

Environmental public health tracking

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

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8 **Environmental Public Health Tracking: A Cost-Effective System for Characterising**
9 **the CausesSources, Distribution and Public Health Impacts of Environmental**
10 **Hazards.**

Comment [PS1]: Reviewer 2

11 **Saunders PJ¹, Middleton JD² and Rudge G³**

12
13 ¹ **Professor of Public Health, University of Staffordshire**

14 ² **Professor of Public Health, University of Wolverhampton**

15 ³ **Research Fellow, Institute of Applied Health Research, University of Birmingham**

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17 **Background**

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20 Most of the great public health achievements have been delivered through improving
21 physical and social environments. While these domains have improved so dramatically over
22 the last 150 years that the potential for further gains can be overlooked, there is abundant
23 evidence that environmental interventions present real opportunities for further major health
24 dividends.¹⁻³ The nature and distribution of environmental stresses has changed with new
25 challenges emerging and old ones affecting us in unexpected ways. Professional and lay
26 interests also appear to be divergent reflected in a research focus on large-scale issues
27 such as climate change rather than more immediate local impacts. This presents a
28 challenge for public health practice today; environmental regulation has changed little since
29 the 1950s and there seems to be a dislocation between what is important to local
30 communities and what is being actively researched or promoted for research funding. This
31 is at least partly due to a political, scientific and public perception that a problem has been
32 solved, typically following a response to a crisis, without establishing a mechanism for
33 subsequent vigilance and timely responses as understanding matures and/or
34 circumstances change enabling a recurrence or evolution of the problem. The recent re-
35 emergence of air pollution as a significant public health issue is a case in point, highlighted
36 by the recent RCP review.² There are other examples, of course, and all are complicated by
37 the interactions between environmental, biological and social systems meaning that
38 relatively little is actually known about which parts of the contemporary environment, or
39 combinations thereof, have the most important effects or indeed how.⁴ These uncertainties
40 lead to widely differing estimates of the impacts in the literature^{1,5}, a modest and
41 fragmented research investment, and a consequent lack of evidence based intervention. In
42 2000 the US Pew Environmental Health Committee identified this “environmental health
43 gap,” a lack of basic information needed to document links between environmental hazards
44 and chronic disease. As Tom Burke of John Hopkins University put it ‘We can track flu,
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8 West Nile virus, and mad cow disease but not enough of the chronic illnesses that are the
9 biggest killers.....because we just don't have enough of that basic information'.⁶ However
10 one thing is abundantly clear; poor people are almost invariably more exposed to
11 environmental and public health pressures.^{2,3,7} There is also an emerging consensus that
12 there is something about being poor that makes people more vulnerable to those
13 exposures,^{2,8} an indefensible injustice. However, affluence does not confer complete
14 immunity from these impacts. There is evidence that some relatively better off areas include
15 pockets of intense deprivation hidden from conventional surveillance.⁹ Some elements of air
16 pollution can be higher in some wealthy zones such as Central London due to traffic levels²,
17 and Michael Marmot emphasises the concept of proportionate universalism to both raise
18 everybody's health experience while narrowing the gap between the richest and poorest.³
19 Developing a rational and realistic response is not as daunting as might be thought once
20 the key principles are distilled; these are the timely and routine intelligence on exposures,
21 hazards and health outcomes, integration and analysis of these data to identify trends and
22 potential relationships, the testing of those relationships, and the development of evaluated
23 interventions that reflect and utilise public, professional and political priorities. These are the
24 principles of Environmental Public Health Tracking (EPHT), a system which has been
25 advocated for decades by many scientists, practitioners and policy makers^{10,11} and which
26 underpinned the establishment of a US National Tracking programme in 2002 currently
27 involving projects in 26 states. While UK public health agencies can only fantasise about
28 the level of the Centers for Disease Control and Prevention (CDC) funding for this
29 programme (\$35 million in 2015),¹² they actually have a number of advantages including
30 political and organisational structures, and the coverage, availability, quality and
31 consistency of key data. A different (and cost neutral) Tracking model has been developed
32 to meet local needs in Sandwell MBC in the West Midlands, one of the poorest parts of
33 Europe with a major post-industrial environmental contamination legacy. This includes
34 analyses of public health nuisance to reflect public concerns, the efficacy of local authority
35 practice, local horizon scanning¹³, and the innovative use of industrial quality control
36 methods to target interventions most effectively as well as the routine background
37 surveillance of environmental insult and environmentally related disease.¹⁴
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50 The 2013 public health reforms with public health returning to locally accountable Councils
51 which hold most of the levers of influence in this field presents an opportunity to begin
52 underpinning intervention with both evidence and popular consent. There is now a real
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8 opportunity to apply new epidemiological tools to routine environmental practice, redefining
9 how we manage hazards. Sandwell's experience shows this can be achieved with modest
10 investment and this first EPHT system outside the US is being taken up by other local
11 authorities including an unlikely alliance with one of the more affluent 'middle England'
12 Boroughs demonstrating its utility across very different administrations.
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15 **Methods**

