Small-Area Indices of Potential Environmental Health Risk: Construction and Application to Environmental Health Equity in England and Wales

Ben Wheeler, Yoav Ben-Shlomo & Elise Whitley

Department of Social Medicine
University of Bristol, UK
Phone: +44 (0)117 928 7279
Email: benwheeler@lycos.co.uk

Presented at GeoHealth 2002
Victoria University of Wellington
December 3-5th 2002

ABSTRACT

This study developed small-area environmental indices and applied them in an investigation of environmental health equity. Publicly available, georeferenced environmental datasets were obtained, and GIS-based methods were used to construct indices of potential environmental health risk for standard small-area geographies of England and Wales. Associations between these indices, socio-economic and health outcome measures were assessed using both individual and aggregate data sources. Indicators of socio-economic status, such as deprivation indices and social class, were found to be strongly associated with several of the environmental indices. The environmental indices were also found to have measurable adverse effects on some health outcomes following adjustment for socio-economic status and may, to a small extent, explain gradients between area deprivation and morbidity/mortality. Small-area environmental indices, such as those constructed here, are proposed as a means by which the distribution of environmental health risk may be considered in the context of national and regional health, social and planning policy.

***Keywords and phrases*:** environmental health risk, environmental equity, health inequalities, environmental indices.

1.0 INTRODUCTION

Research over the past 20 years in the USA (e.g. Commission for Racial Justice, 1987; Neumann *et al.*, 1998; Graham *et al.*, 1999), and more recently in the UK (McLaren *et al.*, 1999; McLeod *et al.*, 1998; Pye *et al.*, 2001) and elsewhere (Salmond *et al.*, 1999; Jerrett *et al.*, 2001), has suggested that exposures to potential environmental health risks, such as air pollution, are not equitably distributed across racial and socio-economic population sub-groups. The body of research concerned with environmental equity has evolved from calls for 'environmental justice', which developed in the context of the civil rights movement in the US in the late 1970s.

There also exists a very well established body of research demonstrating the presence and growth of inequalities in health in the UK, with individuals and populations of lower socio-economic status (SES) generally experiencing poorer health and earlier death than those of higher SES (see, for example, Phillimore *et al.*, 1994; Gordon *et al.*, 1999).

The aim of the study described in this paper was to bring together the issues of environmental equity and health inequalities to address the following research question:

> *"Are environmental inequalities apparent in England and Wales, and if so, do they play any part in the determination of socio-economic health inequalities?"*

In doing so, it was necessary to integrate national environmental datasets with others commonly used for health inequalities research. Small-area environmental indices, analogous to deprivation indices, were developed in

order to allow assessment of the spatial distribution of potential environmental health risk across the country. This paper first briefly describes these indices, then summarises results of environmental health equity analyses, and concludes with recommendations and implications for policy.

2.0 ENVIRONMENTAL INDEX CONSTRUCTION

Four environmental indices were constructed using publicly available, national datasets that include geographic referencing at a reasonably high resolution:

- Ambient Air Quality (AAQ) – 1 km grid cell estimates of annual mean pollutant concentrations (Nitrogen Dioxide [NO_2], particulates [PM_{10}], Sulphur Dioxide [SO_2] and Benzene) for 1996 from the National Air Quality Archive (Source: http://www.airquality.co.uk)
- Pollution Inventory (PI) – data on licensed releases of chemicals to the environment from large scale industrial processes, from the Environment Agency (Source: http://www.environment-agency.gov.uk)
- Sites registered under Control of Major Accident Hazards regulations – from the Health and Safety Executive Hazardous Installations Division (Source: http://www.hse.gov.uk/hid)
- Waste landfill sites licensed by the Environment Agency (Source: Data obtained from Landmark Information Group, now available via the Environment Agency)

The AAQ and PI datasets contain information on a variety of chemicals in the environment, and selection of those relevant to indices with public-health pertinence was necessary. This process required a list of anthropogenic substances that are significant in terms of potential public health impact, i.e. substances that are a) potentially hazardous to human health and b) released to the environment in substantial quantities. The World Health Organisation Air Quality Guidelines for Europe are drawn up for substances on this basis, and these guidelines were used to select data from the AAQ and PI databases.

