

Chemical And Physical Characterisation of Biomass Burning Aerosol



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Introduction

Biomass burning contributes significantly to the global trace gas and aerosol burden. It is also an important source of elemental carbon as well as organic aerosols. Large scale wildfires occur naturally as well as the results of human activities in various parts of the world. Vegetation fire is among the most important biomass burning in terms of the climate effects and its particles primarily consist of decomposed lignin, cellulose, hemicellulose products as well as elemental carbon. Although considerable effort has been made by various studies to identify compounds in the biomass burning aerosol, only a limited number of data exist for the size segregated physical and chemical characterization of biomass burning particles under controlled condition. Thus, there is a need to characterize simultaneously biomass burning for physical and chemical properties in order to understand its effect on climate.

Experimental

A laboratory combustion facility designed to study gaseous species from biomass burning was used to produce aerosols under controlled conditions. The emission from the combustion facility was diluted in a container equipped with internal fans as a buffer in order to minimize sample overloading and temporal variability of samples. A field laboratory container was directly located underneath to sample particles in the first stage buffer container. The sample transfer line from the buffer container to a dilution tunnel was approximately 1.5 m. The sample was diluted 20 times with a dilution tunnel in the field laboratory container using clean compressed air. The dilution tunnel was connected to particle sampling devices for chemical analysis together with various physical instruments for the measurements of size distribution, scattering, absorption and total particle concentration. In order to simulate wildfire conditions rather than fireplace or domestic heater burning conditions various parts of tree were burned in different mixture depending on the availability of burning materials. In order to have representative and comparable data for different kind of combusted biomass fuels, an average around 7% for the ratio of excess CO to CO₂ (dCO/dCO₂) was set as a target for the combustion condition which is generally found in typical biomass burning in nature. Table 1 shows general experimental information for the selected experiments. Pine wood, pine wood with dry underbrush and pine wood with green needles were chosen to show the influence of vegetation parts combusted on the emitted particles. Indonesian peat and Northern German peat were also selected in order to illustrate the differences between fresh biofuels and "fossil" biofuels.

Table 1. General experimental information

Date	Exp. No.	Fuel	Average dCO/dCO ₂ (%) ^b
01.07.03	9a	Pine with green needles	6
02.07.03	11a	Pine with dry needles	3
03.07.03	12a	Pine	4
25.07.03	25a	Indonesian peat ^a	47
26.07.03	26a	Northern German peat ^a	39

^a: samples were dried prior to the combustion session
^b: courtesy of Dr. R. S. Parmar and Dr. G. Helas, Max Planck Institute for Chemistry, Mainz.

Chemical analysis

Samples for chemical analysis were taken using two 5 stage Berner type impactors and four stack filters. The methods used for the chemical analysis were a thermographic method for OC/EC, ion chromatography for inorganic ions, Shimadzu TOC (total organic carbon) analyzer for WSOC, CE-ESI-MS (Capillary Electrophoresis Electrospray Ionization Mass Spectroscopy) for individual organic species.

Figure 1 shows the ratio of OC and EC to TOC (Total Organic Carbon) for the pine, pine with dry underbrush, pine with green needles, Indonesian peat and northern German peat. Higher EC values can be explained by the lower dCO/dCO₂ ratio as the flaming fire produces much higher concentration of EC. Smoldering fires of both kinds of peat materials produced much lower EC fractions than flaming fire from pine woods because the smoldering process produces more volatile/semi-volatile wood decomposition compounds by direct vaporization of wood structure.