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18 The first stage was to establish a real confederation of the key agencies and individuals.
19 The data, other intelligence, statistical techniques, and communication skills do not lie with
20 one body and identifying the necessary resources and then building a structure to bring
21 these together was critical. The long tradition of joint public health work in the Borough was
22 built on to recruit NHS, local authority departments, Health Protection Agency (HPA),
23 Environment Agency and University academics to a project steering group. This group
24 ensured the system contributed to the statutory and service obligations and business plans
25 of the respective partners and provided ready access to existing datasets without placing
26 additional burdens on partners. The Steering Group identified the key environmental public
27 health challenges in the Borough based on the data and professional and public
28 perceptions (local politicians and a review of public health nuisance complaints by the
29 public were critical to this phase), and biological, temporal and spatial plausibility. While
30 underpinned by evidence wherever possible, it was important not to allow an undeveloped
31 scientific base to work against the inclusion of factors relevant in the borough; the absence
32 of evidence is not the same as evidence of absence. A hierarchy based on the WHO
33 Children's Environmental Health Action Plan programme was accordingly used to ensure
34 the capture of important factors open to realistic intervention.¹⁵ These issues included
35 environmental stressors including air quality, contaminated land, and chemical releases
36 reflecting Sandwell's industrial legacy, food hygiene standards reflecting the density of
37 takeaway outlets associated with high levels of deprivation but also environmental assets
38 including access to green spaces (see table 1). Ostensible 'quality of life' issues such as
39 nuisance complaints are important in their own right with a direct impact on health, an
40 emerging evidence base of a potential to act in concert with other stressors such as
41 poverty, and reflect the experiences of local people.¹¹ The study area is Sandwell MBC and
42 while the system covers the whole population (c.317,000)¹⁶, the impact on susceptible
43 populations was specifically assessed given the relationships and interactions between
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8 environmental stresses and other factors such as deprivation and ethnicity. This pilot covers
9 the period 1995-2014 although given data were accessed from different organisations and
10 collection systems, the time periods for specific issues varies. |

Comment [PS2]: First 3 bullets reviewer 2

11 12 13 *Environmental Exposures*

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16 NO₂ was identified as the most important air pollutant in the borough given the multiple
17 exceedences of the government's Air Quality Strategy annual mean objective. Accordingly,
18 exposure coefficients were derived using NO₂ data for the period 2004-11 and two
19 methods, asthma prevalence studies giving a broadly based effect measure and a multi-
20 pollutant model, used to estimate the health cost of these levels. Annual mean pollutant
21 concentrations were obtained from three local monitoring sites. The urban increment was
22 taken to be the difference between these and those at a rural site in Harwell Oxfordshire.
23 Given the difficulty in accurately assigning populations to air quality areas Mosaic Public
24 Sector profiling¹⁷ was used to compare populations living in high NO₂ zones with Sandwell
25 as a whole. The University of Birmingham was consulted in exploring the potential of
26 emerging innovations to both reduce levels of NO₂ and enhance local environments
27 including 'greening' urban corridors.
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34 HPA had previously reported that 37% of Sandwell's children live within 250 m of a busy
35 road (> 10,000 vehicles per day), much higher than the regional average of 24%¹⁴ The
36 number and characteristics of people living within 50m of heavily trafficked roads were
37 identified and Automatic Number Plate Recognition data on vehicle types to apportion
38 emission sources.
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42 Public health nuisance complaints to the local authority are a potentially powerful metric of
43 environmental quality and well-being. Sandwell MBC provided nuisance complaint data for
44 the years 2004-2009 which were grouped into four categories-Total (n=20,252), Noise
45 (n=6,523), Environmental (air, land and water pollution, n=3,676) and Public Health
46 (infestations, animals and drainage 10,053). Post-coded incidents were used to calculate
47 weighted and unweighted complaint rates and 99% confidence intervals at Lower Super
48 Output Area (LSOA) level. Descriptive and analytical assessments were conducted together
49 with spatial mapping where appropriate. Statistical Process Charts (SPC) were used to
50 identify LSOAs exhibiting special cause variation and those that had significantly
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8 deteriorated or improved over the study period. These 'hot spot' and 'cold spot' areas were
9 subject to a 'case review' assessment including inspections by a student Environmental
10 Health Practitioner (EHP), to identify plausible physical and/or social causes,. The
11 relationship with deprivation was assessed using the LSOA Index of Multiple Deprivation
12 score (IMD).
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16 The distribution and impact of chemical incidents in Sandwell was established using data
17 from the national HPA Chemical Incident Surveillance system and local Public Health
18 Management Systems. Sites of industrial processes were obtained from Integrated
19 Pollution Prevention regulatory system and populations living within 1km, based on the
20 experience of planning authorities and WHO recommendations⁵ and 500m, given the large
21 populations in the 1km buffer, were characterised using census data.
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24 25 *Health Outcomes* 26

