Risk of adverse birth outcomes in populations living near landfill sites

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Abstract

Objective To investigate the risk of adverse birth outcomes associated with residence near landfill sites in Great Britain.

Design Geographical study of risks of adverse birth outcomes in populations living within 2 km of 9565 landfill sites operational at some time between 1982 and 1997 (from a total of 19 196 sites) compared with those living further away.

Setting Great Britain.

Subjects Over 8.2 million live births, 43 471 stillbirths, and 124 597 congenital anomalies (including terminations).

Main outcome measures All congenital anomalies combined, some specific anomalies, and prevalence of low and very low birth weight (<2500 g and <1500 g).

Results For all anomalies combined, relative risk of residence near landfill sites (all waste types) was 0.92 (99% confidence interval 0.907 to 0.923) unadjusted, and 1.01 (1.005 to 1.023) adjusted for confounders. Adjusted risks were 1.05 (1.01 to 1.10) for neural tube defects, 0.96 (0.93 to 0.99) for cardiovascular defects, 1.07 (1.04 to 1.10) for hypospadias and epispadias (with no excess of surgical correction), 1.08 (1.01 to 1.15) for abdominal wall defects, 1.19 (1.05 to 1.34) for surgical correction of gastroschisis and exomphalos, and 1.05 (1.047 to 1.055) and 1.04 (1.03 to 1.05) for low and very low birth weight respectively. There was no excess risk of stillbirth. Findings for special (hazardous) waste sites did not differ systematically from those for non-special sites. For some specific anomalies, higher risks were found in the period before opening compared with after opening of a landfill site, especially hospital admissions for abdominal wall defects.

Conclusions We found small excess risks of congenital anomalies and low and very low birth weight in populations living near landfill sites. No causal mechanisms are available to explain these findings, and alternative explanations include data artefacts and residual confounding. Further studies are needed to help differentiate between the various possibilities.

Introduction

Waste disposal by landfill accounts for over 80% of municipal waste in Britain.[1] Human exposure to toxic chemicals in landfill (which include volatile organic compounds, pesticides, solvents, and heavy metals[2–4]) may occur by dispersion of contaminated air or soil,[2] leaching or runoff,[5] or by animals and birds, although evidence for any substantial exposures is largely lacking.[6] Excess risks of congenital anomalies and low birth weight near landfill have been reported,[6–9] including from recent European and UK studies,[10,11] although some have reported less significant[12] or negative findings.[13] The aim of our present study was to examine risk of adverse birth outcomes associated with residence near landfill using data on all known sites in Great Britain.

Methods

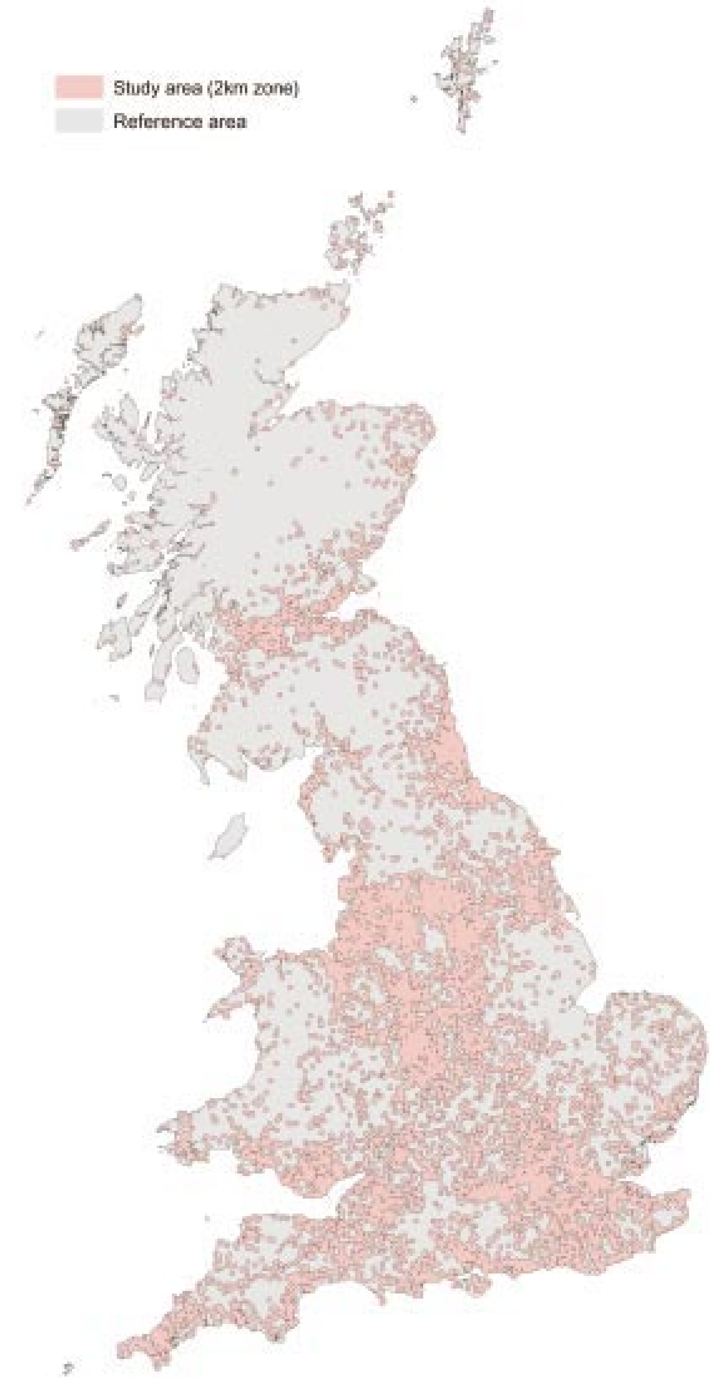
Classification of populations near landfill sites

