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Evaluation of biomass burning across North West Europe and its impact on air quality

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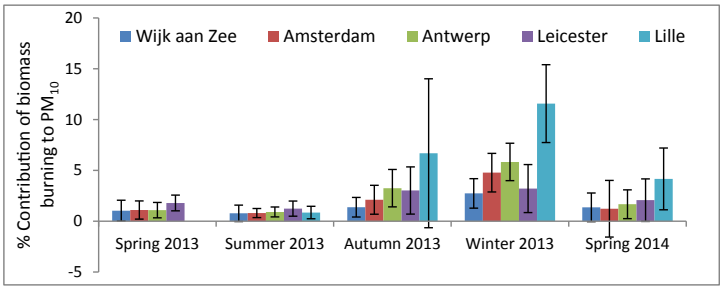
HIGHLIGHTS

- Biomass burning has the largest contribution to PM_{10} between November and March.
- The contribution of biomass burning in winter to PM_{10} ranges from 2.7% to 11.6%.
- Poor temperature correlation shows biomass burning is not a primary heating source.
- Effects of burning on air quality are normally only likely to be evident locally.
- Large organised biomass burning events can threaten air quality on a wider scale.

GRAPHICAL ABSTRACT



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ABSTRACT

Atmospheric particulate pollution is a significant problem across the EU and there is concern that there may be an increasing contribution from biomass burning, driven by rising fuel prices and an increased interest in the use of renewable energy sources. This study was carried out to assess current levels of biomass burning and the contribution to total PM_{10} across five sites in North-West Europe; an area which is frequently affected by poor air quality. Biomass burning was quantified by the determination of levoglucosan concentrations from PM_{10} aerosol filters collected over a 14 month period in 2013/2014 and continued for a further 12 months at the UK site in Leicester. Levoglucosan levels indicated a distinct period of increased biomass combustion between November and March. Within this period monthly average concentrations ranged between 23 ± 9.7 and 283 ± 163 ng/m^3, with Lille showing consistently higher levels than the sites in Belgium, the Netherlands and the UK. The estimated contribution to PM_{10} was, as expected, highest in the winter season where the season average percentage contribution was lowest in Wijk aan Zee at 2.7 ± 1.4% and again highest in Lille at 11.6 ± 3.8%, with a PM_{10} mass

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concentration from biomass that ranged from 0.56 μg/m^3 in Leicester to 2.08 μg/m^3 in Lille. Overall there was poor correlation between the levoglucosan concentrations measured at the different sites indicating that normally biomass burning would only affect atmospheric particulate pollution in the local area; however, there was evidence that extreme burning events such as the Easter fires traditionally held in parts of North-West Europe can have far wider ranging effects on air quality. Network validation measurements were also taken using a mobile monitoring station which visited the fixed sites to carry out concurrent collections of aerosol filters; the result of which demonstrated the reliability of both PM_{10} and levoglucosan measurements.

1. Introduction

Exposure to atmospheric particulate matter (PM) has been shown to have detrimental effects on health, in particular in vulnerable groups such as the elderly, children and those with pulmonary or cardiovascular disease (Englert, 2004; Peden, 2005; Pope et al., 2002). There are a variety of anthropogenic activities which contribute to total PM_{10} including energy production, transport, agriculture and industry; emissions from many of which have decreased over the last 20 years (European Environment Agency, 2014). There is, however, increasing concern regarding the increasing contribution of biomass burning to total PM_{10}. Air pollution from biomass burning in some regions of Europe, such as in Scandinavia and Alpine areas, has for a long time been considered a significant contributor to atmospheric PM (Fuller et al., 2013). In some alpine areas in Europe, where wood burning is the predominant domestic heat source, biomass smoke can comprise more than 50% of the organic PM produced in the winter season (Puxbaum et al., 2007). More recently, evidence is emerging suggesting that this problem is no longer limited to these areas and that biomass burning is becoming an increasingly widespread problem across the whole of Europe (Puxbaum et al., 2007; Maenhaut et al., 2012; Yttri et al., 2009; Piazzalunga et al., 2011; Fuller et al., 2014).

