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Significant contributions of fungal spores to the organic carbon and to the aerosol mass balance of the urban atmospheric aerosol

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ABSTRACT

Fungal spores are ubiquitous components of atmospheric aerosols and are therefore also contributors to the organic carbon (OC) component and to the mass of PM_{10} (PM—particulate matter) aerosols. In this study we use spore counts and an experimentally derived factor of 13 pg C and of 33 pg fresh weight per spore for assessing quantitatively the contribution to OC and PM_{10}. The concentrations of airborne fungal spores were determined at a suburban (Schafberg) and a traffic-dominated urban site (Rinnböckstrasse) in Vienna, Austria, during spring and summer. Fungal spores OC ranged from 22 to 677 ng m^{-3} with a summer mean value of around 350 ng m^{-3} at the suburban site and 300 ng m^{-3} at the urban traffic site. At the suburban site fungal spores contributed on average 6% in spring and 14% in summer to aerosol OC mass concentration. At the traffic-dominated site fungal spores accounted for 2% of OC in spring and for 8% in summer. The fungal contribution to PM_{10} was also notable and amounted to 3% and 7% at the suburban and to 1% and 4% at the urban site in spring and summer, respectively. Impactor measurements of OC at the suburban site showed that in summer fungal spores were predominant contributors to the coarse aerosol OC, and accounted on average for 60% of the OC in the PM_{2-10} fraction. Fungal spores thus can be regarded as main components to PM_{10}, total OC and, most importantly, coarse OC even in urban areas.

1. Introduction

The importance of the contribution of primary biogenic particles to the organic ambient aerosol has become increasingly apparent in recent years. Bioparticles might be allergenic, they might be harmful themselves or carry harmful substances (e. g. endotoxins) (Menetrez et al., 2007), and, because of their size, they might contribute significantly to particulate matter (PM) mass concentrations even if they have low number concentrations compared with non-bioparticles. If PM_{10} is regulated for public health reasons, the relative contribution of non-anthropogenic sources is also of interest for policy-makers.

Quantitative assessment of bioparticles can be achieved by several approaches, including counting individual particles such as bacteria and fungal spores under the microscope (e.g. Glikson et al., 1995; Sattler et al., 2001; Ho et al., 2005). Other biomaterials, such as leaf matter, can be estimated by measuring cellulose which is considered as a macro-tracer (Kunit and Puxbaum, 1996; Puxbaum and Tenze-Kunit, 2003). Alternatively, some minor chemical compounds can be used as micro-tracers once the numerical factors have been established. Polysaccharides (Douwes et al., 1999), phospholipids (Womiloju et al., 2003), sugar alcohols (Carvalho et al., 2003; Graham et al., 2003; Bauer et al., 2008), proteins (Boreson et al., 2004) and ergosterol (Miller and Young, 1997) have

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all been considered in this role. Quite a different approach is to build a chemical profile of each source material and to analyze the total PM by Chemical Mass Balance modelling (e.g. Simoneit and Mazurek, 1982; Simoneit, 2005; Rogge et al., 2006). Other studies (Matthias-Maser et al., 2000; Jaenicke, 2005) have estimated the contribution of bioparticles to the total aerosol in terms of number concentrations. Whichever approach is adopted, the aim is to apportion the total PM to different sources so that they can be ranked in order of their contribution.

Earlier work on atmospheric bioparticles focused on the detection of pathogenic or allergenic microorganisms or pollen. As the spores of many fungal species are known to be potential respiratory allergens (Green et al., 2003; Panaccione and Coyle, 2005; Crameri et al., 2006), most studies concerning fungal spores deal with exposure estimates for airborne fungi. Such studies report concentrations of fungal spores or of spores of different fungal species in the atmosphere (Glikson et al., 1995; Sattler et al., 2001; Ho et al., 2005). The majority of investigations into bioaerosols in general and airborne fungi in particular refer only to the culturable part of the fungal spectrum (e.g. Boreson et al., 2004; Di Giorgio et al., 1996; Lin and Li, 2000; Fang et al., 2005), however, culturable fungi (concentrations expressed as colony-forming units CFU m^{-3}), represent only a limited fraction (usually $<40\%$) of the total airborne fungal spectrum (Lappalainen et al., 1996; Lee et al., 2006). In fact, all bioaerosols—pathogenic or not, allergic or not, dead or alive, are contributors to the aerosol organic carbon (OC), and need to be assessed in terms of their mass contribution to the PM aerosol.