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28 Cancer, congenital anomaly and hospital admissions data have been advocated for
29 environmental public health surveillance and CDC, for example, has identified seven
30 categories of health outcomes for studies of landfill sites including birth defects/reproductive
31 disorders, lung/respiratory diseases, and some cancers¹⁸. The International Agency for
32 Research on Cancer had identified 99 chemicals or exposure circumstances plausibly
33 associated with environmental contamination as carcinogenic to humans¹⁹. These
34 monographs were assessed for plausible links between cancer site and exposure to an
35 environmental chemical. Exposures were assessed for plausibility based on current
36 industrial activity and discussions with the local authority on historical processes. This
37 identified 32 plausible relationships between cancer and an environmental exposure in
38 Sandwell including dye manufacture, coal gasification, coke production, coal-tar distillation,
39 acid mists, and coal tar works and the following cancers: lung, leukaemia, urinary bladder
40 cancer, liver, digestive system cancers, multiple melanoma, nasopharyngeal cancer,
41 mesothelioma, skin cancer, scrotal cancer, and bladder cancer. Discussions with key
42 experts in the field also identified prostate cancer as being associated with exposure to
43 cadmium and pesticides, and foetal exposure to endocrine disrupting chemicals. Three
44 methods were explored for assessing potential relationships for 1995-99, 2000-2004 and
45 2005-09: standardisation (direct and indirect), SPCs and kernel risk contouring. Areas with
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8 cancer admissions between 1 and 5 (but not 0) were suppressed. Annual population
9 estimates were based on the census.

10 11 *Food Safety*

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14 Sandwell's compliance with national food hygiene standards was around 68% of 80%
15 nationally in 2009. The relationship between average area food safety score and
16 deprivation was assessed using the IMD. Sandwell had used the flexibility encouraged by
17 government to supplement individual premise risk assessments with interventions in high-
18 risk geographical areas since April 2008 and the impact of this was assessed by comparing
19 individual premise score before and after local authority intervention in two areas using a
20 Wilcoxon signed-rank test and paired T Test. As the food hygiene score uses professional
21 judgment rather than objective microbiological measures, funding was secured for testing
22 surfaces, foods and equipment. Sampling was targeted on retailers and caterers handling
23 both ready to eat (RTE) and raw foods. Sampling included one RTE product together with
24 two environmental samples in line with accepted methods. Samples were tested for the
25 following as appropriate: aerobic colony count, E. coli, Enterobacteriaceae, Coagulase
26 positive Staphylococci, Listeria species including L. monocytogenes. Results were
27 assessed against accepted standards and comparisons made before and after
28 inspection/action including the introduction of food safety zones, and over a range of time
29 intervals to assess whether any effect was mediated over time using paired T-test and χ^2
30 for individual and area comparisons respectively.
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39 Obesity is a major issue In Sandwell with over a third of year 6 children being obese or
40 overweight.²⁰ Access to healthy foods was assessed using location of premises together
41 with quality, cost and range of a 'basket' of healthy foods provided by a dietician. A
42 composite indicator was developed using principal component analysis to reduce the
43 components to a minimum and a transformation process to minimise skewness and
44 kurtosis. Index scores were mapped and populations in poorly served areas identified and
45 characterised. Officers and members had expressed concern about the proliferation of hot
46 food takeaways and the market pressure to use cheaper and more hazardous ingredients
47 such as Trans Fatty Acids (TFA) given the small margins these businesses operate under.
48 Access to these sources of cheap, energy dense takeaway foods was described through a
49 spatial analysis of the relationship between populations and takeaway food outlets using
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7 walking distance as a proxy for access. Samples of a cross section of takeaway foods were
8 taken for analysis for total fat, saturated and unsaturated fats, TFA, salt and sugar. This
9 work is described in detail elsewhere.²¹
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12 *Environmental Goods*

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

24 *Environmental Exposures*

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30 Traffic generated NO₂ is the most important pollutant in the borough with levels of NO₂
31 estimated to be associated with up to 1300 cases of bronchitis in asthmatic children. The
32 urban increment of NO₂ was estimated to be associated with 180 additional children with
33 wheeze and around 900 additional asthmatic children with bronchitic symptoms. Population
34 profiling of NO₂ hotspots showed that, unlike other parts of the country, more affluent
35 people in Sandwell are likely to live in areas of poor air quality. Over 27% of Sandwell
36 families were found to live close to busy roads but, given the wide distribution of such roads
37 in Sandwell, there was little evidence that any specific groups were disproportionately
38 represented. Buses were found to contribute 57% of NO_x and 32% of particulate emissions
39 despite making up only 6% of vehicle flow by 2014. Overall cars made up 86% of the total
40 vehicle flow and contributed to 31% of NO_x emissions and 54% of particulate emissions;
41 the largest contribution being from diesel vehicles. There appeared to be no technical fixes
42 short of total pedestrianisation of busy high roads or condemning the living accommodation
43 as unfit for habitation, neither of which were realistic or politically acceptable. These zones
44 were also in areas with limited access to green space leading to consideration of the
45 potential of 'greening' urban corridors in worst affected areas. Modelling different options
46 revealed the potential to reduce levels of NO_x and particulates by up to 30%. A successful
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8 funding bid was made for the installation of green screens at strategic points to protect
9 vulnerable populations including a primary school.

