UTILITY OR FUTILITY OF ORDINARY MORTALITY STATISTICS IN THE STUDY OF AIR POLLUTION EFFECTS

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1. Introduction

Interest in the disease producing potential of air pollution in the United States was stimulated by the Donora episode which occurred in October 1948. This audience may be interested in a brief description of that episode which prefaces the exhaustive and now classic report [1] of the epidemic:

"This particular smog encompassed the Donora area on the morning of Wednesday, October 27. It was even then of sufficient density to evoke comments by the residents. It was reported that streamers of carbon appeared to hang motionless in the air and that visibility was so poor that even natives of the area became lost.

The smog continued through Thursday, but still no more attention was attracted than that of conversational comment.

On Friday, however, a marked increase in illness began to take place in the area. By Friday evening the physicians' telephone exchange was flooded with calls for medical aid, and the doctors were making calls increasingly to care for their patients. Many persons were sent to nearby hospitals, and the Donora Fire Department, the local chapter of the American Red Cross, and other organizations were asked to help with the many ill persons.

There was, nevertheless, no general alarm about the smog even then. On Friday evening the annual Donora Halloween parade was well attended, and on Saturday afternoon a football game between Donora and Monongahela High Schools was played on the gridiron of Donora High School before a large crowd.

The first death during the smog had already occurred, however, early Saturday morning at 2:00 a.m., to be precise. More followed in quick succession during the day and by nightfall word of these deaths was racing through the town. By 11:30 that night 17 persons were dead. Two more were to follow on Sunday, and still another who fell ill during the smog was to die a week later on November 8.

On Sunday afternoon rain came to clear away the smog. But hundreds were still ill, and the rest of the residents were still stunned by the number of deaths that had taken place during the preceding 36 hours . . ."

In retrospect it appears that despite the fact that almost 6000 people, 43 per cent of the population of the Donora area, were affected by the smog, the episode would probably have gone unnoticed except for the occurrence of 17 deaths in a single day. In Figure 1 the death rates by month for Donora are shown for the period 1945 through 1948. The logarithmic vertical scale tends to minimize the amplitude of the peaks but the episode is clearly reflected in the time series. However, there are other monthly peaks, one of which is particularly striking since it actually exceeds the episode peak. During this earlier month, April 1945, excess deaths were not concentrated into a few days nor could the Donora investigators find any evidence of an outbreak of illness. Nevertheless, Weather Bureau records indicate that meteorological conditions of low average daily wind velocity with high average early morning valley stability made the period from 7 to 14 April 1945 more favorable for nocturnal retention of smoke than for any other time from 1945 up to the October 1948 episode. Thus one is tempted to also attribute the excess mortality of April 1945 to the effects of air pollution.

While the problems inherent in the study of time series are undoubtedly well known to this audience, it might be worthwhile to mention briefly those most relevant to the study of the mortality effects of air pollution.

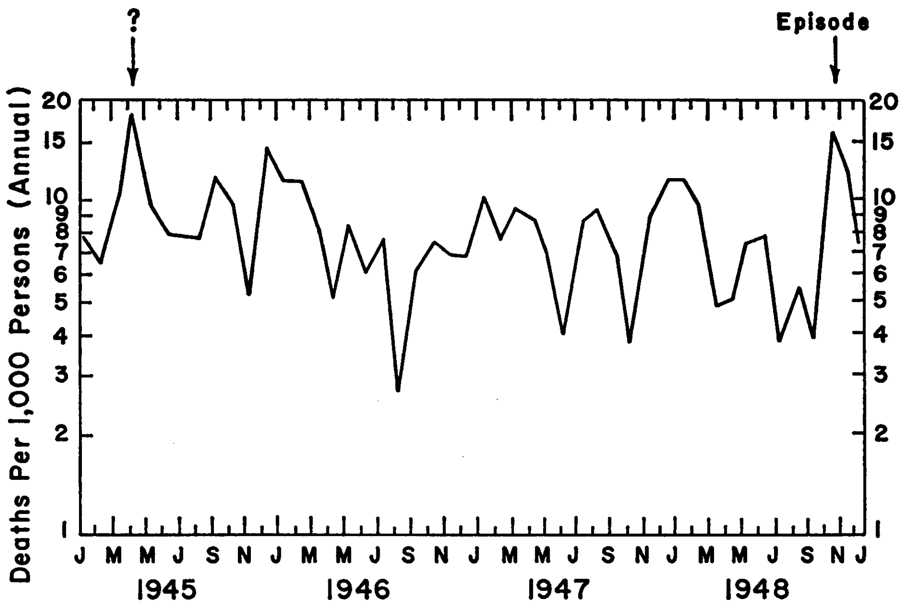

FIGURE 1

Death rates per 1,000 by month, Donora, Pennsylvania, and environs, 1945–1948 [1].