Data provided by the national regulatory agencies were merged in a geographical information system to give a database containing 19 196 sites. Data on boundaries were unavailable for most sites, so point locations had to be used. These comprised the site centroids for 70% of sites and, for the remainder, the location of the site gateway at the time of reporting. Data for site locations were of low accuracy (often rounded to 1000 metres), and data on area were inadequate to allow estimation of the extent of most sites. Landfill sites also change considerably over time as old areas are closed and new areas develop, while postcodes (used to define the location of cases and births) give only an approximation of place of residence, accurate to 10-100 metres in urban areas but >1 km in some rural areas; also, landfill sites are highly clustered, so that individual postcodes may lie close to 30 or more sites. Therefore, distance from nearest landfill site was not regarded as a meaningful proxy for exposure. As a compromise between the need for spatial precision and the limited accuracy of the data, we constructed a 2 km zone around each site (figure), giving resolution similar to or higher than that of previous studies,[10,11] and at the likely limit of dispersion for landfill emissions.[14] Postcodes within the 2 km buffer zone were classified hierarchically by operational status, year on year, such that sites still operating took precedence over those closed earlier in the study period, which took precedence over sites opening later in the study period.[15] People living more than 2 km from all known landfill sites during the study period comprised the reference population.

Because of concerns about the quality of landfill data for earlier years, and because health data were available only to 1998, we excluded 9631 sites (25% of the population) that closed before 1982 or opened after 1997 (to allow a one year lag period for the birth outcomes) or for which there were inadequate data. The remaining 9565 sites comprised 774 sites for special (hazardous) waste, 7803 for non-special waste, and 988 handling unknown wastes. The 2 km surrounding these sites included 55% of the national population; 20% were included in the reference area.

Health and denominator data

We used national postcoded registers held by the Small Area Health Statistics Unit. These comprised the National Congenital Anomaly System in England and



Map of Great Britain showing 2 km zones around landfill sites and reference area

Wales, 1983-98, and data on terminations, 1992-8, performed for "grounds E" of the 1967 Abortions Act ("where there is a substantial risk that if the child were born it would suffer from such physical or mental abnormality as to be seriously handicapped"); congenital anomaly and terminations data for Scotland, 1988-94; hospital admissions data for England and Scotland, 1993-8 (Welsh data were considered unreliable); and national births and stillbirths data, 1983-98.