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11 91% of the population of Sandwell lived within 1 km of a regulated site, 29% within 1 km of
12 an upper tier regulated industrial process compared with 10% nationally. Over half the
13 population of Sandwell lived within 500m of a regulated site. No significant difference
14 between the level of deprivation or the numbers of minority ethnic communities living within
15 500m of a site and the population living more than 500m away was found.

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

25 26 27 28 *Health Outcomes*

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

36 37 38 39 *Food Safety*

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42 There was a clear relationship with deprivation with poorer areas experiencing significantly
43 poorer average food hygiene scores ($R^2=0.6$). The area targeting approach had a highly
44 significant impact on improving the individual premise score in the two areas considered
45 ($p=0.001$) and had coincided with an increase in overall food premises compliance from
46 68% to over 77%. While overall microbiological standards improved after the intervention
47 this difference was not significant ($p= 0.1$). This is not to say such inspections are not
48 worthwhile. The study used a relatively small sample size (53 premises) and the
49 microbiological metric is not the only measure of effectiveness. However, it does prompt the
50 question of the most effective use of the EHP resource to protect and improve health. Very
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8 few people die from food poisoning in Sandwell while 1000s die from dietary related
9 diseases. Availability of healthy foods is critical and previous work had demonstrated the
10 poor access to fresh fruits and vegetables in the Borough ('food desert') and the utility of a
11 healthy food access indicator.²² A holistic approach to the issue of diet led to consideration
12 of the availability of unhealthy food as well as healthy options. Mapping food outlets showed
13 Sandwell was effectively saturated with hot food takeaways with virtually nowhere more
14 than a very short walk from an outlet. The density of outlets also increased with deprivation
15 effectively doubling the chance of living close to such takeaways. Sampling and analysis of
16 a range of takeaway foods identified that people in Sandwell were exposed to large portion
17 sizes and unacceptable levels of fats, saturated fats and salt, some of which had increased
18 since 2010.²¹

23 24 *Environmental Goods*

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27 Almost 17% of the Borough area was found made up of accessible green space with an
28 average of 4 ha of accessible green space for every 1000 people. 321 of the 539 sites had
29 unrestricted access, 170 limited access and 48 inaccessible. However, there was
30 considerable variation in the amount of green space across the six towns.

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34 Cycle ownership was found to be much higher than cycle use, suggesting that many people
35 would like to cycle more if conditions were right. Fewer than 2% of people in the Sandwell
36 population cycled to work and only 5% cycled regularly. However over 4000 people in
37 Sandwell cycled for 30 minutes or more on an average day. Assuming a typical cycling
38 speed of 10 mph this alone saved 2.3 lives and at least £2.1m annually. Achieving a
39 realistic average of 4000 more daily cycling trips of around 5km would save an additional
40 £1.3 m.

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

44 45 **Discussion**

46 47 **Main finding of this study**

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

Comment [PS4]: Rewritten in response to reviewer 2

22 23 What is already known on this topic

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25 It is increasingly evident that we will are simply not able to deliver improved and equitable
26 standards of health, wellbeing and health care in the medium to longer term without, as a
27 society, paying much more attention to the environment. What we do or don't do in our
28 towns, cities and rural communities not only influences local environments in health-
29 relevant ways but also changes global ecosystems in ways which damage health. Tracking
30 has the utility to both address local environmental issues and contribute to the international
31 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