(1) As indicated in Figure 1, choice of an appropriate time interval is crucial if effects are to be detected. If the interval is too long the effect may be missed and if too short, it may be attenuated. Appropriate end points for intervals must be chosen.

(2) Allowance must be made for latent periods between exposure and mortality. For example, at Donora in 1948 the bulk of the deaths occurred on the fourth and last day of extreme smog.

(3) Other causes of excess mortality such as epidemics of infectious disease, accidents, and natural disasters must be removed from consideration.

(4) If specific causes of death are studied as effects, the usual cautions with respect to diagnostic criteria must be invoked.

(5) Since air pollution is a generic term, it is necessary to specify insofar as possible the particular component under consideration. Unfortunately, it is usually impossible to separate out particular components for study and whatever pollutant is measured becomes, in reality, the "index" of air pollution.

After the Donora episode, epidemiological research on the effects of air pollution in the United States took two general forms. On one hand there were studies of time series, notably those of Greenberg [2], McCarroll [3], and most recently of Hexter [4], and, on the other hand, geographical comparisons best exemplified by the Nashville [5] and Erie County [6] studies.

Some of the studies of time series demonstrated that acute episodes of high air pollution, measured by a variety of indices, were associated with detectable excess mortality. The geographic comparisons showed an association of high air pollution at place of residence with excess mortality, both general and from specific causes. However, these findings frequently have been questioned because of methodological problems.

In the remainder of this presentation I will discuss some of these methodological problems as they relate to the Erie County study.

2. The study plan

Buffalo and Erie County, New York, seemed to be a good place to examine the association of air pollution and mortality since the major contribution to air pollution here is derived from large industries located to the windward of the city. This produces wide bands of heavy pollution traversing areas of varied economic status, a factor of considerable importance. The design of the study was straightforward. Ambient air characteristics for the study area were determined by a network of air sampling stations designed to measure suspended particulates, settleable solids, and oxides of sulfur. Sampling was continued over a period of two years from July 1961 through June 1963. It was then possible to construct isopleths for particular pollutant levels for the study area. Those for suspended particulates are shown in Figure 2.

Using these isopleths, the approximately 125 census tracts making up the study area were classified into four groups according to two year average levels of suspended particulates. The areas are shown in Figure 3. Resident deaths for the pericensal period 1959–1961 were then utilized in conjunction with 1960 population data to construct age, sex, race, and cause specific death rates for each of the four census tract groups [7]. An exactly analogous approach was

