Effect of air-pollution control on death rates in Dublin, Ireland: an intervention study

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Summary

Background Particulate air pollution episodes have been associated with increased daily death. However, there is little direct evidence that diminished particulate air pollution concentrations would lead to reductions in death rates. We assessed the effect of air pollution controls—ie, the ban on coal sales—on particulate air pollution and death rates in Dublin.

Methods Concentrations of air pollution and directly-standardised non-trauma, respiratory, and cardiovascular death rates were compared for 72 months before and after the ban of coal sales in Dublin. The effect of the ban on age-standardised death rates was estimated with an interrupted time-series analysis, adjusting for weather, respiratory epidemics, and death rates in the rest of Ireland.

Findings Average black smoke concentrations in Dublin declined by 35·6 μg/m^3 (70%) after the ban on coal sales. Adjusted non-trauma death rates decreased by 5·7% (95% CI 4–7, p<0·0001), respiratory deaths by 15·5% (12–19, p<0·0001), and cardiovascular deaths by 10·3% (8–13, p<0·0001). Respiratory and cardiovascular standardised death rates fell coincident with the ban on coal sales. About 116 fewer respiratory deaths and 243 fewer cardiovascular deaths were seen per year in Dublin after the ban.

Interpretation Reductions in respiratory and cardiovascular death rates in Dublin suggest that control of particulate air pollution could substantially diminish daily death. The net benefit of the reduced death rate was greater than predicted from results of previous time-series studies.

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Introduction

Results of many epidemiological studies have suggested an association between particulate air pollution and daily deaths.[1–3] Despite these findings, it does not follow that a reduction in particulate air pollution would diminish daily deaths or increase life-expectancy.[4] Great improvements in air quality in Dublin after the introduction of domestic coal-burning regulations offered an opportunity to assess the effects of reduced particulate air pollution on death rates in the general population.

Dublin's air quality deteriorated in the 1980s after a switch from oil to cheaper and more readily available solid fuels, mainly bituminous coal for domestic space and water heating.[5] Periods of high air pollution were associated with increased in-hospital respiratory deaths.[6]

On Sept 1, 1990, the Irish Government banned the marketing, sale, and distribution of bituminous coals within the city of Dublin.[7] The effect of this intervention was an immediate and permanent reduction in average monthly particulate concentrations.[8] We assessed the effect of the ban of coal on death in Dublin.

Methods

Procedures

We compared air pollution, weather, and deaths for 72 months before (Sept 1, 1984, to Aug 31, 1990) and after (Sept 1, 1990, to Aug 31, 1996) the ban, by seasons. We defined spring as March–May, summer as June–August, autumn as September–November, and winter as December–February. We calculated mean daily air pollution (black smoke and sulphur dioxide) concentrations with measurements from six residential monitoring stations in the city of Dublin (Dublin County Borough).[8] We obtained mean daily temperatures (°C) and mean daily relative humidity (%) from Dublin airport. We calculated the change in mean air pollution and weather variables before and after the ban on coal sales, and assessed significance by *t* test of the means. We calculated daily age-stratified numbers of Dublin city residents who died within the city for total non-trauma deaths (international classification of diseases, 9th revision [ICD9] <800), respiratory deaths (ICD9 480–496 plus 507), cardiovascular and cerebrovascular deaths (ICD9 390–448), and all other non-trauma deaths (total minus cardiovascular and respiratory).

We noted substantial changes in age-distribution of the Dublin population during this study period. To adjust for these population changes, we calculated the directly age-standardised death rate adjusted to the 1991 Irish census population. We calculated daily total and cause-specific death rates for each age-group (15-year intervals up to age 74 years, 5-year intervals from 75 to 84 years, and age 85 years and older) as the reported number of deaths divided by the Dublin population estimated by linear interpolation of age-specific census population counts in 1981, 1986, 1991, and 1996. We then calculated age-standardised total and cause-specific death rates as the sum of the day-specific death rate for each age-group,

