Air Pollution in Belfast

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The purpose of this paper is to compare the average levels of air pollution present in different areas of Belfast during the five-year period commencing 1st January, 1961, and to examine these levels in relation to the mortality rates from bronchitis which occurred in the central and in the peripheral wards or part-wards of the city during the same five-year period. An assessment is made of the smoking habits of persons resident in Belfast and the effects of these smoking habits upon mortality from bronchitis is discussed.

In the International Statistical Classification of Diseases, Bronchitis (I.C.D. No. 500–502) comprises three disease groups, namely Acute bronchitis, Unqualified bronchitis and Chronic bronchitis (I.C.D. No. 500, 501 and 502 respectively). Eighty-seven per cent of all deaths due to bronchitis in the United Kingdom during the year 1964 were due to chronic bronchitis.

The Annual Reports of the Registrar-General for England and Wales have for many years shown that death rates from bronchitis are higher in urban than in rural areas and that these rates are considerably higher in males than in females. In both sexes bronchitis mortality rates increase with advancing age.

A number of factors have been identified as of aetiological importance in chronic bronchitis. Unusually high bronchitis mortality rates are found in areas of the United Kingdom which also have high levels of air pollution (Pemberton and Goldberg, 1954; Daly, 1954). Within a city, deaths from bronchitis and from all causes are significantly higher in wards with high air pollution (Burn and Pemberton, 1963). The number of deaths from bronchitis increases during periods of very high air pollution, for example, during London fogs (Ministry of Health, 1954). Low air temperatures and decreases in absolute humidity also influence bronchitis mortality (Boyd, 1960). Social factors, including domestic overcrowding, may influence bronchitis mortality independently of air pollution (Hewitt, 1956; Daly, 1959). Cigarette smoking also predisposes to increased mortality from bronchitis (e.g. Doll and Hill, 1956).

The most serious air pollution problem in Northern Ireland occurs in Belfast where the population density per square mile is very high. Air pollutants in Belfast are emitted not only from shipping and from factories but also from a high density of domestic premises. Air pollution from domestic sources is emitted at a low level and with a low velocity of

discharge so that it tends to remain suspended at a low level in the city and river basin under conditions of atmospheric stability. Thus, high concentrations of air pollution at or near ground level may occur during cold winter days when air turbulence is low and when domestic heating requirements are high.

METHODS

(1) *Air Pollution Data*

The concentrations in air of solid dark matter and of gaseous acid (subsequently referred to as smoke and sulphur dioxide respectively) were obtained from 24 hour volumetric air samples using standard D.S.I.R. instruments (Department of Scientific and Industrial Research, 1957) sited at eight points in the city (see Fig. 1). Smoke concentrations were determined by the reflectance method using an Evans Electroselenium (' EEL ') electrophotometer and the results expressed as micrograms of smoke per cubic metre of air. Gaseous acid concentrations were determined by passing the air samples through 1·5 volume hydrogen peroxide, titrating the solution against N/250 sodium borate using British Drug Houses ' 4·5 ' indicator and then expressing the results as micrograms of sulphur dioxide per cubic metre of air.

In what follows the analysis of air pollution data relates to the five year period commencing 1st January, 1961.

(2) *Mortality data*

The preliminary air pollution measurements taken during the winter of 1958–59 suggested that the inner part of the city was exposed to about double the concentrations of smoke and sulphur dioxide occurring in the suburbs. There are fifteen wards in Belfast of which four are entirely contained in a central area approximately 1½ miles radius from the city centre. The remaining eleven wards, which extend from the boundary of the city to the central area, were divided for comparison purposes into inner and outer part-wards.

With the invaluable co-operation of the Registrar-General for Northern Ireland the enumeration areas at the 1961 Census were arranged in such a way that the analyses by age and sex of the populations of the four wards that lay entirely within the inner zone, and of each half of the divided wards, were made available to us.

