

Environmental Public Health Tracking: a cost-effective system for characterizing the sources, distribution and public health impacts of environmental hazards

P.J. Saunders¹, J.D. Middleton², G. Rudge³

¹University of Staffordshire, Stoke-on-Trent, UK

²University of Wolverhampton, Wolverhampton, UK

³Institute of Applied Health Research, University of Birmingham, Birmingham, UK

Address correspondence to Patrick Saunders, E-mail: carolan57@icloud.com

ABSTRACT

Background The contemporary environment is a complex of interactions between physical, biological, socio-economic systems with major impacts on public health. However, gaps in our understanding of the causes, extent and distribution of these effects remain. The public health community in Sandwell West Midlands has collaborated to successfully develop, pilot and establish the first Environmental Public Health Tracking (EPHT) programme in Europe to address this 'environmental health gap' through systematically linking data on environmental hazards, exposures and diseases.

Methods Existing networks of environmental, health and regulatory agencies developed a suite of innovative methods to routinely share, integrate and analyse data on hazards, exposures and health outcomes to inform interventions.

Results Effective data sharing and horizon scanning systems have been established, novel statistical methods piloted, plausible associations framed and tested, and targeted interventions informed by local concerns applied. These have influenced changes in public health practice.

Conclusion EPHT is a powerful tool for identifying and addressing the key environmental public health impacts at a local level. Sandwell's experience demonstrates that it can be established and operated at virtually no cost. The transfer of National Health Service epidemiological skills to local authorities in 2013 provides an opportunity to expand the programme to fully exploit its potential.

Keywords environment, epidemiology, health impact assessment

Background

Most of the great public health achievements have been delivered through improving physical and social environments. While these domains have improved so dramatically over the last 150 years that the potential for further gains can be overlooked, there is abundant evidence that environmental interventions present real opportunities for further major health dividends.^{1–3} The nature and distribution of environmental stresses has changed with new challenges emerging and old ones affecting us in unexpected ways. Professional and lay interests also appear to be divergent reflected in a research focus on large-scale issues such as climate change rather than more immediate local impacts. This presents a challenge for public health practice today; environmental regulation has changed little since the 1950s and

there seems to be a dislocation between what is important to local communities and what is being actively researched or promoted for research funding. This is at least partly due to a political, scientific and public perception that a problem has been solved, typically following a response to a crisis, without establishing a mechanism for subsequent vigilance and timely responses as understanding matures and/or circumstances change enabling a recurrence or evolution of the problem. The recent re-emergence of air pollution as a significant public health issue is a case in point, highlighted by the recent Royal College of Physicians review.² There are

P.J. Saunders, Professor of Public Health

J.D. Middleton, Professor of Public Health

G. Rudge, Research Fellow

other examples, of course, and all are complicated by the interactions between environmental, biological and social systems meaning that relatively little is actually known about which parts of the contemporary environment, or combinations thereof, have the most important effects or indeed how.⁴ These uncertainties led to widely differing estimates of the impacts in the literature,^{1,5} a modest and fragmented research investment and a consequent lack of evidence-based intervention. In 2000, the US Pew Environmental Health Committee identified this 'environmental health gap', a lack of basic information needed to document links between environmental hazards and chronic disease. As Tom Burke of John Hopkins University put it 'We can track flu, West Nile virus, and mad cow disease but not enough of the chronic illnesses that are the biggest killers...because we just don't have enough of that basic information'.⁶ However, one thing is abundantly clear; poor people are almost invariably more exposed to environmental and public health pressures.^{2,3,7} There is also an emerging consensus that there is something about being poor that makes people more vulnerable to those exposures,^{2,8} an indefensible injustice. However, affluence does not confer complete immunity from these impacts. There is evidence that some relatively better off areas include pockets of intense deprivation hidden from conventional surveillance.⁹ Some elements of air pollution can be higher in some wealthy zones such as Central London due to traffic levels,² and Michael Marmot emphasizes the concept of proportionate universalism to both raise everybody's health experience while narrowing the gap between the richest and poorest.³ Developing a rational and realistic response is not as daunting as might be thought once the key principles are distilled; these are the timely and routine intelligence on exposures, hazards and health outcomes, integration and analysis of these data to identify trends and potential relationships, the testing of those relationships, and the development of evaluated interventions that reflect and utilize public, professional and political priorities. These are the principles of Environmental Public Health Tracking (EPHT), a system that has been advocated for decades by many scientists, practitioners and policymakers^{10,11} and which underpinned the establishment of a US National Tracking programme in 2002 currently involving projects in 26 states. While UK public health agencies can only fantasize about the level of the Centers for Disease Control and Prevention (CDC) funding for this programme (\$35 million in 2015),¹² they actually have a number of advantages including political and organizational structures, and the coverage, availability, quality and consistency of key data. A different (and cost neutral) tracking model has been developed to meet local needs in Sandwell MBC in the West Midlands,