36 37 What this study adds

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39 We have demonstrated that such a system can be developed in the UK at marginal cost
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43 ~~The Sandwell programme has been operating in pilot form since April 2011 and has~~
44 ~~developed innovative integration and analysis of NHS and local authority data, hazard and~~
45 ~~disease surveillance at small area level, several publications, an active horizon scanning~~
46 ~~programme which has already highlighted important emerging issues¹³, and a range of~~
47 ~~practice and research initiatives. The table summarises the activities and methods used.~~
48 several local authorities are now collaborating with Sandwell on extending the service
49 across the region and beyond, a development, which has attracted WHO endorsement. It
50 is important that the public health community re-evaluates the role and application of routine
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8 environmental monitoring and service data and learns to apply these using innovative
9 methods. There is still much to be improved in our physical environment through the actions
10 of local government, national and international regulators. The local focus of environmental
11 tracking has been largely overlooked until now. In England, the return of public health
12 responsibilities to local authorities gives a renewed impetus to the relationship between
13 public and environmental health. There are still gains to be made for the protection of the
14 public's health and benefits for quality of life and health improvement through the
15 recognition and development of environmental assets. However we recognise the
16 challenges that local government faces with a seemingly endless round of swingeing
17 budget cuts and the inevitable focus on the 'big ticket' and high-risk responsibilities of adult
18 social care and children's services. In these circumstances health surveillance and related
19 activity can be viewed as a discretionary spend. Indeed despite the recognised value of the
20 pilot work described in this paper and the strong relationships forged, the organisational
21 turmoil around the implementation of the 2012 Health and Social Care Act has stymied its
22 development.
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30 Public health departments need to embrace and exploit smart working and low cost
31 solutions including crowd sourcing data from residents about environment and health^{24,25},
32 new low cost technologies for sensing²⁶, and maximising the value of integrating existing
33 routinely collected data. The flight of qualified staff from the public health function and the
34 concentration of the more technocratic parts of that workforce in PHE to work on national
35 priorities have seriously reduced the opportunities for informed, effective, local surveillance.
36 Local government faces many barriers to innovation including internal structures and
37 organisation, inadequate citizen focus, a culture of risk aversion, and cost.²⁷ The drivers for,
38 and location of, Tracking may therefore have to change. This is by no means a bad thing;
39 necessity being the mother of invention could herald more use of engaged citizens, virtual
40 groups, the third and private sectors, and social enterprises, and the pooling of resources.
41 There is surely also a role in this context for Health and Wellbeing Boards, PHE and, where
42 they exist, elected Mayors? Tracking could serve as a catalyst for new ways of effectively
43 and efficiently working together across multiple public health, professional and political
44 geographies.
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51 **Limitations of this study**

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

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

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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

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3 biggest killers.....because we just don't have enough of that basic information'.⁶ However
4 one thing is abundantly clear; poor people are almost invariably more exposed to
5 environmental and public health pressures.^{2,3,7} There is also an emerging consensus that
6 there is something about being poor that makes people more vulnerable to those
7 exposures,^{2,8} an indefensible injustice. However, affluence does not confer complete
8 immunity from these impacts. There is evidence that some relatively better off areas include
9 pockets of intense deprivation hidden from conventional surveillance.⁹ Some elements of air
10 pollution can be higher in some wealthy zones such as Central London due to traffic levels²,
11 and Michael Marmot emphasises the concept of proportionate universalism to both raise
12 everybody's health experience while narrowing the gap between the richest and poorest.³
13 Developing a rational and realistic response is not as daunting as might be thought once
14 the key principles are distilled; these are the timely and routine intelligence on exposures,
15 hazards and health outcomes, integration and analysis of these data to identify trends and
16 potential relationships, the testing of those relationships, and the development of evaluated
17 interventions that reflect and utilise public, professional and political priorities. These are the
18 principles of Environmental Public Health Tracking (EPHT), a system which has been
19 advocated for decades by many scientists, practitioners and policy makers^{10,11} and which
20 underpinned the establishment of a US National Tracking programme in 2002 currently
21 involving projects in 26 states. While UK public health agencies can only fantasise about
22 the level of the Centers for Disease Control and Prevention (CDC) funding for this
23 programme (\$35 million in 2015),¹² they actually have a number of advantages including
24 political and organisational structures, and the coverage, availability, quality and
25 consistency of key data. A different (and cost neutral) Tracking model has been developed
26 to meet local needs in Sandwell MBC in the West Midlands, one of the poorest parts of
27 Europe with a major post-industrial environmental contamination legacy. This includes
28 analyses of public health nuisance to reflect public concerns, the efficacy of local authority
29 practice, local horizon scanning¹³, and the innovative use of industrial quality control
30 methods to target interventions most effectively as well as the routine background
31 surveillance of environmental insult and environmentally related disease.¹⁴
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53 The 2013 public health reforms with public health returning to locally accountable Councils
54 which hold most of the levers of influence in this field presents an opportunity to begin
55 underpinning intervention with both evidence and popular consent. There is now a real
56 opportunity to apply new epidemiological tools to routine environmental practice, redefining
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3 how we manage hazards. Sandwell's experience shows this can be achieved with modest
4 investment and this first EPHT system outside the US is being taken up by other local
5 authorities including an unlikely alliance with one of the more affluent 'middle England'
6 Boroughs demonstrating its utility across very different administrations.
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10 11 **Methods**