The Registrar General for Northern Ireland also arranged that from 1st January, 1961, all deaths of persons domiciled in Belfast should be coded by inner and outer wards and part wards in relation to the deceased person's domicile. It was therefore possible to calculate age and sex specific death rates for the inner and outer zones of the city and for individual wards and part wards for 1961 and all subsequent years, all rates being based on population data obtained at the 1961 Census.

(3) *Tobacco smoking data*

A one in eighty random sample of all persons aged 21 years and over resident in Belfast and whose names appeared on the 1959 electoral lists

was drawn using random numbers. Every person in this sample was visited by a social worker who recorded the age, sex, address and smoking habits of the person interviewed. Tobacco smoking was listed in five categories: Group 0 (non smokers)—never smoking as much as one cigarette a day for one year; Group 1—smoking only one to four cigar ettes a day; Group 2—smoking five to fourteen cigarettes a day; Group 3 —smoking fifteen to twenty four cigarettes a day; Group 4—smoking more than twenty five cigarettes daily. For purposes of analysis (see Table VII) Groups 1 and 2 have been amalgamated. Any present non smoker with a history of past smoking was classified as an ' ex-smoker ' and excluded from further analysis.

RESULTS

Table I shows the average monthly levels of smoke (micro/gms/cu. m.), based on the means of the readings of all four sites in each zone, by month of the year for the 5-year period 1961–65. The data have been grouped in six ' winter ' months (January to March and October to November inclusive) and six ' summer ' months (April to September inclusive) in an attempt to identify the amount of air pollution which is created by heating demands during the colder months of the year. Similar data are shown in Table II for average monthly levels of sulphur dioxide. The range referred to is that of the highest and lowest mean value for smoke (or sulphur dioxide) for all four sites in the zone during the specified month in any one of the five years under consideration.

It will be seen from Table I that there was a well-defined yearly cycle of smoke pollution, highest in January and December and lowest in June and July. On average, in either zone, the mean levels of smoke in the 6 month winter period were about three times higher than in the equivalent summer period. In the winter and in the summer periods the average levels of smoke in the inner zone were about 1·7 times greater than in the outer zone. Inspection of the basic data showed that there were large variations in some level from day to day at individual sites and that these variations depended on meteorological conditions of temperature and air movement. On the other hand, the variations in average winter smoke levels from year to year were small, about $\pm$ 6% around the five year mean, suggesting that the overall levels of air pollution in the city have remained relatively constant for at the least the past five years.

Table II shows that a well-defined yearly cycle of sulphur dioxide pollution was present and followed a pattern similar to that of the smoke cycle, except that the amplitude of this cycle was less than that for smoke. On average in either zone the mean winter sulphur dioxide levels were about 2·3 times higher than in the summer period. Both in the winter and in the summer periods the mean levels of sulphur dioxide in the inner zone were about 1·9 times greater than in the outer zone. There were consider-differences from day to day in sulphur dioxide levels at individual sites, depending on weather conditions. The variations in average winter sulphur dioxide levels were considerably greater than those observed for smoke,

about ± 11% around the five year mean, but the basic data showed no evidence of any trend during the five year period in either improvement or deterioration in the sulphur dioxide problem in the city.

Table III shows the mean and range for the five years 1961–65 inclusive of smoke and sulphur dioxide pollution during the winter and summer periods at each of the four sampling sites in the inner and in the outer zone of the city. It will be seen that those sites which have the highest mean values for smoke pollution do not necessarily have the highest values for sulphur dioxide pollution. The sampling sites having the highest mean values for winter and for summer smoke in the inner zone are situated at Templemore Avenue (east of the city centre) and at Mountcollyer Street (north of the city centre). In the outer zone an unexpected finding was that higher than average smoke levels, both in the summer and in the winter period, were recorded at the Falls Road site which is at the western, and generally windward, side of the city.

