Atmospheric Environment xxx (2015) 1–17

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Characterisation of nanoparticle emissions and exposure at traffic intersections through fast–response mobile and sequential measurements

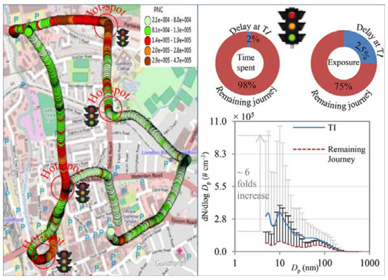
Anju Goel [a], Prashant Kumar [a, b, *]

[a] Department of Civil and Environmental Engineering, Faculty of Engineering and Physical Sciences (FEPS), University of Surrey, Guildford, GU2 7XH, United Kingdom
[b] Environmental Flow (EnFlo) Research Centre, FEPS, University of Surrey, Guildford, GU2 7XH, United Kingdom

HIGHLIGHTS

- Particle number size distributions were measured inside and outside the car.
- Peak number concentration at traffic signal was 29-fold of those during free–flow.
- Size-resolved inside to outside concentration ratio follows a power-law fit form.
- Number concentration is exponentially dependent on driving speed at intersections.
- About 2% of total commuting time at intersections corresponded to ~25% of total doses.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 19 November 2014
Received in revised form
1 February 2015
Accepted 2 February 2015
Available online xxx

Keywords:
Particle number concentration
Number size distribution
In–vehicle exposure
Respiratory deposition doses
Traffic intersections

ABSTRACT

Quantification of disproportionate contribution made by signalised traffic intersections (TIs) to overall daily commuting exposure is important but barely known. We carried out mobile measurements in a car for size–resolved particle number concentrations (PNCs) in the 5–560 nm range under five different ventilation settings on a 6 km long busy round route with 10 TIs. These ventilation settings were windows fully open and both outdoor air intake from fan and heating off (Set$_1$), windows closed, fan 25% on and heating 50% on (Set$_2$), windows closed, fan 100% on and heating off (Set$_3$), windows closed, fan off and heating 100% on (Set$_4$), and windows closed, fan and heating off (Set$_5$). Measurements were taken sequentially inside and outside the car cabin at 10 Hz sampling rate using a solenoid switching system in conjunction with a fast response differential mobility spectrometer (DMS50). The objectives were to: (i) identify traffic conditions under which TIs becomes hot–spots of PNCs, (ii) assess the effect of ventilation settings in free–flow and delay conditions (waiting time at a TI when traffic signal is red) on in–cabin PNCs with respect to on–road PNCs at TIs, (iii) deriving the relationship between the PNCs and change in driving speed during delay time at the TIs, and (iv) quantify the contribution of exposure at TIs with respect to overall commuting exposure. Congested TIs were found to become hot–spots when vehicle accelerate from idling conditions. In–cabin peak PNCs followed similar temporal trend as for on–road

---

* Corresponding author. Department of Civil and Environmental Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, GU2 7XH, United Kingdom.
E-mail addresses: P.Kumar@surrey.ac.uk, Prashant.Kumar@cantab.net (P. Kumar).

http://dx.doi.org/10.1016/j.atmosenv.2015.02.002
1352-2310/© 2015 Elsevier Ltd. All rights reserved.

peak PNCs. Reduction in in–cabin PNC with respect to outside PNC was highest (70%) during *free–flow traffic conditions* when both fan drawing outdoor air into the cabin and heating was switched off. Such a reduction in in–cabin PNCs at TIs was highest (88%) with respect to outside PNC during *delay conditions* when fan was drawing outside air at 25% on and heating was 50% on settings. PNCs and change in driving speed showed an exponential–fit relationship during the delay events at TIs. Short–term exposure for ~2% of total commuting time in car corresponded to ~25% of total respiratory doses. This study highlights a need for more studies covering diverse traffic and geographical conditions in urban environments so that the disparate contribution of exposure at TIs can be quantified.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Epidemiological studies have found an association between airborne nanoparticles (referred here to those below 300 nm to represent majority of particle number concentrations, PNCs) and cardiovascular and respiratory diseases (Gwinn and Vallyathan, 2006; Valavanidis et al., 2008). Recent studies have shown that commuters' exposure to average PNCs in urban areas can be ~1.5–times higher while travelling by car and buses compared with walking along roadsides (Kaur et al., 2005). Even a brief exposure to high PNCs can contribute to significant proportion of daily average exposure. For instance, the work of Fruin et al. (2008) showed that ~6% of total commuting time spent in car in American road environment can contribute ~36% of daily average exposure (i.e. sum of indoor, outdoor and in–vehicle exposure) to PNCs. Similarly, Dons et al. (2012) showed that ~3.6% of daily time spent in transport microenvironment (i.e. car) in Belgium contributed to ~14.5% of average daily exposure to PNCs. Similar contribution of exposure to PNCs during commuting can be expected for individuals living in UK and elsewhere (Knibbs et al., 2011). What is currently unknown from published studies is that how much fraction of total commuting exposure occurs while travelling through the traffic intersections (TIs), which is one of focus area of this study.