one of the poorest parts of Europe with a major post-industrial environmental contamination legacy. This includes analyses of public health nuisance to reflect public concerns, the efficacy of local authority practice, local horizon scanning¹³ and the innovative use of industrial quality control methods to target interventions most effectively as well as the routine background surveillance of environmental insult and environmentally related disease.¹⁴

The 2013 public health reforms with public health returning to locally accountable councils which hold most of the levers of influence in this field present an opportunity to begin underpinning intervention with both evidence and popular consent. There is now a real opportunity to apply new epidemiological tools to routine environmental practice, redefining how we manage hazards. Sandwell's experience shows that this can be achieved with modest investment and this first EPHT system outside the USA is being taken up by other local authorities including an unlikely alliance with one of the more affluent 'middle England' Boroughs demonstrating its utility across very different administrations.

Methods

The first stage was to establish a real confederation of the key agencies and individuals. The data, other intelligence, statistical techniques and communication skills do not lie with one body and identifying the necessary resources and then building a structure to bring these together was critical. The long tradition of joint public health work in the Borough was built on to recruit National Health Service, local authority departments, Health Protection Agency (HPA), Environment Agency and University academics to a project steering group. This group ensured the system contributed to the statutory and service obligations and business plans of the respective partners and provided ready access to existing datasets without placing additional burdens on partners. The Steering Group identified the key environmental public health challenges in the Borough based on the data and professional and public perceptions (local politicians and a review of public health nuisance complaints by the public were critical to this phase), and biological, temporal and spatial plausibility. While underpinned by evidence wherever possible, it was important not to allow an undeveloped scientific base to work against the inclusion of factors relevant in the borough; the absence of evidence is not the same as evidence of absence. A hierarchy based on the WHO Children's Environmental Health Action Plan programme was accordingly used to ensure the capture of important factors open to realistic intervention.¹⁵ These

issues included not only environmental stressors including air quality, contaminated land and chemical releases reflecting Sandwell's industrial legacy, food hygiene standards reflecting the density of takeaway outlets associated with high levels of deprivation, but also environmental assets including access to green spaces (see Table 1). Ostensible 'quality of life' issues, such as nuisance complaints, are important in their own right with a direct impact on health, an emerging evidence base of a potential to act in concert with other stressors such as poverty, and reflect the experiences of local people.¹¹ The study area is Sandwell MBC and while the system covers the whole population (c. 317 000),¹⁶ the impact on susceptible populations was specifically assessed given the relationships and

interactions between environmental stresses and other factors such as deprivation and ethnicity. This pilot covers the period 1995–2014 although given data were accessed from different organizations and collection systems, the time periods for specific issues vary.