(4) *Mortality*

The average annual number of deaths and death rates per 1,000 population by age, sex and area of residence in Belfast are given in Table IV for deaths from all causes and in Table V for deaths from bronchitis (I.C.D. No. 500–502). Mortality from vascular lesions affecting the central nervous system (I.C.D. No. 330–334) is unlikely to be affected by environmental conditions such as air pollution and analyses of mortality due to this disease group are shown in Table VI for purposes of comparison with the data shown in Tables IV and V.

The average annual numbers of deaths and corresponding average annual death rates for the five year period have been used in this analysis because comparison of death rates between individual years gives rise to complex problems of survivorship from one year to the next. Another difficulty arose in the choice of the most appropriate method for calculation of the reliability of a series of annual death rates, so that the method described by the Registrar-General of England and Wales was used throughout in Tables IV, V and VI for the calculation of standard errors and standard errors of the differences between average annual death rates. Details of the method are given in Explanatory Note No. 11 of the Registar-General's Statistical Review of England and Wales for the year 1964.

About 90 per cent of deaths from all causes and 97 per cent of deaths due to bronchitis occur after the age of 45 years. For this reason mortality data have been grouped for all persons aged 0 to 44 years. Mortality data have also been grouped for all persons aged 75 years and over partly because the numbers of persons in certain categories of age and residence were small and partly because problems of competing causes of death and survivorship arise mainly in the oldest age groups.

The data in Table IV show that in age groups 0–44 and 45–64 years, and at all ages, the death rates from all causes in males and in females were significantly* higher in the inner than in the outer zone. Within each zone

* The level of significance used throughout is $P<0{\cdot}05$.

the death rate for males was always higher than the corresponding rate for females of the same age group.

The data in Table V show that for males, but not for females, the bronchitis death rate in the inner zone was significantly higher than that in the outer zone at ages 45–64, over 65 years and at all ages. Within each zone the bronchitis death rates for males aged 45–64, over 65 years and at all ages were always higher than the corresponding rate for females. In the inner zone about 12 per cent of all deaths in men aged 45–64 and 65 years and over were due to bronchitis, compared with about 5 per cent for women in each of these two age groups. In the outer zone about 8 per cent of all deaths in males aged 45–64 and over 65 years of age were due to bronchitis, compared with 4 per cent for women in either age group.

The data in Table VI show that in neither sex nor in any age group were there significant differences between zones in the death rates from vascular lesions affecting the central nervous system.

Smoking is an aetiological factor in the epidemiology of chronic bronchitis and comparison must be made between the smoking habits of the populations resident in each zone. These comparisons are shown in Table VII. The only group in which significant differences were found between the two zones was that of females aged 65 years and over and in this comparison there were only 5 smokers resident in the inner zone. In no other group were there significant differences between zones in the age–sex distributions of smoking habits.

DISCUSSION

The data presented in this paper have shown that air pollution levels are considerably higher in the inner than in the outer zone of Belfast. Bronchitis death rates in men aged over 45 years were significantly higher in the inner zone of the city but the smoking habits of a random sample of men of this age group did not differ significantly between the two zones. This suggests that an urbanisation factor may operate independently of smoking habit in the causation of death (but not necessarily morbidity) from bronchitis. An urbanisation factor of this nature may be operative throughout Northern Ireland in that Dean (1966) has shown that an urban–rural gradient of bronchitis mortality exists, even in non-smokers, between truly rural areas of the province which have the lowest rates, and inner Belfast, which has the highest rates.

Environmental causes other than air pollution may affect bronchitis mortality rates in different areas of a city. For example, domestic overcrowding may be greatest in the central area of Belfast where housing density and air pollution levels are high.

The Registrar-General of Northern Ireland had made available to us details of the average number of persons per room in each ward and part-ward of the city at the 1961 Census. Unfortunately it was not possible to analyse these indices of overcrowding in relation to bronchitis mortality and air pollution levels with any degree of precision because (1) the sampling errors of the distributions of persons per room in each of the 26 wards or part-wards were not known and (2) the air pollution data were

not sufficiently detailed (being based on only four sites in each zone) to enable reliable estimates to be made of smoke and sulphur dioxide levels in individual wards or part wards.

