Daily mortality and environment in English conurbations

1: Air pollution, low temperature, and influenza in Greater London

ALISON MACFARLANE

From the Department of Medical Statistics and Epidemiology, London School of Hygiene and Tropical Medicine, and Medical Statistics Division, Office of Population Censuses and Surveys, London

SUMMARY With the decline in concentrations of suspended particulate pollution in Greater London the association seen in the 1950s and early 1960s between daily mortality and air pollution in the conurbation is no longer apparent. Associations between unusually cold weather and short-term increases in mortality have been noted; there appears to be a tendency for influenza epidemics to follow cold spells.

In western medicine, interest in short-term environmental changes and their effects on health can be traced back at least as far as Hippocrates, who wrote about it in his *Airs, Waters and Places* (translated in Adams, 1849). For example, he said '..... if the winter be southerly, showery, and mild but the spring northerly, dry and of a wintry character, the aged have catarrhs from their flabbiness and melting of the veins, so that some of them die suddenly and some become paralytic on the right side or the left'.

Associations between exceptionally cold weather and increases in mortality in England and Wales were reported by William Farr (Farr, 1840; 1841). He recognised that the London fogs were injurious to health but found no evidence that they increased mortality (Farr, 1843). Later in the nineteenth century, however, severe fogs lasting a week or more were associated with rises in the death rate in London (Russell, 1924; 1926) and in Glasgow. In this century (Young, 1924; Woods, 1927; Wright and Wright, 1945) found an association between low temperature and mortality but did not study the possible effects of fog.

More recently Boyd (1960) concluded that only respiratory mortality was correlated with air pollution. Like Russell, he found this association only when temperatures were low. Rose (1966) found that winter 'excess' deaths from ischaemic heart disease were correlated with low temperature but not with air pollution or rainfall.

Daily death totals and background to the present study

In many of the studies described above the scope of the analysis was narrowed by the choice of inappropriate statistical techniques. However they all suffered from a much more serious limitation; they were only able to use totals of weekly registrations or monthly occurrences of deaths.

Farr pointed out in 1865 (reprinted in Farr, 1885) that these were not sufficiently sensitive to detect sudden changes in mortality. 'Any investigation of the laws of health and sickness, life and death, in connexion with meteorological phenomena, which is confined in its scope to mean temperatures must be imperfect The temperature, weight, humidity of the atmosphere, and other physical forces should not be masked under mean values but laboriously traced through their course from day to day, and if it were possible from morning to night and from night to morning, and observed in connexion with contemporaneous facts that relate to human life as these also are successively recorded, if the sway which they exercise is to be appreciated in its full significance'.

Farr extracted daily totals of deaths from cholera in London during the epidemics of 1849, 1854, and 1866; in 1866 he used these to identify a suspect water supply (Farr, 1868). It was not until the 1920s that the first comprehensive studies of daily deaths were done, and this was in the USA (Huntington, 1930). Daily death totals were not produced again

in England until the 1950s.

The government committee set up to report on the London fog of 5 to 9 December 1952 asked the Registrar General to produce daily death totals as weekly registrations did not give sufficient detail. From these it could be seen that the onset of the fog was accompanied by an immediate rise in mortality and that mortality remained higher on the days after the fog than on the days which preceded it.

The first study of daily mortality throughout entire winters was done by the London County Council from 1954 to 1957 (Gore and Shaddick, 1958). During the fog of January 1956 an increase in the number of deaths from bronchitis was observed among the elderly. This was followed by an increase in cardiovascular mortality during a cold spell in February.

The present study

DATA

Mortality

The General Registry Office, which now forms part of the Office of Population Censuses and Surveys (OPCS), originally extracted daily death totals for the Greater London conurbation specially for the study. This was done for the following winters: 1958-1959 (November to February); 1959-1960 (November to February); 1960-1961 (October to February); 1961-1962 (October to February); 1962-1963 (November to February); 1963-1964 (October to February); 1964-1965 (October to February). In the first winter, subtotals for deaths from pneumonia and bronchitis were provided. In subsequent winters subtotals were provided for each sex for those deaths for which the underlying cause was coded as cardiovascular (400-468) or respiratory (influenza (480-483), pneumonia (490-493), and bronchitis (500-502)) according to the 7th Revision of the *International Classification of Diseases* (1957).

