Brit. J. prev. soc. Med. (1969), **23**, 133–140

PATTERNS OF MORTALITY IN MIDDLE AND EARLY OLD AGE IN THE COUNTY BOROUGHS OF ENGLAND AND WALES

BY

M. J. GARDNER, B.Sc., Dip. Math. Stat.
M. D. CRAWFORD, M.D.

AND

J. N. MORRIS, D.Sc., F.R.C.P., D.P.H. (Hon. Director)

Medical Research Council's Social Medicine Unit, The London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1

It is common knowledge that death rates vary from area to area, year to year, and between different groups of the population. These differences have been extensively studied but, very often, only in relation to a particular cause of death or a particular feature of the environment—the association of bronchitis with air pollution, for example, or population density with respiratory death rates. This paper, reporting a fairly comprehensive search for associations between the environment and death rates from four major 'causes' at ages 45–74 in the large towns of England and Wales, has, as its reason, the systematic presentation of some accepted facts and the posing of new, as well as continuing, questions.

Material

The data were originally collected to investigate the finding that mortality rates from cardiovascular disease were higher in areas supplied with soft (or acid) drinking water in several very different countries, for example, in Japan (Kobayashi, 1957), the U.S.A. (Schroeder, 1960a, 1960b, 1966), and England and Wales (Morris, Crawford, and Heady, 1961, 1962; Crawford, Gardner, and Morris, 1968a).

In the England and Wales study many other environmental indices were also examined in an attempt to 'explain away' this association. A large amount of data describing environmental characteristics was gathered, a mixture of readily available statistics (for which the County Boroughs are very suitable) together with some specially prepared material. From the censuses we extracted details of population structure, for example of social class composition, density and quality of housing, home ownership, and of intercensal changes in some of these indices. Figures on car licensing from the Ministry of Transport, and specially obtained data on income and unemployment levels, make up a group of socio-economic factors. Also included were measures of air pollution; the provision of general practitioner services, local authority expenditure on provision of child and old people care, schooling; cigarette smoking habits; records of climate; and nature of the local water supplies in a total of almost 80 socio-environmental indices.

At the same time, death rates for all sizeable causes of death in middle age were calculated from unpublished data provided by the General Register Office. We have included death rates for seven-year periods* around the two latest censuses (1951 and 1961), for each sex, and at ages 45–64 and 65–74, making eight rates for each cause of death per County Borough. A finer breakdown by age is not possible, but we do not believe that differences in age distribution within these ranges could importantly affect the findings.

The 61 County Boroughs having over 80,000 total population in 1961 have now been examined for patterns of mortality from four major 'causes', namely, cardiovascular disease, bronchitis, cancer of lung, and cancer of stomach. The 22 smaller County Boroughs were omitted to reduce errors in estimates of death rates due to small numbers.

Results

Trends and Ranges of Mortality

The Registrar-General's Decennial Supplements were used for an initial historical study of trends in mortality from all causes. On average the rates in these 61 County Boroughs during this century have fallen similarly to those for the country as a whole. However, there is still substantial variation between

*Except for the age-group 65-74 years where the earlier death rates are for 1950-54.

TABLE I

MORTALITY FROM ALL CAUSES AT AGES 45-64 IN ENGLAND AND WALES AND IN THE COUNTY BOROUGHS* SINCE 1911

Sex	Period	England and Wales	County Boroughs Mean	County Boroughs Lowest	County Boroughs Highest
Male	1911–20	2040	2267	1604 (Croydon)	3045 (Liverpool)
	1921–30	1692	1869	1461 (Ipswich)	2414 (Oldham)
	1948–54	1404	1586	1177 (Ipswich)	2042 (Salford)
	1958–64	1380	1524	1096 (Ipswich)	1987 (Salford)
Female	1911–20	1517	1667	1122 (Bournemouth)	2292 (Oldham)
	1921–30	1259	1352	1048 (Norwich)	1889 (Oldham)
	1948–54	831	885	718 (Bournemouth)	1180 (Oldham)
	1958–64	739	785	627 (Oxford)	1037 (Burnley)

Average annual rates per 100,000 living in age-sex group
*61 County Boroughs over 80,000 population in 1961 in all tables