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14 The first stage was to establish a real confederation of the key agencies and individuals.
15 The data, other intelligence, statistical techniques, and communication skills do not lie with
16 one body and identifying the necessary resources and then building a structure to bring
17 these together was critical. The long tradition of joint public health work in the Borough was
18 built on to recruit NHS, local authority departments, Health Protection Agency (HPA),
19 Environment Agency and University academics to a project steering group. This group
20 ensured the system contributed to the statutory and service obligations and business plans
21 of the respective partners and provided ready access to existing datasets without placing
22 additional burdens on partners. The Steering Group identified the key environmental public
23 health challenges in the Borough based on the data and professional and public
24 perceptions (local politicians and a review of public health nuisance complaints by the
25 public were critical to this phase), and biological, temporal and spatial plausibility. While
26 underpinned by evidence wherever possible, it was important not to allow an undeveloped
27 scientific base to work against the inclusion of factors relevant in the borough; the absence
28 of evidence is not the same as evidence of absence. A hierarchy based on the WHO
29 Children's Environmental Health Action Plan programme was accordingly used to ensure
30 the capture of important factors open to realistic intervention.¹⁵ These issues included
31 environmental stressors including air quality, contaminated land, and chemical releases
32 reflecting Sandwell's industrial legacy, food hygiene standards reflecting the density of
33 takeaway outlets associated with high levels of deprivation but also environmental assets
34 including access to green spaces (see table 1). Ostensible 'quality of life' issues such as
35 nuisance complaints are important in their own right with a direct impact on health, an
36 emerging evidence base of a potential to act in concert with other stressors such as
37 poverty, and reflect the experiences of local people.¹¹ The study area is Sandwell MBC and
38 while the system covers the whole population (c.317,000)¹⁶, the impact on susceptible
39 populations was specifically assessed given the relationships and interactions between
40 environmental stresses and other factors such as deprivation and ethnicity. This pilot covers
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3 the period 1995-2014 although given data were accessed from different organisations and
4 collection systems, the time periods for specific issues varies.
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7 *Environmental Exposures*

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11 NO₂ was identified as the most important air pollutant in the borough given the multiple
12 exceedences of the government's Air Quality Strategy annual mean objective. Accordingly,
13 exposure coefficients were derived using NO₂ data for the period 2004-11 and two
14 methods, asthma prevalence studies giving a broadly based effect measure and a multi-
15 pollutant model, used to estimate the health cost of these levels. Annual mean pollutant
16 concentrations were obtained from three local monitoring sites. The urban increment was
17 taken to be the difference between these and those at a rural site in Harwell Oxfordshire.
18 Given the difficulty in accurately assigning populations to air quality areas Mosaic Public
19 Sector profiling¹⁷ was used to compare populations living in high NO₂ zones with Sandwell
20 as a whole. The University of Birmingham was consulted in exploring the potential of
21 emerging innovations to both reduce levels of NO₂ and enhance local environments
22 including 'greening' urban corridors.
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33 HPA had previously reported that 37% of Sandwell's children live within 250 m of a busy
34 road (> 10,000 vehicles per day), much higher than the regional average of 24%¹⁴ The
35 number and characteristics of people living within 50m of heavily trafficked roads were
36 identified and Automatic Number Plate Recognition data on vehicle types to apportion
37 emission sources.
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43 Public health nuisance complaints to the local authority are a potentially powerful metric of
44 environmental quality and well-being. Sandwell MBC provided nuisance complaint data for
45 the years 2004-2009 which were grouped into four categories-Total (n=20,252), Noise
46 (n=6,523), Environmental (air, land and water pollution, n=3,676) and Public Health
47 (infestations, animals and drainage 10,053). Post-coded incidents were used to calculate
48 weighted and unweighted complaint rates and 99% confidence intervals at Lower Super
49 Output Area (LSOA) level. Descriptive and analytical assessments were conducted together
50 with spatial mapping where appropriate. Statistical Process Charts (SPC) were used to
51 identify LSOAs exhibiting special cause variation and those that had significantly
52 deteriorated or improved over the study period. These 'hot spot' and 'cold spot' areas were
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3 subject to a 'case review' assessment including inspections by a student Environmental
4 Health Practitioner (EHP), to identify plausible physical and/or social causes,. The
5 relationship with deprivation was assessed using the LSOA Index of Multiple Deprivation
6 score (IMD).
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11 The distribution and impact of chemical incidents in Sandwell was established using data
12 from the national HPA Chemical Incident Surveillance system and local Public Health
13 Management Systems. Sites of industrial processes were obtained from Integrated
14 Pollution Prevention regulatory system and populations living within 1km, based on the
15 experience of planning authorities and WHO recommendations⁵ and 500m, given the large
16 populations in the 1km buffer, were characterised using census data.
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22 *Health Outcomes*

