Clark, D. E. (1955). *J. Amer. med. Ass.*, **159**, 1007.
—— and Rule, J. H. (1955). Ibid., **159**, 995.
Court-Brown, W. M., and Doll, R. (1957). *Spec. Rep. Ser. med. Res. Coun. (Lond.)*, No. 295. H.M.S.O., London.
Curran, R., Eckert, H., and Wilson, G. M. (1958). *J. Path. Bact.*, **76**, 541.
Delarue, J., Tubiana, M , and Dutreix, J. (1953). *Bull. Ass. franç. Cancer*, **40**, 263.
Doniach, I. (1958). *Brit. med. Bull.*, **14**, 181.
Duffy, B. J., jun., and Fitzgerald, P. J. (1950). *Cancer (N.Y.)*, **3**, 1018.
Franco, V. H., and Quina, M. G. (1956). *Brit. J. Radiol.*, **29**, 434.
Fraser, R., Abbatt, J. D., and Stewart, F. S. (1954). Ibid., **27**, 23.
Goldberg, R. C., and Chaikoff, I. L. (1952). *A.M.A. Arch. Path.*, **53**, 22.
Gordon, E. S., and Albright, E. C. (1950) *J. Amer. med. Ass.*, **143**, 1129.
Hamilton, J. G., and Lawrence, J. H. (1942). *J. clin. Invest.*, **21**, 624.
Hertz, S., and Roberts, A. (1942). Ibid., **21**, 624.
Kellgren, J. H., and Lawrence, J. S. (1956). *Ann. rheum. Dis.*, **15**, 1.
Kelly, F. J. (1954). *J. clin. Endocr.*, **14**, 326.
Kilpatrick, R., Blomfield, G. W., Neal, F. E., and Wilson, G. M. (1957). *Quart. J. Med.*, **26**, 209.
King, E. L., and Herring, J. S. (1939). *J. Amer. med. Ass.*, **113**, 1300.
Kurland, G. S., and Freedberg, A. S. (1951). *J. clin. Endocr.*, **11**, 843.
Macgregor, A. G. (1957). *Brit. med. J.*, **1**, 492.
Maloof, F., Dobyns, B. M., and Vickery, A. L. (1952). *Endocrinology*, **50**, 612.
Medical Research Council (1956). *Hazards to Man of Nuclear and Allied Radiations*. H.M.S.O., London.
Mortensen, J. D., Woolner, L. B., and Bennett, W. A. (1955). *J. clin. Endocr.*, **15**, 1270.
Osborn, S. B., and Smith E. E. (1956). *Lancet*, **1**, 949.
Pochin, E. E. (1958). In *Modern Trends in Endocrinology*, pp. 46–51, edited by H. Gardiner-Hill. Butterworth, London.
—— Myant, N. B., and Corbett, B. D. (1956). *Brit. J. Radiol.*, **29**, 31.
Quimby, E. H., and Werner, S. C. (1949). *J. Amer. med. Ass.*, **140**, 1046.
Rawson, R. W., and Rall, J. E. (1955). Cited by Pochin *et al.* (1956).
Sandler, G., and Wilson, G. M. (1959). *Quart. J. Med.* In press.
Schlesinger, M. J., Gargill, S. L., and Saxe, I. H. (1938). *J. Amer. med. Ass.*, **110**, 1638.
Seed, L., and Jaffé, B. (1953). *J. clin. Endocr.*, **13**, 107.
Seidlin, S. M., Siegel, E., Melamed, S., and Yalow, A. A. (1955). *Bull. N.Y. Acad. Med.*, **31**, 410.
—— Yalow, A. A., and Siegel, E. (1954). *Radiology*, **63**, 797.
Simpson, C. L., and Hempelmann, L. H. (1957). *Cancer (Philad.)*, **10**, 42.
—— —— and Fuller, L. M. (1955). *Radiology*, **64**, 840.
Skillern, P. G., McCullagh, E. P., and Hays, R. A. (1951). *Trans. Amer. Goiter Ass.*, p. 184.
Sloan, L. W. (1954). *J. clin. Endocr.*, **14**, 1309.
Williams, R. H., Jaffe, H., Towery, B. T., Rogers, W. F., and Tagnon, R. (1949). *Amer. J. Med.*, **7**, 718.
Wilson, G. M., Kilpatrick, R., Eckert, H., Curran, R., Jepson, R. P., Blomfield, G. W., and Miller, H. (1958). *Brit. med. J.*, **2**, 929.

