AIR POLLUTION IN DUBLIN CITY

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Abstract: Annual emissions of smoke in Dublin city now are comparable to the total from the Greater London area, giving an air pollution potential for serious health effects during unfavourable dispersion conditions. Comparisons with other cities, and the lower than expected concentrations at which health effects have been detected, raise questions as to the accuracy of the monitoring procedures. An underestimation of smoke concentrations, perhaps by a factor of up to 2.5 may be occurring. Further concerns exist about the degree to which the shrinking monitoring network may be representative of exposure conditions. EEC mandatory daily limit values have now been breached frequently for both smoke and sulphur dioxide. Winter median values for the former have also exceeded the standard. Though adverse winters were required for these to occur in the early 1980s, more recently significant breaches have been registered in winters characterised by average dispersion conditions. This is indicative of a continuing increase in emissions to a level at which mortality increases may be anticipated under some climatic circumstances. One such episode is discussed for January 1982 during which smoke concentrations over 1800 ug/m3 were measured and excess deaths totalling 56 were reported in one hospital study. The policy options available to improve air quality are reviewed.

INTRODUCTION

The acceleration in industrial growth which occurred in Ireland in the 1970s, the virtual cessation of emigration which it enabled, and the consequent increase in population in the Dublin region which resulted, ushered in problems of pollution and environmental degradation which had hitherto not been of serious concern. Among the most intractable of these has been the problem of air pollution in Dublin city, a problem exacerbated by the major changes which have occurred in fuel prices and fuel preferences over the past six years. The evidence now available points to a deterioration in air quality, in terms of smoke pollution, to a present position at which measurable health effects can be expected in an average winter. The potential also appears to exist for major excess mortality events to occur in particularly unfavourable meteorological conditions.

SMOKE AND SULPHUR DIOXIDE EMISSIONS IN DUBLIN

Suspended particulates less than 15um in diameter (smoke) and sulphur dioxide (SO2) are the most extensively monitored air pollutants in Ireland. Both derive from the combustion of fossil fuels. Smoke, consisting mainly of unburnt carbon, grit, and ash, results mainly from the incomplete combustion of coal and peat. Sulphur dioxide, on the other hand, is produced by the burning of trace sulphur compounds, particularly fuel oil.

Table 1 shows the emissions of smoke and SO2 which may typically be expected per unit of fuel burnt. In practice these emission factors may vary depending on the particular characteristics of the fuel concerned, the efficiency of the combustion process, and the presence or absence of any emission control equipment. However, coal and peat burning are clearly going to produce about 50 times more smoke emissions than the same weight of some of the lighter oil distillates. Fuel oil, on the other hand, is much more important as a source of SO2 than any of the other fuels listed. It is also worth noting at this stage that diesel oil is a significantly more prolific source of both smoke and SO2 than petrol. In fact the sulphur content of diesel fuel in Dublin is typically three times higher than that used in the U.K. This is due to the nature of the supply used in Dublin (imported from the USSR), particularly on public transport vehicles.

Table 1: Emission Factors for Fuels Burnt in Dublin

Fuel Type	Emissions as a % of total weight burnt	
	Smoke	SO2
Coal		
Bituminous	3.5	1.6
Anthracite/Processed	0.5	2.0
Peat	2.4	0.3
Oil		
Petrol	0.2	0.1
Diesel	1.8	1.6
Gas Oil	0.1	1.0
Fuel Oil	0.1	6.0

A knowledge of emission factors, plus details of fuel consumption, enables emission quantities to be calculated. The most recent published estimates of these for the Dublin urban area are for 1981 and were compiled using the Household Budget Survey, housing density data, and a questionnaire survey of industrial premises (Bailey, 1984). Annual emissions of smoke were estimated at 15,900 tonnes, and of SO2 at 55,400 tonnes (Table 2). This relates to an area of 290 km2, bounded by Dun Laoghaire, Tallaght, and the northern city boundary.

Table 2: Estimated Annual Emissions of Smoke and SO2 in the Dublin Area (tonnes) (after Bailey, 1984)

Category	Smoke	SO2
Domestic	12,900	6,400
Commercial/Industrial	500	11,400
Power Stations	300	35,800
Motor Vehicles	2,200	1,800

81% of smoke emissions are seen to be of domestic origin, overwhelmingly from coal burning. Mobile sources provide a further 14%, caused by diesel burning vehicles. Only small contributions to smoke emissions originate from commercial/industrial sources and from power stations. With SO2, however, these sources contribute over 85% of emissions, with power station emissions in the Dublin urban area constituting by far the largest proportion. This high contribution is not reflected in ground level concentrations. Stack heights of 207m at Poolbeg and 70 and 65 m at the North Wall installations ensure dispersion of emissions over a large area before being mixed down to ground level, and thus only a relatively small increment to ground level concentrations results from these sources. More recent reductions in SO2 emissions from the power stations have occurred as they have increased their use of natural gas, and the total SO2 emission figure is now probably 37,000 tonnes. Omitting power station emissions from the total thus gives a truer picture of influences on ground level concentrations and makes domestic and other low level sources relatively more important.

