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A study of leukaemia in Glasgow in connection with chromium-contaminated land

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Abstract

Background In 1991, soil pollution was found around the site of a former chromium-processing factory in Glasgow, Scotland. Levels of chromium in soil were above limits considered as safe, although a risk assessment concluded that population exposure was likely to be below occupational levels. As an excess incidence of leukaemia has been suspected in the area, it was decided to investigate a possible relationship between the pollutant and the illness.

Methods The ensuing study was descriptive–geographical. In the absence of better data, levels of exposure were assumed to decrease with distance from the centre of the polluted area. Leukaemia and population figures were obtained for each of nine concentric rings by aggregation of data available at the Enumeration District level. The null study hypothesis was that relative risk (as measured by Poisson regression) would not follow a definite trend with distance from the centre. Sex, age and levels of deprivation were taken into account.

Results Relative risks by variables other than distance followed previously known patterns for leukaemia. No evident pattern by distance was found. After regroupings inside the variables, a significant excess of leukaemia was found for intermediate distances from the pollutant.

Conclusions No evidence was found of a possible relationship between soil pollution by chromium and leukaemia in the general population. Nonetheless, the excess noticed by the study warrants further research.

Keywords: leukaemia, chromium

Introduction

Early in 1991, extensive soil contamination by chromium slag was discovered in Rutherglen and Cambuslang, in the southeast of Glasgow, Scotland. This slag had originated from a chromium-processing factory, which had been operating from the mid-19th century until its closure in 1967. Investigation by the local Environmental Health Department revealed the pollution to exceed levels considered as safe in two areas.[1,2] These areas were the site of the now disappeared factory and its adjoining grounds, with a mean soil concentration of 900 parts per million (ppm) of Cr(VI). This is an oxidation state of chromium known to cause adverse health effects.[3,4] Also, land 2–3 km to the southeast showed a mean concentration of chromium in soil around half that of the first area.[5]

An excess incidence of leukaemia, particularly of the childhood type, has been reported in the past for some areas of southeast Glasgow. In this respect, the view supported in a study by the Scottish Health Service was that of a case of random excess;[6] other hypotheses put forward have related the excess to inheritance[7] or to an infectious agent.[8]

Non-occupational exposure of the local population to the chromium-polluted soil could occur through already well-identified routes. These are direct contact with the pollutant, inhalation of airborne dust and accidental ingestion of soil.[9] An exploratory risk assessment showed that this exposure was likely to take place at levels below those currently considered as safe in occupational settings.[10] Nevertheless, the geographical coincidence of a suspected excess of illness with high levels of a pollutant warrants the research of a possible connection between both. To date, such a relationship between leukaemia and chromium has not been suggested by the medical literature.

Methods

In the absence of better local data on the spread of pollution, the levels of exposure to chromium of an individual through all three routes have been assumed to be inversely proportional to the distance from his or her point of residence to the centre of the main polluted area, i.e. the former factory's site. Accordingly, the null hypothesis of the study is that the incidence of leukaemia does not follow a definite trend with distance from this site. The alternative hypothesis would be that such a trend exists, a decreasing trend pointing towards a cause–effect relationship between chromium and leukaemia. A similar

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approach has already been utilized in some previous environmental studies.[11,12]

The study design is of the descriptive geographical type. The study area consists of a circle 10 km in radius centred on the midpoint of the factory site, a distance beyond which exposure to the pollutant can be expected to be unlikely. Health and population data for such an area, which does not coincide with any pre-existing territorial subdivision, can be obtained in only an approximate way. The best estimate would be that based on the smallest geographical subdivisions for which data are readily available. In the United Kingdom, these areas are the Enumeration Districts (EDs), whose typical range of population for Scotland is 350–500.[13] Each ED has a centroid, defined by Ordnance Survey grid references. Therefore, once the references for the middle point of the factory site were defined, and through simple triangulation, numbers of leukaemia cases and population were computed by aggregating those for individual EDs whose centroids lay inside a 10 km distance from this middle point.

The whole 10 km circle was then subdivided into ten concentric rings each of 1 km width. This was done to assess any possible trend with distance by comparing incidences (relative risks) of leukaemia along these rings. Similarly, as had been done for the whole area, health and population data for each ring were computed by grouping data for EDs whose centroids' distance to the centre lay between the two distances defining the ring. The site containing most of the chromium is fully contained inside the first 1 km distance. Nevertheless, numbers of cases inside each of the two innermost rings were much lower than in any of the rest, 17 for the first and 63 for the second, as compared with a range for the rest of the rings of 110–175. This was due to their comparatively small area, and therefore these two rings were pooled into a larger one. The resulting first ring (of a total of nine) was in fact a circle whose radius went from 0 to 2 km from the centre of pollution.