Cerebral Palsy—Advances in Understanding and Care is published by the Association for the Aid of Crippled Children in New York (624 pages. Obtainable from Arthur F. Bird, 66, Chandos Place, London, W.C.2. Price 42s. 6d., plus postage 1s. 6d.). The author, Viola E. Cardwell, enlisted a team of expert advisers to help her in the preparation of the book, the primary objective of which "is to promote greater understanding, improved treatment, and more sympathetic guidance of the patient and his family who are faced with the multiplicity of the all but overwhelming problems engendered by cerebral palsy." The first part of the book is concerned with the medical aspects of cerebral palsy: aetiology, pathology, and diagnosis are all discussed in detail in the light of modern advances in neuroanatomy and neurophysiology. "The Individual with Cerebral Palsy and his Total Habilitation" is the heading of the second part, and here the author describes physical and psychological treatment and discusses the social and educational aspects of cerebral palsy so far as the individual is concerned. Finally, there is a section on community aspects of cerebral palsy, with chapters on research and prevention. This book gives a detailed account of how an advanced society is attempting by voluntary and municipal effort to meet the challenge which cerebral palsy presents to the medical and social services.

CANCER AND BRONCHITIS MORTALITY IN RELATION TO ATMOSPHERIC DEPOSIT AND SMOKE

BY

PERCY STOCKS,* C.M.G., M.D., F.R.C.P.
Colwyn Bay, North Wales

Residents in large towns of England and Wales have always been subject to higher death rates than country dwellers, and much attention has been given to this in the Registrar-General's reports during the last century. Subdivision into sex, region, and social class does little to explain the urban excess; in 1930–2, for example, the standardized mortality figures for men aged 35–64 in unskilled and semi-skilled occupations showed urban/rural ratios of 134/80 in the north and 105/73 in the south and east outside Greater London, and for their wives the corresponding ratios were 128/104 and 103/92 (Registrar-General, 1938).

Two diseases for which the urban excess is very pronounced are bronchitis and lung cancer, and this is so in some regions for gastric cancer, whereas cancers of the intestine and breast show little relation to urbanization in Britain. The death rates from bronchitis and lung cancer are higher than in any other country, as is also the amount of air pollution from domestic chimneys; and in countries where coal is little used for domestic heating the urban excess is much smaller. In view of these facts atmospheric pollution of the kind found in British towns has been under suspicion as a causative agent both for bronchitis and for lung cancer, and I have suggested that pollution of food by exposure to dirty air might be a cause of the higher incidence of gastric cancer in towns. This paper records an attempt to obtain more conclusive evidence on these points by relating standardized mortality from bronchitis and cancers of four sites, with measurements of atmospheric deposit and suspended matter (smoke), in the county boroughs of England and Wales and in the administrative areas of Lancashire and the West Riding of Yorkshire, where such measurements have been made. Throughout the paper "S.M.R." (standardized mortality ratio) means 100 times the actual deaths of residents in the area divided by the number which would have occurred if the death rates at each age had been the same as the rates for England and Wales as a whole.

Previous Work

Bronchitis.—In the period 1950–3 the S.M.R. for males increased with degree of urbanization from 60 in rural districts to 133 in the conurbations, and for females from 69 to 129 (Registrar-General, 1956). The crude death rate per 100,000 in 1954 was 63 in all towns of England and Wales and 42 in rural areas, compared with only 5 to 7 in Copenhagen and rural parts of Denmark (Christensen and Wood, 1958), whilst the smoke concentration in Copenhagen was similar to that in a small urban district of Anglesey (Campbell and Clemmesen, 1956). In 10 subdivisions of London the S.M.R. of females in 1955 was correlated with smoke ($r=0.71$), but how much of this was due to variables such as length of residence in London and social class distribution remained in doubt (Gore and Shaddick, 1958).

*In receipt of a grant from the Medical Research Council.

Lung Cancer.—In 1950–3 the S.M.R. for males increased with the degree of urbanization from 64 in rural districts to 126 in the conurbations, and for females it rose from 76 to 121 (Stocks, 1958b); in the towns it increased according to the number of inhabited dwellings (Stocks, 1952), and in rural districts it increased with population per acre (Curwen *et al.*, 1954). In the Liverpool and North Wales region death rates of male non-smokers and pipe smokers resident in urban Merseyside were twice as great as in the seaboard areas of Wales; for moderate cigarette smokers the ratio was 1.7, but for heavy cigarette smokers there was no urban excess (Stocks, 1958a). After correcting for differences in smoking habits urban residence appeared to add about 1 per 1,000 to the death rate at ages 35–74 in this region, compared with about one-fifth of that amount in the United States of America (Hammond and Horn, 1958). Smoke measurements at 15 places in the same region gave correlation coefficients of 0.83 both with lung cancer and population density in the districts around the instruments, and when population density was held constant the partial coefficients with lung cancer were 0.35 for total smoke concentration and 0.28 for 3:4-benzpyrene, 0.48 for 1:12-benzperylene, 0.19 for pyrene, and 0.13 for fluoranthene contents of the smoke particles, the number of localities being too small, however, to allow firm conclusions from these results (Stocks, 1958b).

