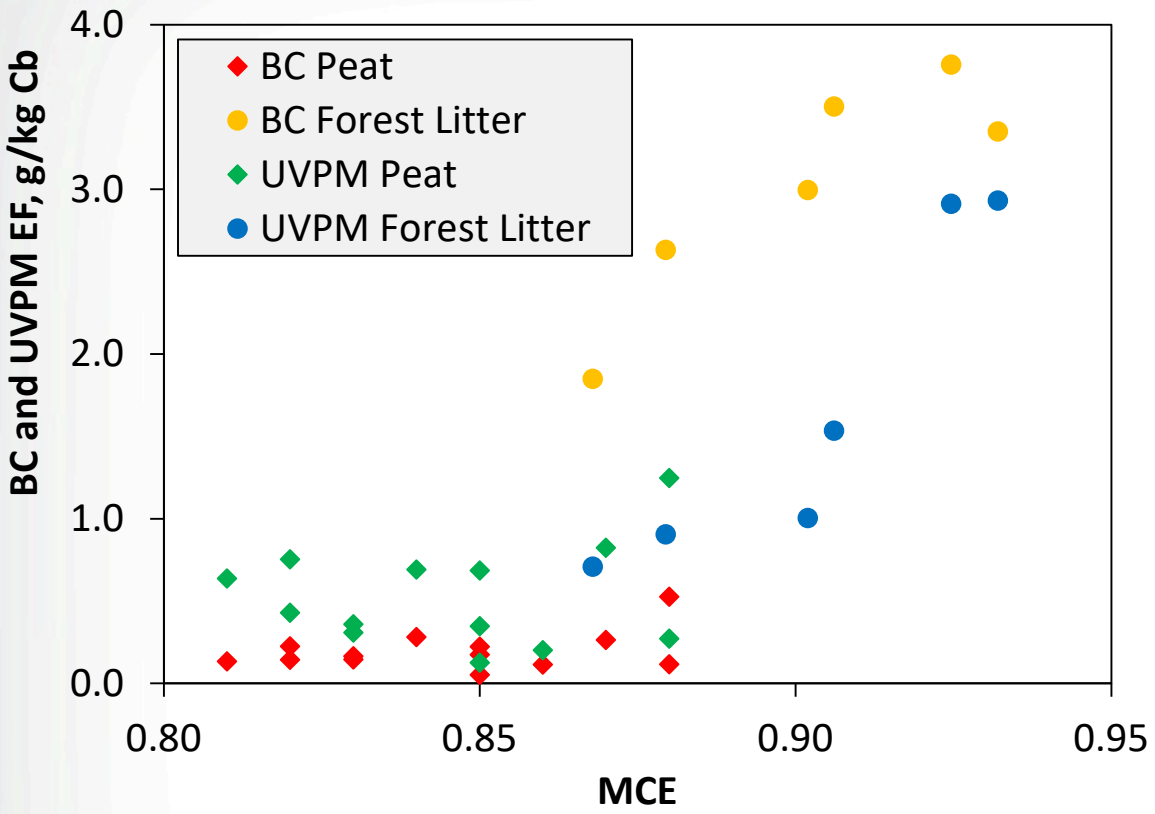
The most abundant trace elements were Cl, S, and Si