Cases were coded to ICD-9 (international classification of diseases, ninth revision) from 1983 to 1994, and to ICD-10 thereafter. Outcomes were all congenital anomalies combined (ICD-9 740-59; ICD-10 Q00-Q99); neural tube defects (ICD-9 740.0-740.2, 741.0-741.9, 742.0; ICD-10 Q00.0-Q00.2, Q05.0-Q05.9, Q01.0-Q01.9); cardiovascular defects (ICD-9 745.0-747.9; ICD-10 Q20.0-Q28.9); abdominal wall defects (ICD-9 756.7; ICD-10 Q79.2-Q79.4); hypospadias and epispadias (ICD-9 752.6; ICD-10 Q54.0-Q54.9, Q64.0); surgical correction of hypospadias and epispadias (M731, M732); and surgical correction of gastroschisis and exomphalos (T281). Multiple anomalies were counted under each outcome (once only for all anomalies combined).

Surgical corrections (England and Scotland only) were analysed by date of birth, not date of surgical procedure. For hypospadias and epispadias, we included only procedures carried out before the age of 3 years, and, for gastroschisis and exomphalos, in the first year of life only. Low and very low birth weights were defined as <2500 g and <1500 g respectively. The relevant denominators and years of analysis are shown in table 1.

Statistical methods

We calculated risks for the population within 2 km of landfill relative to the reference population by indirect standardisation, assuming a common relative risk for all landfill sites. We used model predictions from Poisson regression of data from the reference area to provide standard rates. The regression function included year of birth, administrative region (n = 10), sex (for birth weight and stillbirths), and deprivation. We obtained deprivation by assigning postcodes to tertiles of the national distribution of the Carstairs' deprivation index[16] based on 1991 census statistics at enumeration district level (we used tertiles rather than quintiles of the Carstairs index because of the small number of events for the rarer outcomes in the most deprived part of the reference area). We used a descending stepwise selection procedure starting from the fullest model including all possible interactions. This was repeated without deprivation, and then the two models were constrained (where necessary) to differ only in terms of deprivation (table 2). For the hospital admissions data (where there were fewer years), unadjusted and deprivation-adjusted results only were obtained, and no modelling was done.

Some degree of overdispersion and a widening of the confidence intervals is to be expected if our model assumptions fail to hold (for example, because of data anomalies, unmeasured confounding, or sampling variability of the rates). We therefore calculated Poisson 99% (rather than 95%) confidence intervals, but this does not necessarily ensure that all additional variability has been captured—we emphasise estimation of relative risks and their stability (or otherwise) to choice of model confounders rather than significance testing.

We assessed the sensitivity of our results to model choice by using an alternative model for each birth outcome (table 2). We also included urban or rural status and examined risks for rural areas only, and for birth weight (where data were sufficient) we examined sensitivity to the use of quintiles (rather than tertiles) of the Carstairs index. For abdominal wall defects, we also examined maternal age (<20 and ≥20 years, available 1986-98 for England and Wales only).[17]

The main analysis identified at outset was for all landfill sites for the combined period during their

Table 1 Denominators and years for analyses of birth outcomes near landfill sites (within 2 km) and in reference area (⩾2 km from any site), and before opening and during operation and after closure for sites that opened during the study period

Analysis	Denominator	Years	All operating and closed sites by waste type: All	Special waste	Non-special waste	Reference area	Sites that opened during study period (all waste types) by operating status: Before opening	During operation and after closure
Congenital anomalies*	Live births, stillbirths, and terminations	E, W 1983-98; S 1988-94	5 825 575	803 833	4 517 196	2 026 074	429 160	4 150 320
Surgical corrections (hypospadias and epispadias)†	Live male births	E, S 1993-5	585 414	67 281	469 149	199 974	9 982	424 271
Hospital admissions (abdominal wall defects) or surgical corrections (gastroschisis and exomphalos)†	Live births	E, S 1993-7	1 903 892	222 179	1 522 851	646 415	21 282	1 384 135
Stillbirths	Live births and stillbirths	E, S, W 1983-98	6 062 700	825 456	4 725 120	2 177 796	461 776	4 295 686
Low and very low birth weight	Live births	E, S, W 1983-98	6 030 429	821 124	4 699 860	2 166 596	459 358	4 272 510

E=England, W=Wales, S=Scotland.
*Includes terminations for England and Wales 1992-8, for Scotland 1988-94. For hypospadias and epispadias, denominator data are male live births and stillbirths only: numbers are 2 983 963 (all landfill sites), 412 201 (special waste sites), 2 313 135 (non-special waste sites), 1 037 320 (reference area), 220 227 (before opening of sites), 2 125 477 (after opening of sites).
†England and Scotland only.

