

## 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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Review

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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 PJ<sup>1</sup>, Middleton JD<sup>2</sup> and Rudge G<sup>3</sup>**

12  
13 <sup>1</sup> **Professor of Public Health, University of Staffordshire**

14 <sup>2</sup> **Professor of Public Health, University of Wolverhampton**

15 <sup>3</sup> **Research Fellow, Institute of Applied Health Research, University of Birmingham**

16  
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.<sup>1-3</sup> 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.<sup>2</sup> 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.<sup>4</sup> These uncertainties  
40 lead to widely differing estimates of the impacts in the literature<sup>1,5</sup>, 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'.<sup>6</sup> However  
10 one thing is abundantly clear; poor people are almost invariably more exposed to  
11 environmental and public health pressures.<sup>2,3,7</sup> There is also an emerging consensus that  
12 there is something about being poor that makes people more vulnerable to those  
13 exposures,<sup>2,8</sup> 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.<sup>9</sup> Some elements of air  
16 pollution can be higher in some wealthy zones such as Central London due to traffic levels<sup>2</sup>,  
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.<sup>3</sup>  
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<sup>10,11</sup> 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),<sup>12</sup> 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 scanning<sup>13</sup>, 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.<sup>14</sup>  
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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.<sup>15</sup> 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.<sup>11</sup> The study area is Sandwell MBC and  
42 while the system covers the whole population (c.317,000)<sup>16</sup>, 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 NO<sub>2</sub> 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 NO<sub>2</sub> 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 profiling<sup>17</sup> was used to compare populations living in high NO<sub>2</sub> 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 NO<sub>2</sub> 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%<sup>14</sup> 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 recommendations<sup>5</sup> 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 cancers<sup>18</sup>. The International Agency for  
32 Research on Cancer had identified 99 chemicals or exposure circumstances plausibly  
33 associated with environmental contamination as carcinogenic to humans<sup>19</sup>. 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  $\chi^2$   
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.<sup>20</sup> 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.<sup>21</sup>  
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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 NO<sub>2</sub> is the most important pollutant in the borough with levels of NO<sub>2</sub>  
31 estimated to be associated with up to 1300 cases of bronchitis in asthmatic children. The  
32 urban increment of NO<sub>2</sub> 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 NO<sub>2</sub> 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<sub>x</sub> 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<sub>x</sub> 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<sub>x</sub> 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.<sup>22</sup> 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.<sup>21</sup>

#### 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 health<sup>23</sup>  
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  
40 and

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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 issues<sup>13</sup>, 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<sup>24,25</sup>,  
32 new low cost technologies for sensing<sup>26</sup>, 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.<sup>27</sup> 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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## **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.<sup>1-3</sup> 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.<sup>2</sup> 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.<sup>4</sup> These uncertainties lead to widely differing estimates of the impacts in the literature<sup>1,5</sup>, 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'.<sup>6</sup> However  
4 one thing is abundantly clear; poor people are almost invariably more exposed to  
5 environmental and public health pressures.<sup>2,3,7</sup> There is also an emerging consensus that  
6 there is something about being poor that makes people more vulnerable to those  
7 exposures,<sup>2,8</sup> 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.<sup>9</sup> Some elements of air  
10 pollution can be higher in some wealthy zones such as Central London due to traffic levels<sup>2</sup>,  
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.<sup>3</sup>  
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<sup>10,11</sup> 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),<sup>12</sup> 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 scanning<sup>13</sup>, 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.<sup>14</sup>  
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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 **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.<sup>15</sup> 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.<sup>11</sup> The study area is Sandwell MBC and  
38 while the system covers the whole population (c.317,000)<sup>16</sup>, 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 NO<sub>2</sub> 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 NO<sub>2</sub> 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 profiling<sup>17</sup> was used to compare populations living in high NO<sub>2</sub> 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 NO<sub>2</sub> 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%<sup>14</sup> 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 recommendations<sup>5</sup> 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 cancers<sup>18</sup>. The International Agency for  
30 Research on Cancer had identified 99 chemicals or exposure circumstances plausibly  
31 associated with environmental contamination as carcinogenic to humans<sup>19</sup>. 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% of 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  $\chi^2$  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.<sup>20</sup> 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.<sup>21</sup>  
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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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## 20 21 **Results**

### 22 23 24 *Environmental Exposures*

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27 Traffic generated NO<sub>2</sub> is the most important pollutant in the borough with levels of NO<sub>2</sub>  
28 estimated to be associated with up to 1300 cases of bronchitis in asthmatic children. The  
29 urban increment of NO<sub>2</sub> 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 NO<sub>2</sub> 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<sub>x</sub> 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<sub>x</sub> 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<sub>x</sub> 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.<sup>22</sup> 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.<sup>21</sup>

### 12 13 14 15 16 17 18 19 20 *Environmental Goods*

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

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

## 38 39 40 41 42 43 44 **Discussion**

### 45 46 47 48 **Main finding of this study**

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51 While still in a pilot form, the Sandwell programme, using routinely available data and  
52 consultation with professionals, politicians and the public, has identified the most important  
53 environmentally related public health issues in Sandwell, described their distribution,  
54 quantified their impact, and influenced practice. Using an ecological model of public health<sup>23</sup>

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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<sup>24,25</sup>,  
16 new low cost technologies for sensing<sup>26</sup>, 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.<sup>27</sup> 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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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