High bronchitis mortality rates may be associated with overcrowding in the inner zone of Belfast in that the average number of persons per room was 0·856 for all inner wards and part-wards and 0·730 for the remainder of the city. The difference between these average levels of domestic overcrowding may well be real, but it may explain only a small part of the observed difference in bronchitis mortality between the two zones. In this connection, Hewitt (1956) found that only 20 to 25 per cent of the differences in bronchitis mortality rates between London boroughs could be attributed to factors other than air pollution, for example domestic overcrowding and social class differences. Daly (1959) found that factors related to social class, domestic overcrowding and population density accounted for one one-third of the differences in bronchitis mortality observed between 83 county boroughs in England dnd Wales.

Although differences in local levels of air pollution may account for some of the differences in local bronchitis mortality rates, it is difficult to to determine the relative importance of smoke and of sulphur dioxide pollution in the causation of mortality from bronchitis. Further studies will be required to investigate this problem. Such studies should be prospective in nature and might be most usefully undertaken in a city, such as Belfast, in which the Local Authority is about to designate certain districts as smoke control areas. This suggestion is based on the assumption that the burning of smokeless fuels by the domestic consumer will lead to a relatively greater reduction in smoke than in sulphur dioxide pollution. Comparison could then be made of future changes in bronchitis mortality rates in relation to changes in the relative levels of smoke and of sulphur dioxide.

SUMMARY

During the five year period 1961–65, air pollution due to smoke and to sulphur dioxide was consistently higher in the inner than in the outer part of Belfast.

Average annual death rates from all causes, and in males from bronchitis, were significantly higher in the inner zone despite the fact that smoking habits were very similar between the two zones.

Domestic overcrowding (average number of persons per room) was higher in the inner than in the outer zone and may explain, in part, the differences observed in the local mortality rates. However, differences in local air pollution were considered to be a more important factor than overcrowding in the causation of death from bronchitis.

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TABLE I

SMOKE (micrograms per cubic metre of air): AVERAGE MONTHLY LEVELS AND RANGE AT 4 SITES IN INNER AND 4 SITES IN OUTER ZONE. BELFAST COUNTY BOROUGH: YEARS 1961–65 INCLUSIVE

Month	Inner Zone		Outer Zone		(*a*)/(*b*) %
	Mean (*a*)	Range	Mean (*b*)	Range	
January ...	300	265–406	199	169–240	151
February ...	274	195–354	163	116–207	168
March	219	188–269	123	108–160	178
October ...	210	165–260	118	100–161	178
November ...	309	218–411	187	131–250	165
December ...	322	250–467	199	170–265	162
Winter mean (*c*)	274	252–292	165	156–172	166
April	145	96–207	77	56–115	188
May	93	70–125	54	44– 67	172
June	58	43– 67	36	28– 41	161
July	54	39– 63	32	26–37	169
August	66	58– 73	45	35– 55	147
September ...	101	90–114	61	55– 66	166
Summer mean (*d*)	86	73–102	51	46– 56	169
(*c*)/(*d*) % ...	319	—	324	—	—

TABLE II

SULPHUR DIOXIDE (micrograms per cubic metre of air): AVERAGE MONTHLY LEVELS AND RANGE AT 4 SITES IN INNER AND 4 SITES IN OUTER ZONE. BELFAST COUNTY BOROUGH: YEARS 1961–65 INCLUSIVE