operation and after closure. Subsidiary analyses examined risks separately for special and non-special waste sites, and in the period before and after opening for the 5260 landfill sites with available data.[17]

Results

Urban or rural status and Carstairs index were strongly correlated. Within the reference area, 49% of the most affluent tertile of areas was classified as rural (7% for the most deprived tertile), while for all outcomes rates were higher in the most deprived areas compared with the most affluent areas: the ratio ranged from 1.02 (surgical correction of hypospadias and epispadias) to 1.52 (very low birth weight).[17] The area within 2 km of the 9565 landfill sites tended to be more deprived than the reference area: 34% (*v* 23%) of the population were in the most deprived tertile of Carstairs score (36% for special waste sites). The area near landfill also had a higher proportion of births to mothers under 20 years of age (7.7% *v* 6.1%) and, among women aged 15-44, included (1991 census) a higher proportion of women of Indian, Pakistani, or Bangladeshi origin (4.8% *v* 3.2%) and a lower proportion of black women (2.0% *v* 3.4%).

Table 3 shows the numbers of cases for each birth outcome and relative risks for the area near landfill compared with the reference area. The relative risk for all congenital anomalies combined was 0.92 (99% confidence interval 0.907 to 0.923) unadjusted, and 1.01 (1.005 to 1.023) adjusted for deprivation and other confounders. After adjustment for deprivation (which reduced excess risks) relative risk was 1.05 (1.01 to 1.10) for neural tube defects, 1.08 (1.01 to 1.15) for abdominal wall defects (and 1.07 (0.98 to 1.18) for hospital admissions), 1.19 (1.05 to 1.34) for surgical correction of gastroschisis and exomphalos, and 1.05 (1.047 to 1.055) and 1.04 (1.03 to 1.05) for low and very low birth weight respectively. The risk was 0.96 (0.93 to 0.99) for cardiovascular defects and 1.07(1.04 to 1.10)

Table 2 Models chosen by the stepwise selection procedure in the reference area for each outcome*

Outcome	Model	No of parameters in chosen model	Terms added in alternative model†
Deprivation unadjusted			
All anomalies	Year+region+region:year	151	—
Neural tube defects	Year+region	25	Region:year
Cardiovascular defects	Year+region	25	Region:year
Hypospadias and epispadias	Year+region	25	Region:year
Abdominal wall defects	Year+region	25	Region:year
Stillbirth	Year+region+sex+region:sex	35	Region:year
Low birth weight	Year+region+sex	26	Region:year
Very low birth weight	Year+region	25	Region:year
Deprivation adjusted			
All anomalies	Deprivation+year+region+region:deprivation+region:year	171	Year:deprivation
Neural tube defects	Deprivation+year+region	27	Region:year
Cardiovascular defects	Deprivation+year+region+region:deprivation	45	Region:year
Hypospadias and epispadias	Deprivation‡+year+region	27	Region:year
Abdominal wall defects	Deprivation+year+region	27	Region:year
Stillbirth	Deprivation+year+region+sex+region:sex	37	Deprivation:year
Low birth weight	Deprivation+year+region+sex+region:deprivation+deprivation:sex	48	Region:year
Very low birth weight	Deprivation+year+region+region:deprivation	45	Deprivation:year

Interactions are denoted by ":"
*No modelling was done for the hospital admissions data.
†Terms added in alternative model used in sensitivity analysis, defined as the most important term excluded at the last step (no alternative is shown for all anomalies combined, deprivation unadjusted, because the model is already saturated).
‡Deprivation not selected by stepwise selection process but was added as a main effect.

Table 3 Risks of congenital anomalies, stillbirths, and low and very low birth weight in populations living within 2 km of a landfill site (all waste types) during operation or after closure compared with those in the reference area (⩾2 km from any site)

