Spatial and Spatio-temporal Epidemiology 13 (2015) 1–6

Contents lists available at ScienceDirect

Spatial and Spatio-temporal Epidemiology

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

Original Research

Assessing environmental inequalities in ambient air pollution across urban Australia

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ARTICLE INFO

Article history:
Received 6 December 2013
Revised 23 December 2014
Accepted 19 March 2015
Available online 25 March 2015

Keywords:
Air pollution
Environmental justice
Indigenous
Socio-economic
Australia

ABSTRACT

Identifying inequalities in air pollution levels across population groups can help address environmental justice concerns. We were interested in assessing these inequalities across major urban areas in Australia. We used a land-use regression model to predict ambient nitrogen dioxide (NO_2) levels and sought the best socio-economic and population predictor variables. We used a generalised least squares model that accounted for spatial correlation in NO_2 levels to examine the associations between the variables. We found that the best model included the index of economic resources (IER) score as a non-linear variable and the percentage of non-Indigenous persons as a linear variable. NO_2 levels decreased with increasing IER scores (higher scores indicate less disadvantage) in almost all major urban areas, and NO_2 also decreased slightly as the percentage of non-Indigenous persons increased. However, the magnitude of differences in NO_2 levels was small and may not translate into substantive differences in health.

1. Introduction

Environmental injustices occur when more disadvantaged populations bear a disproportionate burden of the adverse impacts of pollution or other environmental hazards (Brulle and Pellow, 2006). They have been the focus of numerous studies over the past 50 years, which have identified injustices associated with a range of contaminants among low-socioeconomic status (SES) communities and racial minorities (Clark et al., 2014; Jerrett, 2009). Environmental inequality is a closely-related but distinct concept that refers to differences in levels of contaminants among different population groups (Marshall, 2008). Air pollution is a particularly relevant environmental exposure due to its ubiquitousness in urban areas and because it is one the top 10 risk factors in the global disease burden (Lim et al., 2012). Determining whether environmental inequalities in air pollution exposure exist can inform policy measures and interventions to reduce their impacts (Bell et al., 2005).

Australia (population ~23 million) has an advanced economy and its Human Development Index (HDI) was ranked second in the world by in 2013 (United Nations Development Programme, 2014). However, parts of Australia's population are subject to pronounced disadvantages that are juxtaposed against its overall development. This is best exemplified by the greater than 10-year shortfall in life expectancy among Indigenous (i.e. Aboriginal and Torres Strait Islander) compared with non-Indigenous Australians (Australian Institute of Health and Welfare, 2012). Also, more socio-economically disadvantaged Australians exhibit higher prevalence of health risk factors (e.g. smoking) and experience poorer health than less disadvantaged persons (Australian Institute of Health and Welfare, 2012).

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http://dx.doi.org/10.1016/j.sste.2015.03.001
1877-5845/

Despite the considerable socio-economic and racial gradients in health among Australians, there is a conspicuous absence of studies addressing environmental inequalities or injustices in Australia (Chakraborty and Green, 2014). This lack of basic information makes it impossible to determine if policy-based responses are required. To contribute towards filling this knowledge gap, we sought to assess if environmental inequalities in ambient air pollution exposure exist in Australia.

2. Methods

2.1. Population and socio-economic predictors

We obtained population data based on the 2011 census from the Australian Bureau of Statistics (Australian Bureau of Statistics, 2011). The data were at ABS Statistical Area Level 1 (SA1), which is the smallest spatial unit for which specific census data (e.g. socio-economic variables) are released (Australian Bureau of Statistics, 2011). There are almost 55,000 SA1s across Australia and together they cover the entire country. Their median population is 385 persons (range = 0–6434), and their median size is 0.22 km^2 (range = 0.002–329,722 km^2). SA1s in urban areas are smaller than those in rural and remote areas (Australian Bureau of Statistics, 2011). We determined the total population density (per km^2) in each SA1. The total number of people identifying as Aboriginal Torres Strait Islander or both (i.e. all Indigenous persons) in each SA1 was used to calculate the Indigenous population percentage and population density.