Month	Inner Zone		Outer Zone		(*a*)/(*b*) %
	Mean (*a*)	Range	Mean (*b*)	Range	
January ...	213	164–344	119	93–182	179
February ...	195	135–303	104	80–148	188
March	167	110–201	85	57– 89	196
October ...	136	107–167	73	49– 88	186
November ...	189	158–239	82	73–130	230
December ...	196	137–250	99	59–122	198
Winter mean (*c*)	183	163–218	97	87–111	189
April	122	99–144	59	46– 67	207
May	88	82– 94	48	35– 52	183
June	70	62– 87	36	25– 48	194
July	60	39– 81	32	19– 44	188
August	58	46– 69	34	25– 40	171
September ...	85	63–115	45	32– 55	189
Summer mean (*d*)	80	72– 86	43	36– 49	186
(*c*)/(*d*) % ...	229	—	226	—	—

TABLE III

MEAN AND RANGE OVER 5 YEAR OBSERVATION PERIOD FOR 6 WINTER AND 6 SUMMER MONTHS (see text) FOR LEVELS OF SMOKE (μgm./cu. m.) AND SULPHUR DIOXIDE (μgm/cu. m.) AT 8 SITES IN BELFAST: YEARS 1961–65 INCLUSIVE

Location of Samples	Winter Months (Jan.–Mar. and Oct.–Dec.)				Summer Months (April–Sept. incl.)			
	Smoke		Sulphur Dioxide		Smoke		Sulphur Dioxide	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Inner Zone—								
College St. (Health Dept.)	243	202–264	201	178–238	71	44– 88	77	62–84
Grosvenor Rd. (Inst. of Clinical Science)...	232	209–284	153	117–209	72	51– 87	81	65–99
Templemore Ave. ...	331	308–348	174	162–184	104	84–119	82	74–97
Mountcollyer St. ...	292	268–323	202	168–229	95	86–109	82	76–98
Outer Zone—								
North Rd.	154	150–156	98	88–113	49	41– 60	42	37–47
Balmoral Ave. ...	143	135–150	83	72– 99	44	40– 51	36	27–46
Falls Rd. (City Cemetery)	183	172–193	83	72– 97	58	54– 62	40	29–49
Antrim Rd. (Lowwood Park)	178	163–202	123	103–133	52	47– 62	51	43–57

TABLE IV

AVERAGE ANNUAL NUMBER OF DEATHS AND DEATH RATES PER 1,000 FROM ALL CAUSES, BY AGE, SEX AND AREA OF RESIDENCE. BELFAST COUNTY BOROUGH: YEARS 1961–65 INCLUSIVE

Sex	Age-group (years)	Inner Zone			Outer Zone			Difference between mean rates ± S.E.
		No. deaths (mean)	Rate per 1,000 (mean)	S.E. of rate	No. deaths (mean)	Rate per 1,000 (mean)	S.E. of rate	
Males	0–44	166·8	2·3	0·18	116·4	1·8	0·17	0·5* ±0·24
	45–64	452·8	19·4	0·91	330·6	15·3	0·84	4·1* ±1·24
	Over 65	741·0	88·1	3·24	643·0	85·0	3·35	3·1 ±4·66
	All ages	1,360·4	13·2	0·36	1,090·0	11·7	0·35	1·5 ±0·50
Females	0–44	133·0	1·9	0·16	90·2	1·3	0·14	0·5* ±0·21
	45–64	274·2	9·8	0·59	197·0	7·4	0·53	2·4* ±0·79
	Over 65	904·0	66·0	2·19	767·2	61·8	2·23	4·2 ±3·13
	All ages	1,311·2	11·6	0·32	1,054·4	9·9	0·30	1·7* ±0·44

* Difference between means significant at $P<0·05$ level.