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26 Cancer, congenital anomaly and hospital admissions data have been advocated for
27 environmental public health surveillance and CDC, for example, has identified seven
28 categories of health outcomes for studies of landfill sites including birth defects/reproductive
29 disorders, lung/respiratory diseases, and some cancers¹⁸. The International Agency for
30 Research on Cancer had identified 99 chemicals or exposure circumstances plausibly
31 associated with environmental contamination as carcinogenic to humans¹⁹. These
32 monographs were assessed for plausible links between cancer site and exposure to an
33 environmental chemical. Exposures were assessed for plausibility based on current
34 industrial activity and discussions with the local authority on historical processes. This
35 identified 32 plausible relationships between cancer and an environmental exposure in
36 Sandwell including dye manufacture, coal gasification, coke production, coal-tar distillation,
37 acid mists, and coal tar works and the following cancers: lung, leukaemia, urinary bladder
38 cancer, liver, digestive system cancers, multiple melanoma, nasopharyngeal cancer,
39 mesothelioma, skin cancer, scrotal cancer, and bladder cancer. Discussions with key
40 experts in the field also identified prostate cancer as being associated with exposure to
41 cadmium and pesticides, and foetal exposure to endocrine disrupting chemicals. Three
42 methods were explored for assessing potential relationships for 1995-99, 2000-2004 and
43 2005-09: standardisation (direct and indirect), SPCs and kernel risk contouring. Areas with
44 cancer admissions between 1 and 5 (but not 0) were suppressed. Annual population
45 estimates were based on the census.
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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

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3 taken for analysis for total fat, saturated and unsaturated fats, TFA, salt and sugar. This
4 work is described in detail elsewhere.²¹
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7 8 *Environmental Goods*

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11 The level of cycle ownership and use was identified for 2010 and the WHO's health
12 economic tool used to estimate the annual healthcare cost savings of increasing cycling
13 uptake in Sandwell. The number, size and accessibility of green spaces in the Borough
14 were identified and mapped. Accessibility was assessed as unrestricted; limited by cost,
15 social or physical barriers; or not accessible.
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19 20 21 **Results**

22 23 24 *Environmental Exposures*

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27 Traffic generated NO₂ is the most important pollutant in the borough with levels of NO₂
28 estimated to be associated with up to 1300 cases of bronchitis in asthmatic children. The
29 urban increment of NO₂ was estimated to be associated with 180 additional children with
30 wheeze and around 900 additional asthmatic children with bronchitic symptoms. Population
31 profiling of NO₂ hotspots showed that, unlike other parts of the country, more affluent
32 people in Sandwell are likely to live in areas of poor air quality. Over 27% of Sandwell
33 families were found to live close to busy roads but, given the wide distribution of such roads
34 in Sandwell, there was little evidence that any specific groups were disproportionately
35 represented. Buses were found to contribute 57% of NO_x and 32% of particulate emissions
36 despite making up only 6% of vehicle flow by 2014. Overall cars made up 86% of the total
37 vehicle flow and contributed to 31% of NO_x emissions and 54% of particulate emissions;
38 the largest contribution being from diesel vehicles. There appeared to be no technical fixes
39 short of total pedestrianisation of busy high roads or condemning the living accommodation
40 as unfit for habitation, neither of which were realistic or politically acceptable. These zones
41 were also in areas with limited access to green space leading to consideration of the
42 potential of 'greening' urban corridors in worst affected areas. Modelling different options
43 revealed the potential to reduce levels of NO_x and particulates by up to 30%. A successful
44 funding bid was made for the installation of green screens at strategic points to protect
45 vulnerable populations including a primary school.
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4 91% of the population of Sandwell lived within 1 km of a regulated site, 29% within 1 km of
5 an upper tier regulated industrial process compared with 10% nationally. Over half the
6 population of Sandwell lived within 500m of a regulated site. No significant difference
7 between the level of deprivation or the numbers of minority ethnic communities living within
8 500m of a site and the population living more than 500m away was found.
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14 A very strong relationship between LSOAs with significantly high levels of nuisance
15 complaint and deprivation was identified ($R^2=0.9$). The SPC analysis of nuisance
16 complaints identified 15 areas that were consistently poor and/or deteriorating over the
17 period which were inspected and any real or potential nuisances recorded, photographed
18 and referred to the local authority for intervention.
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23 24 *Health Outcomes*

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27 No clear spatial relationship was found between any of the areas of elevated cancer
28 incidence and landfill sites, foundry waste sites, regulated industrial processes, or areas of
29 elevated nuisance complaints, for any of the three time periods considered. The pilot
30 revealed under-ascertainment in the data recording processes prompting development of
31 improved systems.
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37 38 *Food Safety*