1991 Census geographic ward boundaries, of which there are 9,527 covering England and Wales, were chosen as the appropriate spatial units for the indices, in the context of the following analyses, for the following reasons:

- Wards are small enough to be sensitive to small-area variations - larger areas (e.g. Local Authority Districts) may have high internal heterogeneity in terms of both socio-economic and environmental characteristics;
- They are large enough to be attributed appropriately with environmental data - smaller areas (e.g. Enumeration Districts) would be inappropriately precise, given the resolution at which the environmental data is produced (e.g. 1 km grid for ambient air quality data, point locations accurate to approximately 150m);
- Many health and socio-economic datasets are produced at ward level - e.g. census, death certificate mortality data, hospital episode statistics;
- Consistency - many previous analyses of health inequalities have used wards as their spatial basis.

Once cleaned, the environmental and boundary data were analysed using a combination of ArcView and Arc/Info Geographic Information Systems (GIS) software. Essentially, the environmental data were overlaid on and attributed to underlying wards. Table 1 summarises the processes used in the construction of the indices.

Environmental Data	Description	Data attributed to wards	Ward Level Index
Ambient Air Quality	1 km grid of pollutant concentrations derived for the UK Government using a combination of modelling and monitoring.	Annual mean concentrations of NO2, SO2, Benzene & PM10, based on the area-weighted mean of grid cell values intersecting a ward	Sum of ratios relating each pollutant to its guideline/standard value
Pollution Inventory	Point locations representing licenced releases of chemicals to the environment from large industrial processes	Atmospheric releases of 14 substances included in the WHO Air Quality Guidelines. A 1 km radius buffer was constructed around each point location, and data were attributed to underlying wards proportionally by area	Scores relating to the quantity of chemical release attributed to each ward were generated and summed.
Sites registered under Control of Major Accident Hazard regulations	Point locations	Area-weighted count of sites based on 1 km radius buffers	Count of sites
Waste landfill sites	Point locations	Area-weighted count of sites based on 1 km radius buffers	Count of sites

Note: Buffers around point locations were used to account for artificial boundary effects that are possible with use of point-in-polygon methods.

Table 1: Environmental Indices Summary

3.0 ENVIRONMENTAL HEALTH EQUITY

The indices were used in conjunction with a) area socio-economic status (SES) measures, to investigate environmental equity and b) health outcome data, to investigate the possibility that environmental exposures are involved in determining health inequalities.

SES data included small-area deprivation indices, social class, an index of area dissatisfaction ('misery') and an index of social fragmentation. Aggregate health data included limiting long-term illness (1991 census) and mortality due to ischaemic heart disease, chronic obstructive pulmonary disease, lung cancer and all-causes (1991-95 death certificate data). Individual health data included that from the Health Survey for England, including all-cause mortality, limiting long-term illness, asthma, lung function and psychiatric morbidity (GHQ-12).

Positive associations were found between SES measures and environmental indices. An urban ward in the most deprived 20% compared to one in the least deprived 20% (Carstairs Index) was 6.7 [95% CI 4.8-9.3] times as likely to be within 1 km of a large atmospheric release site, 1.6 [1.2-2.0] times as likely to be within 1km of a landfill and 4.0 [3.1-5.0] times as likely to be within 1km of a COMAH-registered site (odds ratios). Associations persisted in rural areas, but were generally weaker. The relationship between socio-economic status and the ambient air quality index was more complex, with positive associations in urban areas and negative associations in rural areas.

Ecological analyses demonstrated small adverse effects of increased environmental hazard on mortality. Environmental effect estimates were mostly attenuated when adjusted for deprivation. Inclusion of environmental indices in regression models did not attenuate deprivation effects. Analysis of individual-level data produced complementary results, with the most striking effect being that of ambient air pollution on lung function. Residence in the 20% of wards with highest levels of ambient air pollution compared to the lowest 20% was associated with a reduction in mean height-adjusted FEV_1 of 8.3% [4.9-11.7] in boys and 4.5% [0.9-8.2] in girls, after adjustment for social class of head of household, passive smoke exposure and urban-rural status. In some individual analyses, socio-economic health gradients were very slightly attenuated by adjustment for environmental measures.