	1984–90	1990–96	Change	p
Black smoke (μg/m³)				
Autumn	62·4	18·3	–44·1	<0·0001
Winter	85·4	21·5	–63·8	<0·0001
Spring	39·6	10·9	–28·7	<0·0001
Summer	14·4	8·2	–6·2	<0·0001
Total	50·2	14·6	–35·6	<0·0001
Sulphur dioxide (μg/m³)				
Autumn	35·7	21·7	–14·1	<0·0001
Winter	40·4	24·9	–15·5	<0·0001
Spring	31·2	21·2	–10·0	<0·0001
Summer	26·3	20·7	–5·6	<0·0001
Total	33·4	22·1	–11·3	<0·0001
Temperature (°C)				
Autumn	10·3	10·1	–0·2	0·24
Winter	5·8	5·6	–0·2	0·28
Spring	8·5	8·5	0·0	0·89
Summer	14·4	14·6	0·1	0·26
Total	9·8	9·7	–0·1	0·56
Relative humidity (%)				
Autumn	81·7	83·7	2·0	<0·0001
Winter	81·2	84·8	3·6	<0·0001
Spring	77·7	81·1	3·3	<0·0001
Summer	79·6	79·9	0·2	0·61
Total	80·1	82·3	2·2	<0·0001

Autumn=September–November; winter=December–February; spring=March–May; summer=June–August.

Table 1: **Average air pollution and weather characteristics for 72 months before (1984–90) and after (1990–96) ban of sale of coal in Dublin, by season**

weighted by the fraction of the 1991 Irish census population in that age-group, separately for all ages and for ages 0–59, 60–74, and 75 years and older. We estimated annual numbers of deaths as the age-standardised death rates multiplied by the 1991 Dublin census population.

Epidemics of respiratory disease (influenza) produce excess deaths that can vary between years. There is not a surveillance system for such epidemics in Ireland. We empirically identified epidemics of respiratory disease as periods in which the 14-day moving average of influenza plus pneumonia deaths for the entire country was above the 95th percentile. Five epidemics were identified during the 12-year study (March 1985; February to March 1986; December, 1989, to January, 1990; November, 1993; and December, 1995, to January, 1996). We compared these periods with influenza periods identified from surveillance data from the UK.

Death rates can also change because of secular changes in social or health-care systems or population changes in personal habits that are not captured by population, climatic, and epidemic data. We therefore controlled for unmeasured secular changes by adjustment of directly age-standardised total and cause-specific death rates for the rest of Ireland, excluding Dublin County Borough and the surrounding Dublin County.

We assessed the effect of the ban on coal sales on population-standardised death rates as an interrupted time series,[9] adjusting for time-varying covariates. We regressed the log of age-standardised Dublin death rates on an indicator of the post-ban period, adjusting for mean temperatures on the same day and the mean of the previous 5 days, mean relative humidity on the same and previous days, indicators of day of week and respiratory epidemics, and directly standardised death rates in the rest of Ireland, in a robust generalised linear model assuming a Poisson distribution. We constructed and assessed models separately for total (non-trauma), cardiovascular, respiratory, and other causes of death. We expressed the effect of the ban as percentage change compared with expected deaths, calculated as the exponential of the Poisson regression coefficient minus one multiplied by 100. We did statistical analyses with SAS version 7 (SAS Institute, Cary, NC) and S-Plus 4.5 (MathSoft, Cambridge, MA).

Role of the funding source

The sponsors of this study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Mean black smoke concentrations were highest in winter (table 1). A substantial reduction in black smoke concentrations was seen after the ban on sale of coal on Sept 1, 1990 (figure 1). Overall, mean black smoke concentration fell by about two-thirds after introduction of the ban on coal sales (table 1). This concentration declined in all months, but the largest fall was noted in winter. Sulphur dioxide concentrations were also higher in winter than in other seasons (table 1) and gradually declined over time (figure 1). Mean concentrations of sulphur dioxide dropped by a third after the ban on coal sales (table 1), with a reduction in concentration seen in all seasons. No difference in mean temperature was noted before or after the ban on coal sales, but mean relative humidity was significantly lower before than after the ban (table 1).

Mean age-standardised total (non-trauma) death rates differed by season, with highest death rates in winter; slightly lower total death rates were noted after the ban of coal sales (figure 2, table 2). Age-standardised total non-trauma death rate was 9·41 (95% CI 9·28–9·53) per 1000 person-years before the ban compared with 8·65 (8·54–8·77) after the ban (table 2), a difference of 0·75 per 1000 person-years (p<0·0001). The largest decrease was noted in winter (table 2).