TABLE V

AVERAGE ANNUAL NUMBER OF DEATHS AND DEATH RATES PER 1,000 FROM BRONCHITIS (I.C.D. No. 500–502) BY AGE, SEX AND AREA OF RESIDENCE. BELFAST COUNTY BOROUGH: YEARS 1961–65 INCLUSIVE

Sex	Age-group (years)	Inner Zone			Outer Zone			Difference between mean rates ± S.E.
		No. deaths (mean)	Rate per 1,000 (mean)	S.E. of rate	No. deaths (mean)	Rate per 1,000 (mean)	S.E. of rate	
Males	0–44	2·6	0·04	0·02	1·8	0·03	0·02	0·01 ± 0·03
	45–64	52·2	2·3	0·32	27·0	1·3	0·24	1·0* ± 0·40
	Over 65	94·8	11·3	1·16	53·4	7·1	0·97	4·2* ± 1·51
	All ages	151·6	1·5	0·12	82·2	0·9	0·10	0·6* ± 0·15
Females	0–44	1·4	0·02	0·02	1·8	0·03	0·02	−0·01 ± 0·03
	45–64	14·0	0·5	0·13	6·6	0·3	0·10	0·2 ± 0·16
	Over 65	51·2	3·7	0·52	29·6	2·4	0·44	1·3 ± 0·68
	All ages	66·6	0·6	0·07	38·0	0·4	0·06	0·2 ± 0·10

* Difference between means significant at $P<0.05$ level.

TABLE VI

AVERAGE ANNUAL NUMBER OF DEATHS AND DEATH RATES PER 1,000 FROM VASCULAR LESIONS AFFECTING CENTRAL NERVOUS SYSTEM (I.C.D. No. 330–334) BY AGE, SEX AND AREA OF RESIDENCE. BELFAST COUNTY BOROUGH: YEARS 1961–65 INCLUSIVE

Sex	Age-group (years)	Inner Zone			Outer Zone			Difference between mean rates ± S.E.
		No. deaths (mean)	Rate per 1,000 (mean)	S.E. of rate	No. deaths (mean)	Rate per 1,000 (mean)	S.E. of rate	
Males	0–44	3·0	0·04	0·02	2·4	0·04	0·02	0·0 ±0·03
	45–64	30·8	1·3	0·24	20·4	0·9	0·21	0·4 ±0·32
	Over 65	84·0	10·0	1·10	91·8	12·2	1·27	—2·2 ±1·67
	All ages	117·8	1·1	0·11	114·6	1·2	0·12	—0·1 ±0·16
Females	0–44	4·8	0·07	0·03	1·6	0·02	0·02	0·05±0·03
	45–64	33·8	1·2	0·21	30·6	1·1	0·22	0·1 ±0·29
	Over 65	169·4	12·4	0·95	157·2	12·7	1·01	—0·3±1·41
	All ages	208·0	1·8	0·13	189·4	1·8	0·13	0·00±0·18

TABLE VII

SMOKING HABITS OF 1/80 RANDOM SAMPLE OF 1961 POPULATION OF BELFAST AT AGES 45–54, 55–64 AND 65–74 BY SEX AND AREA OF RESIDENCE (EX-SMOKERS EXCLUDED)

Age-group (yesrs)	Tobacco (gm./day)	Males			Females		
		Inner	Outer	Total	Inner	Outer	Total
45–54	None	17	15	32	97	98	195
	1–14	37	31	68	44	45	89
	15–24	44	52	96	8	15	23
	Over 25	36	19	55	44	7	11
	Total	134	117	251	153	165	318
55–64	None	15	10	25	128	100	228
	1–14	34	33	67	29	24	53
	15–24	42	23	65	2	2	4
	Over 25	21	10	31	2	2	4
	Total	112	76	188	161	128	289
65–74	None	9	9	18	88	66	154
	1–14	28	26	54	4	10	14
	15–24	16	15	31	—	4	4
	Over 25	7	2	9	1	3	4
	Total	60	52	112	93	83	176