Disaggregating the SO2 emission data on a one kilometre square grid basis produces a pattern reflecting housing density and the location of major industrial point sources (Figure 1a). Values range from 5 to over 2750 tonnes/km2/year. On average, Dublin produces 68 tonnes of SO2/km2/year when power station emissions are removed, slightly greater than the comparable figure for Greater London. Smoke emissions (Figure 1b) more closely mirror housing density with the greatest concentration of high emission grid

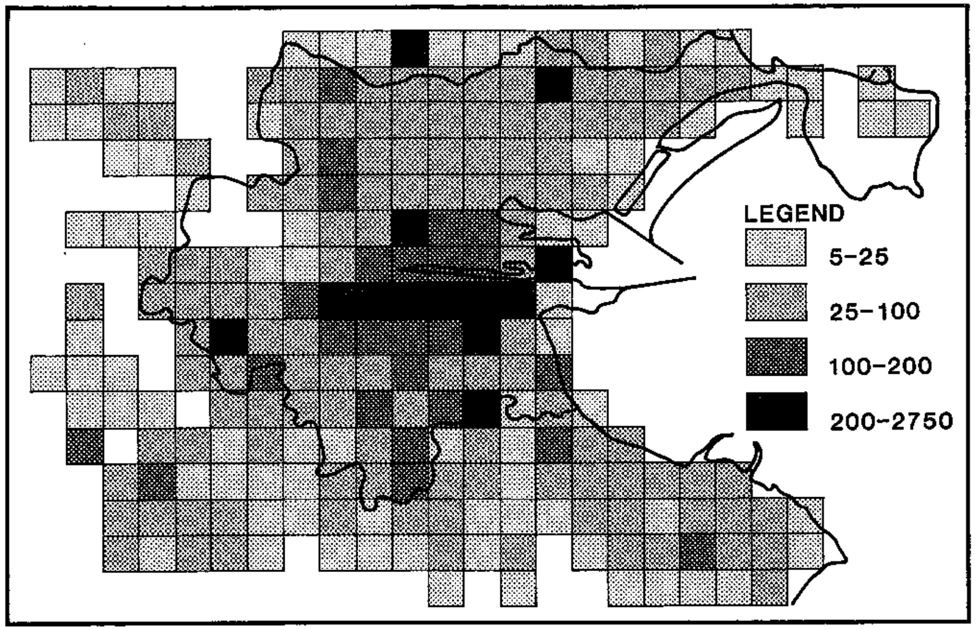

Figure 1a Annual Pollutant Emissions (tonnes/km2) of SO2

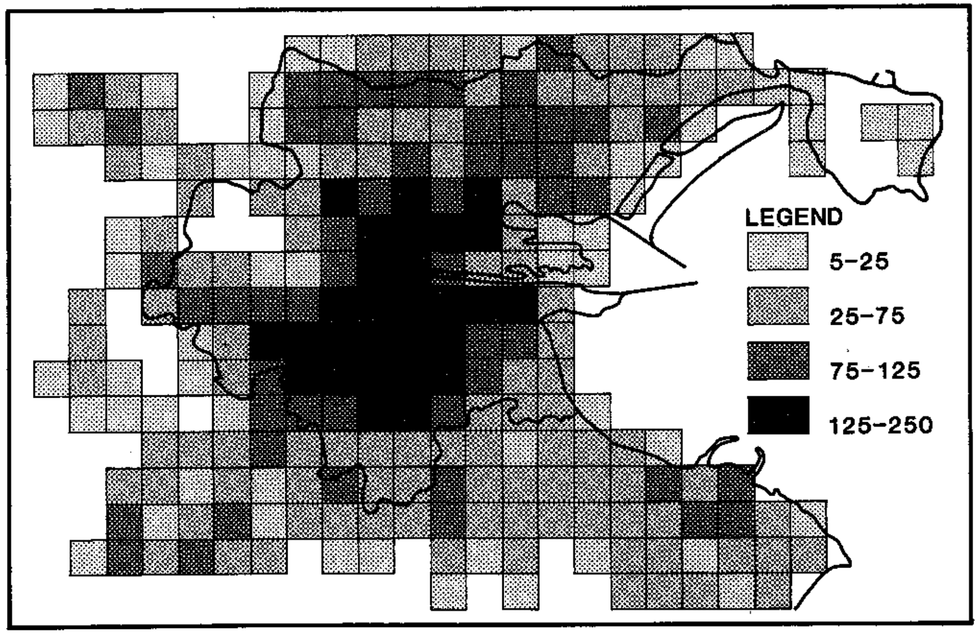

Figure 1b Annual Pollutant Emissions (tonnes/km2) of Smoke

squares in the inner city area. Several suburban areas, with relatively low housing densities, however are important contributors, especially in the north and west of the city, producing in excess of 100 tonnes/km2/year. Overall, Dublin compares unfavourably with Greater London for smoke emissions, producing an average of 55 tonnes/km2/year. This is more than six times the comparable figure for Greater London. In fact Dublin today produces more smoke in total than the entire Greater London area, despite the enormous discrepancies in area and population involved.

AIR POLLUTION AND HEALTH

Human beings have always had to contend with unwanted airborne substances, and to a large extent natural selection has equipped us to cope with most. However, this applies mainly to substances in the organic categories, such as pollen spores, infective bacteria etc. Genetically we have not evolved to cope with combustion products and high concentrations of toxic gases.

Some defences are operative against these, however. In the upper respiratory tract nasal hairs filter incoming air to a certain extent. In the bronchi smaller particles are trapped in the mucous lining and expelled via the co-ordinated wavelike motions of the tiny hair structures (cilia) lining the respiratory passages. Even at the alveoli- the ends of the air tract- particles may be attacked and decomposed by scavenger cells (phagocytes). This is the last line of defence, however, and if overwhelmed the pollutant substance may become an irritant causing discomfort, a susceptibility to infection, and may constitute a strain on the cardio-vascular system. It may also be carcinogenic.

Threshold concentrations above which adverse health effects can be expected are difficult to establish. World Health Organisation criteria (Figure 2) suggest minor health effects may appear with annual levels of smoke or SO2 above 80 ug/m3. Such chronic effects become more pronounced at higher concentrations and above 250 ug/m3 acute symptoms may be anticipated. These may be manifested in an increase in hospital admissions for respiratoy and cardio-vascular complaints. Daily values above 500 ug/m3 are expected to be associated with increases in mortality, especially among the very old, very young, or those already predisposed to respiratory problems.

On 1st April 1983 an EEC Directive specifying limit values for smoke and SO2 became mandatory, providing a framework for air quality management throughout the Community. It would be nice to

