PREVENTIVE MEDICINE 9, 206–211 (1980)

General Air Pollution and Cancer in the United States[1]

E. CUYLER HAMMOND [2] AND LAWRENCE GARFINKEL

American Cancer Society, 777 Third Avenue, New York, New York 10017

COMMITTEE MEMBERS

HARRY DEMOPOULOS, M.D.
Department of Pathology
New York University Medical Center

PETER GREENWALD, M.D.
Division of Epidemiology
New York State Department of Health

MERRIL EISENBUD, SC.D.
Department of Environmental Medicine
New York University Medical Center

JOHN HIGGINSON, M.D.
International Agency for Research on Cancer
World Health Organization

JOSEPH FRAUMENI, M.D.
Epidemiology Branch
National Cancer Institute

HERMAN F. KRAYBILL, PH.D.
Scientific Coordinator for Environmental Cancer
National Cancer Institute

GREGORY T. O'CONOR, M.D.
Division of Cancer Cause and Prevention
National Cancer Institute

General air pollution may be defined as a body of contaminated air extending over a population area of appreciable size (a town, city, etc.). It excludes occupational, personal, or neighborhood pollution exposure to dusts or fumes. In the American Cancer Society's study of a half million men, subjects who had lived in the same neighborhood for at least 10 years were classified into various categories by place of residence, and whether or not they were occupationally exposed to dusts, fumes, or vapors. Lung cancer rates were computed standardized by age and smoking habits. Men who said they were occupationally exposed had mortality rates of lung cancer 14% greater than the nonexposed. Among those not exposed, there were little or no differences in mortality ratios by urban–rural place of residence, in Los Angeles and nearby counties; by whether they lived in cities with high, medium, or low levels of total suspended particulate matter or benzene-soluble organic matter. We conclude the general air pollution at present has very little effect, if any, on the lung cancer death rate.

There is overwhelming evidence that prolonged and heavy exposure to any one of several different sorts of air contaminants increases the risk of cancer. Examples include: tobacco smoke, benzo(a)pyrene (BaP), vinyl chloride, radon gas, and dust composed primarily of asbestos fibers, radioactive materials, or chromates. Most of our knowledge about these has come from extensive studies of the effects of smoking and studies of people with relatively heavy and prolonged occupational exposure to a specified substance by way of inhalation. Such studies have also shown that, at least in some instances, exposure to two different factors

[1] Presented at the American Health Foundation/Deutsche Krebshilfe Conference on the Primary Prevention of Cancer: Assessment of Risk Factors and Future Directions, N.Y., N.Y., June 7–8, 1979.
[2] To whom requests requests for reprints should be addressed.

0091-7435/80/020206-06$02.00/0

can act synergistically to increase the risk of cancer to a far greater degree than would be predicted by the hypothesis of a simple additive effect (e.g., occupational exposure to asbestos dust or radioactive material combined with cigarette smoking). A large proportion of all human cancers may result from exposure to two or more different agents; one of the agents taken alone may be either a noncarcinogen or a very weak carcinogen. Furthermore, exposure to one of the members of such a "carcinogen combination" could be by way of inhalation while exposure to another member could be by some other mode such as ingestion.

This brief paper is confined to the subject of cancer in relation to *general air pollution* in the United States. Our first problem is that while "general air pollution" is frequently discussed in the lay press, it is an ill-defined term. We will not attempt to write a precise definition but at least a rough description is required.

By general air pollution we mean a body of contaminated air extending over a populated area of appreciable size—at least, for example, the entire central area of town, but more usually extending in varying degrees over an area the size of a city, a county, or several counties. (Occupational exposure to contaminated air, smoking, and the deliberate breathing of aerosols, vapors, or gases for pleasure or for medical purposes are excluded by this definition; special situations such as the concentration of motor vehicle exhaust fumes and gases in a parking garage are also excluded.)

It may be true that the effects of general air pollution may combine with occupational air pollution effects to produce an excess risk, whereas they might not produce a meaningful effect independent of each other. For example, roofers exposed to BaP in their work may only have a risk of lung cancer if they have an added exposure to BaP in the ambient air of the environment in which they work.

General air pollution should be distinguished from "neighborhood pollution" of fumes or particulate matter from a factory or similar source. The effects of this type of exposure may certainly increase the risk of cancer in people living across the street from a factory from which chemical or mineral contaminants are discharged. But the effects of such risks for people living within several miles of such factories have not yet been clearly delineated.

It is clear that studies of "general air pollution" must take into account many factors. Among these are: (a) Individual smoking habits; (b) Within the same metropolitan area, the type and amount of pollution varies in different neighborhoods and varies from day to day and year to year. Furthermore, qualitative and quantitative analyses of air samples have not been carried out on a routine basis in many localities until recent years. Even now, one may question the adequacy of such sampling for determining the current exposure of individuals living in different neighborhoods of the same metropolitan area; (c) A large proportion of Americans live at some distance from their place of work. They may be exposed to different types and degrees of air pollution at home, on their way to work, and in their place of work; and (d) Americans are remarkably mobile; many move from one location to another every few years. This complicates the problem of ascertaining the type and extent of exposure. Furthermore, state of health can influence whether a person moves from one location to another. This is an additional complicating factor.