Table 2 summarizes the list of detected softwood/hardwood tracers for various biofuels. Emission ratios of tracers cannot be determined at this moment as some key parameters for the determination of emission ratio calculation are still in progress. No hardwood tracer was found from all pine wood combustions as the pine wood contains gymnosperm lignin enriched in coniferyl alcohol products. It is interesting to note that the addition of green or dry needle produced 4-hydroxycinnamic acid which is typically found in grass combustion. Contrary to softwood characteristics of pine wood combustion, peat smoke is enriched in all three groups of tracer compounds. This is not surprising as the peat is formed through a sequence of geo-bio-physical and chemical transformation of various plant remains. Therefore, tracers in peat smoke are expected to be maturity and origin (i.e. sampling location) specific. The mass fraction of impactor samples from Indonesian peat and German peat show significant differences for smaller particles. Figures 2A and 2B show the mass fraction of OC, EC, WSOC, inorganic ions and unresolved mass found on impactor stages from the samples of Indonesian and Northern German peat combustions (exp. 25 and 26). Notable differences are relatively high WSOC and inorganic ion fractions of Northern German peat on the stage 1 compared to Indonesian peat. This data seems to support the finding of the CCN (Cloud Condensation Nuclei) measurement from MPI which showed higher number of activated CCN for smaller particles from Northern German peat.

