International Journal of Hygiene and Environmental Health 220 (2017) 494–502

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

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

Investigating the relationship between environmental factors and respiratory health outcomes in school children using the forced oscillation technique

Jonathon Boeyen[a], Anna C. Callan[b], David Blake[a], Amanda J. Wheeler[a], Peter Franklin[c], Graham L. Hall[d], Claire Shackleton[e], Peter D. Sly[e], Andrea Hinwood[a,*]

[a] Centre for Ecosystem Management, Edith Cowan University, 270 Joondalup Drive, Joondalup, WA 6027, Australia
[b] School of Medical and Health Sciences, Edith Cowan University, 270 Joondalup Drive, Joondalup, WA 6027, Australia
[c] School of Population Health, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
[d] Children's Lung Health Telethon Kids Institute, School of Physiotherapy and Exercise Science Curtin University, Centre for Child Health Research, University of Western Australia, PO Box 855, West Perth WA 6872 Australia
[e] Child Health Research Centre, The University of Queensland, 62 Graham St, South Brisbane, Qld 4101 Australia

ARTICLE INFO

Article history:
Received 27 August 2016
Received in revised form
28 December 2016
Accepted 3 January 2017

Keywords:
Children
FOT
Green space
Industry
Traffic
Respiratory health

ABSTRACT

The environmental factors which may affect children's respiratory health are complex, and the influence and significance of factors such as traffic, industry and presence of vegetation is still being determined. We undertook a cross-sectional study of 360 school children aged 5–12 years who lived on the outskirts of a heavy industrial area in Western Australia to investigate the effect of a range of environmental factors on respiratory health using the forced oscillation technique (FOT), a non-invasive method that allows for the assessment of the resistive and reactive properties of the respiratory system. Based on home address, proximity calculations were used to estimate children's exposure to air pollution from traffic and industry and to characterise surrounding green space. Indoor factors were determined using a housing questionnaire. Of the outdoor measures, the length of major roads within a 50 m buffer was associated with increased airway resistance (Rrs_8). There were no associations between distance to industry and FOT measures. For the indoor environment the presence of wood heating and gas heating in the first year of life was associated with better lung function. The significance of both indoor and outdoor sources of air pollution and effect modifiers such as green space and heating require further investigation.

1. Introduction

It is well established that children are more vulnerable to the effects of air pollution as they spend more time participating in outdoor physical activities, display elevated breathing rates, inhale and retain more air than adults per unit of body weight, and their narrow bronchioles are more prone to constriction upon exposure to environmental irritants (Hansen et al., 2003; Committee on Environmental Health, 2004). Environmental factors have been shown to have an influence on the respiratory health of children and both indoor and outdoor sources of air pollution have been implicated (Brauer et al., 2007; Markandya and Wilkinson, 2007; Fuentes-Leonarte et al., 2009; Gillespie-Bennett et al., 2011).

Exposure to traffic-related air pollution has been associated with the prevalence and exacerbation of asthma and respiratory symptoms in children (Brauer et al., 2007; Gehring et al., 2010; Gordian et al., 2006; Kim et al., 2008; McConnell et al., 2006; Nordling et al., 2008). However adverse effects to respiratory health are not observed in all studies (Fuertes et al., 2013; Rosenlund et al., 2009).

Exposure to industry-related air pollution may also result in adverse respiratory health effects in children (Cara et al., 2007; Rusconi et al., 2011), however, the type and volume of pollutants emitted from industrial facilities varies enormously, and hence the potential for health impacts is also variable. Industrial activities which may influence children's respiratory health include fossil fuel electricity generation (Markandya and Wilkinson, 2007), metal

* Corresponding author.
E-mail addresses: j.boeyen@ecu.edu.au (J. Boeyen), a.callan@ecu.edu.au (A.C. Callan), d.blake@ecu.edu.au (D. Blake), a.wheeler@ecu.edu.au (A.J. Wheeler), peter.franklin@uwa.edu.au (P. Franklin), graham.hall@telethonkids.org.au (G.L. Hall), p.sly@uq.edu.au (P.D. Sly), a.hinwood@ecu.edu.au (A. Hinwood).

