Reprinted from the Archives of Environmental Health
September 1968, Volume 17

Health and the Urban Environment

VII. Air Pollution and Disease Symptoms in a "Normal" Population

Isabel M. Mountain, PhD; Eric J. Cassell, MD; Doris W. Wolter, RN, MPH; Col Joseph D. Mountain, USAFR, Ret; Judith R. Diamond; and James R. McCarroll, MD, New York

The effect of each of several pollutants on the health of urban families on the lower East Side of New York city has been assessed. Prevalence of certain symptoms on one day of the week (Monday) was assessed according to level of each pollutant (low, medium, or high). Prevalence was treated as a binomial variable (number of "yes" responses/number of "yes" and "no" responses) whereas pollutant level was a continuous variable (but ordered, by thirds), according to the method of Armitage.

In summer, in children under 8 years of age, prevalence of respiratory symptoms was directly related to increasing levels of particulate matter and of carbon monoxide.

In heavy smokers, prevalence of eye irritation and headache was directly related to increasing levels of carbon monoxide.

During various episodes of excessive atmospheric pollution, the occurrence of an unusually high number of severe illnesses, some terminating in death, has been recognized repeatedly. However, the effect of exposure to daily fluctuating levels of pollutants in the environment on the health of urban families is more difficult to pinpoint. No one doubts that people feel miserable during days of high pollution, but how can we assess the toll, and evaluate critical levels of prime offenders in the atmosphere?

Families living in lower- and middle-income housing on the lower East Side of New York city have been observed for a period of nearly three years. These "normal" individuals lived within a 2,000-foot radius of the monitoring station where concentrations of various air pollutants were being measured concurrently. The relationship between the prevalence of certain symptoms and the level of the pollutants has been subjected to statistical analysis. The applicability of the method used, and the outcome of the analysis will be discussed in this paper. The analysis so far deals with "single symptom-single pollutant" pairs, although we recognize that the problem is in fact multivariate. We present this analysis as a first-step approach to solution of an admittedly complex problem.

Submitted for publication Nov 21, 1967; accepted April 18, 1968.

From the Division of Epidemiologic Research, Department of Public Health, Cornell University Medical College, New York (Drs. Mountain and Cassell, Mrs. Wolter, Col Mountain, and Mrs. Diamond). Dr. McCarroll is now at the Division of Environmental Health, University of Washington School of Medicine, Seattle.

Reprint requests to 1300 York Ave, New York 10021 (Dr. Mountain).

Definition of Population

Population.—Three groups of people living in the lower East Side of New York city were studied. The nature of the groups and their selection have already been described.[1,2] Briefly, following a preliminary survey, a stratified sample was selected, representing a cross section of lower- and middle-income groups, living within an area of one-half square mile, considered relatively homogenous in its air environment. Altogether, 1,820 individuals participated, representing 469 family units.

Subpopulations.—*Under 8 Years of Age.*—This group consisted of those children who were born on or after Feb 12, 1956, and thus had not reached their eighth birthday by mid-February 1964, the approximate midpoint of the study. This age break provided a contrast between young children known to have unusually high prevalence of respiratory disease and all older individuals. Limitations of the extent of the analysis precluded other age breaks.

Eight Years of Age and Over.—In this group are all those individuals whose birth date was before Feb 12, 1956, and thus had passed their eighth birthday by the midpoint of the study. In regard to smoking habits, the extremes were selected among adolescents and adults: those individuals 12 years or older at time of entry to study were divided among the following categories.

Heavy Cigarette Smokers.—These individuals smoked 20 or more cigarettes per day.

NONCIGARETTE SMOKERS.—These people had never smoked cigarettes.

The highest and lowest groups offered the greatest contrast in smoking habits. Inclusion of intermediate groups was desirable but not feasible.

Duration of Study.—Interviews were carried out over a period of nearly three years, less six weeks. The average stay of an individual in the study was 46 weeks.

Definition of Symptoms

Symptom-Days.—Interviewers trained by our staff visited each family once a week. He, or she, filled in a structured questionnaire according to answers given by one responsible adult, usually the mother, who responded for herself and for other members of the family. The precoded questions concerned the daily presence or absence of 21 symptoms of disease. The present analysis is concerned with only four of these symptoms: cough, eye irritation, "common cold," and headache, which were defined as follows.