From 1 April 1965 the study area was changed marginally to that covered by the newly formed Greater London Council and the data were provided for the whole year. From 1 January 1968 coding was done in accordance with the 8th Revision of the *International Classification of Diseases* (1967). Under this revision the respiratory category remained much the same (asthma was added but this is not frequently coded as an underlying cause of death), but the cardiovascular (390-458) category was significantly enlarged. From this date also, subtotals for the age groups 0-4, 5-14, 15-44, 45-59, 60-74, 75+ were given for each sex,

for cardiovascular, respiratory, and total deaths.

Since 1 April 1969 subtotals of deaths ascribed to myocardial infarction (410), cerebrovascular disease (430-436), influenza (470-474), pneumonia (480-486), and bronchitis and asthma (466 plus 490-493) have been produced. From this date also OPCS began to code routinely the date of all deaths occurring in England and Wales, and daily death totals were produced for the other conurbations, as defined and used by OPCS before local government reorganisation in 1974. The current paper, however, is confined to a discussion of the data for Greater London.

Air Pollution

Equipment to monitor daily totals of suspended particulates (smoke) and sulphur dioxide had been installed in 1954 at seven ground level sites spread over the Greater London conurbation for use in the London County Council study mentioned above. These sites continued to provide data for the present study and also became part of the National Survey of Air Pollution conducted by the Warren Spring Laboratory at Stevenage. They were taken over by the Greater London Council when it superseded the London County Council in 1965 and will be referred to in what follows as the GLC sites. The daily average concentrations of smoke and sulphur dioxide for each site are derived from the total amount of the pollutant collected on filters in the measuring equipment from noon to noon. The data from the seven sites have been used to calculate average daily concentrations for the conurbation. The use of this average may be criticised on the grounds that pollution levels vary widely throughout Greater London, as can be seen from the National Survey of Air Pollution. Some of the differences in pollution levels are, however, very local and should average out over the conurbation. It is probably more useful to think of the daily average value as a pollution indicator rather than as an estimate of the average concentration of the pollutants over the area.

Weather

Although only temperature is discussed in the current paper, other data were obtained at the same time. Because of the potentially large volume of data involved, choice of weather data for this analysis was made from those readings already available on magnetic tape. For this reason data from the meteorological station at Heathrow airport were obtained to represent weather conditions in Greater London.

When the original request for weather data was made to the Meteorological Office, daily summaries

were not available, but hourly readings were. More recently, daily summaries have become available, but for the work described in this paper the minimum of the hourly temperatures for the period 9 p.m. to 9 a.m. and the maximum of the hourly temperatures for the period 9 a.m. to 9 p.m. were used.

FINDINGS

Before any comprehensive analytical work was started, the data were examined graphically using the microfilm facilities available at the University of London Computer Centre. Some of the salient features apparent in the data are described below.

Effects associated with air pollution

The daily mean values, taken over the seven GLC sites of the 24 hour averages of sulphur dioxide are shown in Fig. 1 (with one point plotted for each day and the lines joined).

The high peaks in pollution apparent in the late 1950s had disappeared by the late 1960s. The most notable peak in this series was in December 1962, on the anniversary of the 1952 fog, when another similar, but not so severe episode occurred. When

the averages for both suspended particulate matter and sulphur dioxide were plotted on a logarithmic scale, it was seen that the decrease in levels of suspended particulate matter during the period 1958-72 was greater than that for sulphur dioxide.