TABLE II

MORTALITY AT AGES 45–64 IN ENGLAND AND WALES AND IN THE COUNTY BOROUGHS DURING 1958–64

Sex	Certified Cause of Death*	England and Wales	County Boroughs Mean	County Boroughs Lowest	County Boroughs Highest
Male	Cardiovascular disease (17–21)	582	673	499 (Ipswich)	862 (Halifax)
	Bronchitis (24)	111	140	53 (Ipswich)	270 (Salford)
	Cancer of lung (11)	178	203	150 (Bath)	292 (Salford)
	Cancer of stomach (10)	53	60	35 (Bournemouth)	99 (South Shields)
Female	Cardiovascular disease	247	310	216 (Croydon)	453 (Burnley)
	Bronchitis	22	29	10 (Ipswich)	59 (Salford)
	Cancer of lung	24	25	12 (Doncaster)	42 (Brighton)
	Cancer of stomach	22	26	11 (York)	43 (South Shields, Walsall

Average annual rates per 100,000 living in age-sex group
*Figures in parentheses after cause of death refer to Registrar General's Abridged List

the towns, the same group of towns having consistently experienced low rates, and another group high rates. As an example, Table I gives death rates at 45–64 years of age.

Concurrently with the falling *average* death rate, the *range* of differences between these towns has become smaller, but the highest death rates are consistently just less than double the lowest. Female rates show the expected greater decrease than male; indeed, now, the highest female death rate is similar to the lowest male figure. Thus, during 1958-64 on average, 1% of males aged 45–64 in Ipswich died annually compared with 2% in Salford; 0·6% of females at this age in Oxford compared with 1% in Burnley. A similar picture is found at ages 65–74 years, with the same towns regularly coming at the ends of the ranges*.

Each of the four major causes studied shows similarly large differences between the towns. Table II, again as an example, shows mortality at ages 45–64 during 1958-64.

For separate causes of death somewhat different towns come at the ends of the ranges, suggesting that different causes were active in different areas.

ENVIRONMENTAL ASSOCIATIONS

We now turn to the search for associations of mortality with the social and environmental characteristics of the towns. Correlation analysis was used in the initial screening of the large number of indices included for their association, or lack of association, with mortality. We confined our search to environmental factors having consistent associations with cause-specific death rates, bearing in mind other and our own previous work (as will be described, we later probed for possible new associations). It is virtually impossible to start examining a correlation matrix of the size we had, roughly 20,000 coefficients, in any other way, although techniques of cluster analysis could be helpful (Hills, 1969). Indices reflecting four aspects of environment gave consistently high correlations with some or all causes of death (Table III).

First, a collection of indices of bad *socio-economic circumstances* (and population structure) are positively correlated with mortality. Of the many indices of this type in our available data we have concentrated on nine, representative of the whole,

*Since 1964 a large number of boundary changes have meant that recent mortality figures are not comparable to those of earlier periods for some towns. However, the death rates for males aged 45-64 during 1965-67 in Ipswich and Salford, which have not undergone changes, were 1295 and 2004 per 100,000 respectively.

TABLE III

CORRELATIONS OF MORTALITY FROM ALL CAUSES DURING 1958-64 WITH LOCAL ENVIRONMENTAL INDICES IN THE COUNTY BOROUGHS

Environmental Index	Sex-age Group			
	Male		Female	
	45–64	65–74	45–64	65–74
*Socio-economic indices***				
Population density	+0·49	+0·43	+0·41	+0·35
Overcrowding in households	+0·48	+0·44	+0·32	+0·31
Social class	+0·55	+0·64	+0·48	+0·57
Education	+0·45	+0·58	+0·43	+0·62
Pre-war unemployment	+0·62	+0·50	+0·55	+0·45
Income levels	+0·60	+0·66	+0·50	+0·68
Households per car	+0·75	+0·66	+0·72	+0·60
% population aged under 15	+0·40	+0·53	+0·31	+0·46
Migration	+0·48	+0·51	+0·36	+0·44
Air pollution				
'Domestic' air pollution*	+0·74	+0·67	+0·57	+0·56
Smoke†	+0·48	+0·45	+0·37	+0·42
SO_2†	+0·53	+0·51	+0·39	+0·40
Climate				
Latitude	+0·65	+0·58	+0·53	+0·60
Sunshine‡	−0·53	−0·61	−0·55	−0·73
Temperature‡	−0·54	−0·53	−0·54	−0·67
Rainfall‡	+0·52	+0·38	+0·61	+0·44
Water supplies §				
Total hardness	−0·55	−0·59	−0·58	−0·58
Calcium content	−0·66	−0·64	−0·65	−0·65