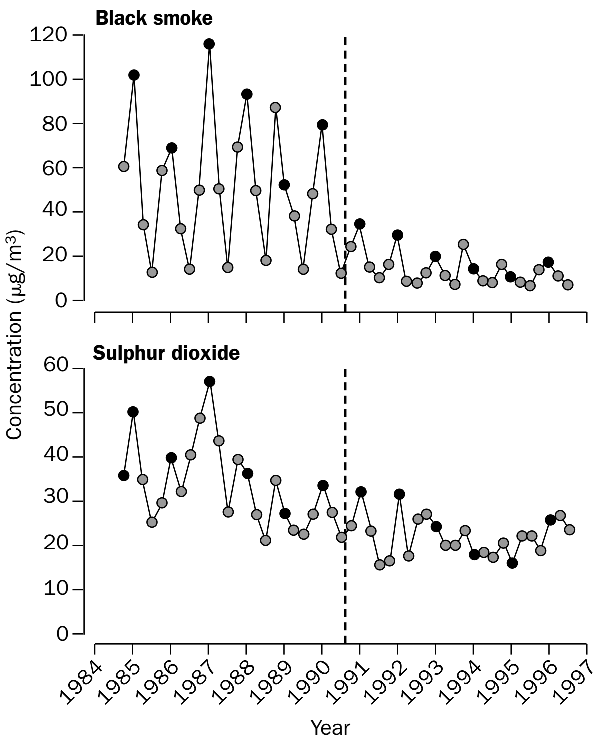

Figure 1: **Seasonal mean black smoke (upper) and sulphur dioxide (lower) concentrations, September 1984–96**
Vertical line shows date sale of coal was banned in Dublin County Borough. Black circles represent winter data.

No difference in age-specific total non-trauma death rates was recorded after the ban. Total non-trauma deaths decreased from 1·68 to 1·54 per 1000 person-years (8·1% decrease, p<0·0001) in people younger than 60 years of age, from 29·2 to 26·7 (8·6% decrease, p<0·0001) in those aged 65–74 years, and from 105·8 to 97·8 (7·6% decrease, p<0·0001) in those 75 years and older.

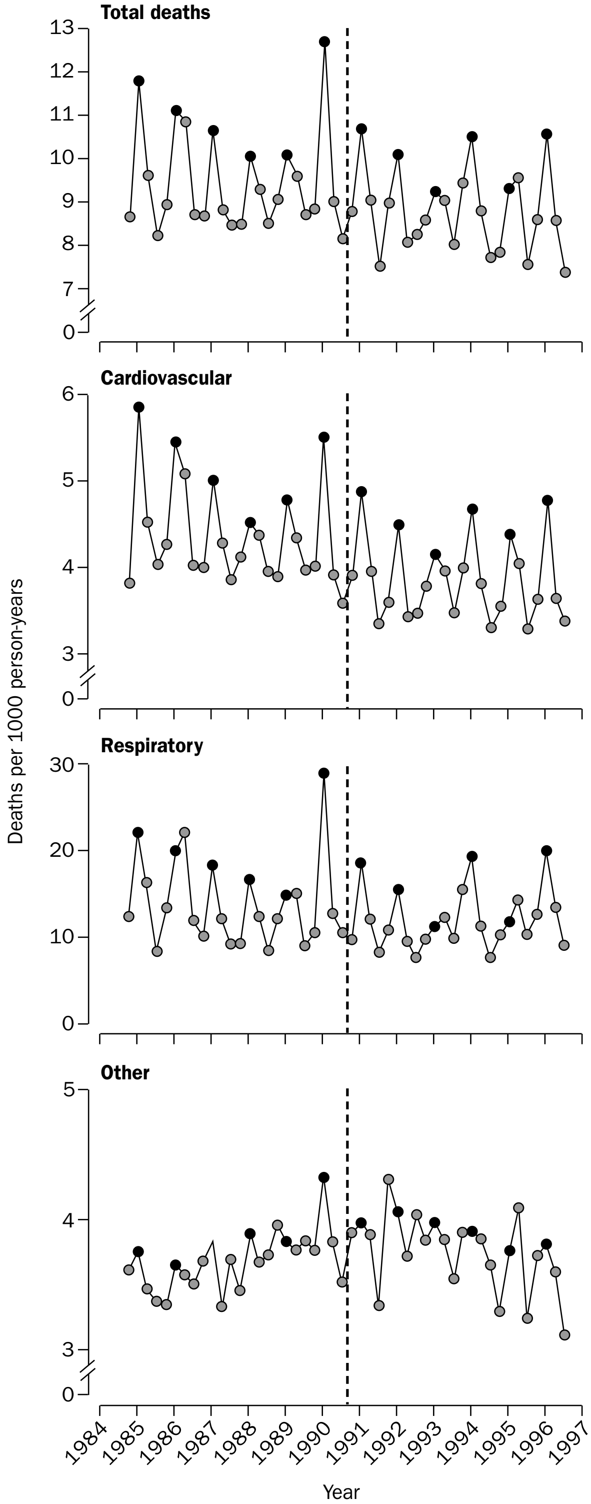

Figure 2: **Seasonal mean directly standardised death rates in Dublin, September 1984–96**