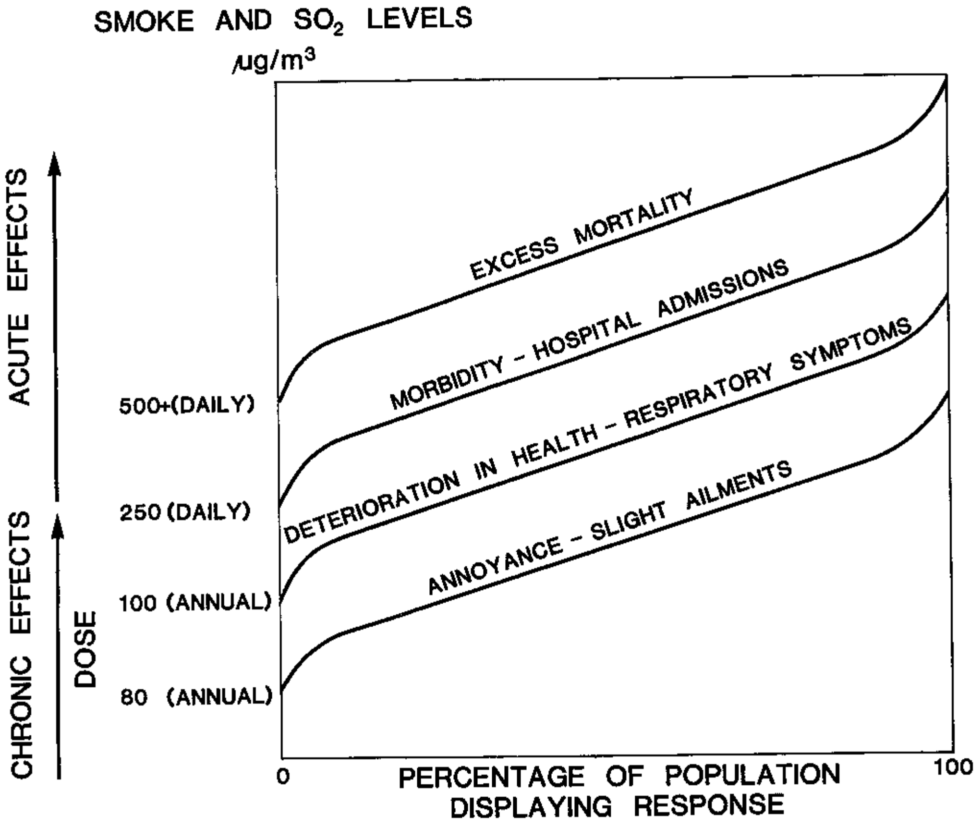

Figure 2 Health responses to Smoke and SO2 concentrations

think that Community wide adoption of these standards reflected exclusively a concern for health, but in reality they owe almost as much to the regulation of competition between polluting industries between member states. Annual, winter and daily limits are specified (Table 3). Of particular concern to the Dublin situation is the specification regarding smoke. A winter median of 130 ug/m3 is the maximum allowed. Furthermore, 98% of daily values should fall below 250 ug/m3, and member states must:

> "take all appropriate steps to ensure that this value is not exceeded for more than three consecutive days. Moreover, member states must endeavour to prevent and reduce such incidences in which this value is exceeded."

These mandatory limits should be borne in mind in turning to consideration of air quality trends in the Dublin area.

Table 3: EEC Air Quality Directive Values (ug/m3)

Reference Period	Limit Value for SO2	Assoc. Value for Smoke	Absolute Limit Value for Smoke
Year (Median of Daily Means)	80	>40	80
	120	<40	
Winter (Median of Daily Means)	130	>60	130
	180	<60	
Day (98 percentile of daily mean values)	250(i)	>150	250(i)
	350(i)	<150	

(i) Member States must take all apppropriate steps to ensure that this value is not exceeded for more than three consecutive days. Moreover, Member States must endeavour to prevent and to reduce any such instances in which the value has been exceeded.

Source: Council of the European Communities, 1980.

AIR QUALITY TRENDS IN DUBLIN

To assess the level of exposure to a pollutant a monitoring network reasonably representative of conditions throughout the area it extends over is required. A single central site, or a few central monitors, is not sufficient to represent the air quality characteristics of a large metropolitan area (Goldstein, Landovitz and Block, 1974). Studies, such as Clifton et al (1959) and Stalker, Dickinson and Kramer (1962), indicate that a monitor at least every 1km is necessary to estimate daily pollution levels within +/- 20%. Viewed in this perspective the present Dublin network is totally inadequate.

At recently as 1980 36 monitors were in operation in Dublin city, 24 of which were maintained by the E.S.B. (Bailey and Walsh, 1980). These observations have now been discontinued, leaving only 14 stations operated by Dublin Corporation. As figure 3 shows, these are clearly inadequate to portray conditions for the city as a whole. They also exhibit severe spatial bias towards the eastern inner city, with the rapidly growing western parts of the city poorly under-represented. Indeed the data produced by the network has recently been questioned by Williams et al (1983) who suggest