Final samples had larger Si content than the initial samples

Final samples also had lower EC content than the initial samples

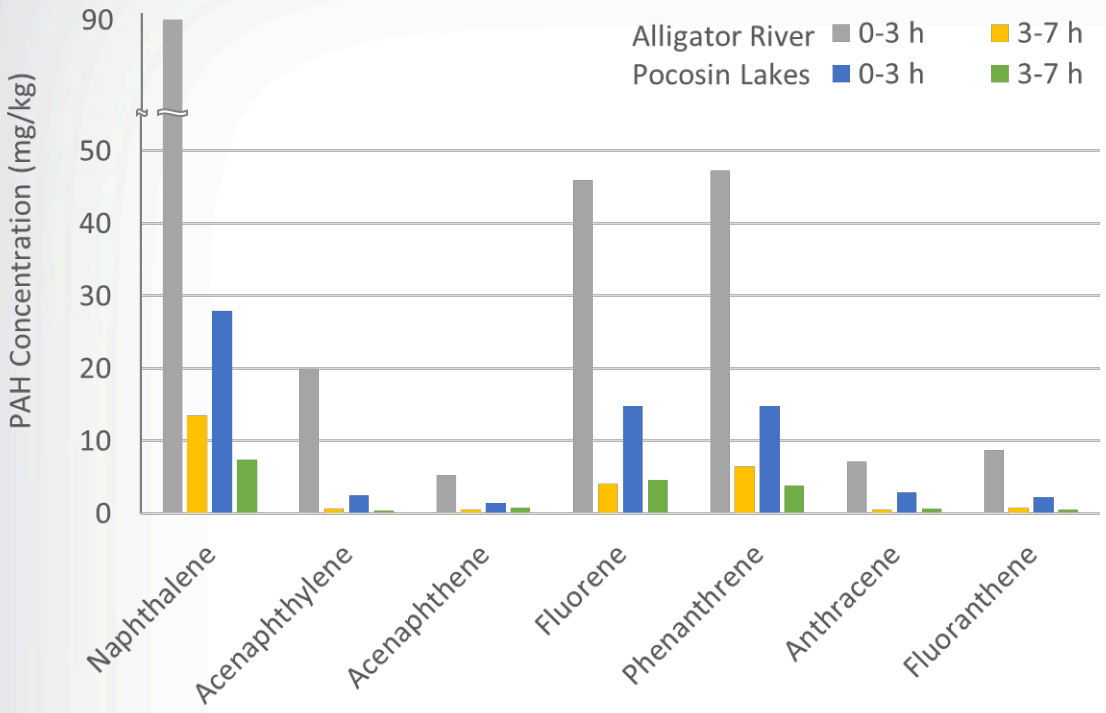
	Alligator River		Pocosin Lakes	
	0-3 h	3-7 h	0-3 h	3-7 h
OC/EC (mg/mg)	99	194	54	143
C (%)	97.26	97.03	98.61	97.88
O (%)	0.47	0.52	0.49	1.07
Al (%)	0.01	0.03	0.00	0.00
Si (%)	0.05	0.12	0.01	0.22
Cl (%)	1.90	2.02	0.05	0.41
Br (%)	0.04	0.00	0.00	0.00
S (%)	0.28	0.26	0.30	0.54
Fe (%)	0.07	0.13	0.17	0.06
Cr (%)	0.06	0.00	0.06	0.00
Na (%)	0.01	0.02	0.00	0.00

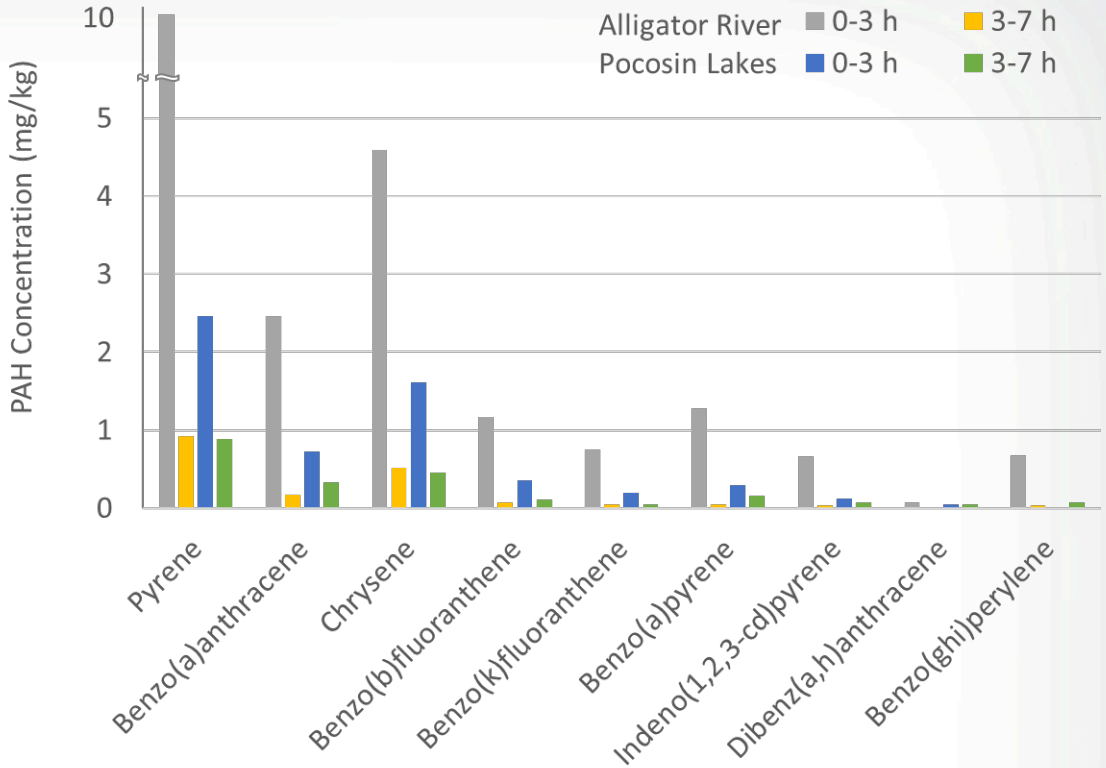
Results – Light absorbing carbon emission factors