This decline in levels of concentrations of suspended particulate matter is usually attributed to the Clean Air Act of 1956 (Commings and Waller, 1967; Craxford *et al.*, 1970). It has also been noticed that air pollution concentrations have declined in areas where the Clean Air Act has not been implemented. This is a result of voluntary changes from coal towards gas, oil, and electricity as domestic and industrial fuels (Aulicciems and Burton, 1973).

With this reduction in the concentrations of black suspended particulates in the atmosphere it has become increasingly possible for the sun's heat to penetrate and break up temperature inversions when they occur. While emissions of sulphur dioxide have not decreased as much as those of suspended particulates, they tend nevertheless to be dispersed, thus preventing the build-up of the high concentrations of sulphur dioxide seen during the earlier winters shown in Fig. 1. Within winters, however, smoke and sulphur dioxide levels follow a similar

Fig. 1 Daily deaths and sulphur dioxide concentrations, 1958-72

pattern.

In Fig. 1, total daily deaths in Greater London for days from 1 November 1958 to 31 December 1972 for which data are available are also shown. (Data for 1973 are not yet available.) The most pronounced feature in these death totals is the cyclic seasonal variation. The most persistent deviations from this are associated with influenza epidemics. In the first five winters, however, very short peaks in deaths can be seen and although it is difficult to discern the details at this scale, many of these appear to coincide with days on which concentrations of sulphur dioxide were high.

This is particularly evident when the data for the first winter, 1958-59, are examined on a larger scale in Fig. 2. (On one occasion it appears that the peak in deaths on 29 January precedes that in air pollution on 30 January, but as mentioned above pollution was measured from noon to noon and thus high levels in the late afternoon of 29 January would contribute to the following day's reading.) The highest daily death total was when a severe fog occurred during the influenza epidemic in February 1959. Concentrations of suspended particulates tended to be higher at that time than those of sulphur dioxide. The events of this winter and that of 1959-60 were reported very fully at the time (Martin and Bradley, 1960; Martin, 1961).

Figure 3 shows, plotted in the same way as in Fig. 2, the daily deaths and air pollution concentrations during the winter of 1962-63. During the fog episode in December 1962, daily average sulphur dioxide concentrations reached a maximum value of approximately 3500 $\mu\text{g}/\text{m}^3$. This is more than twice the maximum attained during the relatively foggy winter of 1958-59. Another major fog

occurred later in the winter of 1962-63. Except for the periods during these two fogs, concentrations of smoke were on average lower than in 1958-59. Concentrations of suspended particulates in 1962-63 were invariably lower than those of sulphur dioxide.

When these death data were presented graphically in terms of deviations from 15-day moving averages by Waller *et al.* (1969) the peak associated with the second fog was not discernible. The overall level of mortality was increasing at the time. Their paper did not present the subtotals of deaths from respiratory and cardiovascular causes which had been provided from the winter of 1959-60 onwards. In Fig. 3 respiratory totals are represented by the lower dotted line and cardiac totals by the broken line above it. The peak in respiratory deaths associated with the December fog was more prolonged than the peak in cardiovascular deaths while the peak in respiratory deaths associated with the second fog occurred later than the one in circulatory deaths.

Effects associated with cold weather

In the earlier winters of this study (1958-63) most of the short spells (three to five days) of exceptionally cold weather were associated with temperature inversions and hence with high concentrations of air pollution. In contrast with this, in late January 1972 there was a sudden short cold spell in the middle of a mild winter. This was not accompanied by a peak either in air pollution, or in total deaths, but a small peak was seen in cardiac deaths, mainly in deaths ascribed to myocardial infarction.