Gastric Cancer.—In 1954 mortality at ages 35–74 was about 10% higher in large urban areas than in rural districts (Registrar-General, 1957). In 1949–51 the urban/rural ratio of incidence was about 1.3 in Connecticut and 1.15 in New York State, but in Scandinavian countries no appreciable urban excess has been found. A steady fall in death rates in the U.S.A. contrasts with unchanging rates in Britain (Haenszel, 1958). Relations with air pollution do not appear to have been investigated.

Intestinal Cancer.—In Connecticut and in New York and Iowa States the urban/rural ratios of incidence exceed 1.3 for males (Haenszel, 1958), but in the Liverpool and North Wales region no evidence was found of any relation between the incidence of cancers of the intestine and rectum and previous residence in an urban area (Stocks, 1958a). In the latter region there was no correlation between smoke concentrations at 15 places and mortality in the districts around the instruments (Stocks, 1958b).

Breast Cancer.—No statistical evidence for any influence of urbanization on incidence of this form of cancer has been found.

Method of Study

Four groups of places have been used in this study; (*a*) county boroughs throughout England and Wales having the necessary air-pollution data; (*b*) administrative areas within the boundaries of Lancashire and the West Riding of Yorkshire having the necessary data; (*c*) all urban districts in Lancashire; and (*d*) all administrative areas within the boundaries of Lancashire. Deaths from cancer of the lung and bronchus in the five years 1950–4, and from cancers of the stomach, intestine with rectum, and breast (females), and from bronchitis, in 1950–3* were obtained from the statistical reviews for each county borough, and from the county medical officers of health for each of the 198 administrative districts of the counties of Lancashire and the West Riding. Ratios of deaths in England and Wales in the same years to the census population at six age groups for each sex were multiplied by the corresponding local census populations, and the resulting products were aggregated to give the expected deaths, the S.M.R.s being 100 times the ratio of actual to expected deaths for males, females, or both sexes combined. The six age groups used for cancer were 0–34, 35–44, 45–54, 55–64, 65–74, and 75 and over; for bronchitis the first two groups were modified to 0–4 and 5–44.

The Department of Scientific and Industrial Research (1955) issued a report on "The Investigation of Atmospheric Pollution" during 10 years ending in March, 1954, and in Table 8 the average amounts were given of deposited matter in summer and winter per 100 square metres per month during the periods of years when deposit gauges were operating at over 250 stations, distinguishing total undissolved matter (subdivided into tar, ash, and other) and matter dissolved in the rain-water. Attention has been confined to the former total, using averages of the summer and winter figures for 1949–54 or the most recent period of years available, bringing in several towns where records have been obtained since the issue of the 10-year report. In most of the large towns multiple gauges were operating at different points, and in such cases those which had been sited intentionally close to special sources of pollution were not included —for example, in Sheffield an average for 15 sites was used after exclusion of 6, and in Middlesbrough 7 were used after excluding 3. Data were thus obtained from 207 gauges in respect of 53 county boroughs and from 174 gauges in the 74 Lancashire and West Riding areas.

Table 9 of the same report gives average concentrations of smoke per 100 cubic metres of air as determined by daily filters in 95 places, and, after excluding sites aimed at measuring special sources of pollution and adding a few places where smoke filters have been operating in Lancashire for the British Empire Cancer Campaign's survey, data were assembled for 58 localities. The average state of the air being inspired by the population of a large town cannot be measured accurately by observations made at a single point in it, but in choosing a site for a filter the aim was to sample the air at a point which appeared to be representative of the locality as a whole. Failure to achieve this aim in some places would lead to underestimation rather than exaggeration of the true correlation between mortality in a population and the state of the air to which it had been exposed. Another difficulty is the fact that pollution in some towns will have changed during the long period needed to produce the chronic disease under investigation, and measurements further back in time might be more appropriate. Despite these weaknesses, however, it was thought worth while to find whether or not correlations do exist between deposited matter and/or smoke and mortality from cancer and bronchitis in large towns and smaller areas, taking account of the population densities which could produce such correlations indirectly.

Results from County Boroughs

Table I shows the relevant data for 58 county boroughs with records of deposited matter or of smoke,

*The year 1954 was not included because of the change in General Register Office rules for allocating to place of residence deaths of persons in institutions for the chronic sick, which may have affected some local rates for these diseases, though not for lung cancer.

30 having the former only, 5 the latter only, and 23 having both. The first 53 are ranked in order of the "deposit index" or monthly average number of grammes of undissolved matter deposited per 100 square metres of surface. The "smoke index" is determined by drawing a measured volume of air continuously through a white filter-paper which is changed daily, and the darkness of the stain is matched with a standard scale and expressed in milligrams per 100 cubic metres of air and averaged throughout the period of years. The population density per acre is that in 1951, and the "social class index" is the number of men in class IV and V occupations per 100 of those in all occupations as given in Table XCVII of the *Statistical Review for 1934* (Registrar-General, 1936).