Vertical line shows date sale of coal was banned in Dublin County Borough. Black circles represent winter data.

	1984–90	1990–96	Change	p
Deaths per 1000 person-years				
Non-trauma				
Autumn	8·73	8·54	–0·19	<0·0001
Winter	11·03	9·88	–1·15	<0·0001
Spring	9·49	8·66	–0·83	<0·0001
Summer	8·40	7·56	–0·85	<0·0001
Total	9·41	8·65	–0·75	<0·0001
Cardiovascular				
Autumn	4·01	3·67	–0·34	<0·0001
Winter	5·18	4·47	–0·71	<0·0001
Spring	4·41	3·71	–0·69	<0·0001
Summer	3·89	3·29	–0·59	<0·0001
Total	4·37	3·78	–0·58	<0·0001
Respiratory				
Autumn	1·11	1·09	–0·02	0·51
Winter	2·00	1·55	–0·44	<0·0001
Spring	1·49	1·16	–0·33	<0·0001
Summer	0·93	0·83	–0·10	0·049
Total	1·38	1·16	–0·22	<0·0001
Other				
Autumn	3·61	3·78	0·17	0·0007
Winter	3·86	3·87	0·01	0·95
Spring	3·58	3·78	0·20	<0·0001
Summer	3·59	3·43	–0·16	0·0009
Total	3·66	3·71	0·05	0·031

Autumn=September–November; winter=December–February; spring=March–May; summer=June–August.

Table 2: **Age-standardised mortality rates for Dublin County Borough before (1984–90) and after (1990–96) ban of sale of coal, by season**

Cardiovascular diagnoses were the most frequent underlying cause specified on death certificates (about 45% of non-trauma deaths). Mean age-standardised cardiovascular death rate before and after the ban on coal sales fell by 0·58 per 1000 person-years (p<0·0001; table 2). Cardiovascular death rates were reduced in all seasons, but the largest reductions were in winter and spring (table 2).

Respiratory deaths accounted for about 15% of non-trauma deaths in Dublin. Mean age-standardised respiratory death rates before and after the ban decreased by 0·22 per 1000 person-years (p<0·0001; table 2). The largest reductions in respiratory death rates were also in winter and spring (table 2).

All other deaths (total non-trauma minus cardiovascular and respiratory deaths) accounted for about 40% of the total. The age-standardised death rate for these deaths had a much reduced seasonal pattern (figure 2, table 2). Age-standardised death rates for other causes rose by 0·05 per 1000 person-years after compared with before the ban (p=0·03; table 2).

Table 3 presents percentage change in age-standardised deaths in Dublin after compared with before the ban. After adjustment of age-standardised Dublin death rates in robust Poisson regression for temperature, humidity, day of week, respiratory epidemics, and death rates in the rest of Ireland, the estimated effects of the ban were reduced but still significant for non-trauma death rates compared with the unadjusted change. Similarly, slightly smaller adjusted effects of the ban were noted for cardiovascular death rates and respiratory death rates (table 3). As in the unadjusted analysis, we noted a small increase in adjusted age-standardised death rates for other causes. We also recorded a small reduction in estimated effect of the ban compared with unadjusted changes within age group (table 3). Thus, climatic factors, respiratory epidemics, or secular changes in death within Ireland did not explain the noted differences in death rate before compared with after the ban on coal sales.

An average 5042 non-trauma deaths per year (adjusted to the 1991 Irish population) were recorded before the ban compared with 4639 after, that is 403 fewer deaths per year.