Most of the cold spells are of longer duration than those just referred to, and the situation is complicated by influenza epidemics. This is illus-

Fig. 2 Daily deaths, sulphur dioxide, and smoke, 1958-59

Fig. 3 Daily deaths, sulphur dioxide, and smoke, 1962-63

trated in Figs 4 to 9. Maximum and minimum temperatures, and total deaths as well as those certified as being due to respiratory and cardiovascular causes, during three winters in the early 1960s—that is, 1960-61, 1961-62, and 1962-63—are shown in Figs 4, 5, and 6 respectively. The same

data for three later winters, those of 1967-68, 1968-69, and 1969-70 are shown in Figs 7, 8, and 9. The totals of respiratory and cardiovascular deaths have been omitted for the winter of 1967-68, as they were affected by the change from the 7th to the 8th revision of the *International Classification of*

Fig. 4 Daily deaths and temperature, 1960-61

Fig. 5 Daily deaths and temperature, 1961-62

Fig. 6 Daily deaths and temperature, 1962-63

Fig. 7 Daily deaths and temperature, 1967-68

Fig. 8 Daily deaths and temperature, 1968-69

Fig. 9 Daily deaths and temperature, 1969-70

Diseases; as was mentioned earlier, deaths registered in 1967 were coded according to the 7th revision and those registered in 1968 according to the 8th revision.

During the winters shown in Figs 4 to 9, there was a tendency for periods during which influenza deaths were registered, whether in small or in epidemic numbers, to be preceded by spells of exceptionally cold weather. But the extent of the increase in the number of influenza deaths would appear to be associated with the presence of influenza viruses of different types rather than with the severity of the weather. As temperatures fell in December 1967, a major influenza epidemic broke out and total mortality began to rise sharply. But periods of low temperature in February and March 1968 were not associated with increases in mortality (Fig. 7). At the beginning of the next winter there was a small rise in mortality just after a cold spell (Fig. 8). By the beginning of 1969 a new influenza virus variant A2/Hong Kong/68, to which the population was not yet immune, had appeared and low temperatures in February and March were accompanied by rises in total mortality. This variant reappeared the following winter (Fig. 9) and a more severe epidemic occurred, following a very similar pattern to that of the 1967-68 winter.

During these influenza epidemics increases were seen in the total deaths attributed to respiratory causes as well as in the numbers of those whose underlying cause was coded as influenza. Increases, although proportionately smaller, are also, on most occasions, seen in cardiovascular mortality. It is interesting to note, however, that cardiovascular mortality did not appear to rise during the influenza epidemic in January and February 1961 (Fig. 5), whereas during that in December 1961 and January 1962 (Fig. 6), which was preceded by an exceptionally cold spell, an increase was seen in cardiovascular mortality. Cardiovascular mortality, however, began to decline as temperatures rose again. In late December 1962 mortality from cardiovascular causes increased as temperatures fell (Fig. 7) and remained high during the cold weather whereas numbers of respiratory deaths only began to rise late in January when influenza also began to be reported.

Discussion

These findings arise from a visual rather than a statistical analysis of the data, so conclusions are tentative and based only on the most salient features seen in the data.

The official report on the 1952 fog (Ministry of Health, 1954) suggested that there is a notional

group of susceptible people who are likely to be affected by whatever adverse circumstances may arise. Some may die and others survive to succumb to the next set of adverse circumstances. To investigate whether this is likely to be the case, it is important to consider not only isolated environmental events, but also the way such events follow each other in time.

In the data described above there is evidence that influenza epidemics are often preceded by periods of exceptionally low temperature and that they are usually associated with increases in respiratory mortality and often, but not always, with increases in cardiovascular mortality. The first of these conclusions is supported by an analysis of sickness absence claims (Davey and Reid, 1972), which also suggested that the extent of influenza epidemics is determined by the severity of the winter. This is true to some extent for the years (1966-71) discussed by Davey and Reid but the hypothesis fits the winters of the early 1960s rather less well.

Using a longer series of weekly data, Bainton (1975) suggested an association between influenza and deaths from ischaemic heart disease. It would be unwise to try to assess at this stage in the present study the extent to which increased cardiovascular mortality is associated with cold weather alone, and the extent to which it is associated with influenza infections. Data from multiple cause coded death certificates may allow further investigation of this. They must be treated with some caution, however, as it has been noted that once an influenza epidemic is publicly announced, influenza is more likely to be mentioned on death certificates.