We obtained the 2011 socio-economic indexes for areas (SEIFA) for each SA1 from the Australian Bureau of Statistics. SEIFA comprises 4 indexes: the index or relative socio-economic disadvantage (IRSD), index of relative socio-economic advantage and disadvantage (IRSAD), index of economic resources (IER) and index of education and occupation (IEO). The indexes are based on between 9 (IEO) and 25 (IRSAD) variables including income, education, employment, occupation, housing, mortgage and rent payments, English language skills, disability and single parent families (Australian Bureau of Statistics, 2013). The indexes are numerical scores based on weighted combinations of the input variables and are assigned to approximately 96% of all SA1s (Australian Bureau of Statistics, 2013). Depending on the index, lower scores can mean greater levels of relative disadvantage (with or without a corresponding lack of advantage), a lack of access to economic resources, or people who are unemployed and without qualifications. The technical basis and validation of the indexes is described elsewhere, and they are the standard metric used to evaluate socio-economic patterns in Australia (Australian Bureau of Statistics, 2013).

2.2. Air pollution data

We used a recently developed and validated satellite-based land-use regression (LUR) model to estimate long-term ambient nitrogen dioxide (NO_2) levels. The LUR model is described in detail by Knibbs et al. (2014). Briefly, it uses satellite observations of tropospheric NO_2 columns, land use, roads, and other predictors to estimate ground-level NO_2 across Australia, and captures 81% of spatial variation in annual NO_2 levels between 2006 and 2011 (absolute RMS error = 1.4 ppb). The LUR model is useful for assessing within-urban gradients in NO_2, which made it well-suited to the aims of this study. We focused on NO_2 because it is a strong indicator of traffic and other combustion-related pollution (e.g. industrial processes, coal-fired power generation), is a major component of ambient air pollution, and exhibits greater spatial heterogeneity than other air pollutants (Briggs et al., 1997; Jerrett et al., 2005). For these reasons, NO_2 has been used as proxy in previous environmental inequality studies aimed at air pollution (e.g. Clark et al., 2014; Havard et al., 2009; Padilla et al., 2014; Yanosky et al., 2008).

We used the LUR model to predict average NO_2 concentrations during 2006–2011. Predictions were made at the centroid of each census mesh block (Knibbs et al., 2014), which is a standard method to estimate population exposures to NO_2 using LUR (e.g. Novotny et al., 2011; Hystad et al., 2011). There are approximately 350,000 mesh blocks across Australia and they are the spatial unit that constitutes each SA1 (with no overlap), but unlike SA1s no census data are released for mesh blocks due to their small size (Australian Bureau of Statistics, 2011). The mean NO_2 concentration at each SA1 was estimated using the concentrations predicted at the mesh block centroids within it. We used ArcGIS (version 10.0) to process our data.

We restricted our analysis to include just the major urban areas in Australia, as defined by the Australian Bureau of Statistics (Australian Bureau of Statistics, 2011), and we only included SA1s with a non-zero total population and valid socioeconomic indexes. These criteria resulted in approximately 20,000 SA1s being dropped. Our final sample had 34,866 SA1s, covered approximately 10,100 km^2, and incorporated 69.1% of the Australian population. The major urban areas we included were located near the capital cities of Australia's 8 states and territories. We focused on major urban areas because they have higher and more heterogeneous levels of NO_2 than rural and remote areas (Knibbs et al., 2014).

2.3. Analysis

We aimed to find the best set of predictors of estimated NO_2 at each SA1 from the 4 socio-economic indexes and the following area population variables: (1) non-Indigenous population density per km^2; (2) Indigenous population density per km^2; (3) total population density per km^2 (4) percent Indigenous, and; (5) percent non-Indigenous. We note from our previous work (Knibbs et al., 2014) that there are many features of the environment that are potential predictors of NO_2 (e.g. roads, impervious surfaces, industrial activity). However, our aim was not to produce a model highly predictive of NO_2; instead, we were specifically interested in the role of the selected socio-economic variables. Other strong predictors of NO_2 may be on the casual pathway between the