Cough.—The question "Did you cough on this day?" was asked about all individuals except those who on first entering the study stated that they coughed regularly (called "chronic coughers"). The presence or absence of a cough was recorded for each day of the study.

Eye Irritation.—A positive answer to the question "Did you have itching, burning, or tearing of your eyes on this day?" is considered equivalent to eye irritation. This question was asked of the entire study population.

Common Cold.—A positive answer to the question "Did you have a cold any day this week?" was used. We have found that a "cold" is almost synonymous with rhinitis (or "runny nose"). The question was asked of the entire study population.

Headache.—The statement that a person had a headache on each day was used. The headache question was not asked for children 4 years old and under.

Prevalence.—A symptom-day consisted of one day on which one person answered "Yes" about a symptom. A person-day consisted of one day on which one person answered definitely "Yes" or "No," omitting indefinite or unknown answers. Thus the prevalence of a symptom is the ratio of symptom-days to person-days.

In this analysis, the association of combinations of each of these four symptoms with each of four air pollutants was studied.

Measurement of Pollutants

Air Pollution.—The concentration of each pollutant was measured at a monitoring station in the center of the half square mile in which the three groups lived. The pollutants analyzed consisted of particulate matter, carbon monoxide, total hydrocarbons, and sulfur dioxide. Hourly averages of continuous readings of each were recorded (except particulate matter which was averaged each two hours). They were measured as follows.

Particulate Matter.—This was measured in coefficient of haze (COH) units at roof level (189 feet) by smoke sampler—optical density of the spot produced by collecting the filtrate of a given volume of air. The source is chiefly burning of fossil fuels. Particles under 100μ in diameter only are collected; almost all of these are less than 10μ, and are relatively evenly dispersed. Particles in this size range are known to be capable of reaching the alveoli of the lung.

Total Hydrocarbons.—Total hydrocarbons, reported as parts per million of methane measured at third floor level (30 feet) consist almost entirely of methane. The source is principally from automobiles.

Carbon Monoxide.—Carbon monoxide (CO), measured in parts per million at third floor level comes from a combined source of furnaces and automobiles.

Sulfur Dioxide.—Sulfur dioxide (SO_2), measured in parts per million at third floor level, was determined by an SO_2 conductivity meter which is known to measure more than SO_2 alone, including reducing substances and sulfates. Any ionizing substances, a sulfur compound, or carbon dioxide present in the sample may alter the measurement.

The meter employs a conductivity method for the measurement of SO_2. On July 28, 1964 the electrical bridge in the meter was changed from selenium to germanium in an effort to improve the functioning of the machine. Subsequently it was discovered that the SO_2 values recorded after the change in the electrical bridge were different from those recorded before the alteration. Although initially a source of concern, it was possible to make the data obtained from the beginning of August 1964 comparable to the earlier data by the application of a carefully calibrated linear transformation.

The daily average of the 12 or 24 averages within the 24-hour period of each pollutant was the function used throughout this analysis.

Statistical Analysis

The method of statistical analysis was selected as one applicable to the nature of the variables under study: (1) a proportion