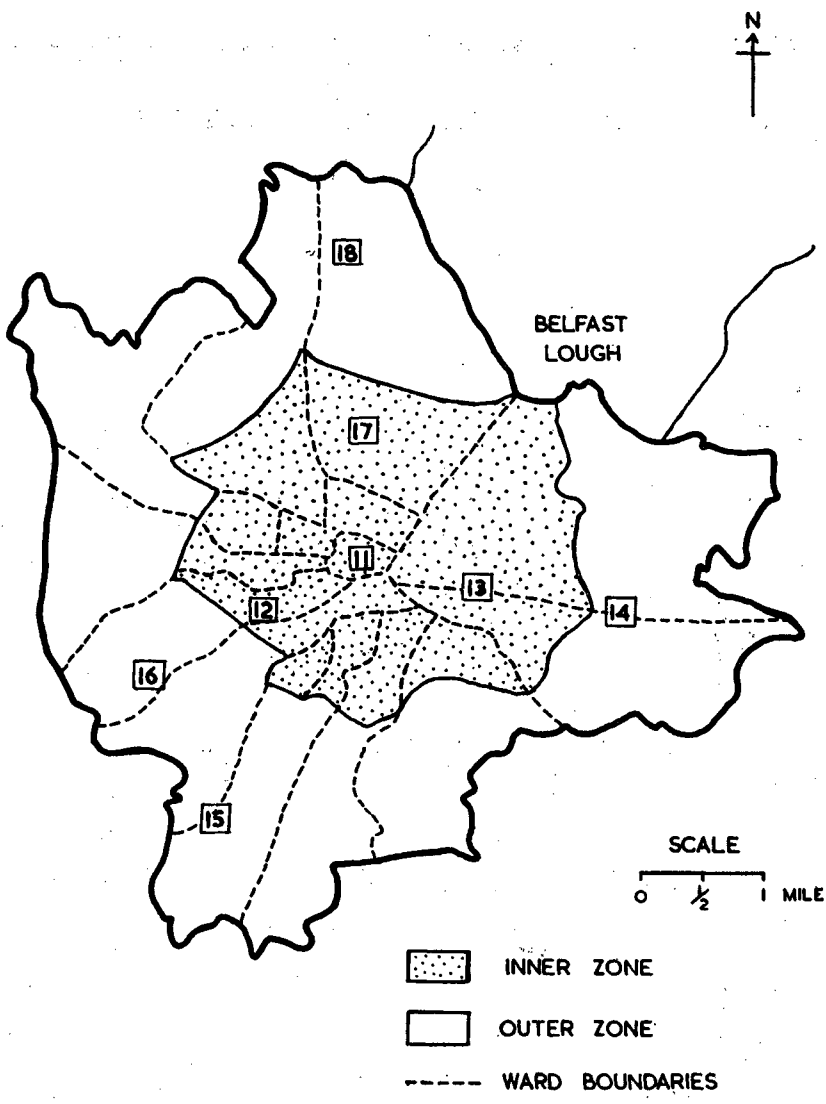
Comparison between inner and outer zones—

Males: aged 45–54 $\chi^2 = 5{\cdot}4509$ D.F.=3 $0{\cdot}2 > P > 0{\cdot}1$
aged 55–64 $\chi^2 = 2{\cdot}3271$ D.F.=3 $0{\cdot}3 > P > 0{\cdot}2$
aged 65–74 $\chi^2 = 2{\cdot}3271$ D.F.=3 $0{\cdot}7 > P > 0{\cdot}5$

Females: aged 45–54 $\chi^2 = 1{\cdot}6763$ D.F.=3 $0{\cdot}7 > P > 0{\cdot}5$
aged 55–64 $\chi^2 = 0{\cdot}1458$ D.F.=3 $P > 0{\cdot}99$
aged 65–74 $\chi^2 = 10{\cdot}1605$ D.F.=3 $0{\cdot}02 > P > 0{\cdot}01$

FIGURE I.

BELFAST



SITE No.	LOCATION	SITE No.	LOCATION
11	HEALTH DEPT., COLLEGE STREET	15	BALMORAL AVENUE
12	ROYAL VICTORIA HOSPITAL	16	FALLS ROAD
13	TEMPLEMORE AVENUE	17	MOUNTCOLLYER ST.
14	NORTH ROAD	18	LOWWOOD PARK