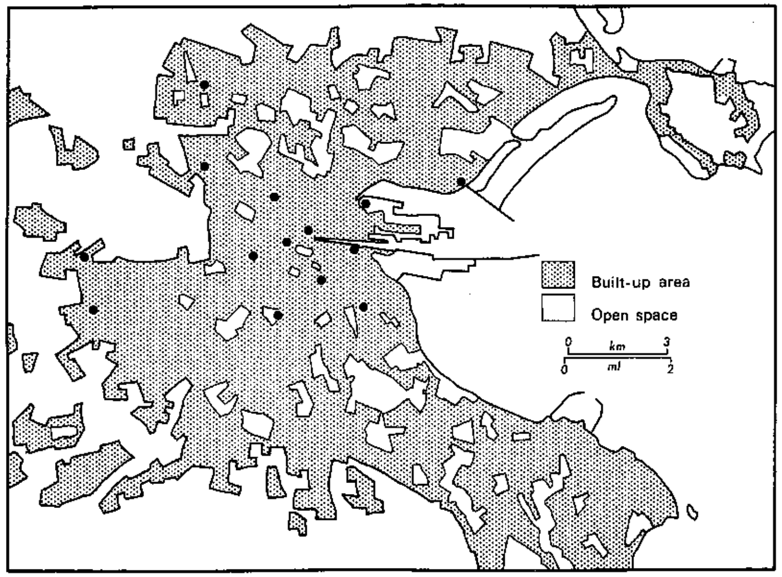

Figure 3 Dublin Corporation monitoring network

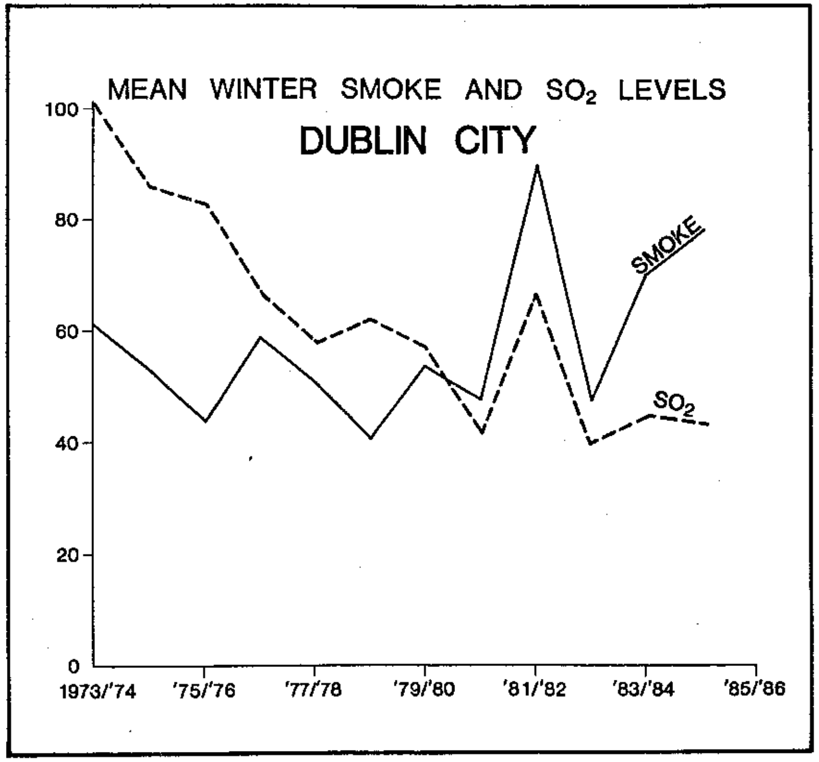

Figure 4 Mean Winter Smoke and SO2 Concentrations: Dublin City Network 1973/74 to 1984/85

that serious underestimation of smoke and SO2 concentrations may be occurring. This may however be a function of a local weather factor, rather than any inefficiency in the measurement process. The sites are quite well maintained and run in accordance with internationally accepted standards. For the case of smoke pollution any undermeasurement may be related to the particular characteristics of smoke produced by peat burning. This produces a light coloured smoke which does not stain the filters used in the measurement process, and also produces particles which may pass through them, avoiding being measured at all. Dublin city centre produces almost 2.5 times as much smoke as the same area of Glasgow city, yet the observed concentrations are almost identical. On this basis underestimation of smoke concentrations by a factor of up to 2.5 is suggested. If so, this is a most serious state of affairs for air quality management. It means the situation is much worse than the measurements suggest, but also that the yardstick by which any progress can be monitored is also suspect. Later in the paper a further hint that serious underestimation of pollution conditions is occurring will be discussed.

Between winter 1973/74 and 1980/81 SO2 levels for the Dublin urban network declined from a mean winter value of over 100 ug/m3 to 42 ug/m3 (Figure 4), a trend which mirrored that in most urban centres in Britain and Ireland. As polluting industry moved out of urban centres and electricity became the preferred source of energy, SO2, and to a lesser extent smoke, levels declined. Following the second oil crisis of 1979, however, this situation changed. A reversal of the smoke trend occurred, reflecting a massive switch to solid fuel by householders. Smoke levels more than doubled in winter 1981/82 to a mean value of 90 ug/m3. Though favourable meteorological conditions enabled a fall in mean concentrations during the following winter, winters 1983/84 and 1984/85 confirmed the upward trend. Smoke had taken over from SO2 as the dominant pollutant, and levels were back to those prevailing in the 1960s.

The EEC standards for smoke have been extended during three recent winters: 1981/82, 1983/84 and 1984/85. 1981/82 was representative of a winter with unfavourable dispersion conditions. Seven out of 13 sites failed the daily smoke limit. At Cornmarket, for example, on January 13th 1981 a smoke level of 1532 ug/m3 was measured. On the following day 1812 ug/m3 was recorded. The consequences of that episode are dealt with later in the paper.

During 1983/84 climatic conditions were near to the long term average. Even so 5 sites still failed the daily smoke standard. A deteriorating situation could be especially detected in the suburbs, where monitoring data is least adequate. At Ballyfermot (now the worst location for smoke in the city) on 41 days of winter 1983/84 the smoke level exceeded 250 ug/m3 (Figure 5). That this occurred during an average winter is evidence of a substantial increase in smoke emissions, something which augured badly for forthcoming winters when less favourable climatic conditions might exist.