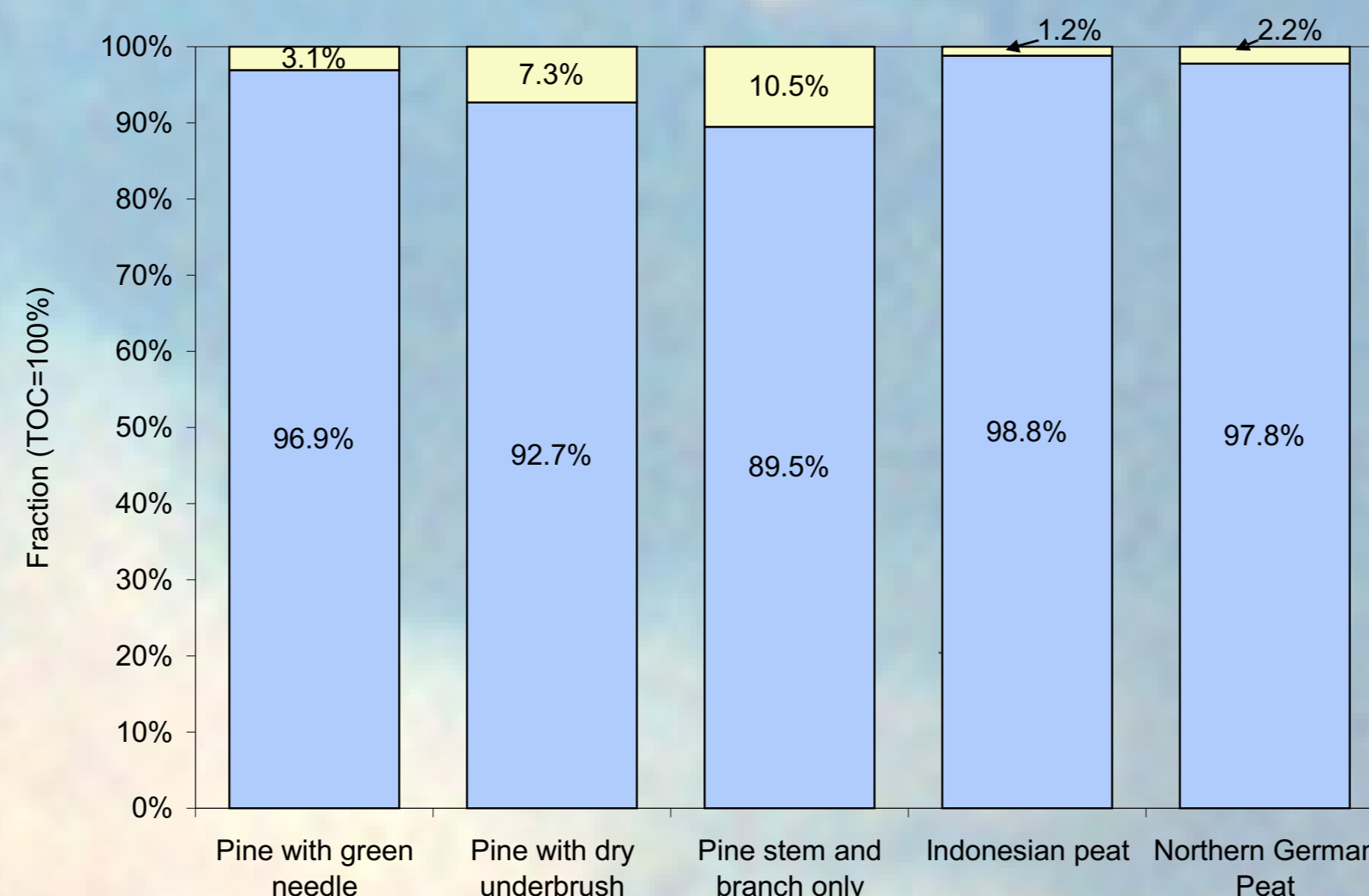


Figure 1. The ratio of OC (Organic Carbon) and EC (Elemental Carbon) to TC (Total Carbon) for various biofuel materials.