TABLE I.—*Air Pollution, Population Density, and Standardized Mortality in 58 County Boroughs of England and Wales*

County Borough	Deposit Index*	Smoke Index†	Persons per Acre	Bronchitis 1950–3		Lung Cancer P 1950–4	Cancer (1950–3) of			
							Stomach		Intestine P	Breast F
				M	F		M	F		
Exeter	96	8	8·3	77	72	78	104	88	100	104
Southport	128		8·7	79	76	109	109	85	107	82
Newport	166		14·3	119	103	112	100	88	97	89
Gloucester	199		12·8	91	82	78	118	88	109	78
Great Yarmouth	200		14·2	86	95	94	67	84	110	151
Southampton	204	11	19·4	87	83	115	101	108	113	99
Darlington	231		13·1	93	121	78	118	120	112	104
Plymouth	239		15·9	73	84	84	106	115	90	87
Kingston-on-Hull	253	31	21·2	139	126	134	112	120	98	89
Wallasey	258		17·1	89	85	108	103	85	100	99
Bradford	268	33	11·4	147	120	104	112	103	113	118
Ipswich	275		11·9	74	81	93	87	95	90	122
Halifax	293		6·9	120	112	97	140	139	120	108
Doncaster	300		9·8	116	115	99	104	85	112	101
Preston	306	24	20·9	125	151	101	128	95	105	115
York	318		16·4	95	75	94	113	102	104	92
Bristol	320	7	16·8	82	90	113	83	95	94	99
Wolverhampton	326	6	17·8	128	110	88	104	100	116	99
South Shields	328		21·9	144	155	128	149	161	95	105
Smethwick	332		30·6	145	128	126	92	93	114	99
Wakefield	359		10·4	147	149	80	105	121	90	65
Walsall	360	25	13·0	140	104	106	106	87	112	112
Cardiff	361	8	16·2	126	98	110	132	111	94	107
Rochdale	364		9·2	126	145	70	134	137	111	96
Stockport	367		17·8	170	180	119	117	128	108	108
Bury	368		7·9	138	140	93	116	107	92	89
Coventry	368		13·5	86	111	96	88	96	98	89
Rotherham	384		8·9	138	134	93	139	131	113	104
West Bromwich	391		12·3	167	127	106	101	114	100	116
Stoke-on-Trent	402	44	13·0	161	168	130	159	150	119	87
Dewsbury	411		7·9	132	158	93	110	143	123	103
Grimsby	414		17·3	97	89	109	93	84	114	73
St. Helens	415	40	13·9	160	141	111	125	109	94	78
Oldham	419		22·7	200	268	94	149	141	114	97
Derby	423		17·4	88	74	89	107	88	92	91
Croydon	424		19·7	106	93	107	77	101	87	103
Huddersfield	434		9·1	107	123	82	95	117	111	96
Leicester	436	19	16·8	99	110	99	83	99	113	110
Nottingham	445	10	9·0	156	137	117	104	92	102	108
Sheffield	446	34	12·9	116	109	118	109	113	103	101
Newcastle upon Tyne	447	20	26·3	114	113	123	127	120	109	77
Liverpool	453	40	28·9	139	138	158	104	128	110	90
West Hartlepool	456		17·4	135	168	110	129	122	108	61
Bootle	483	42	13·1	194	164	146	123	122	106	86
Warrington	485	26	18·3	204	223	115	139	135	114	85
Manchester	488	26	25·8	185	187	150	131	119	115	100
Burnley	494	21	18·1	139	181	92	125	111	120	80
Gateshead	500		25·7	136	111	117	131	134	110	89
Bolton	505	32	10·9	140	176	97	141	129	122	97
Middlesbrough	528		20·7	126	83	123	121	129	112	78
Leeds	573	49	13·2	162	141	131	113	116	104	99
East Ham	704		36·4	131	123	132	127	109	93	104
Salford	731	36	34·2	259	240	159	168	129	120	97
Birmingham		24	21·7	135	137	131	106	106	120	135
Birkenhead		29	16·6	125	116	132	124	116	108	105
Chester		21	11·6	113	81	112	129	109	107	93
Oxford		14	11·7	81	59	116	98	65	90	112
Portsmouth		14	25·3	100	109	107	108	86	100	104

* Average amount of undissolved deposited matter in grammes per 100 square metres per month during 1949–54 or most recent period available.
† Average amount of suspended matter (smoke) in milligrams per 100 cubic metres of air during the most recent period available.

TABLE II

		Persons per Acre	Lung P	Cancer S.M.R.			
				Stomach		Intestine P	Breast F
				M	F		
Means	All 83	15·42	104 8	111·4	106·2	104·1	96·8
	53 (deposit)	16·40	107·8	112·1	112·0	105·4	96·1
	28 (smoke)	18·00	113·1	118·2	109·3	108·7	98·4
Standard errors	53	0·93	2·76	2·74	2·71	1·31	2·09
	28	1·10	4·40	3·49	3·35	1·64	2·10

The figures for the various diseases are the S.M.R.s for males, females, or both sexes together (as indicated by "P").

