Environmental public health tracking

Saunders, Patrick; Middleton, John; Rudge, Gavin

DOI:
10.1093/pubmed/fdw130

Document Version
Peer reviewed version

Citation for published version (Harvard):
Saunders, P, Middleton, J & Rudge, G 2016, 'Environmental public health tracking: a cost-effective system for characterizing the sources, distribution and public health impacts of environmental hazards', *Journal of Public Health*, vol. 39, no. 3, pp. 506-513. https://doi.org/10.1093/pubmed/fdw130

OXFORD UNIVERSITY PRESS | Journal of Public Health

http://mc.manuscriptcentral.com/jph

Environmental Public Health Tracking: A Cost-Effective System for Characterising the Sources, Distribution and Public Health Impacts of Environmental Hazards

Journal:	*Journal of Public Health*
Manuscript ID	JPH-16-0232.R1
Manuscript Type:	Original Article
Date Submitted by the Author:	n/a
Complete List of Authors:	Saunders, Patrick; carolan57 Ltd, Middleton, John D; University of Wolverhampton Rudge, Gavin; University of Birmingham, College of Medical and Dental Sciences
Keywords:	Environment, Epidemiology, Health impact assessment

Environmental Public Health Tracking: A Cost-Effective System for Characterising the ~~Causes~~Sources, Distribution and Public Health Impacts of Environmental Hazards.

Comment [PS1]: Reviewer 2

Saunders PJ[1], Middleton JD[2] and Rudge G[3]

[1] Professor of Public Health, University of Staffordshire
[2] Professor of Public Health, University of Wolverhampton
[3]Research Fellow, Institute of Applied Health Research, University of Birmingham

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 RCP review.[2] There are 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 lead 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 emphasises 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 utilise public, professional and political priorities. These are the principles of Environmental Public Health Tracking (EPHT), a system which has been advocated for decades by many scientists, practitioners and policy makers[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 fantasise 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 organisational 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 scanning[13], 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 presents 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 this can be achieved with modest investment and this first EPHT system outside the US 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 NHS, 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 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 organisations and collection systems, the time periods for specific issues varies.

Comment [PS2]: First 3 bullets reviewer 2

Environmental Exposures

NO_2 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 NO_2 data for the period 2004-11 and two methods, asthma 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 profiling[17] was used to compare populations living in high NO_2 zones with Sandwell as a whole. The University of Birmingham was consulted in exploring the potential of emerging innovations to both reduce levels of NO_2 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 50m 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 2004-2009 which were grouped into four categories-Total (n=20,252), Noise (n=6,523), Environmental (air, land and water pollution, n=3,676) and Public Health (infestations, animals and drainage 10,053). Post-coded incidents were used to calculate weighted and unweighted complaint rates and 99% confidence intervals at Lower Super Output Area (LSOA) level. Descriptive and analytical assessments were conducted together with spatial mapping where appropriate. Statistical Process Charts (SPC) 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 score (IMD).

The distribution and impact of chemical incidents in Sandwell was established using data from the national HPA Chemical Incident Surveillance system and local Public Health Management Systems. Sites of industrial processes were obtained from Integrated Pollution Prevention regulatory system and populations living within 1km, based on the experience of planning authorities and WHO recommendations[5] and 500m, given the large populations in the 1km buffer, were characterised 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, 2000-2004 and 2005-09: standardisation (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, E. 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 minimise skewness and kurtosis. Index scores were mapped and populations in poorly served areas identified and characterised. 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 (TFA) 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 NO_2 is the most important pollutant in the borough with levels of NO_2 estimated to be associated with up to 1300 cases of bronchitis in asthmatic children. The urban increment of NO_2 was estimated to be associated with 180 additional children with wheeze and around 900 additional asthmatic children with bronchitic symptoms. Population profiling of NO_2 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 NOx 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 NOx emissions and 54% of particulate emissions; the largest contribution being from diesel vehicles. There appeared to be no technical fixes short of total pedestrianisation 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 NOx 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.

91% 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 500m of a regulated site. No significant difference between the level of deprivation or the numbers of minority ethnic communities living within 500m of a site and the population living more than 500m 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 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. 321 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 minutes or more on an average day. Assuming a typical cycling speed of 10 mph this alone saved 2.3 lives and at least £2.1m annually. Achieving a realistic average of 4000 more daily cycling trips of around 5km would save an additional £1.3 m.

Comment [PS3]: Completely rewritten in response to reviewer 2

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 health[23] 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 emphasised positive aspects of life in Sandwell. This directly led to investment in 'urban greening' interventions and commitment to improve cycling and walking opportunities.

Comment [PS4]: Rewritten in response to reviewer 2

What is already known on this topic

It is increasingly evident that we will are simply not able to deliver improved and equitable standards of health, wellbeing and health care in the medium to longer term without, as a society, paying much more attention to the environment. What we do or don't 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.