Winter 1984/85 confirmed the deterioration in smoke levels. In a winter during which dispersion conditions were not abnormally unfavourable, 6 sites failed the daily smoke standard, four of which breached the 250 ug/m3 value for more than three consecutive days. This had previously occurred in 1981/82. In 1984/85, however, two stations recorded a double breach, something that had not occurred in the earlier winter. The highest smoke concentration recorded was also up on the previous year, 884 ug/m3 at Ballyfermot on 2nd January 1985. On a more positive note, SO2 levels have continued a steady fall, particularly during the summer months. Some credit for this may be due to the increasing use of natural gas, particularly by the industrial and commercial sectors.

AIR POLLUTION AND HEALTH IN DUBLIN

One of the earliest mentions of Dublin smoke pollution comes from Jonathan Swift (1729) who wrote of:

> "...the smoke which is so thick and has so great an influence that it affects even the blossom and bloom of the flowers in spring"

and goes on to note how the Dublin physicians:

> "made it their constant practice to remove their patients to the purer air near the suburbs out of the smoke of the city."

Since then SO2 has been linked to mortality and morbidity effects by Kevany et al (1975), Bailey et al (1978) and Sweeney (1982). Furthermore a relatively low threshold, of the order of 100 ug/m3, was suggested in two of these studies as statistically significant. This perhaps is a further hint that undermeasurement of the pollution concentrations is occurring in Dublin.

The switchover from SO2 to smoke as the dominant health influence was detected by Sweeney (1982) who found relatively strong associations between pollution levels and admissions to the Dublin hospitals for respiratory and cardio-vascular complaints. It was suggested in that paper that more pronounced effects might be

