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Prevalence of culturable airborne spores of selected allergenic and pathogenic fungi in outdoor air

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Abstract

Temporal and spatial variations in airborne spore concentrations of selected allergenic and pathogenic fungi were examined in Dublin, Ireland, in 2005. Air samples were taken at four outdoor locations in the city every 2 weeks, coupled with measurements of meteorological conditions. Total culturable airborne fungal spore concentrations in Dublin ranged from 30–6800 colony forming units per cubic metre of air (CFU m^{-3}) over the 12-month period. *Cladosporium*, *Penicillium*, *Aspergillus* and *Alternaria* spores were constantly present in the Dublin atmosphere, representing $>20\%$ of the total culturable spore count. Concentrations of *Cladosporium* increased significantly in summer and reached allergenic threshold levels, peaking at over 3200 CFU m^{-3} in August. *Penicillium* spore concentrations never reached allergenic threshold levels, with average concentrations of <150 CFU m^{-3}. Alternaria conidia formed only 0.3% of the total culturable fungal spore count and concentrations never exceeded 50 CFU m^{-3}, attributable to the coastal position of Dublin and its low levels of arable production. The opportunistic human pathogen *Aspergillus fumigatus* was present throughout the year in nominal concentrations (<10 CFU m^{-3}), but sporadic high counts were also recorded (300–400 CFU m^{-3}), the potential health implications of which give cause for concern. Spores of neither *Cryptococcus neoformans* nor *Stachybotrys chartarum* were detected, but airborne basidiospores of *Schizophyllum commune* were evidenced by the dikaryotization of monokaryon tester strains following exposure to the air. The relationships between airborne fungal spore concentrations and meteorological factors were analysed by redundancy analysis and revealed positive correlations between temperature and *Cladosporium* and relative humidity and *Penicillium* and *Aspergillus*.

Keywords: Allergenic fungi; Dublin; Fungal spores; Human pathogens; Seasonal variation; Urban air

1. Introduction

Fungal spores are ubiquitous in outdoor air and often constitute the dominant biological component of air (Gregory, 1973). The diameter of most fungal spores falls in the range 2–10 μm, allowing easy penetration of the lower airways of the human respiratory tract, from where infection by pathogens and their subsequent dissemination is possible. The allergenic and pathogenic potential of a range of fungi is well established, for example, spores of *Alternaria*, *Aspergillus*, *Penicillium* and *Cladosporium* spp. are responsible for causing an array of respiratory conditions, from allergic rhinitis to asthma (Kurup et al., 2000). Aspergilli such as *Aspergillus fumigatus* and *Aspergillus niger* can also

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cause a range of invasive pulmonary diseases, generally termed aspergillosis (Marr et al., 2002). Exposure to fungal spores occurs mostly indoors nevertheless, outdoor air is an important source of both aeroallergens and pathogens (Curtis et al., 2006).

Aspergillus fumigatus is the most prevalent airborne human pathogen, responsible for ca. 90% of all invasive aspergillosis cases (Denning, 1998). Marked increases in the incidence of invasive aspergillosis have occurred over the last two decades, due to increases in the numbers of solid organ and bone marrow transplantations being performed, the development of aggressive immunosuppressive and chemotherapeutic treatments and the emergence of the HIV/AIDS pandemic (Munoz et al., 2006). Lin et al. (2001) reported that from 1995 to 1999 the overall case-fatality rate (CFR) associated with invasive aspergillosis was 58%, with an 87% CFR for bone marrow transplant recipients, despite the availability of new antifungal treatments. *A. fumigatus* is thermotolerant, growing best at 37 °C and capable of growth up to 52 °C (Kozakiewicz and Smith, 1994), a trait that facilitates its proliferation in self-heating compost heaps (Beffa et al., 1998). The necessary mechanical turning/rotation of industrial-scale composters in order to achieve aeration can result in the dispersal of enormous numbers of *A. fumigatus* conidia (typically 100-fold higher than background levels) that migrate in air posing risks to the health of susceptible individuals in adjacent areas (Sánchez-Monedero and Stentiford, 2003). Litigation by at-risk individuals has succeeded in blocking the development of a composting facility in a residential area in Dublin (Moore, 2004).

Large-scale industrial composting of green waste is a relatively new phenomenon in Ireland; of the 32 facilities composting organic waste in 2005, 27 had been established within the past 5 years (Collins et al., 2005). Over the next decade both the private sector and local authorities will come under increasing pressure to find suitable sites for composting as the Irish Government aims to establish biological treatment facilities in order to meet the requirements set out in the European Community Landfill Directive (EC, 1999). This directive was transposed into Irish law on the 2 July 2002, making it a requirement for Ireland to reduce the amount of biodegradable municipal waste going to landfill to some 450,000 tonnes per annum by 2016 (35% of the amount produced in 1995) (DoEHLG, 2006). In order to achieve these targets an estimated 442,000 tonnes per annum of green waste will have to be composted by 2016, >5 times the amount composted in 2004 (Collins et al., 2005; DoEHLG, 2006). In addition to industrial-scale composting, many households now compost garden and domestic waste with incentive from local authorities (Anon, 2005). Notwithstanding this significant increase in composting activity, baseline bioaerosol data is not currently available for outdoor air in Ireland. Sampling is therefore needed in order to determine background levels of *A. fumigatus* and other microbes in air, so that the risks to human health can be assessed, as has already been done in the UK (Taha et al., 2006).

Cryptococcus neoformans, the etiologic agent of cryptococcosis, is another major airborne opportunistic fungal human pathogen, with immuno-compromised patients particularly at risk. The yeast is routinely recovered from bird droppings, especially from pigeons (*Columba livia*) and as such can be found in urban areas where pigeons congregate (Granados and Castañeda, 2005). The incidence of cryptococcosis continues to increase worldwide due to the HIV/AIDS pandemic (Mitchell and Perfect, 1995).

The basidiomycete *Schizophyllum commune* is best known as a saprotroph of woody plant materials but is increasingly being reported as an emerging human pathogen (Baron et al., 2006). It causes both allergic conditions and invasive diseases of the human respiratory system, especially the sinuses (Buzina et al., 2003); however, its occurrence as a human pathogen is probably underestimated since monokaryotic cultures of *S. commune* do not produce the characteristic basidiomes in culture (Pounder et al., 2007). *S. commune* is now of widespread occurrence as a contaminant fungus on baled silage in Ireland (Brady et al., 2005) and sporulating basidiomes are often seen protruding through the polythene film on bales. As *Schizophyllum* basidiospores are readily airborne and dispersed over long distances (James and Vilgalys, 2001), it raises concerns that spores of this emerging human pathogen may be commonly present in air in Ireland.

The toxigenic fungus *Stachybotrys chartarum* is also of concern to human health, as both aerosolized conidia and hyphal fragments of the fungus have been shown to contain mycotoxins (Brasel et al., 2005). Stachylysin, a haemolysin, is produced by the fungus and has been implicated as causing