There are several factors which are likely to be contributing to this ongoing increase in biomass combustion. One large driving force is the effort of the European Union to reduce its use of fossil fuels and increase the use of renewable energy, which is driving a return to biomass burning (Fuller et al., 2013). Current EU forecasts are anticipating a 57–110% increase in biomass burning between 2010 and 2020 (Wagner et al., 2010). Other schemes on a national level have similar aims; for example in the UK the Department for Energy and Climate Change has developed the world's first long-term financial support programme for renewable heat, known as the Renewable Heat Incentive (Department of Energy and Climate Change, 2010). The scheme pays participants who generate and use renewable energy to heat their buildings. Finally, the increasing costs of traditional fuel sources are also having an effect: for example in Denmark increasing fossil fuel costs have contributed to a doubling in the number of wood stoves and boilers over a ten year period (Glasius et al., 2006).

The ability to quantify the contribution of biomass burning to total atmospheric PM is, therefore, becoming increasingly important for air quality management. Although several markers of biomass burning have been applied for this purpose previously, the cellulose-specific monosaccharide anhydride, levoglucosan, is often considered the marker of choice. Levoglucosan has several advantages as a biomass burning marker: it is emitted in relatively large quantities, improving the consistency of its measurement; it is subject to little interference from other sources; it has relatively high stability in the atmosphere (Puxbaum et al., 2007; Fraser and Lakshmanan, 2000) and its reliability has already been demonstrated previously in several studies (Elias et al., 2001; Simoneit, 2002; Simoneit et al., 1999). Examining the ratios of levoglucosan to its isomers can also give further valuable information for the source identification of the specific type of biomass burnt. The combustion of lignite, for example, has been shown to produce either very low or undetectable levels of mannosan or galactosan (Fabbri et al., 2008, 2009), whereas significantly higher levels are produced from the combustion of contemporary biomass. Furthermore different types of contemporary biomass, such as softwoods and hardwoods (Caseiro et al., 2009; Louchouarn et al., 2009; Schmidl et al., 2008) and grasses and scrubland (Garcia-Hurtado et al., 2014) have been shown to exhibit source specific mannosan to galactosan ratios.

Exposure to ambient PM pollution is now ranked 9th worldwide and 11th in Western Europe in the list of risks to public health (Lim et al., 2012) and concentrations of particulate pollution have been particularly problematic over the region in recent years, where there have been several episodes of extended breaches of EU air quality limits. This study aimed to quantify current concentrations of levoglucosan present in atmospheric PM in order to estimate levels of contribution of biomass burning to total PM_{10} and to determine possible biomass sources. The study was carried out between April 2013 and May 2015 as part of the Joint Air Quality Initiative Project (Hofman et al., 2016) over which time PM_{10} filters were collected at five locations in the North-West Europe region: Leicester (UK), Wijk aan Zee and Amsterdam (the Netherlands), Antwerp (Belgium) and Lille (France), (Fig. 1) and levoglucosan levels quantified using a previously validated GC-MS method (Cordell et al., 2014). The sites selected avoided the more studied megacites such Paris or London with very high population densities, in order to capture a more typical representation of biomass derived PM_{10} levels that the majority of the population are exposed to across the region.

2. Experimental

2.1. Aerosol collection, PM_{10}

Samples were collected daily (24 h exposure) onto 47 mm quartz filters (Pall Tissuquartz™, 2500 QAT-UP) using a sequential sampler Sven Leckel SEQ47/50 for Antwerp, Lille and Leicester or a Derenda PNS 16 for Amsterdam and Wijk-aan-zee with a PM_{10} inlet, running at 2.3 m^3/h for 24 h per filter. Filters were weighed before and after sampling in order to determine total PM_{10} collection. For pre- and post-sampling weighing filters were conditioned at 20 ± 1 °C and 50 ± 5% relative humidity for 48 h, weighed, left for a further 24 h and then re-weighed.

Aerosol samples were collected at fixed air quality monitoring sites in Amsterdam, Antwerp, Wijk aan Zee, Lille and Leicester (Table 1). All Leicester measurements were taken at the Defra AURN