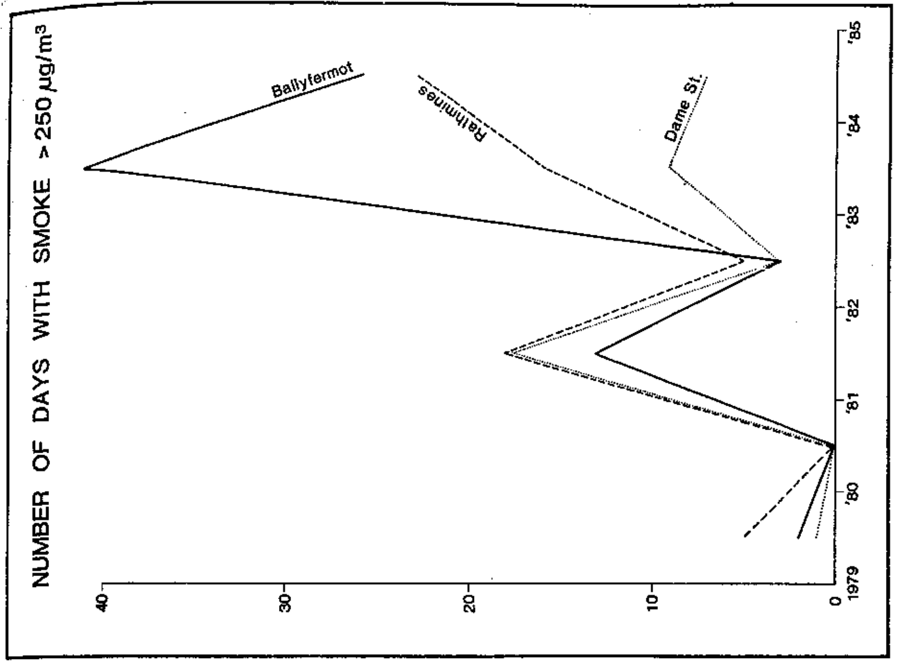

Figure 5 Daily Smoke Concentrations in Excess of 250ug/m3

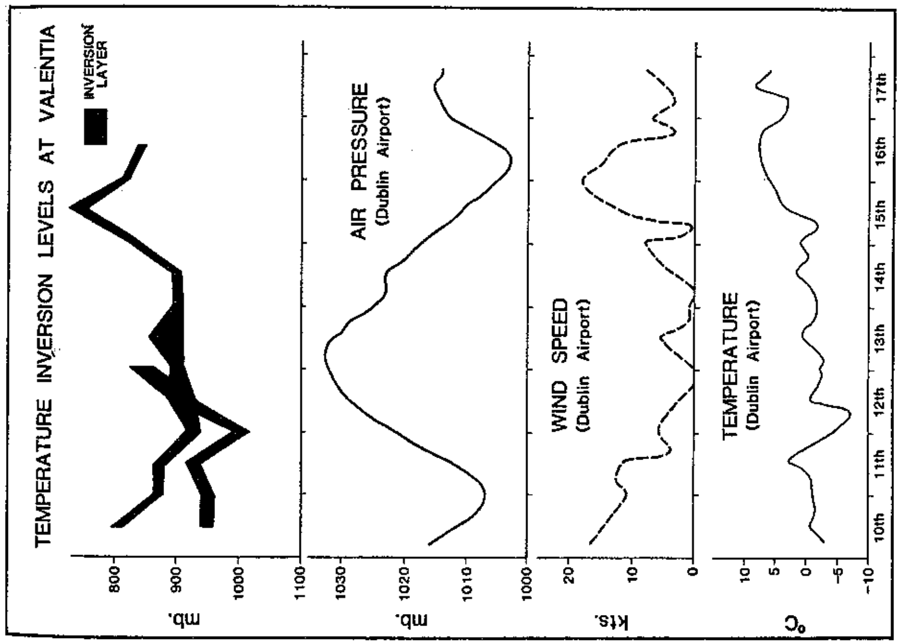

Figure 6 Selected meteorological data, January 1982

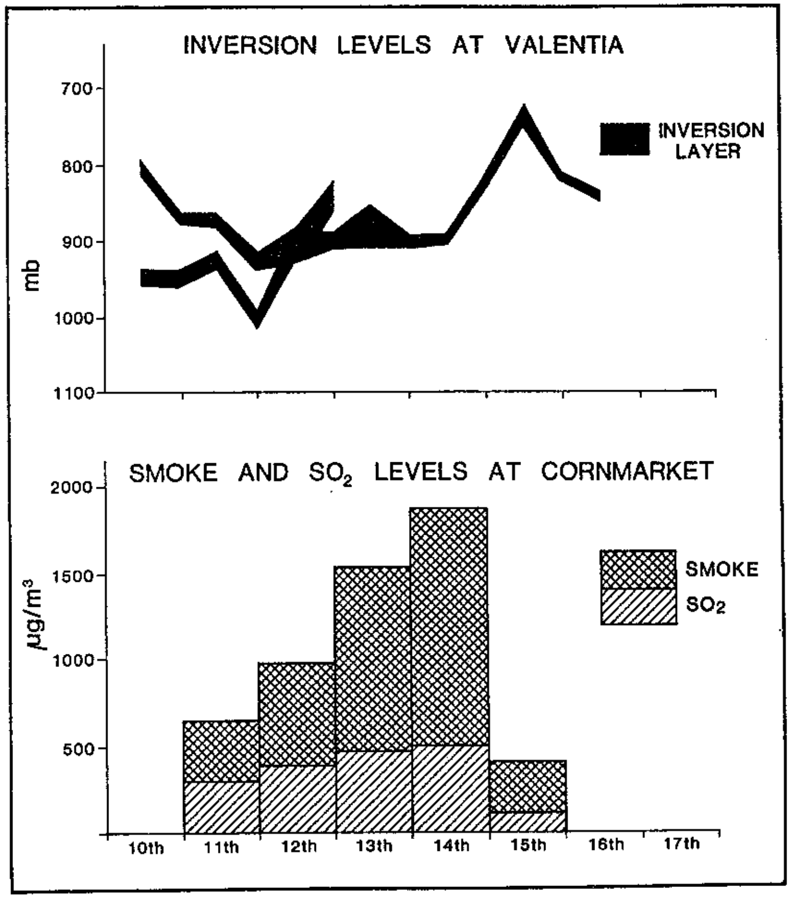

Figure 7 Air pollution episode, January 1982

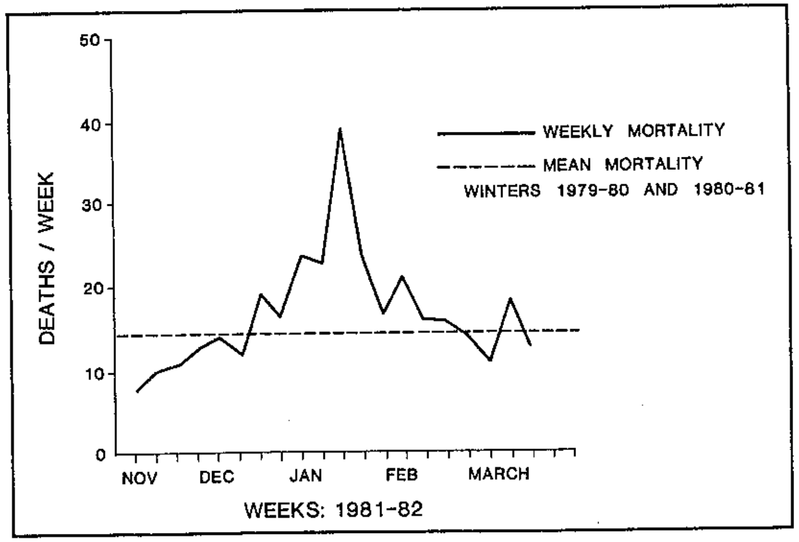

Figure 8 Mortality in St. James' Hospital, January 1982

anticipated in cold winter conditions characterised by strong subsidence inversions of temperatures. This has proven accurate with evidence now available pointing to significant increases in mortality during a recent winter episode of high smoke concentrations.