Comment [PS5]: In response to reviewer 1's request for a 'couple of sentences' on this issue

What this study adds

We have demonstrated that such a system can be developed in the UK at marginal cost and

~~The Sandwell programme has been operating in pilot form since April 2011 and has developed innovative integration and analysis of NHS and local authority data, hazard and disease surveillance at small area level, several publications, an active horizon scanning programme which has already highlighted important emerging issues[13], and a range of practice and research initiatives. The table summarises the activities and methods used.~~ 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 recognise 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 recognised value of the pilot work described in this paper and the strong relationships forged, the organisational 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 sensing[26], 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, local surveillance. Local government faces many barriers to innovation including internal structures and organisation, 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 realised using larger populations and spatial scales. The absence of personal exposure or bio-monitoring data introduces the potential of exposure bias.

1. Prüss-Üstün A et al. *Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks*. Geneva: WHO, 2016.
2. Royal College of Physicians. *Every breath we take: the lifelong impact of air pollution. Report of a working party*. London: RCP, 2016.
3. Marmot M *FairSociety ,Healthy Lives: A Strategic Review of Inequalities in England*. London: University College London, 2010.
4. Briggs, D. Environmental pollution and the global burden of disease. *Br Med Bull* 2003;**68(1)**: 1-24.
5. Health Protection Agency. *Health Protection in the 21st Century - Understanding the Burden of Disease*. Chilton: HPA, 2005.
6. Centers for Disease Control and Prevention. Keeping Track, Promoting Health, Joining the Dots. http://www.cdc.gov/nceh/tracking/pdfs/healthtracks.pdf (1st April 2016 date last accessed).
7. Walker G, Fairburn J, Smith G, Mitchell G. *Environment and Social Justice: Rapid Research and Evidence Review. PSI 2004, Environmental Quality and Social Deprivation R&D Technical Report E2-067/1/TR*. London: Sustainable Development Research Network, 2004.
8. Gee GC, Payne-Sturges DC. Environmental health disparities: a framework integrating psychosocial and environmental concepts. *Environ Health Perspect* 2004;**112(17):**1645–53.
9. Department for Communities and Local Government. The English Indices of Deprivation 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/465791/English_Indices_of_Deprivation_2015_-_Statistical_Release.pdf (21st May 2016 date last accessed).
10. Finkel M, Hays J, Law A.The shale gas boom and the need for rational policy. *Am J Public Health* 2013;**103(7):**1161-1163.

11. Saunders PJ. Establishing an Environmental Public Health Tracking System in the UK. *Eur J Pub Health* 2012;**22 (suppl 2):**142-3.
12. Centers for Disease Control and Prevention The National Environmental Public Health Tracking Program. http://www.cdc.gov/nceh/information/tracking_network.htm (1st April 2016 date last accessed).
13. Urquhart G and Saunders PJ. Wider horizons, wiser choices: Horizon scanning for public health protection and improvement. ***J Pub Health*** 2016; doi: 10.1093/pubmed/fdw039
14. Saunders P. *Environmental Public Health Tracking in Sandwell. Report of First's Pilot. ISBN number: 9781900471114.* Oldbury: Sandwell Metropolitan Borough Council, 2013.
15. World Health Organisation Regional Office for Europe. *Children's Environment and Health Action Plan for Europe. Fourth Ministerial Conference on Environment and Health Budapest, Hungary, 23–25 June 2004*. Copenhagen: WHO, 2004.
16. Sandwell trends http://www.sandwelltrends.info/lisv2/navigation/home.asp (7th October 2016 date last accessed).
17. Mosaic Public Sector http://www.experian.co.uk/assets/marketing-services/brochures/mosaic-ps-brochure.pdf (7th October 2016 date last accessed).
18. Johnson BL. Impact of hazardous waste on human health. New York: CRC Press Inc., 1999.
19. IARC International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risk to Humans. http://monographs.iarc.fr/ (7th October 2016 date last accessed).
20. Health and Social Care Information Centre (2013) National Child Measurement Programme – England, 2012–13 school year [NS]. http://www.hscic.gov.uk/catalogue/PUB13115 (9th February 2015 date last accessed).
21. Saunders P, Saunders A, Middleton J. Living in a 'fat swamp': exposure to multiple sources of accessible, cheap, energy-dense fast foods in a deprived community. *Brit J Nutr* 2015;**113(11):**1828-34.
22. Dowler E, Blair A, Donkin A et al. *Measuring access to healthy food in Sandwell*. West Bromwich: Sandwell Health Action Zone and Warwick University, 2000.
23. Middleton J, Saunders P. 20 years of local ecological public health: the experience of Sandwell in the English West Midlands. *Pub Health* 2015;**129(10):**1344-52.