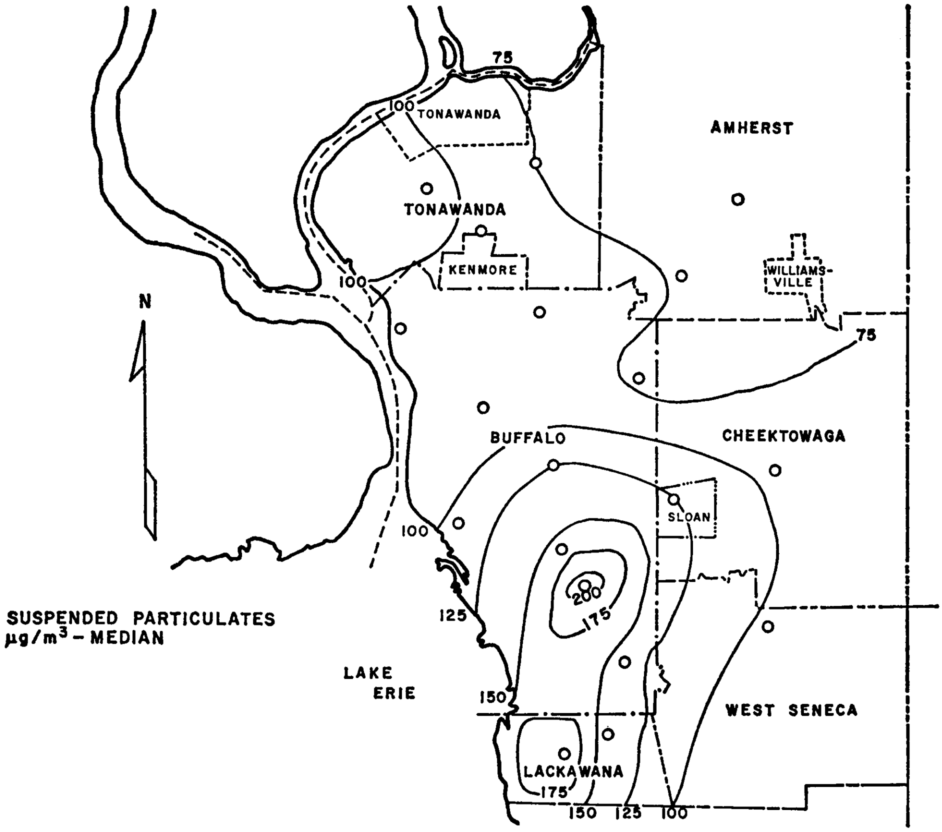

FIGURE 2

Suspended particulate isopleths, Buffalo, New York, and environs, 1961–1963.

used for oxides of sulfur [8]. Since settleable solids and suspended particulate levels were highly correlated, the latter was selected as the index of particulate pollution.

3. Problems to be overcome

There were five major problems to be overcome in the analysis and interpretation of the data generated in this study. They were (1) the strong association between low economic status and high air pollution level of census tracts; (2) the lack of information necessary to adjust the base populations and the deaths with respect to specific covariates known to affect death rates, namely, occupation, national origin, and tobacco smoking habits; (3) the mobility of the population; (4) the inability to separate the effects of various components of air pollution; and (5) the difficulty in making valid inferences from indirect associations.

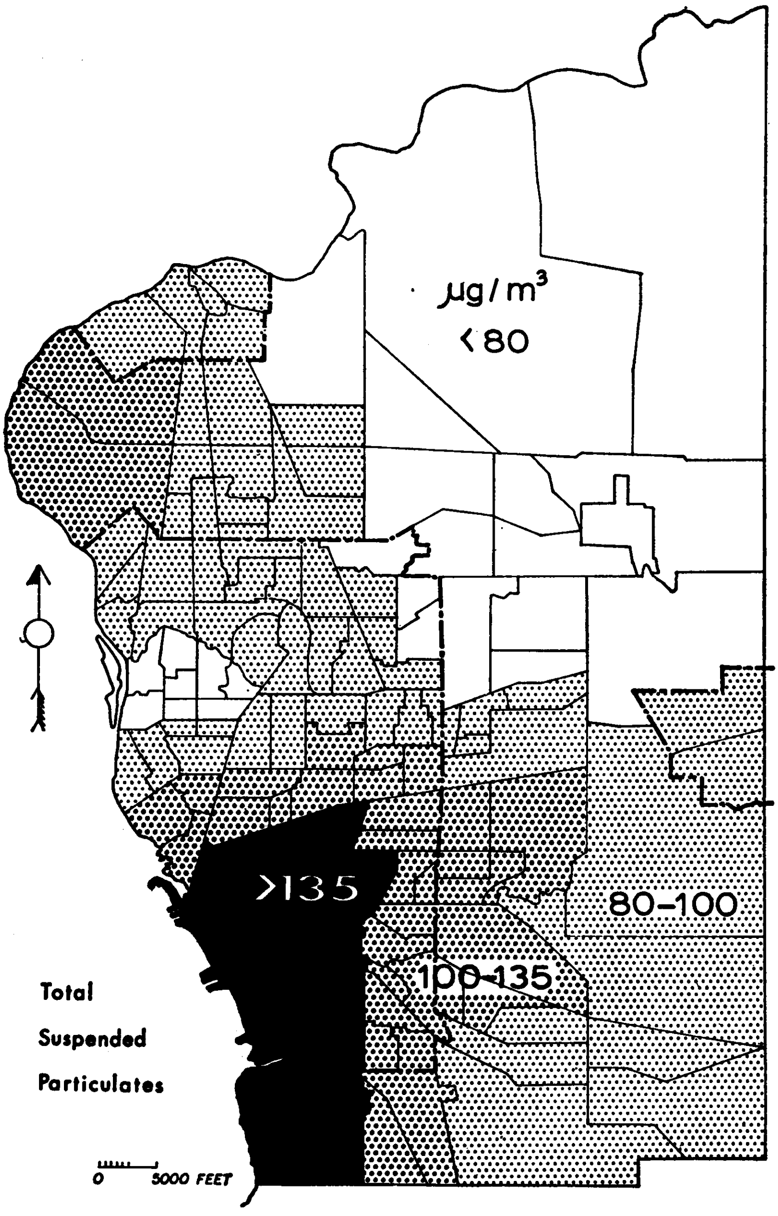

FIGURE 3

Suspended particulate air pollution areas, Erie County, New York Air Pollution Study [7].