Referring to Figure 6 the radiosonde ascent for Valentia indicates the presence of an inversion of temperature around 950 mb on January 10th 1982 which over the course of the next eight hours fell very close to the surface. Light winds and bitterly cold temperatures accompanied the passage of peak subsidence from the anticyclone on the 13th. For the six days following the 10th temperatures in the Dublin area struggled briefly above freezing point; on the 12th they reached a low of -8 C. This had the effect of stimulating emissions enormously at a time when mixing height for them was minimal. The inversion trapped particularly domestic smoke emissions whcih occurred at lower levels and had much more buoyancy than their SO2 counterparts. The concentrations at the Cornmarket site are indicative of the trapping effect of the inversion, reaching a high of 1812 ug/m3 on the 13th when the inversion probably reached its lowest level in the Dublin area (Figure 7). Falling pressure, rising wind speeds, and a rise in temperature, brought the episode to an end after the 15th as the anticyclone moved away.

In St. James's Hospital a peak in mortality of 120 was observed for January 1982 (Kelly and Clancy, 1984). This was about twice the normal monthly average, and when analysed on a weekly basis the peak was seen to occur just after the air pollution episode described (Figure 8). Fifty-six excess deaths were measured, predominantly from respiratory causes. The average age of those dying was 77. Though such deaths may be linked to a multiple causation hypothesis, the extremely high levels of atmospheric pollution preceding them are undoubtedly major contributory factors.

POLICY OPTIONS

Air pollution results from the cumulative action of individuals who, consciously or unconsciously, externalise their pollution costs over the community as a whole. The smoke pollution problem is thus one with fundamental economic underpinnings, and any attempt to alleviate the situation must address itself to this economic reality.

Legislative prohibition on domestic smoke production in designated areas is the most obvious option available. Whether this approach, similar to that of the UK in the 1950s and 60s, would be successful would depend on whether the will and resources would exist for its effective enforcement. Smokeless fuel currently costs 50% more than ordinary household coal, and householders as individuals are unlikely to burden themselves with such additional costs if effective enforcement is lacking. Such enforcement would require an inspectorate and administrative commitment which, at a time of fiscal rectitude, might not attract sufficient funding from central government sources. Substantial subsidies for the conversion of appliances to burn smokeless fuels, and possibly for smokeless fuels themselves, may also be required. Certainly in the absence of incentives which make alternatives to coal burning economically attractive, mere legislation would represent only a cosmetic effort, perhaps designed to assuage our partners in the European Community.

The extension of the natural gas network offers the potential for comprehensive improvements in air quality, both for smoke and SO2. To date the penetration of the domestic solid fuel market has been fairly limited. Since the switch to solid fuel was relatively recent, many householders have newly installed equipment and the incentive to convert to gas is diminished. The price of gas is pitched too high to enable the capital costs of conversion to be recouped in a short enough period. Again subsidisation of gas prices within designated smokeless areas might represent a cost efficient option. This subsidy would require to be of the order of 20p/therm to achieve the necessary reduction in smoke emissions. The gas grid is however fairly restricted; the suburbs are not well served in general. These seem unlikely in some cases to be connected to the distribution grid on a sufficiently comprehensive scale to enable the potential for pollution reduction to be fully realised.

Using the experience of Belfast, Convery (1985) has shown that the cost of intervention and implementation of a conversion programme are not excessive. Tackling some 60,000 houses over a fifteen year period would cost about £35M, or approximately £2.5M p.a. Viewed relative to the costs of doing nothing this would represent a good investment in the health, wellbeing and productivity of Dubliners.

Estimates of the cost of air pollution are generally around 2% of G.N.P. (Downey, 1978). This would mean a figure of about £250M could be suggested for Ireland. About half of these costs would be related to health effects. Although the actual value is likely to be less for a number of reasons it does illustrate the magnitude of potential economic damage involved. Research is now urgently needed into the total cost of air pollution damage in Ireland. One

suspects that a figure might emerge high enough to make even subsidisation of electricity prices an economic option. However, on the basis of the evidence portrayed here the smoke pollution situation has now deteriorated to an extent which calls for radical action. Put simply, the burden society is being asked to bear in return for a warm house is becoming intolerable for large sections of urban Dublin.

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