Since there are 83 county boroughs, of which 25 had no pollution records, the mean values of the cancer and density indices are compared in Table II with those of the 53 and 28 used for correlation with deposit and smoke. With regard to the standard errors, the 53 towns with deposit data could be a random sample of the 83, but the 28 with smoke records have a larger mean population density and rather higher S.M.R.s, though the differences for the latter do not exceed twice the standard errors. Selectivity of the groups is not, therefore, serious. Table III shows that atmospheric deposit within the large towns is correlated with population density to the extent of r=0.219, a surprisingly low value, and between smoke and population density the relation is even slighter (r=0.061). Density per acre is influenced by the extension of boundaries beyond the suburbs, and Table I shows that towns such as Rotherham, St. Helens, Nottingham, Halifax, and Rochdale have densities below 10.

Relations with Deposit

Bronchitis is strongly correlated with amount of deposit, the coefficients for males (r=0.605) and females (r=0.537) being 4.4 and 3.9 times their standard errors. The partial coefficients when population density is held constant are 0.579 and 0.511 respectively. The regression of male bronchitis on deposit is 0.183—that is, the S.M.R. tends to rise by 18.3 for each gramme of deposit per square metre per month, and this is shown graphically in Fig 1 (a).

Lung cancer is related with density per acre (r=0.650), but hitherto it has remained uncertain how much of this is due to the greater air pollution arising from crowding of houses together and how much to other social factors, such as more cigarette-smoking and beer-drinking in congested areas. The correlation with amount of deposit (r=0.513) is 3.7 times its standard error, and a partial coefficient of 0.500 remains when the population density is held constant, the odds against such a high value arising fortuitously being over 5,000 to 1. The regression is 0.0027—that is, an increase of 8.27 in the S.M.R. for each gramme per square metre per month, and Fig. 1 (b) shows that a straight line fits the distribution tolerably well. This undoubted association between lung cancer and deposit from the air does not account for the relation between lung cancer and population density, the partial coefficient when deposit is held constant being 0.60. Lung cancer is correlated with bronchitis in males when deposit is constant (r=0.309).

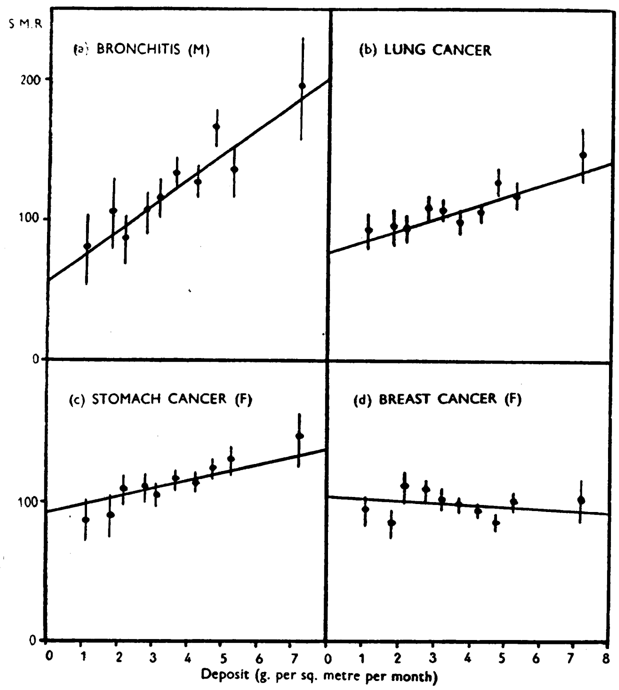

FIG. 1.—Bronchitis and cancer mortality in 53 county boroughs in relation to atmospheric deposit (undissolved). Mean S.M.R.s are denoted by dots, and the vertical lines through them indicate the standard errors above and below the mean. The equations of the regression lines of S.M.R. (m) on deposit (d) are: (*a*) m=61.3−0.183d, (*b*) m=76.5−0.0827d, (*c*) m=89.1−0.0605d, (*d*) m=103.3−0.0190d.

Stomach cancer also gives significant partial correlation coefficients with amount of deposit after eliminating population density—namely, 0.415 for males and 0.373 for females, with odds against these arising by chance of about 100 to 1. The regression line for

TABLE IV

Deposit Index:	50–	200–	250–	300–	350–	400–	450–	500+
Mean stomach S.M.R.	85	107	109	106	115	114	123	122
,, breast ,,	87·5	110	105	101	97	94	87	90
Ratio stomach/breast	0·97	0·97	1·04	1·05	1·19	1·31	1·41	1·35

females is shown in Fig. 1 (c). This form of cancer has a class gradient in towns, and the correlation with the social class index is 0.434. When this index is held constant the coefficient between stomach cancer and amount of deposit is 0.297, which exceeds twice its standard error. *Intestinal cancer* gives a partial coefficient of 0.186, which might arise by chance 1 in 6 times; and *breast cancer* gives an insignificant negative correlation, the regression being shown in Fig. 1 (d). The ratio of stomach to breast cancer S.M.R. increases regularly with the amount of deposit, as indicated in Table IV.