For normally distributed variables these are the significance levels of the product moment correlation coefficient (r) for 61 pairs of observations:

$r < -0{\cdot}33$ or $r > +0{\cdot}33$: $P < 0{\cdot}01$
$r < -0{\cdot}41$ or $r > +0{\cdot}41$: $P < 0{\cdot}001$

**See Table IV for fuller description and references.
*Daly (1959).
†Department of Scientific & Industrial Research (1964)
‡Long period averages; for years 1921-50 for sunshine and temperature, for years 1916-50 for rainfall. Meteorological Office personal communication
§See Appendix

showing the highest correlations with the death rates. Thus, the densely populated towns with their excess proportions in the low social class and income groups, with higher unemployment and lower car ownership, from which people migrate, classically have higher mortality rates. Two interesting features here are the younger age distributions of these disadvantaged towns and the very high correlations with mortality of a recent index of economic status—the number of households per car. The greater this ratio, the fewer the cars owned by the local population and the higher were the death rates. It could be that this index, in an age when a motor car still is something of a status symbol, but a major expense, is an explicit measure of living standards in general.

These various indices are, of course, highly intercorrelated and each can be thought of as reflecting to some degree the general social and economic conditions of the towns over the past 30 years. Consequently, and as each gave similar results in further analyses, they were combined into a single index. We used principal component analysis including the nine indices, and the first component, explaining 67% of the total variation of these indices between towns, we have taken to give a 'social factor score' for each town (see Appendix).

TABLE IV

CORRELATIONS OF SOCIO-ECONOMIC INDICES WITH THE 'SOCIAL FACTOR SCORE'

Socio-economic Index	Correlation Coefficient (r)
1. Persons per acre of built-up area, 1951*†	+0·79
2. % of households with more than 1½ persons per room, 1951*	+0·78
3. Social class index, 1951*†	+0·90
4. % of occupied males who left school under 15 years of age, 1951*	+0·68
5. Average % unemployed, 1927-38**	+0·74
6. % earning under £7 10s. 0d., 1950‡	+0·87
7. Average number of households per car, 1961*§	+0·79
8. % population aged under 15 years, 1961*	+0·74
9. % decrease in population due to balance of causes, 1951-61*	+0·69

*Registrar-General, Census, 1951 or 1961
†Daly (1959)
‡Wilkins (1952)
§Ministry of Transport (1961)
**Morris and Titmuss (1944)

Table IV shows the indices included, and that each has a correlation of +0·68 or more with this social factor score (the 'social factor score' is a weighted linear combination of the nine indices, the weights being proportional to the correlations of Table IV). A similar approach was used by Buckatzsch (1947) in looking at the relationship between infant mortality rates and social conditions.

Secondly, indices of *air pollution* are highly associated with death rates. The index of 'domestic' air pollution, derived from coal bought for consumption on domestic fires (Daly, 1959), gave the highest correlation with mortality and was mainly used. The smoke and SO_2 figures from the National Survey of Air Pollution were not available at comparable sites for all the towns, but, where we could extract figures, they were similar to those of Buck and Brown (1964) and gave expected correlations. However, although Daly's index is very highly correlated with the group of social indices (as a measure of air pollution has to be almost by definition in this country), it seems also to contain a specific pollution measure, and is more applicable to the mortality period studied when few actual measurements of air pollution were available. We hope to make further use of the National Survey data when these have been standardized to allow valid comparison between towns.

Thirdly, *climatic factors* are correlated with death rates. That mortality is higher in the north is well known, presumably reflecting climatic (mainly temperature and sunshine) and also social-industrial conditions.

Fourthly, measures of the *hardness of local drinking water* supplies show strong negative correlations with mortality (the softer the local drinking water, the higher the death rates). The concentration of calcium ion in water gives the highest correlation with mortality, and can be precisely estimated (see Appendix).

Multiple Regression Analysis

We then used multiple regression analysis with each of the death rates from all causes and specific causes in turn as the dependent variable, and four environmental factors (the social factor score, 'domestic' air pollution, latitude, and water calcium) as the independent variables. The ordinary linear additive model was used attempting to explain absolute differences in rates; other approaches by transforming the dependent and independent variables were tried but gave similar results.