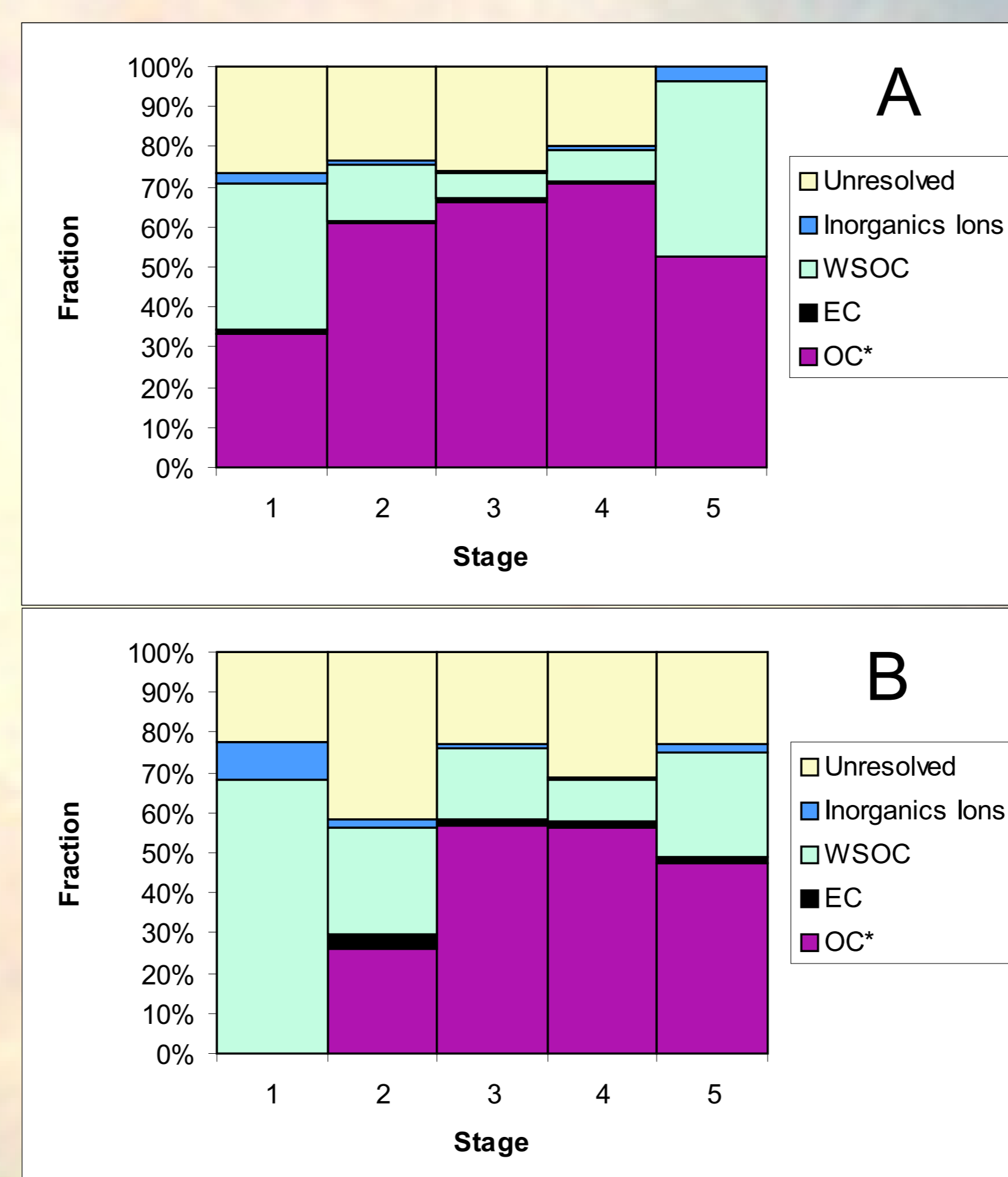


Figure 2A and B. Mass fraction of smoke from Indonesian peat (A) and Northern German peat (B) from Berner impactor sample. (Stage 1: 0.05–0.14µm, 2: 0.14–0.42µm, 3: 0.42–1.2µm, 4: 1.2–3.5µm, 5: 3.5–10µm.)