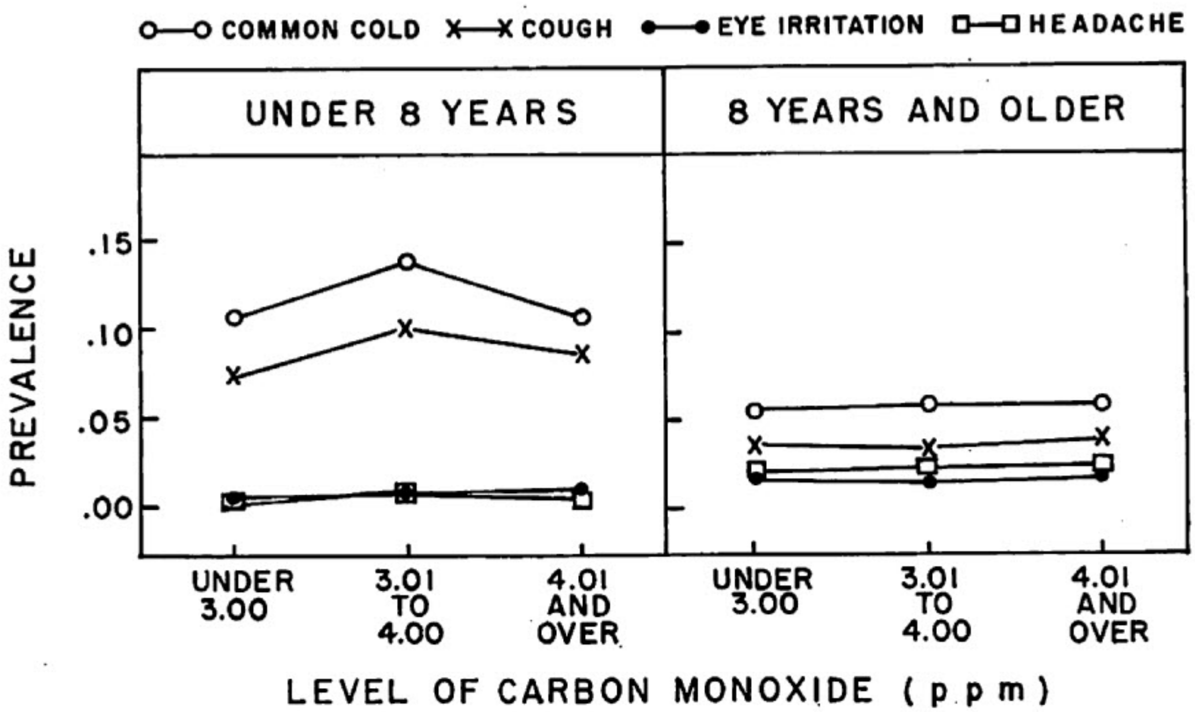

Fig 1.—Prevalence of four symptoms in young vs older individuals associated with level of CO.

(prevalence); (2) a continuous variable (pollutant concentration). Characteristically, any prevalence is a ratio consisting of a value lying between zero and 1 which can be expressed as zero and 100%, whereas pollutant levels can assume any value within a reasonable range. The method was chosen to answer the question: "Does the prevalence of a symptom vary measurably with the level of pollutant?", or, more specifically, "Is the trend which relates prevalence to increasing levels of pollutant a linear one?" Armitage[3] has supplied an appropriate analytic method with tests for the best fit of the linear relationship and, when a line fits, for the significance of the slope of the line. Whether the relationship is linear or not, we can evaluate whether a rise in pollutant level is associated with significant increase in prevalence.

Periodicity.—It has been reported by others[4] that the daily hospital admission rate shows a weekly cycle. We have also found, by autocorrelation analysis,[5] that prevalence of symptoms shows a weekly periodicity, independent of the well-known seasonal effects. Some pollutants showed a similar weekly cyclic effect.[4,6] Thus, to avoid complications from this effect, it was decided in this analysis to use a single day of the week for each run. Monday was selected as one of the more reliable days of reporting and yielded the greatest number of affirmative answers. Expansion to analysis of each day of the week would be desirable, but the requisite cost of computer time was prohibitive.

We have not yet determined to what extent the weekly periodicity of reported affirmative answers which were highest on Mondays reflects a truly higher prevalence of symptoms on this day of the week, or, alternatively, to what extent it might be influenced by the fact that family interviews were carried out at an interval of one week. Although a given family was interviewed on the same day of the week, the preponderance of interviewing was done on the first three weekdays, the last two days being used to catch up on missed interviews.

Persistence.—The fact that some symptoms, such as cough and common cold, characteristically show persistence must also be recognized. Thus, when accumulating total symptom-days, a common cold should contribute only once to the prevalence. Periods of heavy pollution also show a persistence which must be considered when tallying symptom-pollutant association. In an analysis by our group (unpublished data) of per-