Filter samples exhibited yellow color, indicative of high organic to black carbon content. However, UVPM (i.e. absorbing PM at 375 nm) and BC EFs are low compared to burns of forest litter. BC and UVPM tend to increase with increasing MCE.

Results – PAH Emission Factors



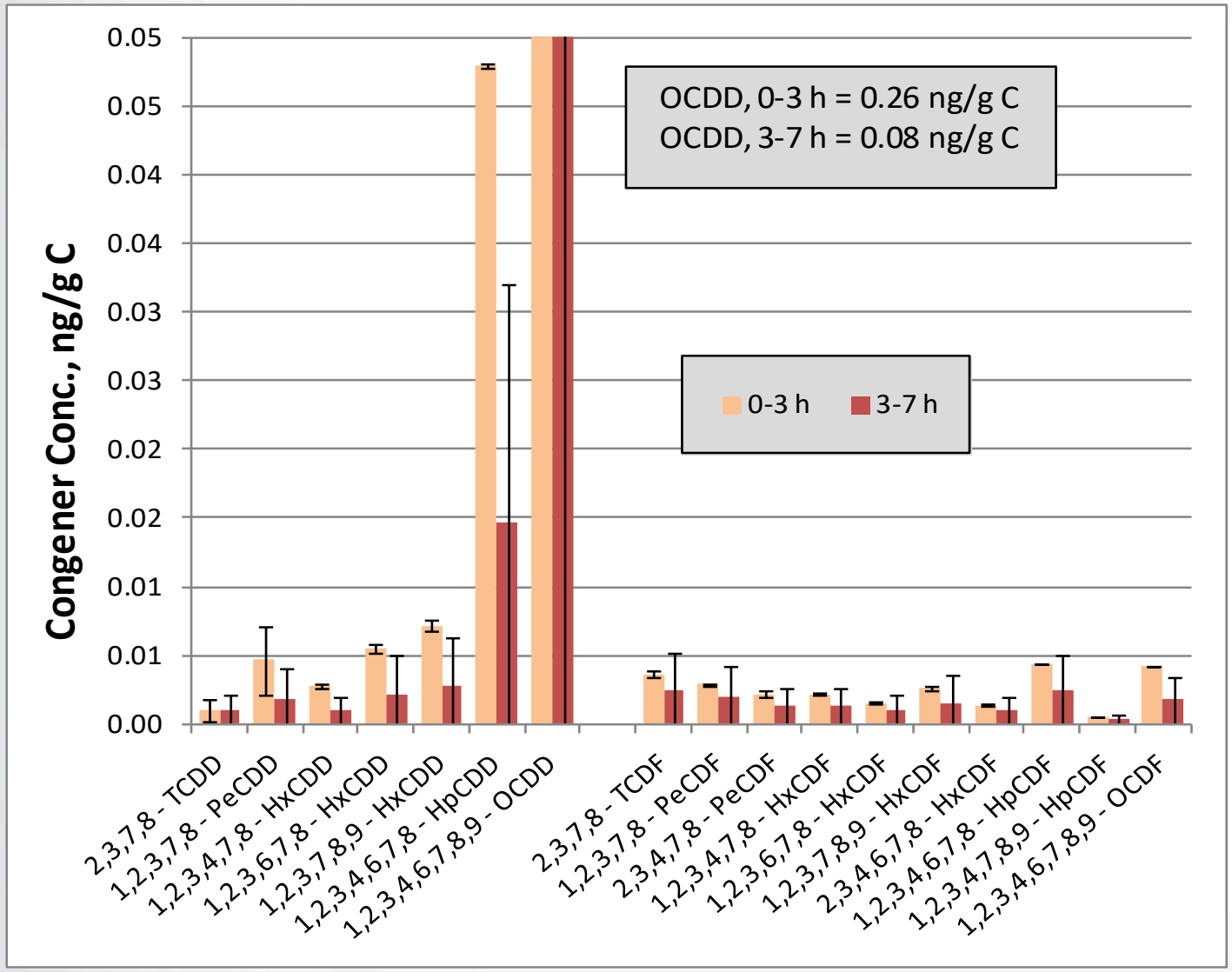


- PAH patterns were consistent among peat samples
- Burn PAHs concentrations were over 100x the raw peat values

- Initial period had 4 – 9x higher PAH concentrations over the final period
- Initial period was 2-20x more carcinogenic than the final period

Toxic equivalency factors were larger (0.12 and 0.16 mg/kg) than other peat studies (0.06 mg/kg, Iinuma et al. 2007)) and consistent with other biomass burning studies (0.1-0.57 mg/kg, Dhammapala et al. 2007, Jenkins et al. 1996)

Results – Dioxin Emission Factors



- PCDD/PCDF emissions were nearly 100x the raw peat values
- Despite higher Cl concentrations at Alligator River PCDD/PCDF emissions were similar for the two locations
- Initial period had larger PCDD/PCDF emissions
- PCDD/PCDF EFs (10 ng TEQ/kgC_b) were larger than forest litter prescribed and laboratory burns (0.2-9.2 ng TEQ/kgC_b)
- Congener patterns were similar for the initial and final sampling periods and for both peat samples, likely consistent formation mechanism

Results – Impact of the 2008 Evans Road Fire in North Carolina

NASA EarthData

Burned 16,813 ha consuming 200 - 600 tons C/ha over a period of 3 months

We estimate this fire contributed:

- ~6% of the annual US wildfire $PM_{2.5}$ emissions (not including secondary organic aerosol formation)
- ~6% of the annual US PCDD/PCDF emissions
- ~5% of the annual US OC emissions

Conclusions

- Laboratory combustion of peat showed distinct differences from other types of biomass fuels (i.e. forest litter)
  - Lower MCEs and nearly constant ΔCO_2 and ΔCO throughout the 7 hr burn period
  - Larger dioxin emissions
  - Lower EC content in the PM
  - Lower emissions of BC and UVPM
- PAHs and Dioxins in the fire emissions were over 100x greater than in the unburned fuel, indicating formation during combustion
- Initial 3 hrs of the burn exhibited greater EFs of PM, PAHs, and dioxins and consumed a greater mass of fuel than the latter 4 hours of the burn

The large amounts of carbon contained in peat and the extensive burn durations (~months) give peat fires the potential to be a considerable source of PM and other toxic pollutants to the atmosphere

Questions?

Contacts:

Dr. Brian Gullett
Email: gullett.brian@epa.gov
Phone:919-541-1534

Dr. Ingrid George
Email: geroge.Ingrid@epa.gov
Phone: 919-541-9780

U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Research Triangle Park, North Carolina 27709

Journal Articles:

Black et al. 2016 Characterization of gas and particle emissions from laboratory burns of peat, Atmospheric Environment **132**:49-57

George et al. 2016 Volatile and semivolatile organic compounds in laboratory peat fire emissions, Atmospheric Environment **132**:163-170