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Effects of exposure to ambient ultrafine particles on respiratory health and systemic inflammation in children

Sam Clifford[a,b,c], Mandana Mazaheri[a], Farhad Salimi[d,e,f], Wafaa Nabil Ezz[g], Bijan Yeganeh[a,f], Samantha Low-Choy[h], Katy Walker[i], Kerrie Mengersen[b,c], Guy B. Marks[f,g,j], Lidia Morawska[a,*]

[a] *International Laboratory for Air Quality and Health, Institute for Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Queensland, Australia*
[b] *School of Mathematical Sciences, Queensland University of Technology, Brisbane, Australia*
[c] *ARC Centre of Excellence for Mathematical and Statistical Frontiers, Queensland University of Technology, Brisbane, Australia*
[d] *University Centre for Rural Health – North Coast, School of Public Health, University of Sydney, Australia*
[e] *Menzies Institute for Medical Research, University of Tasmania, Australia*
[f] *Centre for Air quality and health Research and evaluation (NHMRC Centre of Research Excellence), Australia*
[g] *Woolcock Institute for Medical Research, University of Sydney, Sydney, New South Wales, Australia*
[h] *Griffith Social & Behavioural Research College, Griffith University, Mt Gravatt, Queensland, Australia*
[i] *Health Effects Institute, Boston, MA, USA*
[j] *South Western Sydney Clinical School, University of New South Wales, Sydney, New South Wales, Australia*

A R T I C L E I N F O

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A B S T R A C T

It is known that ultrafine particles (UFP, particles smaller than 0.1 μm) can penetrate deep into the lungs and potentially have adverse health effects. However, epidemiological data on the health effects of UFP is limited. Therefore, our objective was to test the hypothesis that exposure to UFPs is associated with respiratory health status and systemic inflammation among children aged 8 to 11 years.

We conducted a cross-sectional study among 655 children (43.3% male) attending 25 primary (elementary) schools in the Brisbane Metropolitan Area, Australia. Ultrafine particle number concentration (PNC) was measured at each school and modelled at homes using Land Use Regression to derive exposure estimates. Health outcomes were respiratory symptoms and diagnoses, measured by parent-completed questionnaire, spirometric lung function, exhaled nitric oxide (FeNO), and serum C reactive protein (CRP). Exposure-response models, adjusted for potential personal and environmental confounders measured at the individual, home and school level, were fitted using Bayesian methods.

PNC was not independently associated with respiratory symptoms, asthma diagnosis or spirometric lung function. However, PNC was positively associated with an increase in CRP (1.188-fold change per 1000 UFP cm^{-3} day/day (95% credible interval 1.077 to 1.299)) and an increase in FeNO among atopic participants (1.054 fold change per 1000 UFP cm^{-3} day/day (95% CrI 1.005 to 1.106)).

UFPs do not affect respiratory health outcomes in children but do have systemic effects, detected here in the form of a positive association with a biomarker for systemic inflammation. This is consistent with the known propensity of UFPs to penetrate deep into the lung and circulatory system.

1. Introduction

Recently, there has been an increased interest in human exposure to airborne fine (smaller than 2.5 μm, $PM_{2.5}$) and ultrafine (smaller than 0.1 μm, UFP) particles. Previous research has shown that these particles can penetrate to peripheral airways and alveoli and, potentially, have important effects on human health (HEI Review Panel on Ultrafine Particles, 2013; Lim et al., 2012; WHO Regional Office for Europe, 2013). Exposure to ambient particulate matter ($PM_{2.5}$) was ranked 11th out of a list of 79 risk factors contributing to the global burden of disease in 2010 (Forouzanfar et al., 2015). Unlike lifestyle factors, which are under the control of individuals, it is difficult for individuals to take action to control their exposure to air pollution. Hence, this is an important issue for policy and for research.

The relationship between $PM_{2.5}$ exposure and human health is relatively well established (Health Effects Insitute, 2010). However,

* Correspondence to: L Morawska, Queensland University of Technology, PO Box 2434, Brisbane, Queensland, Australia, 4001.
E-mail addresses: g.marks@unsw.edu.au (G.B. Marks), l.morawska@qut.edu.au (L. Morawska).