	Unadjusted % change (95% CI)	p	Adjusted % change* (95% CI)	p
Total				
Non–trauma	–8·0 (–9·8 to –6·2)	<0·0001	–5·7 (–7·2 to –4·1)	<0·0001
Cause-specific				
Cardiovascular	–13·4 (–15·9 to –10·8)	<0·0001	–10·3 (–12·6 to –8·0)	<0·0001
Respiratory	–16·1 (–20·4 to –11·6)	<0·0001	–15·5 (–19·1 to–11·6)	<0·0001
Other	1·4 (–1·6 to 4·6)	0·36	1·7 (–0·7 to 4·2)	0·17
Age-specific				
Younger than age 60 years	–8·1 (–12·3 to –3·7)	<0·0001	–7·9 (–12·0 to –3·6)	<0·0001
Age 60–74 years	–8·6 (–12·3 to –9·6)	<0·0001	–6·2 (–8·8 to –3·5)	<0·0001
Age 75 years or older	–7·6 (–8·1 to –7·0)	<0·0001	–4·5 (–6·7 to –2·3)	<0·0001

*Adjusted in robust Poisson regression for temperature, relative humidity, day of week, respiratory epidemics, and standardised cause-specific death rates in rest of Ireland.

Table 3: **Change in age-standardised total, cause-specific, and age-specific mortality rates for Dublin County Borough for 72 months before and after ban of sale of coal in Dublin**

Of these, there were 120 fewer respiratory deaths, 312 fewer cardiovascular deaths, but 29 more deaths from other causes. After adjustment for weather, epidemics, and death rates in the rest of Ireland, the 5·7% decline in non-trauma death rate (table 3) predicted 287 fewer deaths per year overall. Similarly, the adjusted change in average cause-specific death rates suggested 243 fewer cardiovascular deaths, 116 fewer respiratory deaths, and 33 more deaths from other causes per year. By age groups, an estimated 54 fewer deaths per year were reported in those younger than 60 years of age, 150 fewer in those 60–74 years old, and 119 fewer in those age 75 years and older. Because the effect of the ban on coal sales on cause-specific and age-specific death rates is estimated separately, adjusted cause-specific or age-specific changes do not necessarily add up to adjusted total non-trauma change.

Discussion

We have shown that the 1990 ban on sale of coal in Dublin led to a reduction in average black smoke concentrations by 35·6 μg/m³ and average sulphur dioxide concentrations by 11·1 μg/m³. Non-trauma age-standardised death rates in Dublin decreased by about 5·7% in the 72 months after the ban compared with the same period before, after adjustment for population changes, weather, respiratory epidemics, and secular changes in death rates in the rest of Ireland. The largest decrease was seen in estimated respiratory death rates (15·5%), suggesting an average of 116 fewer respiratory deaths per year. Average annual cardiovascular death rates were estimated to decrease by 10·3%, predicting about 243 fewer deaths per year. We noted small increases in deaths from other causes associated with the ban.

In an analysis of daily death and air pollution from western European countries, Katsouyanni and colleagues[2] reported an increase of 2·9% (95% CI 2·1–3·7) associated with every 50 μg/m³ increase in 24 h black smoke concentration and 2·9% (2·3–3·5) for the same change in sulphur dioxide. Assuming that these results are applicable to Dublin, the noted decrease of 35·6 μg/m³ in mean black smoke concentration would imply a reduction in total deaths of only 2·1%, and the decline of 11·3 μg/m³ in sulphur dioxide would predict a fall in total deaths by 0·7%. Because the noted reductions in mortality were substantially greater than these figures, improvements in public health associated with reductions in cumulative exposure to air pollution are probably not completely captured in studies of acute effects of exposure averaged over several days.

Pope and colleagues[10] recorded that breathable particulate (PM_{10}) pollution concentration in Utah Valley during a 13-month strike at a local steel mill dropped by about 15 μg/m³, and total deaths were reduced by 3·2%. Assuming that PM_{10} and black smoke concentrations are roughly equivalent,[1] the noted drop of 35·6 μg/m³ in mean black smoke concentration would predict a decrease in total deaths of 8·0%. The crude decrease in age-adjusted Dublin deaths was also 8·0% (table 3). Thus our findings accord with those of the only other known study of effects of air pollution interventions on deaths.

Before attributing the substantial reduction in mortality in Dublin specifically to the ban on coal sales, we must consider alternative explanations. Temperature and humidity are well known predictors of death[11,12] and were strong factors in the regression analyses of Dublin death rates. Eng and Mercer[13] noted that monthly mean cardiovascular deaths increased in Ireland with falling monthly mean temperature during our study period (1985–95), and this change with temperature was larger than that seen by them in Norway. This difference in response suggests long-term adaptation to the local climate, and emphasises the importance of careful site-specific adjustment for temperature when assessing effects of other environmental stresses such as air pollution.