Fungal spores as observed from atmospheric sampling occur predominantly in the size range 2–10 μm (Burge, 2002). Size classified analyses of the sugar alcohols mannitol and arabitol which are chemical tracers for fungal spores, performed in Germany (Carvalho et al., 2003) and in Amazonia (Graham et al., 2003) showed that they mainly occur in the coarse size fraction (aerodynamic diameter, aed $> \sim 2.5\,\mu$m). However, at a site in Finland, spore tracers were also found in the fine fraction ($PM_{2.5}$) (Carvalho et al., 2003). In Amazonia both fragments and some entire spores were detected in the fine aerosol (Graham et al., 2003).

The OC associated with bacteria and with fungal spores in background samples collected at an alpine station has already been reported (Bauer et al., 2002a). Elbert et al. (2006) recently reported high contributions to PM—averaging 35% by weight—from fungal spores in Amazonia. However, of greater interest for air quality control authorities in Europe would be the extent of the contribution in densely populated areas. This paper reports spore counts and estimated masses of spores in PM for an urban and a suburban site in Vienna, Austria, and shows that here the contribution especially to the coarse fraction OC is considerable, which helps to account for some of the "unidentified" organic material in airborne PM.

2. Experimental section

2.1. Sampling sites

Samples were taken in parallel at a suburban and an urban site in Vienna from the end of March to July 2005. The suburban site "Schafberg" [16°18′10″E, 48°14′09″N] is

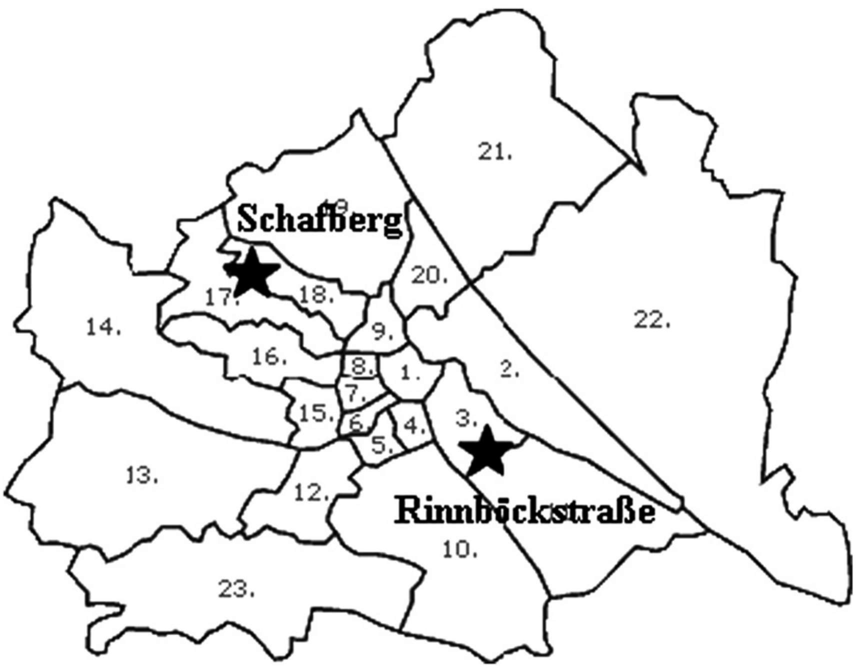

Fig. 1. Map of the city of Vienna, Austria. The urban sampling site (Rinnböckstrasse) is located near the center, the suburban site (Schafberg) is located in the north-west of Vienna.