As on 2013, there are 29.1 million cars and 1.2 million motorcycles in UK, comprising ~30 million personal vehicles; about 67% of UK commuters use a personal vehicle (Statistics, 2014). On an average, the whole UK population spends 1.45 h daily in a vehicle (Deborah Lader, 2006). The time use survey by National Statistics Agency in the UK during 2006 suggests an overall increase by ~16% in travelling time against the year 2000 level of 1.25 h per day (Statistics, 2003). Travelling time is increasing with time in the UK and elsewhere (Transportation, 2011), indicating a growing need of accurate characterisation of exposure at pollution hot–spots such as TIs during daily commuting.

Assessing human exposure to PNCs in urban transport environment is challenging (Ragettli et al., 2013) since PNCs varies throughout the commuting route due to constant changes in driving speed, traffic characteristics (i.e. traffic volume and percentage of petrol and diesel fuelled vehicles) and topography (Goel and Kumar, 2014). Signalised TIs are places where higher peaks of PNCs occur quite frequently compared to the rest of the route with relatively non–congested conditions – these locations are generally termed as pollution hot–spots (Goel and Kumar, 2014). Our recent review (Goel and Kumar, 2014) reported ~17– and 5–fold larger values of peak PNCs at TIs ($5.4 \pm 1.7 \times 10^5$ # cm^{-3}; Tsang et al., 2008) compared with average typical roadside PNCs in European ($3.2 \pm 1.6 \times 10^4$ # cm^{-3}; Kumar et al., 2014) and Asian ($1.2 \pm 1.0 \times 10^5$ # cm^{-3}; Kumar et al., 2014) urban environments, respectively. Characterisation of circumstances under which TIs become a hot–spot is therefore important to understand for reducing the exposure to vehicle emitted PNCs during commuting. However, this aspect is largely unknown and is taken up for investigation in this study.

While a number of commuting exposure assessment studies has emerged in recent past (Hudda et al., 2011; Joodatnia et al., 2013a, b; Knibbs et al., 2010; Zhu et al., 2007), studies focussing on exposure assessment at TIs are still scarce. For example, only a few studies have carried out fixed–site measurements at TIs (Holmes et al., 2005; Morawska et al., 2004; Tsang et al., 2008; Wang et al., 2008). Given that the particle number distributions (PNDs) vary significantly within short distances from roadside, fixed–site measurements away from source may result in underestimation of commuter exposure (Fujitani et al., 2012a; Knibbs et al., 2011; Ragettli et al., 2013). Moreover, the frequency of measurements in fixed–site studies at TIs ranges from 0.0034 to 1 Hz (see Table 1). These measurements offer limited information about the transformation processes (e.g. nucleation, coagulation, condensation and deposition) that occur on very short time scales i.e. much lesser than 1 s (Carpentieri and Kumar, 2011; Kumar et al., 2009, 2010), clearly highlighting a need for fast–response mobile measurements that are capable of capturing the particle dynamics (Kumar et al., 2011) – an aspect that is covered as a part of this study.

Table 1
Summary of fixed site monitoring studies at TIs.

Author (year)	City (Country)	Instrument	Sampling frequency (Hz)	Size range (nm)	Maximum PNC ($\times 10^5$ cm^{-3})	Traffic density (h^{-1})	HDV (%)	Months
Morawska et al. (2004)	Salzburg (Austria)	SMPS	300[a]	13–830	0.2[b]	3600	20–30%	September
Holmes et al. (2005)	Brisbane (Australia)	SMPS	120[a]	9–407	2.6	200–1920	20%[c]	January
Tsang et al. (2008)	MongKok of Kowloon (Hong Kong)	WCPC	1	5–2000	5.4	840	29%	July
Wang et al. (2008)	Texas (USA)	CPC & SMPS with DMA	120[a]	7–290	2.4	10,452–11897	3.7%	December –June
Fujitani et al. (2012b)	Kawasaki City (Japan)	SMPS	–	8–300	~1.4	2167	25%	January

Note: SMPS: Scanning Mobility Particle Sizer; WCPC: Water based Condensation Particle Counter; CPC: Condensation Particle Counter; HDV: Heavy–duty diesel vehicle.

[a] Scan time in seconds.

[b] 90th percentile.

[c] Percentage of diesel vehicles including cars.

Please cite this article in press as: Goel, A., Kumar, P., Characterisation of nanoparticle emissions and exposure at traffic intersections through fast–response mobile and sequential measurements, Atmospheric Environment (2015), http://dx.doi.org/10.1016/j.atmosenv.2015.02.002

Download English Version:

https://daneshyari.com/en/article/6338471

Download Persian Version:

https://daneshyari.com/article/6338471

Daneshyari.com