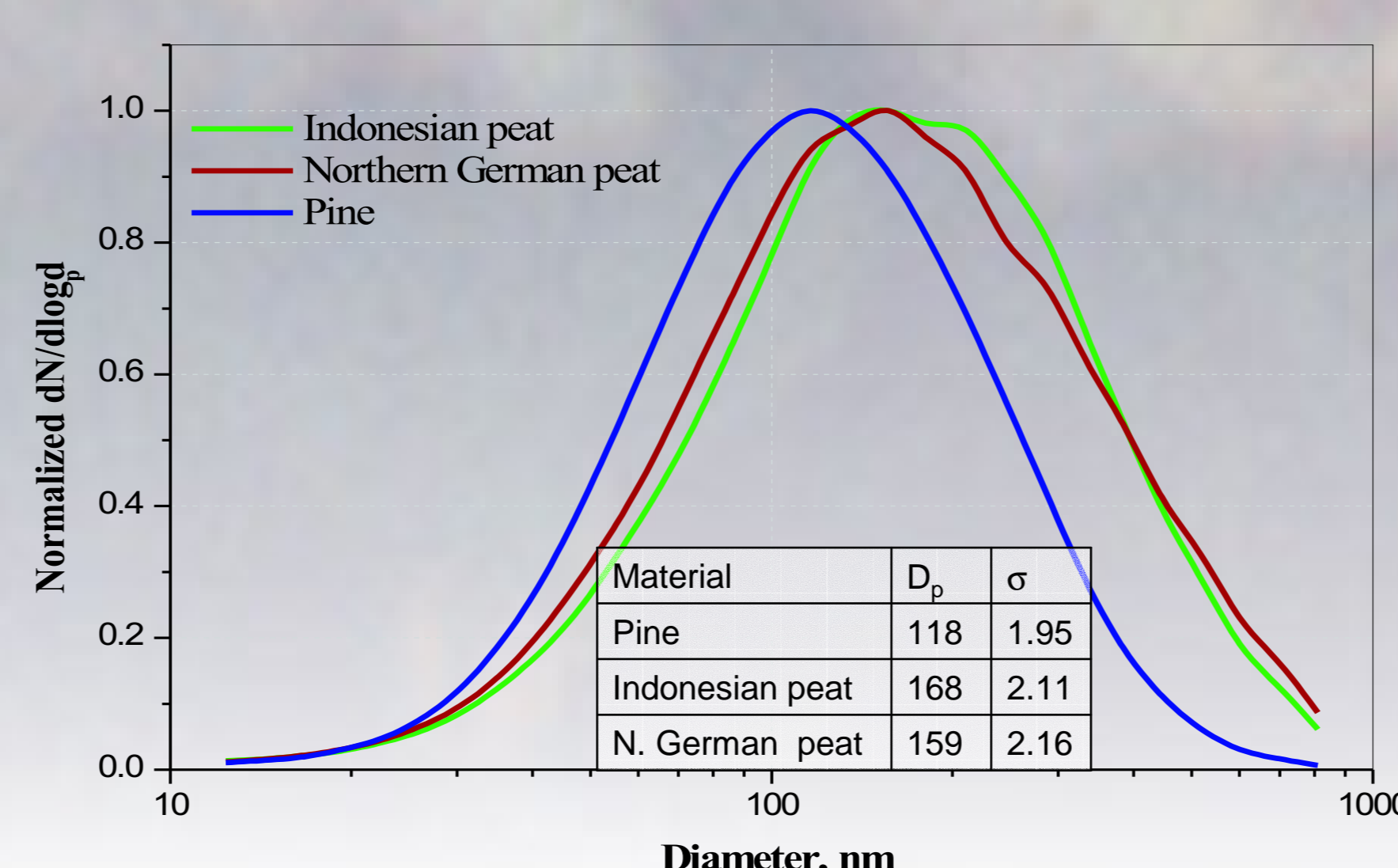


Figure 3. Aerosol particle size distributions for pine and Indonesian peat averaged over the whole experiment (~1hour). Number concentrations are normalized to their

Table 2. List of detected soft/hard wood combustion tracers from various biofuel combustions

Tracer	Source wood type	9a	11a	12a	25a	26a
		01/07/03 Pine with green needles	02/07/03 Pine with dry underbrush	03/07/03 Pine branch and stems only	25/09/03 Indonesian peat	26/09/03 Northern German peat
4-hydroxycinnamic acid	Grass	o	o	x	o	o
3,5-dimethoxy-4-hydroxyacetophenone	Hard	x	x	x	o	o
Sinapic acid	Hard	x	x	x	o	o
Syringic acid	Hard	x	x	x	o	o
3-hydroxy-4-methoxybenzoic acid	Soft	o	o	o	o	o
Coniferyl aldehyde	Soft	o	o	o	o	x
Ferulic acid	Soft	o	x	x	x	o
Homovanillic acid	Soft	x	o	o	o	o
Vanillic acid	Soft	x	x	x	x	o
Vanillin	Soft	o	o	o	o	o
Levogluconan	Soft/Hard	o	o	o	o	o

o: detected, x: not detected

Physical measurements

Size distributions and fitting parameters (mode diameter, D_p and geometric standard deviation, σ) of Indonesian and Northern German peat and pine are shown in Figure 3. Size distributions from both kinds of peat (Indonesian and Northern German) looked very different from boreal wood. The shape of the distribution is similar for both kinds of peat, but it is quite different from the size distributions of pine (size distributions from other boreal wood were similar to pine). The distribution is much wider for peat and much larger particles were produced during the combustion of peat. The combustion of peat was very different from fresh wood materials. After the initial ignition, it moved quickly from flaming to smoldering phase and kept smoldering for the duration of experiments without extinction. On the other hand, boreal wood needed constant addition of fresh wood material otherwise temperatures became too low even for smoldering. Both kinds of peat had very high dCO/dCO₂ ratios, ranging up to 50%, indicating the dominance of smoldering phase during the experiments. The tendency to produce larger particles during the smoldering phase than during flaming was noticed already during experiments with Boreal wood. It is interesting to note that the amount of combusted peat was much smaller than that of boreal wood, yet the emission ratios of both kinds of peat were much higher than that of boreal wood. Much more moderate burning condition of peat means chemical reactions which took place in peat combustion were less destructive and probably produced larger molecular weight compounds with lower vapor pressures leading to more intense particle formation.

Summary

Physical and chemical properties of emitted particles vary significantly by the materials and the phase of combustion. The dataset obtained during the EFEU campaign will be used for the numerical models employed to investigate the impact of biomass burning on the micro to regional scale atmosphere.

Acknowledgements

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