Environmental exposures

NO₂ was identified as the most important air pollutant in the borough given the multiple exceedences of the government's Air Quality Strategy annual mean objective. Accordingly, exposure coefficients were derived using NO₂ data for the period of 2004–11 and two methods, asthma

Table 1 Sandwell's tracking activities and methods

<i>Activity</i>	<i>Methods</i>
Surveillance of environmental hazards: Air quality Proximity to industrial processes Proximity to heavily trafficked roads Environmental inequalities Public health nuisances Chemical incidents	Indirect standardization, Statistical control charts, GIS spatial analysis
Surveillance of key health outcomes: Lung, bladder, prostate cancers Reproductive outcomes including Congenital anomalies and low birth Weight (proposed) Hospital episode statistics (proposed)	Systematic evidence reviews, Indirect standardization, Statistical control charts, Kernel density contouring
Assessment of the relationship between hazards and health outcomes: Landfill sites and cancers Foundry waste and cancers	Geospatial analysis
Access to environmental resources Cycling Walking Green spaces	Geospatial analysis, Public consultation
Horizon scanning	Systematic examination of potential threats, opportunities and likely developments including those at the margins of current thinking and planning (Collaboration with Public Health England and Environment Agency)
Food safety Microbiological assessment Chemical safety assessment Effectiveness of inspection regimes Access to healthy choices Density of unhealthy choices	Principal component analysis, indicator development and mapping; geospatial analysis; food sampling and analysis
Spatial planning	Routine assessment and mapping of planning applications (see also environmental resources)
Research proposals addressing hypotheses generated from the above	Systematic reviews; Physical, chemical and biological sampling and analysis; Geospatial analysis
Risk communication	Interactive on line resource, Public consultation

prevalence studies giving a broadly based effect measure and a multi-pollutant model, used to estimate the health cost of these levels. Annual mean pollutant concentrations were obtained from three local monitoring sites. The urban increment was taken to be the difference between these and those at a rural site in Harwell Oxfordshire. Given the difficulty in accurately assigning populations to air quality areas, Mosaic Public Sector profiling¹⁷ was used to compare populations living in high NO₂ zones with Sandwell as a whole. The University of Birmingham was consulted in exploring the potential of emerging innovations to both reduce levels of NO₂ and enhance local environments including ‘greening’ urban corridors.

HPA had previously reported that 37% of Sandwell’s children live within 250 m of a busy road (>10 000 vehicles per day), much higher than the regional average of 24%.¹⁴ The number and characteristics of people living within 50 m of heavily trafficked roads were identified and Automatic Number Plate Recognition data on vehicle types to apportion emission sources.

Public health nuisance complaints to the local authority are a potentially powerful metric of environmental quality and well-being. Sandwell MBC provided nuisance complaint data for the years 2004–09 which were grouped into four categories—Total ($n = 20\,252$), Noise ($n = 6523$), Environmental (air, land and water pollution, $n = 3676$) and Public Health (infestations, animals and drainage, $n = 10\,053$). Post-coded incidents were used to calculate weighted and unweighted complaint rates and 99% confidence intervals at a lower super output area (LSOA) level. Descriptive and analytical assessments were conducted together with spatial mapping where appropriate. Statistical process charts (SPCs) were used to identify LSOAs exhibiting special cause variation and those that had significantly deteriorated or improved over the study period. These ‘hot spot’ and ‘cold spot’ areas were subject to a ‘case review’ assessment including inspections by a student Environmental Health Practitioner (EHP), to identify plausible physical and/or social causes. The relationship with deprivation was assessed using the LSOA Index of Multiple Deprivation (IMD) score.

The distribution and impact of chemical incidents in Sandwell was established using data from the national HPA chemical incident surveillance and local public health management systems. Sites of industrial processes were obtained from integrated pollution prevention regulatory system, and populations living within 1 km, based on the experience of planning authorities and WHO recommendations⁵ and 500 m, given the large populations in the 1 km buffer, were characterized using census data.