Relations with Smoke

Bronchitis is correlated with smoke concentration in the same degree as with deposit, the partial coefficients after eliminating population density being 0.662 for males and 0.469 for females. *Lung cancer* gives a partial coefficient of 0.510, which is significant, the odds being over 100 to 1 against its occurrence by chance, and the regression of the S.M.R. on smoke is shown in Fig. 2 (a). *Stomach cancer* in males shows about the same degree of association with smoke as with deposit (r=0.440, $P<0.05$), and in females the coefficient is higher (r=0.620, $P<0.001$), whilst *breast cancer* gives a correspondingly high negative relation (r=0.384). The curious inverse association between stomach and breast

TABLE V

Smoke Index:	Under 15	15–29	30–39	40 and Over
Mean stomach S.M.R.	94	111	119	125
,, breast ,,	103	100	100	88
Ratio stomach/breast	0·9	1·1	1·2	1·4

TABLE III.—*Correlation Coefficients Between Mortality, Population Density, and Air Pollution Indices*

	With Population per Acre	With Standardized Mortality Ratio for: Bronchitis M	Bronchitis F	Lung Cancer P	Stomach Cancer M	Stomach Cancer F	Intestinal Cancer P	Breast Cancer F
			Atmospheric Deposit (Undissolved)					
County boroughs (53):								
Population density	—	0·346	*0·245*	0·650	*0·079*	*0·111*	*0·025*	*−0·095*
Deposit index	*0·219*	0·605	0·537	0·513	0·421	0·382	*0·184*	*−0·156*
,, ,, with density constant	—	0·579	0·511	0·500	0·415	0·373	*0·186*	*−0·135*
Lancs and Yorks (W. Riding) (74):								
Population density	—	0·458	0·334	0·625	*0·140*	*0·046*		*−0·017*
Deposit index	0·305	0·469	0·521	0·326	*0·211*	0·229		*0·039*
,, ,, with density constant	—	0·392	0·467	*0·182*	*0·179*	0·225		*0·035*
			Smoke (Suspended Matter)					
County boroughs (28):								
Population density	—	0·353	0·436	0·479	*0·185*	0·248	*0·239*	*−0·132*
Smoke index	*0·061*	0·640	0·448	0·474	0·443	0·617	*0·230*	−0·386
,, ,, with density constant	—	0·662	0·469	0·510	0·440	0·620	*0·222*	−0·384
Lancs and Yorks (W. Riding) (42):								
Population density	—	0·513	0·470	0·762	*0·160*	*−0·010*		*−0·034*
Smoke index	0·526	*0·299*	*0·198*	0·591	*0·208*	*0·200*		*0·015*
,, ,, with density constant	—	*0·040*	*−0·068*	0·345	*0·171*	*0·242*		*0·038*

Note.—Coefficients whose probability of fortuitous occurrence exceeds 1 in 20 are printed in italics.

in females is shown in Table V. *Intestinal cancer* shows a small positive correlation with smoke which is below the conventional level of significance.

Results from Lancashire and Yorkshire

Relations with Deposit.—In the 74 administrative areas with deposit gauges in Lancashire and the West Riding, the correlation between amount of deposit and density of population was 0.305. *Bronchitis* gives rather smaller correlations with deposit than in all county boroughs, but the partial coefficients when density is held constant are again highly significant (males 0.387 and females 0.467, respectively 3.1 and 3.8 times the standard errors). *Lung cancer* gives a coefficient of 0.326 with deposit, reduced to 0.182 with density constant. *Stomach cancer* gives partial coefficients of 0.179 for males and 0.225 for females, the latter being statistically significant (P=0.05). *Breast cancer* shows no relation with deposit.

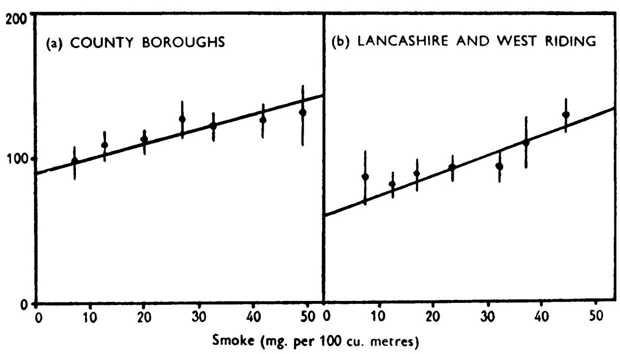

FIG. 2.—Lung cancer mortality in relation to smoke. Mean S.M.R.s are denoted by dots, and the vertical lines through them indicate the standard errors above and below the mean. The equations of the regression lines of S.M.R. (m) on smoke (s) are: (*a*) m=88.0+s. (*b*) m=59.2+1.47s.