24. Kamel Boulos et al. Crowdsourcing, citizen sensing and sensor web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples**.** *Int J Health Geogr* 2011;**10(67):**67.
25. Hasenfratz D, Saukh O, Sturzenegger S et al. *Participatory Air Pollution Monitoring Using Smartphones. In Proceedings of the 2nd International Workshop on Mobile Sensing.* Beijing; ACM/IEEE IPSN, April 2012.
26. Mead MI, Popoola OAM, Baird G et al. The use of electrochemical sensors for monitoring urban air quality in low-cost, high-density networks. *Atmos Environ* 2013;**70**;186-203.
27. LOCALIS discussion notes. Tackling the Barriers to Innovation in Local Authorities October 2008 http://www.localis.org.uk/wp-content/uploads/2016/02/discussion%20note_barriers%20to%20innovation.pdf (21st May 2016 date last accessed).

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.

Environmental Public Health Tracking: A Cost-Effective System for Characterising the Sources, Distribution and Public Health Impacts of Environmental Hazards.

Saunders PJ[1], Middleton JD[2] and Rudge G[3]

[1] Professor of Public Health, University of Staffordshire
[2] Professor of Public Health, University of Wolverhampton
[3]Research Fellow, Institute of Applied Health Research, University of Birmingham

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 RCP review.[2] There are 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 lead 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 emphasises 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 utilise public, professional and political priorities. These are the principles of Environmental Public Health Tracking (EPHT), a system which has been advocated for decades by many scientists, practitioners and policy makers[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 fantasise 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 organisational 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 scanning[13], 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 presents 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 this can be achieved with modest investment and this first EPHT system outside the US 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 NHS, 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 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 organisations and collection systems, the time periods for specific issues varies.

Environmental Exposures

NO_2 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 NO_2 data for the period 2004-11 and two methods, asthma 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 profiling[17] was used to compare populations living in high NO_2 zones with Sandwell as a whole. The University of Birmingham was consulted in exploring the potential of emerging innovations to both reduce levels of NO_2 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 50m 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 2004-2009 which were grouped into four categories-Total (n=20,252), Noise (n=6,523), Environmental (air, land and water pollution, n=3,676) and Public Health (infestations, animals and drainage 10,053). Post-coded incidents were used to calculate weighted and unweighted complaint rates and 99% confidence intervals at Lower Super Output Area (LSOA) level. Descriptive and analytical assessments were conducted together with spatial mapping where appropriate. Statistical Process Charts (SPC) 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 score (IMD).

The distribution and impact of chemical incidents in Sandwell was established using data from the national HPA Chemical Incident Surveillance system and local Public Health Management Systems. Sites of industrial processes were obtained from Integrated Pollution Prevention regulatory system and populations living within 1km, based on the experience of planning authorities and WHO recommendations[5] and 500m, given the large populations in the 1km buffer, were characterised 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, 2000-2004 and 2005-09: standardisation (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, E. 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 minimise skewness and kurtosis. Index scores were mapped and populations in poorly served areas identified and characterised. 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 (TFA) 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 NO_2 is the most important pollutant in the borough with levels of NO_2 estimated to be associated with up to 1300 cases of bronchitis in asthmatic children. The urban increment of NO_2 was estimated to be associated with 180 additional children with wheeze and around 900 additional asthmatic children with bronchitic symptoms. Population profiling of NO_2 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 NOx 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 NOx emissions and 54% of particulate emissions; the largest contribution being from diesel vehicles. There appeared to be no technical fixes short of total pedestrianisation 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 NOx 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.

91% 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 500m of a regulated site. No significant difference between the level of deprivation or the numbers of minority ethnic communities living within 500m of a site and the population living more than 500m 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 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. 321 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 minutes or more on an average day. Assuming a typical cycling speed of 10 mph this alone saved 2.3 lives and at least £2.1m annually. Achieving a realistic average of 4000 more daily cycling trips of around 5km 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 health[23]

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 emphasised 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 will are simply not able to deliver improved and equitable standards of health, wellbeing and health care in the medium to longer term without, as a society, paying much more attention to the environment. What we do or don't 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 recognise 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 recognised value of the pilot work described in this paper and the strong relationships forged, the organisational 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 sensing[26], 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, local surveillance. Local government faces many barriers to innovation including internal structures and organisation, 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 realised using larger populations and spatial scales. The absence of personal exposure or bio-monitoring data introduces the potential of exposure bias.