4. Solutions and partial solutions

4.1. *Controlling for economic status.* Since it was known that there would be a strong socioeconomic effect on mortality rates and that air pollution levels are not independent of living standards, the census tracts in the study area were divided into groups according to median family income as recorded in the 1960 published census data.

Ideally, all of the census tracts within each group should have approximately the same median income; this could be accomplished by making many small groups. However, many small groups would make cross classification with air pollution levels unproductive. The optimal procedure is one in which the variability of median incomes within groups is small compared to that between groups, while the number of groups is minimized. A visual inspection of the distribution of median incomes of the 125 census tracts revealed the five natural groups that are used in the subsequent analyses.

In order to evaluate any advantage in this method of classification over the more conventional percentile approach, a one-way analysis of variance was performed. Examination of the components of variance revealed that for the five visually separated groups, 85 per cent of the variance was attributable to between group variance and 15 per cent to within group variance, while for quintiles the comparable figures were 80 per cent and 20 per cent, and for quartiles, 76 per cent and 24 per cent. It is of interest to note that for deciles the intergroup component of variance was increased to only 89 per cent.

The cross tabulation of the total death rates for white men is shown in Table I. The empty cells indicate census tract groups with no population representation and confirm the hypothesis of a strong association between low economic status and high air pollution level.

The marginal totals show large differences of mortality between areas of low and high economic status and between high and low air pollution exposure. However, the rows and columns of the table indicate independent associations. It is perhaps interesting to note that in the lowest air pollution area the effect of the economic gradient is minimal while in the highest economic area, the effect of the air pollution gradient is minimal. This, of course, suggests an interaction which needs further examination. In economic level 2, where each air pollution level is represented, the death rate in the highest pollution area is 50 per cent greater than in the lowest. The difference between the rate in the highest pollution—lowest economic area and lowest pollution—highest economic area is threefold.

Since economic status was used as an index of a variety of personal and social characteristics, it is of interest to examine the homogeneity of the economic levels based on family income with respect to other characteristics enumerated by the census. Data for median years of school completed, per cent of laborers in the labor force, and per cent of sound housing in each of the economic levels are presented in Table II. It is apparent that family income is remarkably stable

TABLE I

AVERAGE ANNUAL DEATH RATES FROM ALL CAUSES PER 1000 POPULATION ACCORDING TO ECONOMIC AND AIR POLLUTION LEVELS OF CENSUS TRACT OF RESIDENCE, WHITE MEN 50–69 YEARS OF AGE, BUFFALO, NEW YORK AND ENVIRONS, 1959–1961 [7]

Economic level is based on median family income for each census tract: 1 = \$3,005–\$5,007; 2 = \$5,175–\$6,004; 3 = \$6,013–\$6,614; 4 = \$6,618–\$7,347; 5 = \$7,431–\$11,792.
Air pollution level is based on average suspended particulate levels: 1 = <80 micrograms per cubic meter per 24 hours; 2 = 80–100 μg/cu m/24 hr; 3 = 100–135 μg/cu m/24 hr; and 4 = >135 μg/cu m/24 hr.

Economic level of census tract of residence	Air pollution level of census tract of residence				
	1 (low)	2	3	4 (high)	Total
1 (low)	—	36	41	52	43
2	24	27	30	36	29
3	—	24	26	33	25
4	20	22	27	—	22
5 (high)	17	21	20	—	19
Total	20	24	31	40	26

over all four air pollution levels in each economic grouping. However, for median number of years of school completed there is a downward trend with increasing air pollution levels in each of the economic groupings, most marked in the two lower levels. For both per cent of laborers in the labor force and per cent of sound housing, air pollution level 4 seems consistently different from the other three in the direction of higher proportions of laborers and lower proportions of sound housing in the two lower economic groupings.

Despite this evidence that air pollution level 4 may differ from levels 1, 2, and 3 with respect to certain socioeconomic factors, it seems unlikely that these are responsible for the apparent air pollution effects. This is demonstrated by the fact that all of the gradients persist when air pollution level 4 is left out of the comparisons.