4.0 CONCLUSIONS AND IMPLICATIONS

Populations and individuals of lower socio-economic status are more likely to be subject to greater potential environmental health risk associated with indices based on the Pollution Inventory, COMAH and landfills datasets. Associations with the ambient air quality index are less clear, with an association contrary to that hypothesised suggested in some areas.

Results suggest that the environmental indices are associated with increased risk of a variety of health outcomes including lung function, psychiatric morbidity and mortality. Causality is not easily determined with these analyses, and associations could be due to residual confounding by unmeasured smoking, socio-economic status or some other factors. Some analyses suggest that inequitable exposure to environmental hazard may be involved to a small degree in the determination of socio-economic health inequalities across the population of England and Wales.

The study has implications for environmental, public health and planning policy, in that explicit consideration of environmental equity issues should be given when developing strategies for environmental and public health protection and improvement. Environmental indices such as those constructed for this study could be incorporated into small-area measures of deprivation. For example, these indices could form a 'physical environment' domain of the UK government's Indicator of Multiple Deprivation (DETR, 2000).

ACKNOWLEDGEMENTS

This study formed the basis for BW's Ph.D., which was supervised by YBS and EW and funded by the Medical Research Council.

REFERENCES

Commission for Racial Justice (1987) Toxic wastes and race: A national report on the racial and socio-economic characteristics of communities with hazardous waste sites. New York, United Church of Christ.

DETR (2000) Indices of Deprivation 2000: Regeneration Research Summary. London: Department of the Environment, Transport and the Regions.

Gordon, D., M. Shaw, D. Dorling and G. Davey Smith (1999) Inequalities in Health: The evidence presented to the Independent Inquiry into Inequalities in Health, chaired by Sir Donald Acheson. Bristol: Policy Press.

Graham J.D., N.D. Beaulieu, D. Sussman, M. Sadowitz, Y-C Li (1999) Who lives near coke plants and oil refineries? An exploration of the environmental inequity hypothesis. *Risk Analysis*, 19, pp. 171-86.

Jerrett M., R.T. Burnett, P. Kanaroglou, J. Eyles, N. Finkelstein, C. Giovis *et al.* (2001) A GIS - environmental justice analysis of particulate air pollution in Hamilton, Canada. *Environment and Planning A*, 33, pp. 955-73.

McLaren, D., O. Cottray, M. Taylor, S. Pipes and S. Bullock (1999) Pollution Injustice: The geographic relation between household income and polluting factories. London: Friends of the Earth Trust.

McLeod, H., I.H. Langford, A.P. Jones, J.R. Stedman, R.J. Day, I. Lorenzoni and I.J. Bateman (1998) Regional variations in the socio-economic distribution of air pollutants in England and Wales: implications for environmental justice. CSERGE Working Paper GEC 98-11. Norwich: Centre for Social and Economic Research on the Global Environment.

Neumann C.M., D.L. Forman and J.E. Rothlein (1998) Hazard screening of chemical releases and environmental equity analysis of populations proximate to toxic release inventory facilities in Oregon. *Environmental Health Perspectives*, 106, pp. 217-26.

Phillimore P., A. Beattie and P. Townsend (1994) Widening inequality of health in northern England, 1981-91. *British Medical Journal*, 308, pp. 1125-8.

Pye, S., J.R. Stedman, M. Adams and K. King (2001) Further analysis of NO2 and PM10 air pollution and social deprivation. Report AEAT/ENV/R/0865. Abingdon: AEA Technology.

Salmond K., P. Howden-Chapman, A. Woodward and C. Salmond (1999) Setting our sights on justice: contaminated sites and socio- economic deprivation in New Zealand. *International Journal of Environmental Health Research*, 9, pp. 19-29.

WHO Regional Office for Europe (1996) Update and revision of WHO air quality guidelines for Europe. Accessed 22/8/02: http://www.who.dk/envhlth/pdf/airqual.pdf

Yandle T. and D. Burton (1996) Reexamining environmental justice: a statistical analysis of historical hazardous waste landfill siting patterns in metropolitan Texas. *Social Science Quarterly*,77, pp. 477-92.