Data on leukaemia for each sex, for five-year age groups (0–4 to 85+ years), for the period 1975–1989, at the ED level, were obtained from the Scottish Cancer Registration, a branch of the Scottish Health Service's Information and Statistics Division (ISI). Also from ISI, population data at ED level (1981 Census) for the same age groups were obtained. Finally, deprivation category (social class) was also included, as differences in levels of income are well known to have an impact on the incidence and distribution of disease.[14] A list of Deprivation Categories (Depcat) was facilitated by Dr Vera Carstairs, of Edinburgh University.[15] The population file included 2780 EDs inside the 10 km distance. Because of changes in EDs between 1981 (Census year) and 1989 (year of update for health data), only EDs common to both files were considered. This meant a loss of about 1.6 per cent of the study population and cases, which was considered as low enough to have no significant impact on the results, particularly when known to be distributed across the rings. For analyses including deprivation some EDs, for which no Depcats were available because of their very small populations, were also left out. This further loss was well below 1 per cent of the total.

The population analysed was 873 643, with 1205 leukaemia cases (all types) registered between 1975 and 1989. These population and health data were analysed according to each of four variables or combinations of these: distance (grouped by rings) from the designed centre of pollution, sex (gender), age (by five-year age group) and deprivation category (Carstairs' index). Relative risks according to different (grouped) values of these variables were modelled by Poisson regression,[16] taking as reference (i.e. unit risk) that for the lowest values. The analysis was carried out with the Stata package on a microcomputer, using the maximum likelihood method to estimate the variables in the model.

Results

In the regression by distance, taking as reference the relative risk for the ring including the most polluted area, most rings show relative risks lower than unity, but with only one (distance 8–9 km) being significantly so at the 0.05 level. Relative risk

Table 1 Leukaemia in Glasgow (1975–1989) around an area polluted by chromium; relative risk (RR) by distance estimated from a Poisson regression model

Distance from centre of polluted area (km)	Number of cases (1975–1989)	Population by distance (1981 Census)	RR	SE	*p* value	95% CI
0–2	80	51016	1	–	–	–
2–3	110	83660	0.85	0.126	0.289	0.64–1.14
3–4	143	100246	0.92	0.128	0.540	0.70–1.21
4–5	164	83414	1.27	0.173	0.077*	0.97–1.66
5–6	122	100251	0.78	0.113	0.089*	0.59–1.04
6–7	145	118683	0.78	0.109	0.080*	0.60–1.03
7–8	174	122063	0.91	0.124	0.511	0.70–1.19
8–9	140	125980	0.73	0.102	0.024**	0.55–0.96
9–10	127	88330	0.95	0.135	0.700	0.71–1.25

*Nearly significant ($p < 0.10$). **Significant ($p < 0.05$). SE, standard error; CI, confidence interval.

Table 2 Leukaemia in Glasgow (1975–1989) around an area polluted by chromium; relative risk by deprivation category estimated from a Poisson regression model

Deprivation category	Number of cases (1975–1989)	Population by deprivation category (1981 Census)	RR	SE	*p* value	95% CI
1	189	126046	1	–	–	–
2	89	65265	0.89	0.114	0.354	0.69–1.14
3	157	82628	1.24	0.133	0.049**	1.00–1.53
4	132	79787	1.07	0.121	0.553	0.86–1.33
5	133	90574	0.95	0.108	0.672	0.76–1.19
6	199	149143	0.82	0.084	0.056*	0.67–1.01
7	311	272785	0.73	0.068	0.001**	0.61–0.88

Nearly significant ($p < 0.10$). **Significant ($p < 0.05$).
There is a slight difference in total number of cases and population with respect to Table 1 because only Enumeration Districts with known deprivation category were considered.

between 4 and 5 km is higher than unity and nearly significant (Table 1).

Over the whole study area, relative risk for females as a group appeared significantly lower than that for males.

Analysed by deprivation category only, relative risk peaks at middle levels of income, with Depcat 3 having a risk significantly higher than that for the better off, then decreasing and reaching levels significantly low for the most deprived (Table 2).

By five-year age groups for both sexes together, the resulting risks (age 0–4 years = 1) decreased to reach a low at 14–19 years, appeared relatively low for intermediate groups and showed a sharp increase from 55 years of age onwards.

Following the above results, all variables, except sex, were reordered into homogeneous groups. Comparing consecutive risks for significant differences through χ^2 tests, the nine distances were regrouped into three rings: 0–4, 4–9 and 9–10 km. The seven deprivation categories were regrouped into three new ones, combining categories 1 and 2, categories 3 and 4, and categories 5–7. Also, the 18 age groups were recoded as follows: 0–14 years of age (corresponding to childhood leukaemia), 15–54 years, and 55 years and over.