4.2. *Accounting and adjusting for the effects of covariates.* The punched cards from which the mortality data were obtained did not carry all of the data available from the death certificates. Of particular concern in this study was the lack of information on usual occupation. Since residence in an area of high air pollution may be highly correlated with occupation in dusty or dangerous industries, and since such occupations have been associated with excess mortality, it would be useful to study the mortality pattern of a group without such exposures. Thus, one would expect the air pollution—mortality relationship revealed in Table I to disappear for women if occupation was the causal factor. While some women might have such occupational exposure, this would be a very small proportion of the population. The cross tabulation of death rates for white women 50–69 years of age according to economic status and air pollution level of place of residence is shown in Table III. Since the pattern of association

TABLE II

SELECTED POPULATION CHARACTERISTICS ACCORDING TO AIR POLLUTION LEVEL, BUFFALO AND ENVIRONS, 1960 [7]

Population characteristics are family income and years school completed: median of median values for census tracts.
Per cent laborers in labor force and per cent homes sound: median per cent for census tracts.

Economic level	Population characteristics	Air pollution levels				Total
		1 (low)	2	3	4 (high)	
1 (low)	family income	—	4,323	4,274	4,248	4,274
	yrs. school comp.	—	9.1	8.7	8.3	8.4
	% laborers in L.F.	—	19	15	24	19
	% homes sound	—	62	67	59	62
2	family income	5,734	5,852	5,749	5,618	5,764
	yrs. school comp.	9.5	9.4	9.0	8.6	9.1
	% laborers in L.F.	8	7	9	15	8
	% homes sound	86	87	90	65	86
3	family income	—	6,411	6,378	6,178	6,378
	yrs. school comp.	—	10.0	9.4	9.8	10.0
	% laborers in L.F.	—	5	7	15	7
	% homes sound	—	97	93	92	94
4	family income	6,833	6,997	6,789	—	6,906
	yrs. school comp.	11.4	11.6	10.9	—	11.4
	% laborers in L.F.	5	4	8	—	5
	% homes sound	97	97	97	—	97
5 (high)	family income	8,024	8,094	7,431	—	8,000
	yrs. school comp.	12.4	12.5	11.5	—	12.4
	% laborers in L.F.	2	2	5	—	2
	% homes sound	98	99	98	—	99

TABLE III

AVERAGE ANNUAL DEATH RATES FROM ALL CAUSES PER 1000 POPULATION ACCORDING TO ECONOMIC AND AIR POLLUTION LEVELS OF CENSUS TRACT OF RESIDENCE, WHITE WOMEN 50–69 YEARS OF AGE, BUFFALO, NEW YORK AND ENVIRONS, 1959–1961 [7]

Economic level of census tract of residence	Air pollution level of census tract of residence				Total
	1 (low)	2	3	4	
1 (low)	—	16	19	32	22
2	12	13	17	20	15
3	—	13	16	18	14
4	13	11	15	—	12
5 (high)	11	12	9	—	11
Total	12	12	17	22	14

is similar to that for men, we can be reasonably confident that the association is not due primarily to the confounding effect of occupation.

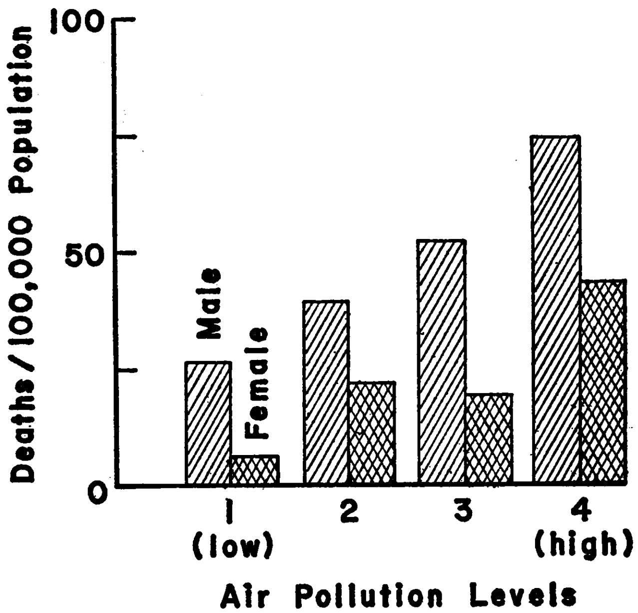

FIGURE 4

Death rates per 100,000 population for gastric cancer in white men and women 50–69 years of age for economic levels 2–4 combined, Buffalo, New York, and environs, 1959–1961 [9].