Health outcomes

Cancer, congenital anomaly and hospital admissions data have been advocated for environmental public health surveillance, and CDC, for example, has identified seven categories of health outcomes for studies of landfill sites including birth defects/reproductive disorders, lung/respiratory diseases and some cancers.¹⁸ The International Agency for Research on Cancer had identified 99 chemicals or exposure circumstances plausibly associated with environmental contamination as carcinogenic to humans.¹⁹ These monographs were assessed for plausible links between cancer site and exposure to an environmental chemical. Exposures were assessed for plausibility based on current industrial activity and discussions with the local authority on historical processes. This identified 32 plausible relationships between cancer and an environmental exposure in Sandwell including dye manufacture, coal gasification, coke production, coal-tar distillation, acid mists and coal tar works and the following cancers: lung, leukaemia, urinary bladder cancer, liver, digestive system cancers, multiple melanoma, nasopharyngeal cancer, mesothelioma, skin cancer, scrotal cancer and bladder cancer. Discussions with key experts in the field also identified prostate cancer as being associated with exposure to cadmium and pesticides, and foetal exposure to endocrine disrupting chemicals. Three methods were explored for assessing potential relationships for 1995–99, 2000–04 and 2005–09: standardization (direct and indirect), SPCs and kernel risk contouring. Areas with cancer admissions between 1 and 5 (but not 0) were suppressed. Annual population estimates were based on the census.

Food safety

Sandwell’s compliance with national food hygiene standards was around 68%, cf. 80% nationally in 2009. The relationship between average area food safety score and deprivation was assessed using the IMD. Sandwell had used the flexibility encouraged by government to supplement individual premise risk assessments with interventions in high-risk geographical areas since April 2008 and the impact of this was assessed by comparing individual premise score before and after local authority intervention in two areas using a Wilcoxon signed-rank test and paired *T*-test. As the food hygiene score uses professional judgment rather than objective microbiological measures, funding was secured for testing surfaces, foods and equipment. Sampling was targeted on retailers and caterers handling both ready to eat (RTE) and raw foods. Sampling included one RTE product together with two environmental samples in line with accepted methods. Samples were tested for the following as appropriate: aerobic

colony count, *Escherichia coli*, Enterobacteriaceae, Coagulase positive Staphylococci, Listeria species including *L. monocytogenes*. Results were assessed against accepted standards and comparisons made before and after inspection/action including the introduction of food safety zones, and over a range of time intervals to assess whether any effect was mediated over time using paired *T*-test and χ^2 for individual and area comparisons, respectively.

Obesity is a major issue in Sandwell with over a third of year 6 children being obese or overweight.²⁰ Access to healthy foods was assessed using location of premises together with quality, cost and range of a 'basket' of healthy foods provided by a dietician. A composite indicator was developed using principal component analysis to reduce the components to a minimum and a transformation process to minimize skewness and kurtosis. Index scores were mapped and populations in poorly served areas identified and characterized. Officers and members had expressed concern about the proliferation of hot food takeaways and the market pressure to use cheaper and more hazardous ingredients such as trans fatty acids (TFAs) given the small margins these businesses operate under. Access to these sources of cheap, energy dense takeaway foods was described through a spatial analysis of the relationship between populations and takeaway food outlets using walking distance as a proxy for access. Samples of a cross section of takeaway foods were taken for analysis for total fat, saturated and unsaturated fats, TFA, salt and sugar. This work is described in detail elsewhere.²¹

Environmental goods

The level of cycle ownership and use was identified for 2010 and the WHO's health economic tool used to estimate the annual healthcare cost savings of increasing cycling uptake in Sandwell. The number, size and accessibility of green spaces in the Borough were identified and mapped. Accessibility was assessed as unrestricted; limited by cost, social or physical barriers; or not accessible.