Because of these difficulties, we are generally unable to obtain an accurate estimate of the degree of exposure of an individual to each of various types of air pollutants during his lifetime. As a poor substitute, we can divide individuals into groups by residence history and use this as a very crude index of exposure history. Alternatively, we can ascertain lung cancer death rates in various localities which currently differ in type or degree of air pollution. In some instances, a compromise may be made between these two procedures, but whichever is used, smoking habits and occupational exposure should be taken into consideration.

Table 1, based on data from the American Cancer Society's prospective study, is confined to male subjects who, at the time of enrollment, said that they had lived in their present neighborhood for at least 10 years. Thus they had a minimum of 10 years of exposure to the type and amount of air pollution occurring in their neighborhoods during those years. The total group was divided into six subgroups; men who never smoked regularly and five sets of smokers classified by type and amount of smoking. Lung cancer death rates were calculated for men in each 5-year group in each of the six subgroups. These death rates were applied to the man-years of exposure to risk of men in each of the various categories shown in Table 1. The resulting figures represent the expected number of lung cancer

TABLE 1

OBSERVED AND EXPECTED NUMBER OF LUNG CANCER DEATHS BY PLACE OF RESIDENCE AND BY OCCUPATIONAL EXPOSURE TO DUST, FUMES, GASES, OR X RAYS[a]

Place of residence	Occupationally exposed to dust, fumes, etc.			Not occupationally exposed to dust, fumes, etc.		
	Obs. No.	Exp. No.	Ratio	Obs. No.	Exp. No.	Ratio
Total, all male subjects	576	530.5	1.09	934	979.7	0.96
Metropolitan area, pop. 1,000,000+	165	134.1	1.23	281	285.7	0.98
City	92	69.1	1.33	168	158.3	1.06
Town or rural	73	65.0	1.12	113	127.4	0.89
Metropolitan area, pop. <1,000,000	166	145.4	1.14	271	280.5	0.97
City	92	83.3	1.10	170	184.0	0.92
Town or rural	74	62.1	1.19	101	96.5	1.05
Non-Metropolitan area	245	251.0	0.98	382	413.5	0.92
Town	102	104.9	0.97	200	199.1	1.00
Rural	143	146.1	0.98	182	214.4	0.85
Los Angeles, Riverside, and Orange Counties, Calif.	30	21.9	1.37	38	39.6	0.96
Farmers	63	77.6	0.81	71	92.9	0.76
8 Cities: High particulates (130–180 μg/m³)	45	32.9	1.37	66	73.9	0.89
11 Cities: Moderate particulates (100–129 μg/m³)	21	18.8	1.12	39	49.5	0.79
14 Cities: Low particulates (35–99) μg/m³)	48	37.4	1.28	110	100.1	1.10
9 Cities: High benz. sol. (8.5–15.0 μg/m³)	28	21.0	1.33	52	51.5	1.01
10 Cities: Moderate sol. (6.5–7.9 μg/m³)	44	32.7	1.35	65	75.1	0.87
12 Cities: Low sol. (3.4–6.3 μg/m³)	33	29.2	1.13	76	81.8	0.93

[a] Adjusted for age and for smoking habits. Confined to men who had lived in same neighborhood for last 10 years.

deaths in each category adjusted for age distribution and smoking habits. The observed number of lung cancer deaths divided by the expected number yields the mortality ratio. By definition, the mortality ratio for all subjects combined is 1.00.

The subjects are divided into various groups by place of residence. Within each of these groups they are subdivided according to whether they said that they were or had ever been occupationally exposed to dust, fumes, vapors, gases, or X rays. The exposure reported covered a wide range (e.g., firemen exposed to smoke, garage workers exposed to automobile exhausts, asbestos workers, miners, farmers exposed to insecticide sprays, etc.) Many of the exposed men probably had only a low level of occupational exposure for a relatively short length of time. Others may have had a high level of exposure for many years.

Disregarding place of residence, the lung cancer mortality ratio was 1.09 for men with occupational exposure and 0.96 for men without occupational exposure, a relative difference of 13.5%. In large metropolitan areas, the relative difference between the exposed and unexposed groups was 26%, in smaller metropolitan area 18%, and in nonmetropolitan areas 7%. These differences are probably due to different types of occupational exposure in different areas.

Clearly, occupational exposure should be taken into consideration in any study of the possible effects of general urban air pollution. The simplest way of doing this is to confine attention to men without occupational exposure.

MEN WITHOUT OCCUPATIONAL EXPOSURE

In the top part of Table 1, the subjects are divided into six groups by size of place of residence according to the 1960 census of the United States. The term "metropolitan area" means a county or a group of contiguous counties with at least one city of 50,000 + inhabitants or "twin cities" with a combined population of at least 50,000. As used here, the term "town" means a place with a population of 2,500 to 49,999 people and "rural" means living in the county or village with less than 2,500 people. In some metropolitan areas, legally independent towns abut a central city and, in a nonlegal sense, are actually a part of the city (a situation similar to Greater London in contrast to the City of London).