Because death certificates contain only a limited amount of information, it was necessary to use an adjustment procedure to deal with national origin. In Figure 4 I have summarized the association between suspended particulate air pollution and cancer of the stomach [9]. Haenszel had previously shown an association between foreign birth, particularly Polish, and stomach cancer [10], and since Buffalo has relatively one of the largest Polish-born populations of any American City, it was imperative to rule out the possibility that the association of mortality and air pollution was the result of confounding by an ethnic factor. In fact, when we examined the composition of the study population, as shown in Table IV, both Polish-born and American-born of Polish parents showed increasing proportions in areas of increasing air pollution. To adjust for this, we assumed a constant Polish mortality differential of 2⅓ times the average death rate for cancer of the stomach observed among white men and women 50–69 years of age. Selection of the factor 2⅓ was based on the data presented by Haenszel. This rate (70/100,000) was then applied to the estimated population of foreign-born and foreign-born Polish plus native-born of Polish or mixed

Polish parentage in the various cells of the air pollution—economic level matrix. The resulting numbers of deaths were then removed from the total deaths. The ethnic populations were estimated by applying the appropriate percentages derived from the 1960 census tabulations to the combined populations of white men and women 50–69 years of age in each cell of the air pollution—economic level matrix. After the population of each ethnic subgroup was subtracted from the total populations, new rates were computed. In effect, the two ethnic subgroups were treated as though they were subject to a constant excess risk but not subject to an additive risk from air pollution.

TABLE IV

ETHNIC COMPOSITION OF STUDY POPULATION ACCORDING TO AIR POLLUTION LEVEL

Study population is at economic levels 2–4.
Polish stock means Polish-born plus native-born of Polish or mixed Polish parentage.

Group designation	Air pollution level			
	1 (low)	2	3	4 (high)
Polish stock	4%	8%	19%	22%
Foreign-born	8%	11%	9%	13%

The recomputed rates are shown in Table V. Since the associations between suspended particulate air pollution and stomach cancer are essentially unchanged after making adjustments for the possible competing risk of high ethnic susceptibility, the results do not indicate that the association can be explained by the ethnic composition of the populations at risk.

TABLE V

AVERAGE ANNUAL DEATH RATE PER 100,000 POPULATION ACCORDING TO AIR POLLUTION LEVELS ASSUMING AN ETHNIC EFFECT: WHITE MALES AND FEMALES, ECONOMIC LEVELS 2–4, BUFFALO AND ENVIRONS, 1959–1961 [9]

Ethnic effect assumed to be $2\frac{1}{8}$ times overall age specific rate.
Polish stock means Polish-born plus native-born of Polish or mixed Polish parentage.
Numbers in parentheses indicate sample sizes.

Group designation	Air pollution level			
	1 (low)	2	3	4 (high)
Total	16 (10)	30 (50)	34 (29)	58 (16)
Less Polish stock	15 (9)	27 (41)	24 (17)	51 (11)
Less foreign-born	10 (6)	25 (37)	31 (24)	54 (13)

Since cigarette smoking has been associated with so many different causes of death, it seemed important to account for the distribution of smoking patterns in the study population. We were, of course, unable to determine the smoking habits of the dead and, unfortunately, the census did not collect information on this characteristic in the 1960 census. However, a population survey had been conducted in Buffalo in 1963 [11] for other purposes and we were able to obtain information from this survey with respect to smoking habits. The distribution of 50–69 year old white male smokers of more than one pack per day is shown in Table VI. While sample sizes are rather small in a number of cells, only in economic levels 2 and 4 is there any suggestion of a positive relationship between heavy smoking and air pollution. Since economic level 2 contained the largest population and had representation in each of the four air pollution levels, it was important to evaluate this trend. The total chi squared value for this row was 3.55 which is not sufficient to permit partitioning to test for regression in the manner suggested by Cochrane [12]. It is of interest to note that the lung cancer rates in economic level 2 followed the pattern of the cigarette smoking habits of the sample [7]. Incidentally lung cancer was not associated with suspended particulate air pollution in this study.

TABLE VI

PER CENT OF SAMPLE OF 50–69 YEAR OLD WHITE MEN SMOKING MORE THAN ONE PACK OF CIGARETTES PER DAY ACCORDING TO ECONOMIC AND AIR POLLUTION LEVELS, BUFFALO ONLY, 1963

Numbers in parentheses indicate sample sizes.