	Near landfill (<2 km)		Reference area		Relative risk (99% CI)		
Birth outcome	No of cases	Rate (per 100 000 births)	No of cases	Rate (per 100 000 births)	Unadjusted	Adjusted (but not for deprivation)	Adjusted (and for deprivation)
Congenital anomalies (register and terminations data*)							
All congenital anomalies	90 272	1550	34 325	1694	0.92 (0.907 to 0.923)	1.01 (1.00 to 1.02)	1.01 (1.005 to 1.023)
Neural tube defects	3 508	60	1 140	56	1.07 (1.02 to 1.12)	1.08 (1.03 to 1.12)	1.05 (1.01 to 1.10)
Cardiovascular defects	6 723	115	2 716	134	0.86 (0.83 to 0.89)	0.95 (0.92 to 0.98)	0.96 (0.93 to 0.99)
Hypospadias and epispadias†	7 363	247	2 485	240	1.03 (1.00 to 1.06)	1.07 (1.04 to 1.10)	1.07 (1.04 to 1.10)
Abdominal wall defects	1 488	26	448	22	1.16 (1.08 to 1.23)	1.14 (1.06 to 1.22)	1.08 (1.01 to 1.15)
Congenital anomalies (hospital admissions)							
Hypospadias and epispadias‡	1 503	257	536	268	0.96 (0.90 to 1.02)	—	0.96 (0.90 to 1.02)
Abdominal wall defects	755	40	227	35	1.13 (1.03 to 1.24)	—	1.07 (0.98 to 1.18)
Gastroschisis and exomphalos‡	467	25	126	19	1.26 (1.12 to 1.42)	—	1.19 (1.05 to 1.34)
Stillbirths and birth weight							
Stillbirths	32 271	532	11 200	514	1.04 (1.02 to 1.05)	1.05 (1.03 to 1.06)	1.00 (0.99 to 1.02)
Low birth weight	422 149	7000	137 958	6367	1.10 (1.095 to 1.104)	1.11 (1.102 to 1.111)	1.05 (1.047 to 1.055)
Very low birth weight	62 191	1031	20 858	963	1.07 (1.06 to 1.08)	1.08 (1.07 to 1.09)	1.04 (1.03 to 1.05)

See table 1 for denominators and years of analysis and table 2 for adjustments.
*Terminations included for England and Wales 1992-8, Scotland 1988-94.
†Excludes terminations (3 cases).
‡Surgical corrections.

and 0.96 (0.90 to 1.02), respectively, for hypospadias and epispadias and their surgical correction (for which deprivation adjustment had little or no effect).

Table 4 summarises findings (adjusted for deprivation) for the special and non-special waste sites, and for the sites that opened during the study period. For special waste sites, risks above one were found for all but two outcomes, ranging up to 1.11 (1.03 to 1.21) for cardiovascular defects and for hypospadias and epispadias. For the specific anomalies, except neural tube and cardiovascular defects, risks were higher in the period before opening of a landfill site compared with after opening, especially for hospital admissions for abdominal wall defects. For birth weight and stillbirth, risks were higher after opening.

Sensitivity analysis showed that the risk estimates were robust to the different models used.[17] Urban or rural status did not materially alter results with deprivation included, though modelling of data for rural areas only (where numbers of cases were much lower than in the main analysis) did reduce risk estimates for neural tube defects and hypospadias and epispadias—relative risks (for all waste types, deprivation adjusted) were 0.99 (0.89 to 1.10) and 1.01 (0.94 to 1.09) respectively. Inclusion of maternal age as a confounder had only a small effect on risk of abdominal wall defects.[17]

Discussion

This is by far the largest study of associations between residence near landfill and adverse birth outcomes. We found a small excess risk of neural tube defects, abdominal wall defects, surgical correction of gastro-

Table 4 Estimated relative risks (99% confidence intervals) of birth outcomes for populations living within 2 km of a landfill site, adjusted for deprivation and other variables* according to waste type and to operating status for those sites that opened during the study period

