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Characterization of aerosol particles from grass mowing by joint deployment of ToF-AMS and ATOFMS instruments

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Abstract

During a measurement campaign at a semi-urban/industrial site a grass-cutting event was observed, when the lawn in the immediate surrounding of the measurement site was mowed. Using a wide variety of state-of-the-art aerosol measurement technology allowed a broad characterization of the aerosol generated by the lawn mowing. The instrumentation included two on-line aerosol mass spectrometers: an Aerodyne Time-of-Flight Aerosol Mass Spectrometer (ToF-AMS) and a TSI Aerosol Time-of-Flight Mass Spectrometer (ATOFMS); in addition, a selection of on-line aerosol concentration and size distribution instruments (OPC, APS, SMPS, CPC, FDMS-TEOM, MAAP) was deployed. From comparison of background aerosol measurements during most of the day with the aerosol measured during the lawn mowing, the grass cutting was found to generate mainly two different types of aerosol particles: an intense ultrafine particle mode (1 h average: $4\,\mu g\,m^{-3}$) of almost pure hydrocarbon-like organics and a distinct particle mode in the upper sub-micrometer size range containing particles with potassium and nitrogen-organic compounds. The ultrafine particles are probably lubricating oil particles from the lawn mower exhaust; the larger particles are swirled-up plant debris particles from the mowing process. While these particle types were identified in the data from the two mass spectrometers, the on-line aerosol concentration and size distribution data support these findings. The results presented here show that the combination of quantitative aerosol particle ensemble mass spectrometry (ToF-AMS) and single particle mass spectrometry (ATOFMS) provides much deeper insights into the nature of the aerosol properties than each of the instruments could do alone. Therefore a combined deployment of both types of instruments is strongly recommended.

Keywords: Lawn mowing; Aerosol mass spectrometry; ToF-AMS; ATOFMS

1. Introduction

A large variety of human activities, not only like driving motor vehicles, domestic heating, and industrial processes, but also recreational and garden care activities, are associated with gaseous and particulate emissions that affect ambient air quality. Especially in urban environments this results in air quality degradation, which can cause adverse health effects such as respiratory or cardiovascular diseases (e.g. Brunekreef and Holgate, 2002 and references therein). Lawn-care activities like grass cutting are typically performed

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using devices equipped with small utility engines. They are dominated by petrol-powered two- and four-stroke engines, known to contribute significantly to urban gas-phase and particulate hydrocarbon loadings as well as to those of other pollutants like CH_4, CO, NO_x, or PAH (Priest et al., 2004; Christensen et al., 2001).

Due to the potential health relevance of these emissions, some investigations of the characteristics of gaseous and particulate exhaust components of small utility engines and lawn mowers have been performed. Most of these studies were made on engine test benches (e.g. Gabele, 1997; Priest et al., 2004; Christensen et al., 2001; Ålander et al., 2005), while only very few investigations of emissions from lawn mowers in real-world use can be found in the literature (Junker et al., 2000; Karl et al., 2001). These studies demonstrate that these engines typically emit large quantities of CO and hydrocarbons (e.g. Priest et al., 2004), mainly because they are not optimized for low emissions like automobile engines, but for maximum power output at low engine weight (Ålander et al., 2005).

In addition to mower engine-related emissions, the lawn mowing also generates a variety of emissions associated with the grass-cutting process itself. One type of these emissions is mechanically generated particles like plant debris or swirled-up soil dust (Junker et al., 2000). The other kind is gaseous emissions of volatile organic compounds from the plants that occur as a consequence of leaf wounding (e.g. Karl et al., 2001; Kirstine et al., 1998). These vapors cause the typical smell of freshly cut grass and can contribute significantly to ambient VOC concentrations in affected environments (Karl et al., 2001), acting as precursors for secondary aerosol particle formation (Kirstine and Galbally, 2004). Milesi et al. (2005) estimate from satellite information that an area of approximately $160{,}000\,km^2$ is cultivated with lawn in the continental United States. This equals almost 2% of the total surface area of the country and about half of the urbanized area, having the potential to significantly contribute to the primary aerosol load and precursors of secondary aerosol components in populated regions and possibly beyond.

Very little information about the physical parameters of the aerosol generated during lawn mowing can be found in the literature (e.g. Junker et al., 2000; Christensen et al., 2001). Even less is available on in-situ characterization of its chemical composition. This is mainly due to the lack of adequate on-line aerosol measurement instrumentation. In recent years, aerosol mass spectrometry has become available as a powerful tool for the chemical on-line characterization of individual aerosol particles (Murphy, 2007) or small aerosol ensembles (Canagaratna et al., 2007). Here we report the measurement and characterization of aerosol particles generated by real-world grass cutting using two types of on-line aerosol mass spectrometers, i.e. the Time-of-Flight Aerosol Mass Spectrometer (ToF-AMS) and Aerosol Time-of-Flight Mass Spectrometer (ATOFMS), as well as a variety of on-line aerosol instrumentation for particle concentration and size distribution measurements. These measurements were performed during a day of a 2-week field campaign, when the lawn around the instruments was mowed.

2. Experimental

2.1. Site description

The measurement site where the grass-cutting aerosol was observed was located on a lawn of approximately $30 \times 80\,m^2$ on the backyard of a small nursing home at a semi-urban/industrial site in Southern Wales, UK. The air-quality situation at the site was characterized by clean background air masses from the central North Atlantic Ocean with pollutants from local emissions of various industrial or traffic-related sources—depending on wind direction. These sources include a motorway, passing the site at a distance of approximately 100 m, a small city (36,000 residents) at a distance of $\sim$4 km and various industrial sites in different directions and distances. Local sources in the immediate vicinity of the site are limited to a few passenger vehicles per day from the nursing home staff and a handful of heavy-duty vehicles delivering or collecting goods for and from the nursing home.

The meteorological situation at the site was dominated by a distinct sea breeze with winds from the land to the sea during the late evening and the night and in the opposite direction during the day. Daily average temperatures ranged between 9 and 13 °C during the night and 10–20 °C during the days. During the measurement period, very little precipitation was observed. The day during which the grass cutting was performed was mainly cloudy, but without precipitation. On this day the ambient temperature increased from $\sim$10 °C in the morning to approximately 14 °C in the afternoon. At the