Economic level of census tract of residence	Air pollution level of census tract of residence			
	1 (low)	2	3	4 (high)
1 (low)	—	100 (4)	32 (22)	75 (4)
2	18 (17)	35 (48)	27 (33)	45 (20)
3	—	47 (34)	55 (9)	37 (8)
4	22 (18)	42 (19)	55 (9)	—
5 (high)	33 (3)	38 (13)	33 (6)	—

4.3. *Mobility.* There are several kinds of mobility that ideally need to be accounted for. These include short term mobility in relation to duration of exposure at place of residence, occupation, and recreation, and long term mobility with respect to change of residence and occupation within the study area or outside of it. Unfortunately, we were unable to devise any very good way of getting at this. The census gave information regarding residence at present address for more than five years and when this was examined we found that the proportion of the population living longer than five years at present residence was lower in the lower economic groups than in the higher, as expected, but there was no relationship to air pollution level.

4.4. *Separating component effects.* Frequently all measurable components of air pollution are highly correlated in their areal distribution. However, in the Erie County Air Pollution Study, sulfation and suspended particulates had sufficiently different distributions to permit an analysis of their independent and compound effects [8]. The data are shown in Table VII. Unfortunately, the population distributed somewhat unevenly among the various areas. However, it is quite apparent that oxides of sulfur are not contributing to the mortality effect either independently or in combination with suspended particulates.

TABLE VII

AVERAGE ANNUAL MORTALITY PER 1000 POPULATION FROM ALL CAUSES IN WHITE MEN, 50 TO 69 (1959–1961) [8]

Suspended particulates: High is >100 μg/cu m/24 hr; low, <100 μg/cu m/24 hr. Oxides of sulfur: high, >0.45 mg/sq cm/30 days; low, <0.45 mg/sq cm/30 days.

	Air pollution level (oxides of sulfur and suspended particulates)							
	Susp. part. low SO_2 low		Susp. part. low SO_2 high		Susp. part. high SO_2 low		Susp. part. high SO_2 high	
Economic level	Pop.	Rate	Pop.	Rate	Pop.	Rate	Pop.	Rate
1 (low)	530	36	—	—	4,413	46	2,822	41
2	13,383	26	—	—	2,245	33	7,908	32
3	7,684	24	—	—	4,189	28	1,063	26
4	13,771	21	735	19	2,639	27	—	—
5 (high)	11,428	19	1,301	16	574	20	—	—
Total	46,796	23	2,036	17	14,060	34	11,793	33

It is of some interest in this regard to note that in London, where suspended particulate air pollution has been drastically reduced, as a result of the enforcement of a "Clean Air Act," while sulfation has remained high, severe fogs of recent years have not been accompanied by nearly the degree of excess mortality characterizing the fogs of earlier years.

4.5. *Inferences from indirect associations.* Epidemiologists and biostatisticians are well aware of the problems involved in the analysis of incomplete cross tabulations based on classifications which are indirect measurements of the characteristics under study, in this case, air pollution level of place of residence controlled for economic status. Because of this, my colleagues and I have refrained from applying ordinary statistical tests to the data from the Erie County Air Pollution Study and have, instead, evaluated the results by inspection of the rates for trends and consistency. This has aroused some comment [13], but I believe that this approach is less risky than the application of inappropriate statistical tests. Further, we have tried to be cautious and guarded in our interpretations of observed associations.

The fundamental problem in interpreting these types of data is the avoidance of what Karl Pearson termed "spurious correlation" and what Professor Neyman has more cogently described as inappropriate methods of studying correlation [14]. In the present study the problem revolves around the possibility that some intervening factor associated with both risk of death and air pollution level has produced the observed associations. In Sections 4.1 through 4.3 I have discussed a number of such possibilities. Professor Neyman suggested that I look further into the question particularly with respect to population size. Specifically, he was concerned with the possibility that the populations of the census tracts and consequently their density might be positively correlated with both air pollution and risk of death. Thus, in Table VIII I have subdivided the 40 census tracts making up economic level 2 into three groups according to their size. When the total death rates for white men 50–69 were computed for each of the four air pollution levels in each size group, the trend revealed in Table I was confirmed in each group. From this evidence, it appears unlikely that the observed association is simply a function of population size. However, it does not dispose of Professor Neyman's basic concern. Perhaps my colleagues and I have overlooked the potential value of more sophisticated correlation techniques because of our belief that the indirect nature of all of our measurements except the counts of deaths and population precluded their use.

In making inferences from the mortality data in the Erie County Study we have given special attention to two characteristics, first, to biological plausibility and, second, to confirmatory evidence from other studies. Thus, of the seven diseases or groups of diseases (all causes [7], chronic respiratory disease [7], cancer of the stomach [9] and prostate gland [15], arteriosclerotic heart disease, cerebrovascular disease [16], and cirrhosis of the liver [17]) for which mortality has been reported associated with suspended particulate air pollution in Erie County, only cirrhosis and cerebrovascular disease have not been reported in association with air pollution in the Nashville Study. With respect to cirrhosis, there is a rational explanation for the association. It is hypothesized that toxic agents in industrial air pollution act individually and synergistically with alcohol to produce mortality. For cerebrovascular disease, greater caution is indicated. While it could be postulated that air pollution in Erie County contains agents toxic to the human vasculature, the data are not as consistent over all economic levels and between the sexes as one would like.