Influenza epidemics cause substantial excess deaths in the winter months when air pollution is also high. Surveillance data for influenza epidemics were not available for Ireland. Therefore, we identified periods of respiratory epidemics on the basis of high numbers of deaths due to pneumonia and influenza for the entire country. Five epidemics were identified, two before the ban and three afterwards, which match influenza periods in England and Wales identified by surveillance methods.[14] The estimated effect of the respiratory epidemics was a 34% rise in Dublin total death rates, and 78% and 27% increases in respiratory and cardiovascular death rates, respectively. Adjustment for respiratory epidemics and weather had a small effect on the estimated effect of the ban on total deaths. The possibility that air pollution increases death rates by exacerbation of influenza and other respiratory infections needs further study.

Secular changes during our study period other than air pollution could also modify the number of noted deaths. Age is by far the strongest predictor of mortality, and changes in age distribution of the general population can produce substantial shifts in death rates. During the late 1980s and early 1990s, substantial population changes were noted in Ireland, because young people emigrated out of the country and the remaining population aged. 5-year census data were available to us, which allowed adjustment for the changing size and age-distribution of the Dublin population.

Death rates fell in Ireland during the study period, especially for cardiovascular deaths. Deaths due to coronary heart disease and cerebrovascular events have been falling in Irish men since the early 1970s, and in Irish women since the 1950s.[15] However, in the 1980s, coronary heart disease and cerebrovascular age-standardised rates for Irish men and women were still high compared with other European communities.[16–18] LaVecchia and colleagues[19] reported that ischaemic heart disease age-standardised rates in 1988–89 for 20 major European countries were highest in Irish women and second highest in Irish men. Between 1988–89 and 1992–93 these researchers reported that death due to ischaemic heart disease dropped by 13·6% for Irish men and 14·9% for Irish women. The cerebrovascular death rate had similarly dropped by 13·9% and 11·9% for Irish men and women, respectively. We saw similar improvements in cardiovascular deaths for the Irish population outside Dublin.

Can these changes in cardiovascular death be ascribed to changes in risk factors? Workers on the Kilkenny Health Project monitored changes in cardiovascular risk factors in two counties in Ireland between 1985 and 1992.[15] Repeated surveys of the same people in the reference county (Offaly) in 1986 and 1991 showed a substantial improvement in all cardiovascular risk factors.[20] Mean systolic and diastolic blood pressure and serum cholesterol concentration each greatly fell between surveys, and mean concentration of HDLs substantially rose. Prevalence of hypertension decreased slightly, and the percentage of hypertensives controlled by treatment increased, but not significantly. Cigarette smoking rates declined. The only risk factor that increased substantially was mean body-mass index. Thus, other than body-mass index, there have been changes in risk factors in rural Irish populations consistent with a gradual decline in cardiovascular death rates.

There also was a general drop in respiratory death rates in Ireland over the study period, which no doubt suggests reduced respiratory risk factors. In the Kilkenny study, cigarette smoking rates declined between 1986 and 1992.[20] The Joint National Media Research Survey[21] also reported a reduction in frequency of cigarette smoking during the period of our study, from 35·0% to 30·3% in Irish men between 1982–85 and 1990–93, and from 30·3% to 27·7% in Irish women. However, these modest improvements in smoking behaviour cannot explain the substantial decrease in Dublin respiratory deaths coincident with the ban on coal sales.

To assess these secular changes for which quantitative data were not available, we adjusted death rates in Dublin County Borough for those in the rest of Ireland. Results of these regression analyses show that there were substantial reductions in Dublin death rates after the ban on coal sales, even after adjustment for measured causes of death (climate and respiratory epidemics) and long-term national trends in mortality and its risk factors, as measured by national death rates.

In conclusion, the ban on coal sales within Dublin County Borough led to a substantial decrease in concentration of black smoke particulate air pollution. After adjustment for age-distribution of the population, known predictors of death (including temperature, humidity, and respiratory epidemics), and death rates in the rest of Ireland as an index of unmeasured secular changes in deaths, we estimated that there were about 243 fewer cardiovascular deaths and 116 fewer respiratory deaths per year in Dublin after the ban on coal sales. These changes were seen immediately in the winter after introduction of the ban. Our findings suggest that control of particulate air pollution in Dublin led to an immediate reduction in cardiovascular and respiratory deaths. These data lend support to a relation between cause and the reported increase in acute mortality associated with daily particulate air pollution. Moreover, our data suggest time-series studies could be underestimating the benefits of particulate air pollution controls.