http://dx.doi.org/10.1016/j.ijheh.2017.01.014
1438-4639/

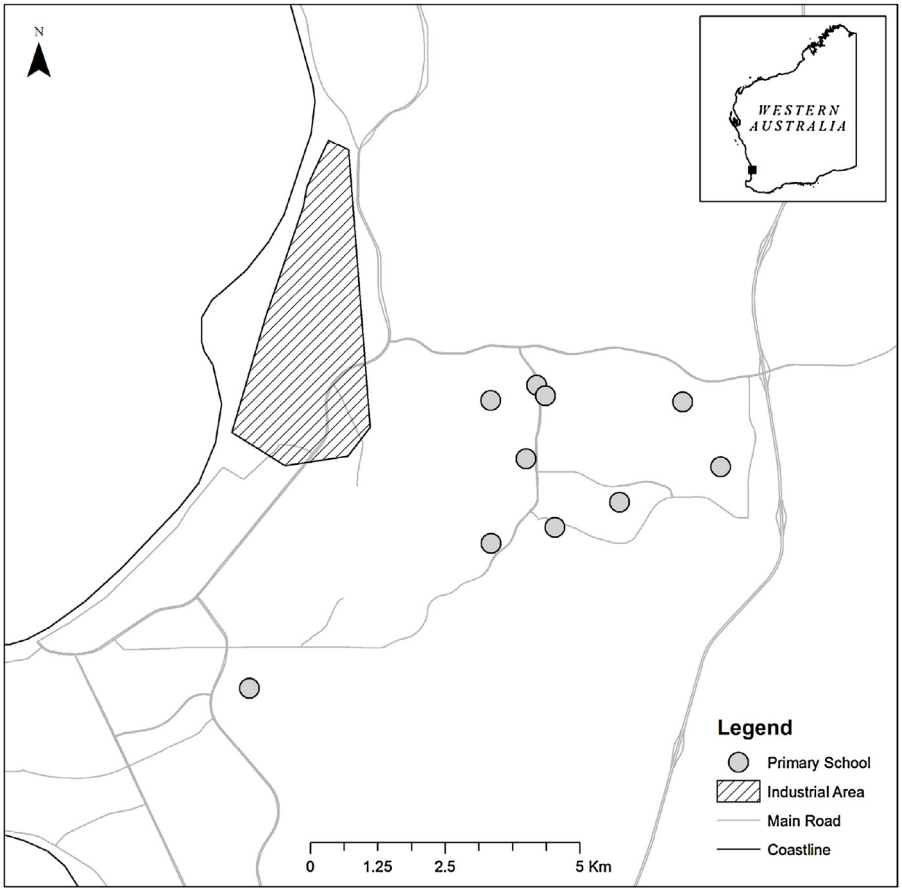

Fig. 1. Map of the study area including the location of the 10 primary schools from which participants were recruited.

works (Cara et al., 2007) and the use of heavy vehicles and their subsequent diesel emissions (Riedl and Diaz-Sanchez, 2005).

Indoor sources of air pollution include gas and wood burning for heating and cooking which have been associated with respiratory symptoms and effects in children (Triche et al., 2002; Fuentes-Leonarte et al., 2009; Gillespie-Bennett et al., 2011). Contrary findings have also been reported (Bennett et al., 2010).

Few studies have investigated the influence of effect modifiers such as urban vegetation on air quality and human exposure to air pollution. Nowak et al. (2006) found that urban trees absorb a variety of air pollutants, improving air quality and potentially reducing exposures and hence reducing the effects of exposure to air pollutants. A study of pregnant women by Dadvand et al. (2012) associated living in greener areas with reduced levels of personally-monitored air pollution exposure to fine particulate matter (PM) and nitrogen oxides (NO_x). Studies investigating the relationship between vegetation density and asthma and allergic sensitisation have generated conflicting results with some showing improvements in health outcomes with increasing greenness and others the reverse (Fuertes et al., 2014; Lovasi et al., 2008, 2013). Given these findings, further work is required to clarify the role of these potential effect modifiers and sources of pollution on children's respiratory health. This is imperative as exposure to pollutants during critical stages of children's growth may affect both lung structure and function (Kajekar, 2007).

The forced oscillation technique (FOT) is a non-invasive lung function method which allows the assessment of respiratory system resistance (Rrs) and reactance (Xrs) related to respiratory system compliance (Oostven et al., 2003). The FOT is an attractive lung function assessment technique for children due to its reduced requirement for participant cooperation and high success rates when compared with other established lung function tests such as spirometry (Navajas and Farré, 2001). The FOT has been used to evaluate alterations in respiratory mechanics in infants, children, young people and adults with common respiratory diseases, including recurrent wheeze, asthma, bronchial hyperresponsiveness, cystic fibrosis and broncopulmonary dysplasia (Oostven et al., 2003; Rosenfeld et al., 2013). Additionally, the FOT has been used to examine the effects of atopy and environmental tobacco exposure among other variables (Calogero et al., 2013; Gray et al., 2015), suggesting that it may be useful when investigating the effects of environmental factors on lung function.

This cross-sectional study was conducted to examine the influence of environmental factors on the lung function (using FOT) of primary school-aged children in the Kwinana region of Western Australia using questionnaire-based information and spatial analyses. The Kwinana Industrial Area contains a range of light and heavy industries and is Western Australia's primary area for industrial development. Industries include oil and alumina refining, nickel processing, cement works, chemical and pesticides manufacturing as well as shipping and metal works-type activities (www.npi.gov.au).

2. Materials and methods

2.1. Study population and recruitment

Children, aged between 5 and 12 years, were recruited from ten primary schools in the Kwinana region of Western Australia (Fig. 1). The number of children recruited for the study was 591 of a total of 2466 who were invited, a response fraction of 24.0%. Parents