The variance of each death rate between the towns unexplained by these four factors was then examined to see whether any further environmental factors should be included. The only factors showing sizeable and consistent correlations with the residuals (a residual is the difference between the observed death rate and that predicted from the regression equation containing the four factors) were long period average rainfall and longitude, those with rainfall being higher, for all causes of death and specifically for cardiovascular disease. These two indices are, of course, highly associated—more rainfall on the west coast and *vice versa*—and rainfall only was thus included in the multiple regression equations.

A repeat examination of the now unexplained variance showed no important independent contribution for any of the causes of death from any other environmental index for which we have data; nor was there any evidence of important departures from the model for the five factors now included. The final multiple regression equations for death rates from all causes, cardiovascular disease, bronchitis, cancer of lung, and cancer of stomach are given in Table V a, b, c, d and e; all the five independent variables have been left in each equation, even if not significant, to show the patterns that emerge.

The analysis can be considered as giving the best estimate of each death rate as a linear combination of these five environmental factors, the importance of any factor for a particular rate being indicated by the size and significance of its coefficient. Standardized partial regression coefficients are shown in Table V to enable comparison across rows and down columns. For example, the first row shows the relationships of the indices to male mortality at ages 45–64 during 1948-54 from all causes—air pollution, rainfall, and water calcium making significant independent contributions to the explanation of variance in that order. Briefly, the pattern for specific causes of death is as follows—latitude, rainfall, and water calcium are associated with cardiovascular disease (broadly similar associations are found for each of the two major components of cardiovascular disease, *i.e.*, coronary heart disease and cerebrovascular disease); all the indices except, surprisingly, latitude show significant coefficients in bronchitis; the air pollution index is associated with lung cancer; the social factor score is associated with stomach cancer.

The proportion of the variance of death rates between the towns that is explained by the linear combinations of these factors is given in the final column of Table V. This percentage is notably high for mortality from all causes, reaching 84% (or, equivalently, a multiple correlation coefficient of 0·92) for the recent rate in middle-aged men. On average, about 70% of the variance in cardiovascular mortality is explained, for bronchitis about 60%, for cancer of stomach and for cancer of lung in males about 50%—showing a differential ability of the environmental factors to explain differences in the various causes of death.

Discussion

This study has shown that there are substantial differences of death rates, among the middle and early old aged population, between the large towns in England and Wales; these differences are associated with local environmental factors, differently however for the various causes of death. However, it is important to realize that these analyses are concerned with studying mortality variations *between* the towns, and may give clues to aetiological factors in the environment, and do not deal with individual risk factors. Thus, if the populations of two towns have the same cigarette smoking habits, differences in their lung cancer death rates will reflect differences in causally related environmental conditions, but there is no doubt what is the main cause of the disease among the individuals of each town. Identification of subgroups of the population of towns similar in both relevant personal and environmental characteristics is likely to raise the explanation of variance of mortality between these subgroups. For example, grouping males by cigarette smoking and morning cough habits in areas of varying urbanization, Buck and Wicken (1967) achieved