A final Poisson regression was carried out including all three regrouped variables and sex. For age, sex and Depcat, results were virtually identical to those before, showing a significant difference in risk between males and females, a decrease from childhood into young and early middle age and an increase in late years, and a peak among middle classes (although not a significant one this time). Analysed together with the other three variables, the ring (circle) covering all the chromium-polluted areas (now both the main polluted area and the secondary one) has the lowest relative risk for

Table 3 Leukaemia in Glasgow (1975–1989) around an area polluted by chromium; Poisson regression, relative risk (RR) by distance (regrouped), sex, Depcat (regrouped) and age (regrouped)

Variable	RR	SE	*p* value	95% CI
Distance (km)				
0–4	1	–	–	–
4–9	1.29	0.124	0.007**	1.07–1.56
9–10	1.002	0.067	0.971	0.88–1.14
Sex				
Male	1	–	–	–
Female	0.65	0.038	<0.001**	0.58–0.73
Depcat				
1 and 2	1	–	–	–
3 and 4	1.03	0.087	0.719	0.87–1.21
5–7	0.80	0.058	0.002**	0.70–0.92
Age (years)				
0–14	1	–	–	–
15–54	0.82	0.096	0.095*	0.65–1.03
55 and over	6.64	0.684	<0.001**	5.43–8.13

*Nearly significant ($p < 0.10$). **Significant ($p < 0.05$).

leukaemia in the general population. Relative risk appeared significantly increased away from these polluted areas and remained slightly higher at the edge of the 10 km circle (Table 3).

Discussion

Analysed on their own or together with other variables, trends of leukaemia with respect to sex, deprivation or age appear in accordance with previous knowledge.[17]

If only distance is taken into account, the incidence of leukaemia does not show any apparent trend with increase in the distance from the centre of pollution. Most of the risks are not far from unity, except for a peak and a trough, both away from the main polluted area and from the secondary area to the southeast of it.

When all variables are analysed together, it becomes evident that the highest incidence of leukaemia occurs at distances from the polluted areas such as to make chromium a very unlikely risk factor.

As far as distribution of leukaemia incidence in Glasgow between 1975 and 1989 appears from the analysis, chromium-polluted soil does not seem to have any effect on it. The results also point towards a higher than expected incidence over a wide area, which should be investigated in more detail, and any possible causal factors sought. Although its presence was made known to the general public recently, the waste has been in the area long enough to ensure lifelong exposures. Even if the incidence of leukaemia appears normal by local (Glasgow) standards, the area including the polluted soil should be compared with chromium-free zones of similar population characteristics to assess any possible increase in leukaemia among the age groups, in particular in those groups for which incidence is highest, that is, the old and the very young.

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References

1 Sheenan PJ, Meyer DM, Sauer MM, Pausterbach DJ. Assessment of the human health risks posed by exposure to chromium contaminated soils. *J Toxicol Environ Hlth* 1991; **32:** 161–201.

2 Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL). *Guidance on the assessment of contaminated land*, 59/83, 2nd edn. London: ICRCL, 1987.

3 World Health Organization. *Chromium*. Environmental Health Criteria 61. Geneva: WHO, 1983.

4 International Agency for Research on Cancer (IARC). *Chromium, nickel and welding*. Monograph 49. Lyon: IARC, 1990.

5 City of Glasgow District Council Environmental Health Department. *Report by the Director of Environmental Health on various sites in the south east of Glasgow thought to be contaminated by chromium waste*. Glasgow: Glasgow District Council, 1991.

6 Wilkie D. Leukaemia in Cambuslang (letter). *Lancet* 1994; **334:** 551–552.

7 Hole DJ, Lamont DW, Brogan RT, *et al*. Concurrent childhood and adult excesses of leukaemia in geographical areas (letter). *Lancet* 1994; **343:** 1349–1350.

8 Alexander FE, Cartwright RA, McKinney PA. Leukaemia in Cambuslang (letter). *Lancet* 1994; **344:** 551.

9 Bidstrup PL, Wagg R. Chromium alloys and compounds. In: *Encyclopaedia of occupational health and safety, Vol. 1*. Geneva: International Labour Office, 1983: 468–472.

10 Eizaguirre D. *Industrial toxic waste and health: a practical case study.* Ph.D. thesis. Glasgow: University of Glasgow, 1996.

11 Elliott P, Westlake AJ, Hills M, *et al*. The Small Area Health Statistics Unit: a national facility for investigating health around point sources of environmental pollution in the United Kingdom. *J Epidemiol Commun Hlth* 1992; **46:** 345–349.

12 Elliott P, Hills M, Beresford J, *et al*. Incidence of cancers of the larynx and lung near incinerators of waste solvents and oils in Great Britain. *Lancet* 1992; **339:** 854–858.

13 Carstairs V, Lowe M. Small area analysis: creating an area base for environmental monitoring and epidemiological analysis. *Community Med* 1996; **8:** 15–28.

14 Jolley J, Jarman B, Elliott P. Socio-economic confounding. In: *Geographical and environmental epidemiology: methods for small areas studies*. Oxford: Oxford University Press, 1992: 115–124.

15 Carstairs V, Morris R. *Deprivation and health in Scotland*. Aberdeen: Aberdeen University Press, 1991.

16 Kleinbaum DG, Kupper LL, Müller KE. *Applied regression analysis and other multivariable methods*. Boston, MA: PWS, 1988: 497–512.

17 Shottenfeld D, Fraumeni JF. *Cancer epidemiology and prevention.* Philadelphia, PA: Saunders, 1982.

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