Relations with Smoke.—In 42 areas of all kinds in this region, of which 31 were in Yorkshire and 11 in Lancashire, there were data available from smoke-measuring instruments, and the correlation between smoke and population density was 0.526. *Bronchitis* is not so strongly associated with smoke as with deposit in this region, and the partial coefficients fall to zero, in contrast with the high values for the county boroughs. *Lung cancer,* however, gives a first order correlation of 0.591, and the partial coefficient of 0.345 is above the conventional level of significance (P<0.05). The regression of the S.M.R. on smoke concentration is shown in Fig. 2 (b). *Stomach cancer* correlations with smoke are similar to those with deposit. *Breast cancer* shows no association with either population density or smoke.

Relation with Population Density in Adjacent Districts.—Death rates from bronchitis and stomach cancer have been shown to be related with smoke concentration in the larger towns, and lung cancer is so related in towns of all sizes and independently of the population density. Since some of the smoke in the air of a town has been brought by the wind from adjacent areas, the total smoke intensity must be a combined function of the number of chimneys in the town itself and in the districts surrounding. Lucas (1958) has shown that domestic chimneys contribute the major part of the sulphur dioxide pollution found near ground level, and has calculated the changes in its intensity as one passes from the windward edge across a town and then across the countryside to the lee of the town. From Fig. 6 (a) of this paper it appears that for a town six miles in diameter assumed to be surrounded by open country the total pollution near ground level spread over a six-mile stretch on the lee side of the town is approximately half of the total pollution affecting the town itself. Since the number of domestic chimneys is proportional to the population it may be deduced from this that the pollution intensity near ground level in a town of that size will be roughly proportional to the density of population in the town itself plus half the density in the districts surrounding the town. This assumes that "smoke" behaves in the same way as sulphur dioxide, that wind direction is fairly evenly distributed round the compass, and that its speed averages 5 feet per second. If lung cancer in a town is in fact affected by smoke in the air, it should be statistically related with the population density in the town itself, independently related with the average density in the districts surrounding the town, and more highly correlated with the first plus half the second of these densities than with either taken separately.

Table VI shows the results of applying this test to the 94 urban districts of Lancashire, and also to the 126 areas of all kinds in that county. In the 94 small towns the lung cancer correlations are 0.464 with population density in the town itself, 0.277 with the average density in the surrounding areas independently of the town, and 0.502 with density in the town plus half that in the surrounding areas, which was the result anticipated on the hypothesis that smoke is concerned in the causation

TABLE VI.—*Correlations Between Cancer Mortality in Lancashire and Population Density in the Same Area and Adjacent Districts*

	Sex	No. of Index Areas	Correlation with Population Density in						
			Index Area	Adjacent Districts to					Combined Areas*
				S.W.	S.E.	N.E.	N.W.	Mean	
Urban districts only:									
Density of population in index area		94	—					0·587	
Lung cancer S.M.R.	P	94	0·464					0·411	0·502
,, ,, with density in index area constant	P	94	—					0·277	
All types of area:									
Density of population in index area		126	—	0·291	0·394	0·384	0·466	0·525	
Lung cancer S.M.R.	P	126	0·573	0·235	0·356	0·410	0·360	0·464	0·603
Stomach cancer S.M.R.	M	126	0·196					*0·100*	
With index area density constant:									
Lung cancer	P	126	—	*0·087*	*0·174*	0·251	*0·147*	0·233	
Stomach ,,	M	126	—					*−0·004*	

* Correlation with sum of density in index area and half the mean density in adjacent districts (see text).
Note.—Coefficients whose probability of fortuitous occurrence exceeds 1 in 20 are printed in italics.

of lung cancer. That these relations could arise fortuitously is hardly credible, nor is any other explanation of them.

When the large towns and rural districts are included the correlation with density in the area itself is larger (0.573) and the partial coefficient with the average density in surrounding districts is smaller (0.233) than when only the small towns are considered, but there is a higher coefficient with population density in the area itself plus half that in surrounding districts (0.603). Differentiation of the adjacent districts into those abutting on four sectors of the boundary shows highest correlation with density of population to the north-east, and lowest with density to the south-west. It has to be remembered that the geography of Lancashire is peculiar, with the Pennine chain along its eastern side and the sea as its western boundary, whilst population and heavy industry tend to be concentrated eastwards in the county. It is a matter of common observation that air pollution in south-west Lancashire is worst when the wind is easterly, and this could more than counteract the greater prevalence of westerly winds.

In males, mortality from cancer of the stomach shows an insignificant correlation with the average population density in the districts surrounding the area, and it becomes zero when the density in the area itself is held constant, indicating no appreciable effect of smoke from adjacent districts on this form of cancer.