TABLE V

MULTIPLE REGRESSION† OF LOCAL DEATH RATES ON FIVE SOCIO-ENVIRONMENTAL INDICES IN THE COUNTY BOROUGHS

Sex-age Group	Period	Social Factor Score	'Domestic' Air Pollution	Latitude	Water Calcium	Long Period Average Rainfall	% of Variance Explained
(a) All Causes							
Males 45–64	1948–54	+0·16	+0·48***	+0·10	−0·23*	+0·27***	80
	1958–64	+0·19*	+0·36***	+0·21**	−0·24**	+0·30***	84
Males 65–74	1950–54	+0·24*	+0·28*	+0·02	−0·43***	+0·17	73
	1958–64	+0·39**	+0·17	+0·13	−0·30**	+0·21	76
Females 45–64	1948–54	+0·16	+0·20	+0·32**	−0·15	+0·40***	73
	1958–64	+0·29*	+0·12	+0·19	−0·22*	+0·39***	72
Females 65–74	1950–54	+0·39***	+0·02	+0·36***	−0·12	+0·40***	80
	1958–64	+0·40**	−0·05	+0·29**	−0·27**	+0·29**	73
(b) Cardiovascular Disease							
Males 45–64	1948–54	−0·32*	+0·25*	+0·39***	−0·30**	+0·50***	75
	1958–64	−0·17	+0·28*	+0·31**	−0·29**	+0·48***	74
Males 65–74	1950–54	−0·12	−0·01	+0·40***	−0·44***	+0·31**	66
	1958–64	+0·07	−0·04	+0·29*	−0·35**	+0·41***	66
Females 45–64	1948–54	+0·14	+0·09	+0·39***	−0·22*	+0·41***	75
	1958–64	+0·18	+0·10	+0·31***	−0·25**	+0·44***	78
Females 65–74	1950–54	+0·24	−0·08	+0·54***	−0·05	+0·48***	73
	1958–64	+0·33*	−0·22	+0·45***	−0·26*	+0·34***	70
(c) Bronchitis							
Males 45–64	1948–54	+0·23	+0·48***	+0·07	−0·14	+0·18	70
	1958–64	+0·29*	+0·32*	+0·14	−0·26*	+0·11	70
Males 65–74	1950–54	+0·35*	+0·37*	−0·16	−0·28*	+0·03	54
	1958–64	+0·33*	+0·31	+0·02	−0·20	+0·14	57
Females 45–64	1948–54	+0·07	+0·49**	+0·12	−0·06	+0·37**	62
	1958–64	+0·22	+0·33*	+0·19	−0·09	+0·27*	61
Females 65–74	1950–54	+0·19	+0·31	+0·08	−0·15	+0·25*	49
	1958–64	+0·19	+0·40*	+0·04	−0·19	+0·16	53
(d) Cancer of Lung							
Males 45–64	1948–54	+0·12	+0·71***	−0·46**	−0·02	−0·07	39
	1958–64	+0·32*	+0·53**	−0·10	−0·08	−0·18	58
Males 65–74	1950–54	−0·12	+0·87***	−0·55***	−0·11	−0·31*	41
	1958–64	+0·19	+0·68***	−0·43**	−0·21	−0·45***	54
Females 45–64	1948–54	+0·03	+0·49*	−0·27	−0·17	−0·12	19
	1958–64	−0·25	+0·64**	−0·10	+0·07	−0·09	18
Females 65–74	1950–54	+0·08	+0·61**	−0·21	+0·13	−0·09	31
	1958–64	−0·06	+0·25	−0·04	+0·27	−0·25	22
(e) Cancer of Stomach							
Males 45–64	1948–54	+0·30	+0·40*	−0·08	−0·12	+0·18	52
	1958–64	+0·45**	+0·40**	−0·08	+0·14	+0·35**	65
Males 65–74	1950–54	+0·48**	+0·06	+0·25	+0·11	+0·28*	54
	1958–64	+0·43*	+0·37*	−0·12	+0·12	+0·23	49
Females 45–64	1948–54	+0·28	+0·11	−0·35*	+0·08	+0·25	46
	1958–64	+0·63***	−0·03	+0·11	+0·10	+0·22	48
Females 65–74	1950–54	+0·48**	−0·04	+0·30*	+0·07	+0·37**	56
	1958–64	+0·51**	+0·16	−0·08	+0·01	+0·30*	48

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

†Standardized partial regression coefficients given, *i.e.*, the variables are reduced to the same mean (zero) and variance (one), to allow values for the five socio-environmental indices in each cause of death to be compared. The higher of two coefficients is not necessarily the more significant statistically.

over 90% explanation of the variance of lung cancer and bronchitis mortality between these groups, compared to our 39–70% between towns. The degree of implication of (lack of) water calcium as a 'cause' of cardiovascular mortality similarly would require knowledge of the distribution of personal risk factors, such as diet and physical activity, in the towns. For each disease dealt with here, however, the large range of mortality between the towns indicates a real possibility of environmental factors being causal. Thus, interpretation of the associations described requires a deal of care.