Results

Environmental exposures

Traffic-generated NO₂ is the most important pollutant in the borough with levels of NO₂ estimated to be associated with up to 1300 cases of bronchitis in asthmatic children. The urban increment of NO₂ was estimated to be associated with 180 additional children with wheeze and around 900 additional asthmatic children with bronchitic

symptoms. Population profiling of NO₂ hotspots showed that, unlike other parts of the country, more affluent people in Sandwell are likely to live in areas of poor air quality. Over 27% of Sandwell families were found to live close to busy roads but, given the wide distribution of such roads in Sandwell, there was little evidence that any specific groups were disproportionately represented. Buses were found to contribute 57% of NO_x and 32% of particulate emissions despite making up only 6% of vehicle flow by 2014. Overall cars made-up 86% of the total vehicle flow and contributed to 31% of NO_x emissions and 54% of particulate emissions; the largest contribution being from diesel vehicles. There appeared to be no technical fixes short of total pedestrianization of busy high roads or condemning the living accommodation as unfit for habitation, neither of which were realistic or politically acceptable. These zones were also in areas with limited access to green space leading to consideration of the potential of 'greening' urban corridors in worst-affected areas. Modelling different options revealed the potential to reduce levels of NO_x and particulates by up to 30%. A successful funding bid was made for the installation of green screens at strategic points to protect vulnerable populations including a primary school.

Ninety-one per cent of the population of Sandwell lived within 1 km of a regulated site, 29% within 1 km of an upper tier regulated industrial process compared with 10% nationally. Over half the population of Sandwell lived within 500 m of a regulated site. No significant difference between the level of deprivation or the numbers of minority ethnic communities living within 500 m of a site and the population living more than 500 m away was found.

A very strong relationship between LSOAs with significantly high levels of nuisance complaint and deprivation was identified ($R^2 = 0.9$). The SPC analysis of nuisance complaints identified 15 areas that were consistently poor and/or deteriorating over the period, which were inspected and any real or potential nuisances recorded, photographed and referred to the local authority for intervention.

Health outcomes

No clear spatial relationship was found between any of the areas of elevated cancer incidence and landfill sites, foundry waste sites, regulated industrial processes or areas of elevated nuisance complaints, for any of the three time periods considered. The pilot revealed under-ascertainment in the data recording processes prompting development of improved systems.

Food safety

There was a clear relationship with deprivation with poorer areas experiencing significantly poorer average food hygiene scores ($R^2 = 0.6$). The area targeting approach had a highly significant impact on improving the individual premise score in the two areas considered ($P = 0.001$) and had coincided with an increase in overall food premises compliance from 68% to over 77%. While overall microbiological standards improved after the intervention, this difference was not significant ($P = 0.1$). This is not to say such inspections are not worthwhile. The study used a relatively small sample size (53 premises) and the microbiological metric is not the only measure of effectiveness. However, it does prompt the question of the most effective use of the EHP resource to protect and improve health. Very few people die from food poisoning in Sandwell while 1000s die from dietary-related diseases. Availability of healthy foods is critical and previous work had demonstrated the poor access to fresh fruits and vegetables in the Borough ('food desert') and the utility of a healthy food access indicator.²² A holistic approach to the issue of diet led to consideration of the availability of unhealthy food as well as healthy options. Mapping food outlets showed that Sandwell was effectively saturated with hot food takeaways with virtually nowhere more than a very short walk from an outlet. The density of outlets also increased with deprivation effectively doubling the chance of living close to such takeaways. Sampling and analysis of a range of takeaway foods identified that people in Sandwell were exposed to large portion sizes and unacceptable levels of fats, saturated fats and salt, some of which had increased since 2010.²¹

Environmental goods

Almost 17% of the Borough area was found made-up of accessible green space with an average of 4 ha of accessible green space for every 1000 people. Three hundred and twenty-one of the 539 sites had unrestricted access, 170 limited access and 48 inaccessible. However, there was considerable variation in the amount of green space across the six towns.

Cycle ownership was found to be much higher than cycle use, suggesting that many people would like to cycle more if conditions were right. Fewer than 2% of people in the Sandwell population cycled to work and only 5% cycled regularly. However, over 4000 people in Sandwell cycled for 30 min or more on an average day. Assuming a typical cycling speed of 10 mph this alone saved 2.3 lives and at least £2.1 m annually. Achieving a realistic average of 4000 more daily cycling trips of around 5 km would save an additional £1.3 m.