Conclusions and Summary

When standardized mortality ratios for bronchitis and cancers in the county boroughs of England and Wales are related to the average amounts of undissolved deposit and smoke from the air in those towns, highly significant statistical correlations are found for bronchitis and lung cancer with both types of pollution after eliminating the effects of population density on the correlations. In all administrative areas in Lancashire and the West Riding of Yorkshire having the necessary pollution data bronchitis is significantly correlated with deposit but not with smoke, whilst for lung cancer the reverse is the case. In Lancashire areas lung cancer is strongly correlated with population density in adjacent districts even when that of the area itself is held constant, and this appears to confirm the effect of wind-borne smoke on the incidence of the disease.

Stomach-cancer mortality is related significantly with both deposit and smoke in the county boroughs, and among females in the Lancashire and Yorkshire districts also, whereas breast cancer shows negative correlations in the county boroughs and no relation with air pollution in the counties. The most likely explanation of this is the exposure of food to dirty air, and this hypothesis is supported by the fact that in the U.S.A., where wrapping of food was the rule long before it began to be practised in Britain, death rates from stomach cancer have fallen steadily in contrast to their lack of improvement in this country. Intestinal cancer also shows small correlations with deposit and smoke in the county boroughs, but they are below the conventional level of significance.

I am indebted to the Fuel Research Station of the Department of Scientific and Industrial Research, to the County Health Departments of Lancashire and the West Riding of Yorkshire, and to the General Register Office for help in assembling the data.

REFERENCES

Campbell, J. M., and Clemmesen, J. (1956). *Dan. med. Bull.*, **3**, 205.
Christensen, O. W., and Wood, C. H. (1958). *Brit. med. J.*, **1**, 620.
Curwen, M. P., Kennaway, E. L., and N. M. (1954). *Brit. J. Cancer*, **8**, 181.
Department of Scientific and Industrial Research (1955). The Investigation of Atmospheric Pollution, 27th Report. H.M.S.O., London.
Gore, A. T., and Shaddick, C. W. (1958). *Brit. J. prev. soc. Med.*, **12**, 104.
Haenszel, W. (1958). *J. nat. Cancer Inst.*, **21**, 213.
Hammond, E. C., and Horn, D. (1958). *J. Amer. med. Ass.*, **166**, 1159.
Lucas, D. H. (1958). *Int. J. Air Pollut.*, **1**, 71.
Registrar-General (1936). *Statistical Review for 1934*, Text.
—— (1938). *Decennial Supplement 1931, Occupational Mortality.*
—— (1956). *Statistical Review for 1953*, Text.
—— (1957). *Statistical Review for 1954*, Text.
Stocks, P. (1952). *Brit. J. Cancer*, **6**, 99.
—— (1958a). Supplement to British Empire Cancer Campaign Annual Report for 1957.
—— (1958b). *Int. J. Air Pollut.*, **1**, 1.

ASSOCIATION OF GASTRO-DUODENAL LESIONS WITH MÉNIÈRE'S SYNDROME

BY

ROGER WYBURN-MASON, M.A., M.D., M.R.C.P.

That an association exists between the function of the inner ears and that of the stomach and duodenum is shown in various ways. Wolf (1946) recorded the activity of the duodenum both by introducing a balloon into it and by barium-meal investigation, and showed that irrigation of the external ear with cold water caused both nausea and narrowing of the lumen of the first part of the duodenum and replacement of its normal pattern of motor activity by slower and larger contractions. These changes were never seen in the absence of nausea, and vice versa. Clinically, irritative lesions of the labyrinth may result in Ménière's syndrome, which consists of attacks of vertigo, tinnitus, nausea, and vomiting, often accompanied by sweating, faintness, and vasomotor changes, and sometimes by actual syncope. They are often associated with progressive deafness and persistent tinnitus on one or both sides. It must be assumed that a nervous connexion exists by which disturbed function of the stomach and duodenum follows stimulation of afferents in the labyrinth.

Conversely, irritation of the stomach and duodenum by poisonous substances or other agents or by gross distension often leads to nausea, vomiting, sweating, tinnitus, and vertigo, symptoms suggestive of labyrinthine disturbance. That an undoubted labyrinthine disturbance may result from a gastro-duodenal lesion does not seem to have been observed previously. Below is given an account of a number of cases in which such a relationship was present. Furthermore, it has often been denied that diverticula of the second or third part of the duodenum ever produce symptoms (Hahn, 1929), but Ogilvie (1941) and others (see Aird, 1949; Elstner and Waugh, 1957) showed that they certainly can do so. In one of the cases described below a diverticulum appeared to give rise to the symptoms of labyrinthine disturbance. An account of five of the cases follows. Six other cases of Ménière's syndrome in association with long-standing duodenal ulcer have been observed.