	All operating and closed sites, by waste type			Sites that opened during study period (all waste types), by operating status†	
Birth outcome	All wastes	Special waste	Non-special waste	Before opening	During operation or after closure
Congenital anomalies (register and terminations data‡)					
All congenital anomalies	1.01 (1.005 to 1.023)	1.07 (1.04 to 1.09)	1.02 (1.01 to 1.03)	1.02 (0.99 to 1.05)	1.00 (0.99 to 1.01)
Neural tube defects	1.05 (1.01 to 1.10)	1.07 (0.95 to 1.20)	1.06 (1.01 to 1.12)	0.98 (0.82 to 1.16)	1.05 (0.99 to 1.10)
Cardiovascular defects	0.96 (0.93 to 0.99)	1.11 (1.03 to 1.21)	0.95 (0.91 to 0.98)	0.92 (0.81 to 1.04)	0.92 (0.88 to 0.95)
Hypospadias and epispadias§	1.07 (1.04 to 1.10)	1.11 (1.03 to 1.21)	1.07 (1.04 to 1.11)	1.08 (0.98 to 1.19)	1.05 (1.02 to 1.09)
Abdominal wall defects	1.08 (1.01 to 1.15)	1.03 (0.86 to 1.25)	1.07 (0.99 to 1.16)	1.24 (0.97 to 1.60)	1.06 (0.98 to 1.14)
Congenital anomalies (hospital admissions)					
Hypospadias and epispadias¶	0.96 (0.90 to 1.02)	0.98 (0.81 to 1.19)	0.96 (0.90 to 1.04)	1.42 (0.94 to 2.16)	0.93 (0.86 to 1.00)
Abdominal wall defects	1.07 (0.98 to 1.18)	1.08 (0.82 to 1.42)	1.05 (0.94 to 1.16)	2.26 (1.23 to 4.15)	1.12 (1.01 to 1.25)
Gastroschisis and exomphalos¶	1.19 (1.05 to 1.34)	1.10 (0.77 to 1.58)	1.18 (1.03 to 1.34)	1.33 (0.46 to 3.81)	1.24 (1.09 to 1.42)
Stillbirths and birth weight					
Stillbirths	1.00 (0.99 to 1.02)	0.99 (0.95 to 1.03)	1.00 (0.99 to 1.02)	1.01 (0.96 to 1.06)	1.02 (1.00 to 1.03)
Low birth weight	1.05 (1.047 to 1.055)	1.05 (1.04 to 1.06)	1.06 (1.052 to 1.062)	1.01 (0.99 to 1.02)	1.07 (1.062 to 1.072)
Very low birth weight	1.04 (1.03 to 1.05)	1.03 (1.00 to 1.06)	1.04 (1.03 to 1.06)	0.98 (0.94 to 1.02)	1.04 (1.03 to 1.05)

See table 1 for denominators and years of analysis.
*See table 2 for other variables adjusted for.
†522 landfill sites with available data for hospital admissions.
‡Terminations included for England and Wales 1992-8, Scotland 1988-94.
§Excludes terminations (3 cases).
¶ Surgical corrections.

schisis and exomphalos, low and very low birth weight. Findings for cardiovascular defects and hypospadias and epispadias were inconsistent, and there was no association with stillbirth. By including all landfill sites in Great Britain and using routine data sources, we avoided the possibility of bias from selective reporting[18 19] and maximised statistical power, but problems with data quality and confounding could have led to spurious associations.[20] These merit further discussion.

Exposure classification and data quality issues
In the absence of information on site or geological factors affecting emissions from landfill, we examined data for special waste sites as a proxy for potential hazard. The UK practice of co-disposal of special and non-special wastes (in contrast, for example, with US "superfund" sites[3]) means that most special waste sites handle small volumes of hazardous wastes. They are subject to stricter management and design standards than other UK sites, while hazardous wastes may have been disposed of, unreported, in non-special sites. Thus exposure risks from special waste sites may be no greater than from other sites. Exposures to environmental contamination from sources other than landfill may also be relevant because sites tend to be located in old mineral or other excavations, often on old industrial or contaminated land or close to current industrial activities.

A key issue was the possibility of misclassification from use of a 2 km zone to define proximity to landfill sites. However, in view of the low spatial resolution of the landfill data (hundreds of metres) and complex nature of landfill sites, using finer subdivisions of the 2 km zone or distance as a continuous measure to examine proxy dose-response relationships would not yield meaningful results. Misclassification of potential exposure to landfill may also have occurred if mothers moved home during the relevant period after conception.[21]

While the data for births and stillbirths are well recorded, the national congenital anomaly system in England and Wales is known to be incomplete[22] (though we found relative over-reporting in Scotland), and there were marked fluctuations in rates of anomalies over the study period, partly because of coding changes[23] and the dates that the terminations data became available. We adjusted for calendar year to deal with fluctuating rates, but ascertainment artefacts could have biased our results (in either direction) if they were differential with respect to landfill locations. Though we had no reason to suspect that this had occurred, such inconsistencies could explain differences of the order detected in this study. On the other hand, we included data on terminations to improve ascertainment, especially for neural tube defects, and included data on hospital admissions and surgical corrections to give an independent source of data for those specific anomalies.

