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Linking particle number concentration (PNC), meteorology and traffic variables in a UK street canyon

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ABSTRACT

Ambient particle number concentration (PNC) has been linked with adverse health outcomes such as asthma, reduced lung function and cardiovascular disease. To investigate the relationship between PNC, meteorology and traffic we measured size segregated respirable particles in a busy commuter street in Swansea, UK for ten months using a Dekati Electrical Low Pressure Impactor (ELPI). The ELPI segregates particles into 12 size fractions between 7 nm and 10 μm. The median PNC for the sampling period was 31,545 cm^{-3}. For the ultrafine particles (7–93 nm), the highest PNC was found in winter (46,615 cm^{-3}; 15 minute average) and the lowest for that size fraction in summer (29,696 cm^{-3}). For the particles below 93 nm there was a trimodal distribution to weekdays (particularly Monday to Wednesday), with PNC peaks at 09:00, 16:00 and 23:00. Wind direction had a significant influence on PNC and differed between particles in the fine range (below 2.5 μm) and more coarse particles (up to 10 μm). For fine particles, winds parallel to the canyon were associated with higher PNCs which were attributed to the replenishment of traffic particles. For coarse particles, PNCs were higher from winds perpendicular to the canyon and this was linked to source distribution around the sampling site and the recirculation of pollutants within the canyon. During times when vehicle volumes were high and vehicles were exhibiting stop–start behaviour, if this was combined with low wind speeds, ultrafine PNC was highest. This effect was generally observed during the morning rush hour. Current mass-based legislation does not take into account exposure to the number of particles or the change in population exposure diurnally.

1. Introduction

Despite decreases in particle emissions over the last fifty years, exposure to airborne particles is currently believed to cause a life length reduction of 6 months averaged across each UK citizen (COMEAP, 2010). Numerous potential health effects have been proposed to result from exposure to particles, including asthma, reduced lung function, and cardiovascular disease (e.g. Link et al., 2013). The investigation into the health effects from exposure to atmospheric particles has traditionally revolved around changes in the mass concentration, in line with legislative standards. Only a very small subset of the studies carried out have investigated the effect of changes in Particle Number Concentrations (PNCs), and results have been mixed. In one bicycle commuting study (Strak et al., 2012), participants were exposed to atmospheric particles for a five hour period. The authors found a consistent relationship between increased PNC and increased acute airway inflammation (measured as fractional exhaled nitric oxide; FE_{NO}). A study across five European cities (Lanki et al., 2006) found a weak association between PNC and acute myocardial infarction. In a multicentre European study (von Klot et al., 2005),

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cardiac readmissions were associated with same day PNCs (RR 1.026 [95% confidence interval 1.005 to 1.048] per 10,000 particles cm^3). This suggests that even short periods of time spent in locations with high PNCs, e.g. during commuting, could have significant health impacts.

Traffic (through both exhaust and non-exhaust inputs) is a major contributor to PNCs near roads (Padró-Martínez et al., 2012; Quiros et al., 2013). There are complex relationships between vehicle inputs to PNC at the roadside, and how these concentrations are transformed by factors including the street geometry and the meteorology (Kumar et al., 2008a). Whilst the length of time spent in roadside locations may be relatively low (e.g. during the daily commute), the high number of particles people are exposed to during this time mean that there may still be significant health consequences. In addition, outdoor particles make a contribution to indoor particles, which people are exposed to for longer periods of time. By furthering our understanding of the short term changes in PNCs in different urban areas, we can begin to provide advice and guidance to the public to enable them to make informed choices about their exposure to particles.

There is currently a lack of detailed understanding of the influence of traffic volume and meteorology on particles in the atmosphere (Kumar et al., 2009). Previous studies investigating the response of PNCs to meteorological conditions and traffic variables have often investigated total PNC (Harrison and Jones, 2005), or have been in-depth but short term (Pirjola et al., 2012). The aim of this study was to investigate the effect of traffic and meteorology on size-segregated PNC in a street canyon with a high temporal and particle size resolution. Our specific objectives were to collect PNC data in twelve size fractions between 0.007 and 10 μm (respirable particles) over the course of ten months. Meteorological and vehicle data were collected simultaneously, and the variables were investigated statistically. The unique strengths of this campaign were the enhanced particle size resolution and ten month sampling period. This meant that this investigation provided novel and statistically vigorous information on the effects of traffic and meteorology on size-segregated particles in the atmosphere.

2. Experimental

2.1. Sampling location

Sampling took place at Neath Road in Swansea, UK. Neath Road is a main commuting road into and out of Swansea, and traffic was expected to be a significant contributor to local PNCs. Neath Road is a secondary road which runs parallel to the railway line (Fig. 1). The site is at the confluence of three valleys and the adjacent hills reduce lateral dissipation and encourage

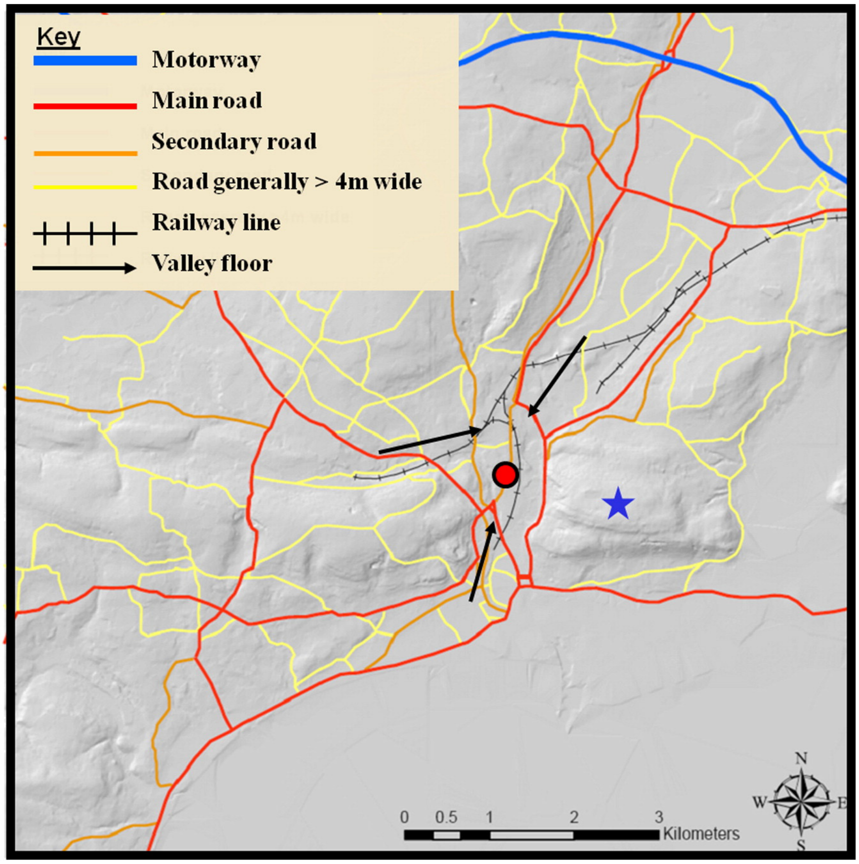

Fig. 1. Topographical map of the area surrounding the site (site indicated by dot at 25 m above sea level). Blue star indicates highest point, 192 m above sea level. Arrows indicate valleys which can funnel pollutants to the site. © Crown copyright 2009. An Ordnance Survey/EDINA supplied service. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)