We have attempted to search out from the information at hand all environmental indices that consistently relate to particular causes of death. In using the multiple regression approach, and including all environmental factors which were significantly associated with differences in mortality between the towns, some interesting findings emerged. The one of particular relevance to the original study is the suggestion that rainfall adds markedly to the explanation of cardiovascular mortality variance between the towns. Rainfall is highly correlated ($r = -0{\cdot}6$) with water calcium, and it was thought that its inclusion in the regression would not add anything extra or new. However, the increasing facilities for computer handling of large-scale data of this type have enabled the testing out of some thoughts that had to remain as such a short while ago. Again, it is interesting how air pollution and the social factor score, also being highly intercorrelated ($r = +0{\cdot}8$), show consistently different and expected relationships with mortality.

The association with rainfall, however, is perplexing. Is it reflecting some climatic or geographical influence not yet considered, or is the long-period average rainfall a better index of long-term local mineral differences in soil and water? Takahashi (1967) has shown a relationship between cerebrovascular mortality and age of the main rock strata within several European countries, and suggested that leeching of minerals by rainfall from the strata may be relevant. A group in Michigan, analysing U.S.A. mortality data, have proposed that 'chronic environmental discomfort (if not actual stress) is in some way associated with the development of coronary heart disease' (Dudley, Beldin, and Johnson, 1969). They find a climatic 'comfort index'—combining levels of relative humidity and temperature—highly negatively correlated with mortality from coronary heart disease, and more important than water hardness in predicting the death rate. Temperature and relative humidity do not have the same large range in this country as in the U.S.A., but their findings are not dissimilar to ours in indicating a climatic factor (rainfall, plus the climatic component of latitude reflecting temperature and sunshine). We are hoping to follow this finding through in collaboration with meteorologists as well as water and soil chemists.

The findings for bronchitis, whilst not identifying any overwhelming factor associated with differences in local mortality rates, do nevertheless consistently indicate the known relationships with air pollution, bad social conditions, and inclement climate (Buck and Brown, 1964; Daly, 1959; Fairbairn and Reid, 1958). The association with the air pollution index is stronger at age 45–64 than in the older group. This may be real or may be related to the higher accuracy of certification of bronchitis in younger deaths.

Stocks (1960, 1966, 1967) has reported an association of air pollution with cancer of the lung both within and between countries. This association seems to be greater for males, for whom the death rates are much higher. One factor which cannot be excluded when discussing lung cancer (or bronchitis) is, of course, cigarette smoking! The two indices we had of smoking levels in these towns were for recent years (Morris, 1964; Tobacco Research Council) and, not surprisingly, showed no association with the lung cancer mortality rates, as probably the relevant figures would be smoking levels in the 1940s or earlier for the death rates used here. There is some evidence (Hulton Readership Survey, 1948) that some 20 years ago cigarette consumption was higher in the south than in the north, but that now the position has been reversed; the negative association with latitude, greater around 1951 than around 1961, possibly is a reflection of this trend.

An association between cancer of stomach death rates and poor living conditions has long been known (Registrar-General, 1938; Stocks, 1947, 1960) and, as expected, the social factor score has a significant relationship. Air pollution is independently associated with death rates in three of the male groups; this may indicate a causative factor and supports the suggestion by Stocks (1962) that hydrocarbons in the air might be important, particularly in men in certain occupations. Rainfall shows a consistent association, and this reflects the known geographic distribution of gastric cancer mortality in this country.

Throughout the discussion the positive findings have been highlighted. However, it is equally important to comment, in terms of describing the patterns of mortality that have emerged, where no associations have been found. Thus, for example, air pollution shows no consistent relationship with cardiovascular mortality, nor water calcium with stomach cancer, nor the social factor score with lung cancer, emphasizing the specific (or stronger) associations between environmental factors and particular causes of death.

There are many questions unanswered which this study only helps to pose. How relatively important are the environmental factors in younger or older ages, or in the different sexes—are their effects greater in individuals with adverse personal risk factors? How do time trends in the death rates relate to changing environmental conditions, for example since the Smoke Control Act? To what extent does inter-town migration in itself create differences in mortality? We need to know to what extent it is that the healthier (richer, progressive) or less healthy leave the north for the south. Do morbidity statistics give the same pattern?

We did not include many indices of local health and welfare services, but a report commissioned by the Royal Commission on Local Government (1968) suggests little relationship between services and need, though Davies (1968) indicates this is not so for all services. However, average general practitioner list size in the towns showed no correlation with mortality from any cause in this study, and it is noteworthy that such an imbalance exists between services and need after so many (more than 50) years of consistent mortality differences. Meanwhile, mortality differentials persist, and are associated with changing, changeable, and unchangeable aspects of town environment.