Discussion

Main finding of this study

While still in a pilot form, the Sandwell programme, using routinely available data and consultation with professionals, politicians and the public, has identified the most important environmentally related public health issues in Sandwell, described their distribution, quantified their impact and influenced practice. Using an ecological model of public health²³ generated assessments and interventions that would not have otherwise been considered, e.g. using SPC for the first time, to the authors' knowledge to target routine nuisance inspections and for routinely monitoring the relationship between hazards and disease. The latter provided reassuring analyses about the impact of residential proximity to landfill and foundry sites and industrial processes, a source of considerable local anxiety. The asset-based approach was attractive to politicians as it emphasized positive aspects of life in Sandwell. This directly led to investment in 'urban greening' interventions and commitment to improve cycling and walking opportunities.

What is already known on this topic

It is increasingly evident that we are simply not able to deliver improved and equitable standards of health, well-being and healthcare in the medium to longer term without, as a society, paying much more attention to the environment. What we do or do not do in our towns, cities and rural communities not only influences local environments in health-relevant ways, but also changes global ecosystems in ways which damage health. Tracking has the utility to both address local environmental issues and contribute to the international action required for long-term sustainable public health improvements.

What this study adds

We have demonstrated that such a system can be developed in the UK at marginal cost, and several local authorities are now collaborating with Sandwell on extending the service across the region and beyond, a development, which has attracted WHO endorsement. It is important that the public health community re-evaluates the role and application of routine environmental monitoring and service data and learns to apply these using innovative methods. There is still much to be improved in our physical environment through the actions of local government, national and international regulators. The local focus of environmental tracking has been largely overlooked until now. In England, the return of public health responsibilities to local authorities gives a renewed impetus to the relationship between public and

environmental health. There are still gains to be made for the protection of the public's health and benefits for quality of life and health improvement through the recognition and development of environmental assets. However, we recognize the challenges that local government faces with a seemingly endless round of swingeing budget cuts and the inevitable focus on the 'big ticket' and high-risk responsibilities of adult social care and children's services. In these circumstances, health surveillance and related activity can be viewed as a discretionary spend. Indeed despite the recognized value of the pilot work described in this paper and the strong relationships forged, the organizational turmoil around the implementation of the 2012 Health and Social Care Act has stymied its development.

Public health departments need to embrace and exploit smart working and low-cost solutions including crowd sourcing data from residents about environment and health,^{24,25} new low-cost technologies for sensing²⁶ and maximising the value of integrating existing routinely collected data. The flight of qualified staff from the public health function and the concentration of the more technocratic parts of that workforce in PHE to work on national priorities have seriously reduced the opportunities for informed, effective and local surveillance. Local government faces many barriers to innovation including internal structures and organization, inadequate citizen focus, a culture of risk aversion and cost.²⁷ The drivers for, and location of, tracking may therefore have to change. This is by no means a bad thing; necessity being the mother of invention could herald more use of engaged citizens, virtual groups, the third and private sectors, and social enterprises, and the pooling of resources. There is surely also a role in this context for Health and Wellbeing Boards, PHE and, where they exist, elected Mayors? Tracking could serve as a catalyst for new ways of effectively and efficiently working together across multiple public health, professional and political geographies.

Limitations of this study

The full utility of such a study can only be realized using larger populations and spatial scales. The absence of personal exposure or bio-monitoring data introduces the potential of exposure bias.

Funding

John Middleton and Gavin Rudge were funded by the National Institute for Health Research (NIHR) Collaborations for Leadership in Applied Health Research and Care for the West Midlands. The views expressed are those of the author(s)

and not necessarily those of the NHS, the NIHR or the Department of Health.

Acknowledgements

Cllr Paul Moore, Jyoti Atri, Ralph Smith, Nathan Lauder, Richard White, Richard Whitehead, Richard Norton, Robert Lloyd, Rishi Bawa, Gregory Barbosa, Turon Karim, Andrew Hood, Dene Stevens (all Sandwell MBC) and Professor Robert McKenzie, Dr Mohammed Mohammed and Gavin Rudge University of Birmingham.

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