Confounding
We addressed confounding in two ways. Firstly, analysis included potential confounders, with and without adjustment for deprivation. Residual confounding may persist if the adjustment did not account completely for relevant individual characteristics such as smoking,[24] drug use,[25] and infections during pregnancy.[26] As in the Eurohazcon study,[10] maternal age (for risk of abdominal wall defects[27]) did not seem to be a strong confounder, and, unlike in the United States,[28] location of waste sites near ethnic minority communities was not a key feature. Increased risks (about 1.5 to 2) of low and very low birth weight,[29 30] and (more weakly) of certain congenital anomalies (especially neural tube defects[31]) have been reported among offspring of women of South Asian origin,[32] but the higher proportions of women of Indian, Pakistani, or Bangladeshi origin living near landfill sites compared with the reference area would explain only around 1% excess in our study.

Secondly, we examined rates both before and after the opening of landfill sites that opened during the study period. Because this analysis is restricted to one set of areas, it is less subject to confounding by socio-demographic factors than comparisons between different areas—although confounding by temporal trends (which are strong for some of the health outcomes studied here[17]) is possible. Consequently, we did not compare the risks before and after opening directly but estimated each with respect to the reference region. We found excess risks for some specific anomalies in the period before opening (and which were higher than in the period during operation or after closure, especially for hospital admission for abdominal wall defects). This implies that factors other than landfill might be responsible. The Nant-y-Gwyddon study also noted an excess risk of all congenital anomalies combined before the site was opened.[11]

A possible causal association with landfill should also be considered. Given the large heterogeneity between landfill sites and the likelihood that the effect of any emissions would be greatest close to the sites,[33] causal effects related to particular landfill sites might have been greatly diluted. None the less, we know of no causal mechanism that might explain our findings, and there is considerable uncertainty as to the extent of any possible exposure to chemicals found in landfills.[6] Further understanding of the potential toxicity of landfill emissions and possible exposure pathways is needed in order to help interpret the epidemiological findings.

What is already known on this topic

Various studies have found excess risks of certain congenital anomalies and low birth weight near landfill sites

Risks up to two to three times higher have been reported

These studies have been difficult to interpret because of problems of exposure classification, small sample size, confounding, and reporting bias

What this study adds

Some 80% of the British population lives within 2 km of known landfill sites in Great Britain

By including all landfill sites in the country, we avoided the problem of selective reporting, and maximised statistical power

Although we found excess risks of congenital anomalies and low birth weight near landfill sites in Great Britain, they were smaller than in some other studies

Further work is needed to differentiate potential data artefacts and confounding effects from possible causal associations with landfill

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My only sermon

After speaking at the medical school in Mangalore, India, in 1992 I stopped at the mission hospital in Miraj to visit a former student and was introduced to the Bishop of Nagpur. We talked of the work done for children paralysed by poliomyelitis at facilities that had formerly been used for patients with advanced leprosy. I talked of the problems of unnecessary injections and their effect of increasing the incidence of paralysis. He talked of the village where he had grown up and invited me to see it.

That Sunday I took the local bus and made my way to his house for tea at his retirement home in the town. We set out for a drive in his old car and stopped at a field where he talked with his brother, a farmer, and inspected the crops. We arrived at the village in a storm, the rain cascading down while we sheltered as best we could. Of course, we were brought cups of tea, but a tour of the village was out of the question. The storm intensified as we rushed across the road to the church; the village was now in darkness because the electricity had failed.

Two hurricane lamps lit the bare church as the rain thundered on the tin roof . The bishop and I sat on chairs facing the congregation who squatted on the floor: men to our left, women and children to the right. In the faint light we rose and sang hymns, accompanied by the organist sitting comfortably on the floor and using his right leg to pump the harmonium. I was happy to be an inconspicuous, although honoured, guest.

Then the bishop leaned across to me. "Give them a sermon," he said. I was horrified. "What about?" I whispered. "About polio immunisation of course," he replied. So, in as simple language as I could muster, I gave a sermon about polio immunisation, which was translated sentence by sentence.

In India I have grown used to giving lectures on polio and other topics with only a moment's notice and without slides. I often wonder if that spontaneous sermon to the villagers did more good than my formal lectures.

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