It is interesting to note that even after mortality from the six associated diseases or groups of diseases are removed from the total, a substantial gradient remains. This may mean that the association is spurious or it may suggest that particulate air pollution is a general environmental stress analogous at our present state of knowledge to poverty. Nevertheless, there were a number of diseases which were definitely not related to suspended particulate air pollution while revealing strong inverse associations with economic status. Notable among these were lung cancer and infant mortality.

TABLE VIII

DEATHS AND DEATH RATES FROM ALL CAUSES PER 1000 POPULATION ACCORDING TO AIR POLLUTION LEVEL OF CENSUS TRACT OF RESIDENCE AND SIZE OF TRACT, WHITE MEN 50–69 YEARS OF AGE, BUFFALO, NEW YORK AND ENVIRONS, 1959–1961

Population of tract	Number of tracts	Air pollutiou level				
		1 low	2	3	4 high	Total
		Population				
99–555	23	470	3,550	1,434	2,181	7,635
592–899	10	2,217	3,963	1,607	—	7,787
939–1925	7	976	2,207	3,927	1,004	8,114
Total	40	3,663	9,720	6,968	3,185	23,536
		Deaths (3 yrs.)				
99–555	23	35	306	109	242	692
592–899	10	167	326	157	—	650
939–1925	7	65	167	364	98	694
Total	40	267	799	630	340	2,036
		Average annual death rate				
99–555	23	25	29	25	37	30
592–899	10	25	27	33	—	28
939–1925	7	22	25	31	33	29
Total	40	24	27	30	36	29

5. Conclusion

There is no particular mystery about the disease producing potential of air pollution. If toxic agents are discharged into the air, whether they be in the form of ionized particles, elemental metals, or complex organic molecules, they will produce disease if they are delivered to a susceptible host in sufficient dosage. It seems to me that this potential has now been demonstrated repeatedly in differently designed studies. The fact that a number of diseases of unknown etiology appear to be related to air pollution suggests that important causal relationships may be revealed through air pollution studies. Such knowledge can, of course, be utilized for the betterment of the public health.

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Discussion

Question: R. J. Hickey, Institute for Environmental Studies, University of Pennsylvania, Philadelphia

You commented on environmental polycyclic hydrocarbons which are known to have carcinogenic properties, such as 3,4-benzopyrene. Do you recommend that people cease the great American custom of favoring charcoal broiled steaks, smoked meats, overly grilled sandwiches, and other foods which are known to, or may, contain these polycyclic hydrocarbons?

As you probably know, Sawicki, Elbert, Hauser, Fox, and Stanley [18] investigated the 3,4-benzopyrene content in the atmosphere of a number of cities in the United States. They also estimated the number of micrograms of this compound inhaled per capita in a year. They observed, in these early studies, that 3,4-benzopyrene data and mortality data for lung cancer in various cities "failed to reveal a significant relationship." In this connection it should be recognized that a mammalian enzyme (or enzyme system) exists, called benzopyrene hydroxylase, which is involved in metabolizing 3,4-benzopyrene and perhaps other polycyclic compounds.

Further, if atmospheric 3,4-benzopyrene is in fact dangerous, through posing a risk of contracting, for example, lung cancer, then it might be expected that high level occupational exposure, such as in certain tarring and roofing occupations, could lead to high risk of lung cancer in people in these occupations. Interestingly, Hammond, Selikoff, and Lawther [19] conducted an investigation on this question and, as I recall, were unable to demonstrate a high frequency of occurrence of lung cancer in these people as compared with comparable people in the average population. Curiously, so far as I know, the paper has not yet been published.

Reply: W. Winkelstein

I would certainly recommend the cessation of cigarette smoking, but I am not sure that total austerity is worth the slight improvement in risk.

Lung cancer was not associated with particulate air pollution in either the Buffalo or Nashville studies.

Question: E. Tompkins, Human Studies Branch, Environmental Protection Agency

Have you looked at the distribution of causes of death in Buffalo as compared to the distribution in other similar cities without comparable air pollution (within economic groups)?

Reply: W. Winkelstein

Except for comparing the results with the Nashville Air Pollution Study, no other comparisons have been made.