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41 There was a clear relationship with deprivation with poorer areas experiencing significantly
42 poorer average food hygiene scores ($R^2=0.6$). The area targeting approach had a highly
43 significant impact on improving the individual premise score in the two areas considered
44 ($p=0.001$) and had coincided with an increase in overall food premises compliance from
45 68% to over 77%. While overall microbiological standards improved after the intervention
46 this difference was not significant ($p= 0.1$). This is not to say such inspections are not
47 worthwhile. The study used a relatively small sample size (53 premises) and the
48 microbiological metric is not the only measure of effectiveness. However, it does prompt the
49 question of the most effective use of the EHP resource to protect and improve health. Very
50 few people die from food poisoning in Sandwell while 1000s die from dietary related
51 diseases. Availability of healthy foods is critical and previous work had demonstrated the
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3 poor access to fresh fruits and vegetables in the Borough ('food desert') and the utility of a
4 healthy food access indicator.²² A holistic approach to the issue of diet led to consideration
5 of the availability of unhealthy food as well as healthy options. Mapping food outlets showed
6 Sandwell was effectively saturated with hot food takeaways with virtually nowhere more
7 than a very short walk from an outlet. The density of outlets also increased with deprivation
8 effectively doubling the chance of living close to such takeaways. Sampling and analysis of
9 a range of takeaway foods identified that people in Sandwell were exposed to large portion
10 sizes and unacceptable levels of fats, saturated fats and salt, some of which had increased
11 since 2010.²¹

12 13 14 15 16 17 18 19 *Environmental Goods*

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22 Almost 17% of the Borough area was found made up of accessible green space with an
23 average of 4 ha of accessible green space for every 1000 people. 321 of the 539 sites had
24 unrestricted access, 170 limited access and 48 inaccessible. However, there was
25 considerable variation in the amount of green space across the six towns.

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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.

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101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 **Main finding of this study**

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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

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3 generated assessments and interventions that would not have otherwise been considered
4 e.g. using SPC for the first time, to the authors' knowledge, to target routine nuisance
5 inspections and for routinely monitoring the relationship between hazards and disease. The
6 latter provided reassuring analyses about the impact of residential proximity to landfill and
7 foundry sites and industrial processes, a source of considerable local anxiety. The asset-
8 based approach was attractive to politicians as it emphasised positive aspects of life in
9 Sandwell. This directly led to investment in 'urban greening' interventions and commitment
10 to improve cycling and walking opportunities.
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17 **What is already known on this topic**

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21 It is increasingly evident that we will be simply not able to deliver improved and equitable
22 standards of health, wellbeing and health care in the medium to longer term without, as a
23 society, paying much more attention to the environment. What we do or don't do in our
24 towns, cities and rural communities not only influences local environments in health-
25 relevant ways but also changes global ecosystems in ways which damage health. Tracking
26 has the utility to both address local environmental issues and contribute to the international
27 action required for long term sustainable public health improvements.
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34 **What this study adds**

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37 We have demonstrated that such a system can be developed in the UK at marginal cost
38 and several local authorities are now collaborating with Sandwell on extending the service
39 across the region and beyond, a development, which has attracted WHO endorsement. It
40 is important that the public health community re-evaluates the role and application of routine
41 environmental monitoring and service data and learns to apply these using innovative
42 methods. There is still much to be improved in our physical environment through the actions
43 of local government, national and international regulators. The local focus of environmental
44 tracking has been largely overlooked until now. In England, the return of public health
45 responsibilities to local authorities gives a renewed impetus to the relationship between
46 public and environmental health. There are still gains to be made for the protection of the
47 public's health and benefits for quality of life and health improvement through the
48 recognition and development of environmental assets. However we recognise the
49 challenges that local government faces with a seemingly endless round of swingeing
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3 budget cuts and the inevitable focus on the 'big ticket' and high-risk responsibilities of adult
4 social care and children's services. In these circumstances health surveillance and related
5 activity can be viewed as a discretionary spend. Indeed despite the recognised value of the
6 pilot work described in this paper and the strong relationships forged, the organisational
7 turmoil around the implementation of the 2012 Health and Social Care Act has stymied its
8 development.
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14 Public health departments need to embrace and exploit smart working and low cost
15 solutions including crowd sourcing data from residents about environment and health ^{24,25},
16 new low cost technologies for sensing²⁶, and maximising the value of integrating existing
17 routinely collected data. The flight of qualified staff from the public health function and the
18 concentration of the more technocratic parts of that workforce in PHE to work on national
19 priorities have seriously reduced the opportunities for informed, effective, local surveillance.
20 Local government faces many barriers to innovation including internal structures and
21 organisation, inadequate citizen focus, a culture of risk aversion, and cost.²⁷ The drivers for,
22 and location of, Tracking may therefore have to change. This is by no means a bad thing;
23 necessity being the mother of invention could herald more use of engaged citizens, virtual
24 groups, the third and private sectors, and social enterprises, and the pooling of resources.
25 There is surely also a role in this context for Health and Wellbeing Boards, PHE and, where
26 they exist, elected Mayors? Tracking could serve as a catalyst for new ways of effectively
27 and efficiently working together across multiple public health, professional and political
28 geographies.
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41 **Limitations of this study**

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45 The full utility of such a study can only be realised using larger populations and spatial
46 scales. The absence of personal exposure or bio-monitoring data introduces the potential of
47 exposure bias.
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55 *assessment of the burden of disease from environmental risks*. Geneva: WHO, 2016.
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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, 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