1. Prüss-Üstün A et al. *Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks*. Geneva: WHO, 2016.

2. Royal College of Physicians. *Every breath we take: the lifelong impact of air pollution. Report of a working party*. London: RCP, 2016.
3. Marmot M *FairSociety ,Healthy Lives: A Strategic Review of Inequalities in England*. London: University College London, 2010.
4. Briggs, D. Environmental pollution and the global burden of disease. *Br Med Bull* 2003;**68(1)**: 1-24.
5. Health Protection Agency. *Health Protection in the 21st Century - Understanding the Burden of Disease*. Chilton: HPA, 2005.
6. Centers for Disease Control and Prevention. Keeping Track, Promoting Health, Joining the Dots. http://www.cdc.gov/nceh/tracking/pdfs/healthtracks.pdf (1st April 2016 date last accessed).
7. Walker G, Fairburn J, Smith G, Mitchell G. *Environment and Social Justice: Rapid Research and Evidence Review. PSI 2004, Environmental Quality and Social Deprivation R&D Technical Report E2-067/1/TR*. London: Sustainable Development Research Network, 2004.
8. Gee GC, Payne-Sturges DC. Environmental health disparities: a framework integrating psychosocial and environmental concepts. *Environ Health Perspect* 2004;**112(17):**1645–53.
9. Department for Communities and Local Government. The English Indices of Deprivation 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/465791/English_Indices_of_Deprivation_2015_-_Statistical_Release.pdf (21st May 2016 date last accessed).
10. Finkel M, Hays J, Law A.The shale gas boom and the need for rational policy. *Am J Public Health* 2013;**103(7):**1161-1163.
11. Saunders PJ. Establishing an Environmental Public Health Tracking System in the UK. *Eur J Pub Health* 2012;**22 (suppl 2):**142-3.
12. Centers for Disease Control and Prevention The National Environmental Public Health Tracking Program. http://www.cdc.gov/nceh/information/tracking_network.htm (1st April 2016 date last accessed).
13. Urquhart G and Saunders PJ. Wider horizons, wiser choices: Horizon scanning for public health protection and improvement. ***J Pub Health*** 2016; doi: 10.1093/pubmed/fdw039

14. Saunders P. *Environmental Public Health Tracking in Sandwell. Report of First's Pilot. ISBN number: 9781900471114.* Oldbury: Sandwell Metropolitan Borough Council, 2013.
15. World Health Organisation Regional Office for Europe. *Children's Environment and Health Action Plan for Europe. Fourth Ministerial Conference on Environment and Health Budapest, Hungary, 23–25 June 2004*. Copenhagen: WHO, 2004.
16. Sandwell trends http://www.sandwelltrends.info/lisv2/navigation/home.asp (7th October 2016 date last accessed).
17. Mosaic Public Sector http://www.experian.co.uk/assets/marketing-services/brochures/mosaic-ps-brochure.pdf (7th October 2016 date last accessed).
18. Johnson BL. Impact of hazardous waste on human health. New York: CRC Press Inc., 1999.
19. IARC International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risk to Humans. http://monographs.iarc.fr/ (7th October 2016 date last accessed).
20. Health and Social Care Information Centre (2013) National Child Measurement Programme – England, 2012–13 school year [NS]. http://www.hscic.gov.uk/catalogue/PUB13115 (9th February 2015 date last accessed).
21. Saunders P, Saunders A, Middleton J. Living in a 'fat swamp': exposure to multiple sources of accessible, cheap, energy-dense fast foods in a deprived community. *Brit J Nutr* 2015;**113(11):**1828-34.
22. Dowler E, Blair A, Donkin A et al. *Measuring access to healthy food in Sandwell*. West Bromwich: Sandwell Health Action Zone and Warwick University, 2000.
23. Middleton J, Saunders P. 20 years of local ecological public health: the experience of Sandwell in the English West Midlands. *Pub Health* 2015;**129(10):**1344-52.
24. Kamel Boulos et al. Crowdsourcing, citizen sensing and sensor web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples**.** *Int J Health Geogr* 2011;**10(67):**67.
25. Hasenfratz D, Saukh O, Sturzenegger S et al. *Participatory Air Pollution Monitoring Using Smartphones. In Proceedings of the 2nd International Workshop on Mobile Sensing.* Beijing; ACM/IEEE IPSN, April 2012.

26. Mead MI, Popoola OAM, Baird G et al. The use of electrochemical sensors for monitoring urban air quality in low-cost, high-density networks. *Atmos Environ* 2013;**70**;186-203.
27. LOCALIS discussion notes. Tackling the Barriers to Innovation in Local Authorities October 2008 http://www.localis.org.uk/wp-content/uploads/2016/02/discussion%20note_barriers%20to%20innovation.pdf (21st May 2016 date last accessed).

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.

Activity	Methods
Surveillance of environmental hazards: air quality proximity to industrial processes proximity to heavily trafficked roads environmental inequalities public health nuisances chemical incidents	Indirect standardisation, 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 standardisation, Statistical Control Charts, Kernal 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