It has been suggested that the seasonal swing in cardiovascular deaths may result from the deaths of people with chronic respiratory disease whose immediate cause of death is cardiovascular. Rogot and Blackwelder (1970) and Rogot (1974) showed, however, using multiple cause coded death certificates, that in Memphis (Tennessee) and Chicago there was a seasonal swing in cardiovascular mortality irrespective of whether respiratory disease was also mentioned on the death certificate. It remains to be seen whether this is also true in England.

In an analysis comparing daily death totals in England and Wales with minimum daily temperatures (Bull and Morton, 1975), it was found that the statistical relationship between daily mortality from cardiovascular disease and temperatures on the days preceding death differed from the corresponding relationship for respiratory disease. In this correlation analysis the daily death totals for 1970, when there was a severe influenza epidemic, were combined with those from 1971 when no such epidemic

occurred. Also the analysis did not allow for the variation in cardiovascular mortality on different days of the week (Macfarlane and White, 1977). So there are reservations about accepting Bull and Morton's conclusion that preceding respiratory infections did not influence mortality from myocardial infarctions and strokes.

As mentioned earlier, daily death data are available for other conurbations in England and Wales with different climates, air pollution levels, and mortality rates from cardiovascular disease. It will also be possible to compare daily variation in mortality with other variables which are thought to be relevant, in particular relative humidity, windspeed, and snowfall which has been associated with increases in cardiovascular mortality in the United States (Rogot and Padgett, 1976).

Thanks are due to Dr A. M. Adelstein, Chief Medical Statistician of the Office of Population Censuses and Surveys for the mortality data and to the staff of the Office's Computer Division who extracted it from their records; to the Meteorological Office for the weather data, in particular to Mr J. Smith who organised its transfer; to the staff of University College London Computer Centre for their advice and help in surmounting the unexpected hardware incompatibilities which hindered the receipt and merging of these data; to the staff of the University of London Computer Centre, in particular John Gilbert whose subroutine library DIMFILM was used in plotting graphs on microfilm; to Professor J. R. T. Colley for advice on the preparation of the work for publication.

The original study relating daily mortality to air pollution was started by Dr A. E. Martin formerly of the Department of Health and Social Security and his data are included in the present study. He continued his study in conjunction with Robert Waller of the Medical Research Council's Air Pollution Unit (now Environmental Hazards Unit), whose advice is gratefully acknowledged together with that of Professor P. J. Lawther and other former colleagues in the Air Pollution Unit.

Reprints from Miss A. Macfarlane, Department of Medical Statistics and Epidemiology, London School of Hygiene and Tropical Medicine, Keppel Street (Gower Street), London WC1E 7HT.

References

Adams, F. (1849). *The Genuine Works of Hippocrates*. Translated from the Greek, with a preliminary discourse and annotations. Vol. 1, p. 203. Sydenham Society: London.