SUMMARY

A study is described of male and female mortality at ages 45–74 years in the larger County Boroughs of England and Wales. Death rates are looked at in relation to changes that have occurred during this century, and to environmental indices associated with the differences between these towns in death rates from four main causes of death—namely, cardiovascular disease, bronchitis, cancer of lung, and cancer of stomach.

The ranking of these towns by their death rates from all causes is similar during each of four periods in the last 50 years, those towns with lower or higher rates remaining so. The highest age-sex specific death rate remains nearly twice the lowest, *i.e.*, there are still substantial differences between towns in mortality.

Indices reflecting five aspects of local environment are shown to explain a large percentage of the variance of the death rates between towns. These are socio-economic conditions, air pollution, latitude, hardness of water supplies, and long-period average rainfall. Multiple regression methods are used to show how these indices are differently related to each cause of death at these ages.

We thank the General Register Office, the Meteorological Office, the water authorities of the County Boroughs and their chief officers, and the Tobacco Manufacturers Standing Committee.

Mrs. R. Glass and Mr. W. Scott of the Centre for Urban Studies kindly provided us with abstracts of census data; Dr. M. Clifton of Warren Spring Laboratory gave useful advice on air pollution measurement, while Mr. R. Waller helpfully commented on an earlier version.

We are also grateful to many colleagues in the M.R.C. Social Medicine Unit, in particular to Dr. J. A. Heady, for advice and assistance.

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APPENDIX

PARTICULARS OF 61 COUNTY BOROUGHS OVER 80,000 TOTAL POPULATION IN 1961

County Borough	Social† Factor Score	Water Supply*	
		Total Hardness (p.p.m.)	Calcium (p.p.m.)
Bath	718	310	105
Birkenhead	1981	63	17
Birmingham	1364	20	5
Blackburn	1708	45	14
Blackpool	825	50	18
Bolton	1596	34	10
Bootle	2646	55	15
Bournemouth	67	228	78
Bradford	1528	40	10
Brighton	979	221	84
Bristol	1118	206	73
Burnley	1787	40	12
Coventry	1128	260	78
Croydon	807	253	96
Darlington	1499	114	20
Derby	1433	142	39
Doncaster	1259	168	39
East Ham	1614	334	122
Exeter	823	68	21
Gateshead	2632	138	44
Grimsby	1592	263	94
Halifax	1373	34	8
Huddersfield	1268	36	9
Ipswich	1030	358	138
Kingston-upon-Hull	1921	260	91
Leeds	1371	56	16
Leicester	1322	127	37
Liverpool	2300	55	15
Manchester	1592	28	8
Middlesbrough	2225	77	26
Newcastle-upon-Tyne	1816	138	44
Northampton	1123	170	59
Norwich	1183	345	133
Nottingham	1458	146	27
Oldham	2046	36	6
Oxford	527	252	107
Plymouth	1375	20	5
Portsmouth	1275	230	90
Preston	1817	33	6
Reading	1013	261	101
Rochdale	1611	52	13
Rotherham	1778	64	14
St. Helens	2448	207	49
Salford	2291	28	8
Sheffield	1531	48	14
Southampton	1158	181	68
Southend-on-Sea	539	140	50
Southport	540	315	75
South Shields	2463	322	71
Stockport	1417	48	13
Stoke-on-Trent	2039	190	57
Sunderland	2443	354	71
Wallasey	1290	85	20
Walsall	1638	189	60
West Bromwich	1639	181	53
West Ham	2251	334	122
Wolverhampton	1419	274	81
York	1204	231	71
Cardiff	1521	36	21
Newport	1677	59	14
Swansea	1465	37	13

†A weighted linear combination of the nine indices described in Table IV (arbitrary units—the 'worse' towns have higher scores).
*The values shown are estimates for the period around 1961; in towns with multiple sources of supply the average for each source was weighted by the proportion of the population it served to give an overall local estimate (Crawford, Gardner, and Morris, 1968b).

The death rates used in this study are not given here. Rates for the earlier period were published in The Registrar-General's 'Quarterly Return No. 432, December, 1956. Appendix D', and figures for the five years 1959-63 in The Registrar-General's 'Decennial Supplement, England and Wales, 1961. Area Mortality, Tables' (1967).