There are exceptions, but generally speaking it may be assumed that urban air pollution tends to be greater in large metropolitan areas than in smaller metropolitan areas, far less in nonmetropolitan areas, and less in rural parts of nonmetropolitan areas. Most of the nonmetropolitan areas included in this study are far removed from any city and many do not even contain a large town.

Among men without occupational exposure, the lung cancer mortality ratio was 0.98 for those living in large metropolitan areas (1,000,000+ population), 0.97 for those living in smaller metropolitan areas, and 0.92 for those living in nonmetropolitan areas. The highest mortality ratios (1.06 and 1.05) were for men living in cities in large metropolitan areas and for men living in towns and rural parts of smaller metropolitan areas. The lowest mortality ratios (0.85 and 0.89) were for men living in rural parts of nonmetropolitan areas and for men living in towns and rural parts of large metropolitan counties. The mortality ratio for men living in towns in nonmetropolitan areas (1.00) was higher than the mortality ratio of men living in cities in smaller metropolitan areas (0.92). This set of figures gives little or no support to the hypotheses that urban air pollution has an important effect upon lung cancer death rates.

Los Angeles county in California and major parts of two adjacent counties (Riverside and Orange) have unusually heavy air pollution in respect to oxidants and carbon monoxide (1). They also have high air pollution rates in terms of total suspended particulate matter and benzene-soluble particulate matter.

The lung cancer mortality ratio for men living in these three counties was the same as for all subjects without occupational exposure (0.96).

Data are shown for farmers, including retired farmers living in towns but excluding (a) farmers living in metropolitan areas of 500,000+ population and (b) retired farmers living in cities or in metropolitan areas of 500,000+ population. The majority of these farmers lived in strictly rural areas far from a large city and far from any major medical center. Their lung cancer mortality ratio was only 0.76. We suspect that this figure is artificially low for two reasons: (a) In strictly rural areas of the United States there are usually few doctors and usually little in the way of medical facilities. Under such conditions, some deaths due to lung cancer may be mistakenly attributed to other causes. (b) In the past when a farmer's health began to fail, he usually remained on the farm and his son took over the work. Today, he is far more likely to move to a city. This selective removal from rural areas of men in ill health reduces the death rate in rural areas.

Data on the mean level of suspended particulate matter in the air of 57 American cities are provided in "Statistical Abstracts in the United States, 1970," (3) for the year 1968. The mean levels ranged from 32 to 306 $\mu g/m^3$. It is likely that the mean level in some of the cities changed considerably during the last four decades or so. However, lacking evidence to the contrary, we will assume that the *rank order* of these cities in respect to suspended particulate matter did not change greatly. Thirty-three of the cities were included in our study and we divided them into three groups by mean level of suspended particulate matter in 1968.

The mortality ratios (for men without occupational exposure) were: 0.89 in cities with the highest mean levels of suspended particulate matter, 0.79 for cities within the intermediate category, and 1.10 in cities with the lowest mean levels of suspended particulate matter. Since it seems unlikely that suspended particulate matter decreases the risk of lung cancer, we conclude that urban air pollution as *measured by this index* is unrelated to death rates from lung cancer.

"Statistical Abstracts of the United States, 1970" (3) also provides information on the mean level of benzene-soluble organic matter for the year 1968 in the air of 55 cities, 31 of which were included in the study. As shown in Table 1, there appears to be little if any association between lung cancer mortality ratio and this index of urban pollution.

CONCLUSION

In a review of the literature published some years ago (2), the authors concluded that there was no firm evidence to support the hypothesis that general urban air pollution increases the risk of lung cancer to an important degree, if at all. Data from our study support that conclusion and we are unaware of any evidence which convincingly leads to a contrary conclusion.

Available evidence does not rule out the possibility that general urban air pollution may perhaps lead to a *slight* increase in the risk of lung cancer. It does not rule out the possibility that if no efforts were made to control air pollution, then at some future date it might increase to a level such that it would result in a significant increase in the risk of lung cancer. Fortunately, for good and sufficient reasons (other than lung cancer risk), steps are now being taken to reduce air pollution. If reasonably successful, these steps should eliminate the possibility that general urban air pollution will result in an increase in risk of lung cancer at some future date.

REFERENCES

1. Buell, P., Dunn, J. E. Jr., and Breslow, L. Cancer of the lung and Los Angeles-type air pollution. Prospective study. *Cancer* 20, 2139–2147 (1967).
2. Cornfield, J., Haenszel, W., Hammond, E. C., Lilienfeld, A. M., Shimkin, M. D., and Wynder, E. L. Smoking and lung cancer: recent evidence and discussion of some questions. *J. Natl. Cancer Inst.* 22, 173–203 (1959).
3. "Statistical Abstract of the United States, 1970." 91st Annual ed. U.S. Bureau of the Census, Washington D.C., 1970.