- Auliciems, A., and Burton, I. (1973). Trends in smoke concentrations before and after the Clean Air Act of 1956. *Atmospheric Environment*, 7, 1063-1070.
- Bainton, D. (1975). An examination of the association between influenza and ischaemic heart disease. Unpublished MSc report, University of London.
- Boyd, J. T. (1960). Climate, air pollution, and mortality. *British Journal of Preventive and Social Medicine*, 14, 123-135.
- Bull, G. M., and Morton, J. (1975). Relationship of temperature with death rates from all causes and from certain respiratory and arteriosclerotic diseases in different age groups. *Age and Ageing*, 4, 232-246.
- Commins, B. T., and Waller, R. E. (1967). Observations from a ten year study of pollution at a site in the city of London. *Atmospheric environment*, 1, 49-68.
- Craxford, S. R., Goorah, B. D., and Weatherley, M.-L. P. M. (1970). Air pollution in urban areas in the United Kingdom: present position and recent national and regional trends. *National Survey of Air Pollution, Warren Spring Laboratory*, SCGB 74/6.
- Davey, M. L., and Reid, D. (1972). Relationship of air temperature to outbreaks of influenza. *British Journal of Preventive and Social Medicine*, 26, 28-32.
- Farr, W. (1840). Letter to the Registrar General. *2nd Report of the Registrar General 1838-1839*, p. 88.
- Farr, W. (1841). Letter to the Registrar General. *3rd Report of the Registrar General, 1839-1840*, p. 102.
- Farr, W. (1843). Causes of the high mortality in town districts. *5th Report of the Registrar General, 1841-1842*, p. 416.
- Farr, W. (1868). Narrative of the proceedings at General Registry Office during the cholera epidemic 1866. *Supplement to the 29th Report of the Registrar General, Appendix II*.
- Farr, W. (1885). *Vital Statistics: a memorial volume of selections from the reports and writings of William Farr*. Edited by N. A. Humphreys. Sanitary Institute of Great Britain: London.
- Gore, A. T., and Shaddick, C. W. (1958). Atmospheric pollution and mortality in the County of London. *British Journal of Preventive and Social Medicine*, 12, 104-113.
- Huntington, E. (1930). *Weather and Health. Bulletin No. 75*. National Research Council: Washington DC.
- Macfarlane, A. J., and White, G. C. (1977). Deaths: the weekly cycle. *Population Trends*, 7, 7-8.
- Martin, A. E. (1961). Epidemiological studies of atmospheric pollution. A review of British methodology. *Monthly Bulletin of the Ministry of Health and the Public Health Laboratory Service*, 20, 42-49.
- Martin, A. E., and Bradley, W. H. (1960). Mortality, fog and atmospheric pollution: an investigation during the winter of 1958-59. *Monthly Bulletin of the Ministry of Health and the Public Health Laboratory Service*, 19, 56-72.
- Ministry of Health (1954). Mortality and morbidity during the London fog of December 1952. *Reports on Public Health and Medical Subjects, No. 95*. HMSO: London.

- Rogot, E. (1974). Associations between coronary mortality and the weather, Chicago 1967. *Public Health Reports*, **89**, 330-338.
- Rogot, E., and Blackwelder, W. C. (1970). Associations of cardiovascular mortality with weather in Memphis, Tennessee. *Public Health Reports*, **85**, 25-39.
- Rogot, E., and Padgett, S. J. (1976). Associations of coronary and stroke mortality with temperature and snowfall in selected areas of the United States, 1962-66. *American Journal of Epidemiology*, **103**, 565-575.
- Rose, G. (1966). Cold weather and ischaemic heart disease. *British Journal of Preventive and Social Medicine*, **20**, 97-100.
- Russell, W. T. (1924). The influence of fog on mortality from respiratory diseases. *Lancet*, **2**, 335-339.
- Russell, W. T. (1926). The relative influence of fog and low temperature on the mortality from respiratory disease. *Lancet*, **2**, 1128-1130.
- Waller, R. E., Lawther, P. J., and Martin A. E. (1969). Clean air and health in London. *Proceedings of the Clean Air Conference, Eastbourne, October 1969, Part 1*. National Society for Clean Air: London.
- Woods, H. M. (1927). The influence of external factors on the mortality from pneumonia in childhood and later adult life. *Journal of Hygiene*, **26**, 36-43.
- World Health Organisation (1957). *International Classification of Diseases*, 7th revision. WHO: Geneva.
- World Health Organisation (1967). *International Classification of Diseases*, 8th revision. WHO: Geneva.
- Wright, G. P., and Wright, H. P. (1945). Etiological factors in broncho-pneumonia amongst infants in London. *Journal of Hygiene*, **44**, 15-30.
- Young, M. (1924). The influence of weather conditions on the mortality from bronchitis and pneumonia in children. *Journal of Hygiene*, **23**, 151-175.