Contributors

L Clancy had the idea for the study, organised the team, and helped with data collection, analysis, interpretation, and writing. H Sinclair compiled the original datasets and did the initial analyses. P Goodman expanded the databases, did the final analyses, and helped with writing.
D W Dockery directed data analysis and report preparation.

Conflict of interest statement

None declared.

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References

1 Dockery DW, Pope CA III. Acute respiratory effects of particulate air pollution. *Annu Rev Public Health* 1994; **15:** 107–32.
2 Katsouyanni K, Touloumi G, Spix C, et al. Short-term effects of ambient sulphur dioxide and particulate matter on mortality in 12 European cities: results from time series data from the APHEA project. *BMJ* 1997; **314:** 1658–63.
3 Samet JM, Dominici F, Currerio FC, Coursac I, Zeger S. Fine particulate air pollution and mortality in 20 US cities. *N Engl J Med* 2000; **343:** 1742–49.
4 McMichael AJ, Anderson HR, Brunekreef B, Cohen AJ. Inappropriate use of daily mortality analyses to estimate longer-term mortality effects of air pollution. *Int J Epidemiol* 1998; **27:** 450–53.
5 Flanagan PJ. Air quality in Ireland: the present position. Dublin: An Foras Forbartha, 1986.
6 Kelly I, Clancy L. Mortality in a general hospital and urban air pollution. *Ir J Med Sci* 1984; **77:** 322–24.
7 Air Pollution Act, 1987 (Marketing, Sale and Distribution of Fuels) Regulations, 1990. SI 123 of 1990. Dublin: Government Publications Office, 1990.
8 Sinclair H, Clancy L. How clean is Dublin's air? *Ir J Med Sci* 1995; **164:** 163.
9 Webster DW, Vernick JS, Hepburn LM. Effects of Maryland's law banning "Saturday Night Special" handguns on homicides. *Am J Epidemiol* 2002; **155:** 406–12.
10 Pope CA III, Schwartz J, Ransom MR. Daily mortality and PM_{10} pollution in Utah Valley. *Arch Environ Health* 1992; **47:** 211–17.
11 Ellis FP. Mortality from heat illness and heat-aggravated illness in the United States. *Environ Res* 1972; **5:** 1–58.
12 Kalkstein LS. Health and climate change: direct impacts in cities. *Lancet* 1993; **342:** 1397–99.
13 Eng H, Mercer JB. Seasonal variations in mortality caused by cardiovascular diseases in Norway and Ireland. *J Cardiovasc Risk* 1998; **5:** 89–95.
14 Fleming DM, Zambon M, Bartelds AIM, de Jong JC. The duration and magnitude of influenza epidemics: a study of surveillance data from sentinel general practices in England, Wales and the Netherlands. *Eur J Epidemiol* 1999; **15:** 467–73.
15 Shelley E, O'Reilly O, Mulcahy R, Graham I. Trends in mortality from cardiovascular diseases in Ireland. *Ir J Med Sci* 1991; **160** (suppl 9)**:** 5–9.
16 Dean G. Respiratory disease and heart attacks among rural workers in Ireland and other countries of the European Economic Community. *Ir Med J* 1982; **75:** 338–42.
17 Dean G, Kelson M. The reported mortality pattern in the countries of the EEC for six common cancers and ischaemic heart disease. *Ir Med J* 1984; **77:** 98–100.
18 McMahon G, Daly L, Hickey N, Conroy RM, Mulcahy R. Mortality from coronary and cerebrovascular disease in EEC countries. *Ir Med J* 1986; **79:** 130–33.
19 LaVecchia C, Levi F, Lucchini F, Negri E. Trends in mortality from major diseases in Europe, 1980–1993. *Eur J Epidemiol* 1998; **14:** 1–8.
20 Shelley E, Daly L, Collins C, et al. Cardiovascular risk factor changes in the Kilkenny Health Project: a community health promotion programme. *Eur Heart J* 1995; **16:** 752–60.
21 Shelley E, Collins C, Daly L. Trends in smoking prevalence: the Kilkenny health project population surveys 1985–1991. *Ir Med J* 1996; **89:** 183–85.