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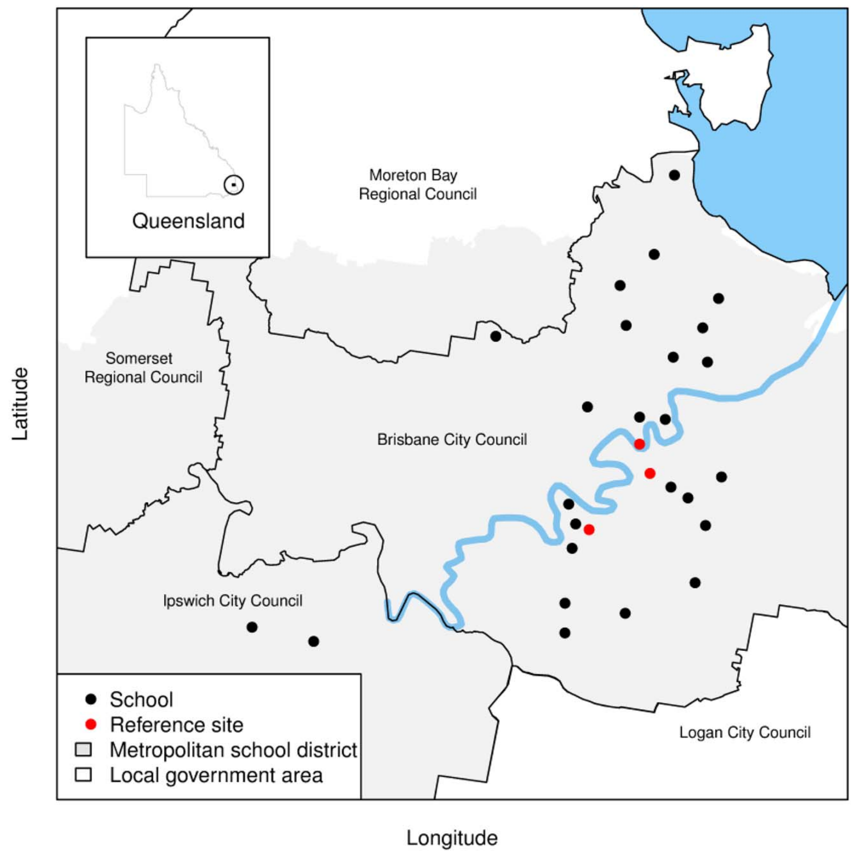

Fig. 1. Location of the 25 schools in the UPTECH project and the reference sites. QUT is the northernmost of the three reference sites.

although the World Health Organization has concluded that there is considerable evidence of the toxicological effects of UFPs on human health (WHO Regional Office for Europe, 2013; World Health Organization, 2006), epidemiological evidence linking UFP exposure to human health is much more limited. There is a need for more evidence to inform public policy in this area.

Studies of the health impacts of children's exposure to air pollution in the school environment have tended to focus on measurements of gaseous pollutants and particle mass rather than particle number concentration (PNC) (Mejía et al., 2011), with only a handful of more recent studies reporting on PNC as a risk factor eg. (Evans et al., 2014; Li et al., 2016). Although toxicological evidence implies that PNC is a more relevant exposure metric for fine and ultrafine particles (Oberdörster et al., 2005), there are only a handful of studies investigating the health impact of UFP measured as PNC in children (Buonanno et al., 2013; Sunyer et al., 2015). Furthermore, as children spend a majority of their time at school inside the classroom, it is important that estimates of indoor, as well as outdoor, concentrations are assessed in epidemiological studies (Sioutas et al., 2005). Finally, many studies have concluded that motor vehicle emissions are the main source of UFPs in urban areas, especially close to main roads (Hitchins et al., 2000; Morawska et al., 1998). Hence, research on exposure UFPs in the school environment needs to consider road traffic as an important exposure source.

Exposure-response functions for the association between exposure to $PM_{2.5}$ and health outcomes, such as ischemic heart disease, stroke, chronic obstructive pulmonary disease, and lung cancer (Burnett et al., 2014) as well as all-cause mortality (Brauer et al., 2011; Fann et al., 2013) have been estimated previously. Exposure-response models have also been used to investigate the links between UFP exposure and mortality (Elder et al., 2000). However, there have been few studies investigating the effects of UFP pollution on more proximate indicators of health status in adults or children, such as diagnosed illness, symptoms of disease, functional impairment or biomarkers for disease. Strak et al. (2012) found that fractional expired concentration of exhaled nitric oxide (FeNO, an index of airway inflammation) and impaired lung function could be explained by changes in PNC, NO_2 and NO_x, after accounting for other pollutants such as PM. C-reactive protein (CRP), a marker of systemic inflammation, has also been linked to increased levels of PM in adults (Li et al., 2012) but this relationship has not been well studied in children (Olsen et al., 2014). Recent, small studies have linked UFP exposure from both outdoor, traffic-related, sources and indoor sources to adverse respiratory and cardiovascular health effects. However, further progress in this field requires careful assessment of pollutant exposure and health status, including measurement of clinically-relevant biomarkers, in an adequate-size, well characterized population with varying exposure to UFP.

Therefore, this study aimed to test the hypothesis that, among children aged 8 to 11 years, variation in exposure to UFP, measured as PNC, is associated with variation in respiratory health status and systemic inflammation and that this association is independent of the effects of other factors including other air pollutants, housing conditions and indoor exposures, and socio-economic factors.

2. Methods and materials

The study design and findings of a pilot study have been previously published (Ezz et al., 2015). The relevant aspects of the design and methods are summarized here. The study protocol was approved by the Human Research Ethics Committee of the Queensland University of Technology (approval number 1000000703).