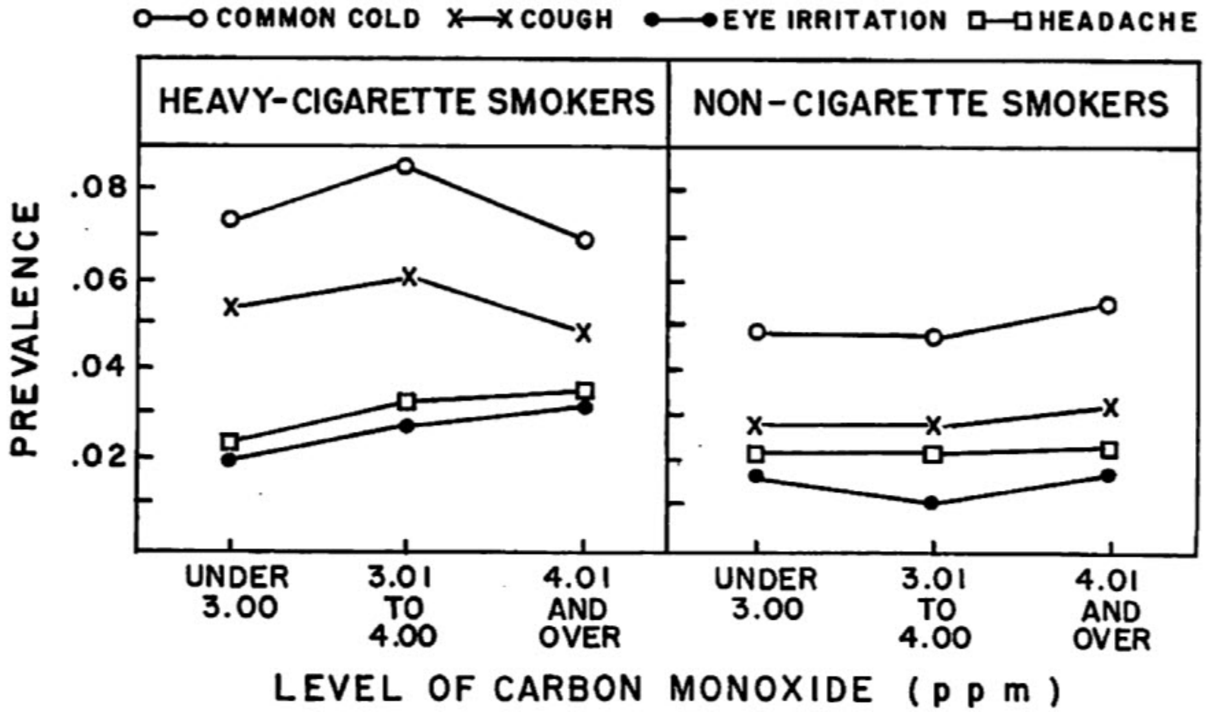

Fig 2.—Prevalence of four symptoms in heavy vs noncigarette smokers associated with level of CO.

sistence of common cold, only 1% of colds reported lasted seven days or more. Colds terminated abruptly after six days. We must consider that this phenomenon, like periodicity, may have been influenced, to a degree as yet unknown, by the practice of spacing the interviews at an interval of seven days, although questions about symptoms were specifically asked regarding each day.

Our decision to base the analysis on a single day of the week appears to circumvent complication due to periodicity and persistence. The method used could be extended to an independent analysis for each day of the week. Comparison of these analyses would provide another measure of the degree of periodicity observed within the week.

Comparison of Prevalence.—Table 1 shows prevalence of four symptoms as a ratio of the number of symptom-days to person-days available for study, by four subpopulation subgroups. The young children and the older group, under 8 years of age, and 8 years of age or older, respectively at the midpoint of the study, together comprise the entire study group. However, the subgroups according to cigarette smoking habit were selected among individuals 12 years of age or older as the extremes of heavy smokers and noncigarette smokers. Thus, this group did not include the total population in that age span. For each pollutant, only those days on which a reading was available were included (no substitutions were made for missing values). The start-up time for getting monitoring equipment into operation and intermittent down-time contributed to missing data. In Table 1, the data are based on particulate matter, for one plained above. For other pollutants, the amount of data was somewhat less, the least day of the week only (Monday), as exfrequent being for (CO), for which about 0.7 as many person-days were available as for the maximum number shown in the table.

A comparison of prevalence in young children vs the older group (Table 1) confirms the well-known observation that the prevalence of the respiratory symptoms, cough and cold, is greater in young children than in older individuals; the cut-off point at 8 years of age serves to emphasize this contrast. However, the prevalence of headache and eye irritation was found to be greater in the older group than in young children (for each comparison, $P < 0.001$). A similar comparison between smokers and nonsmokers

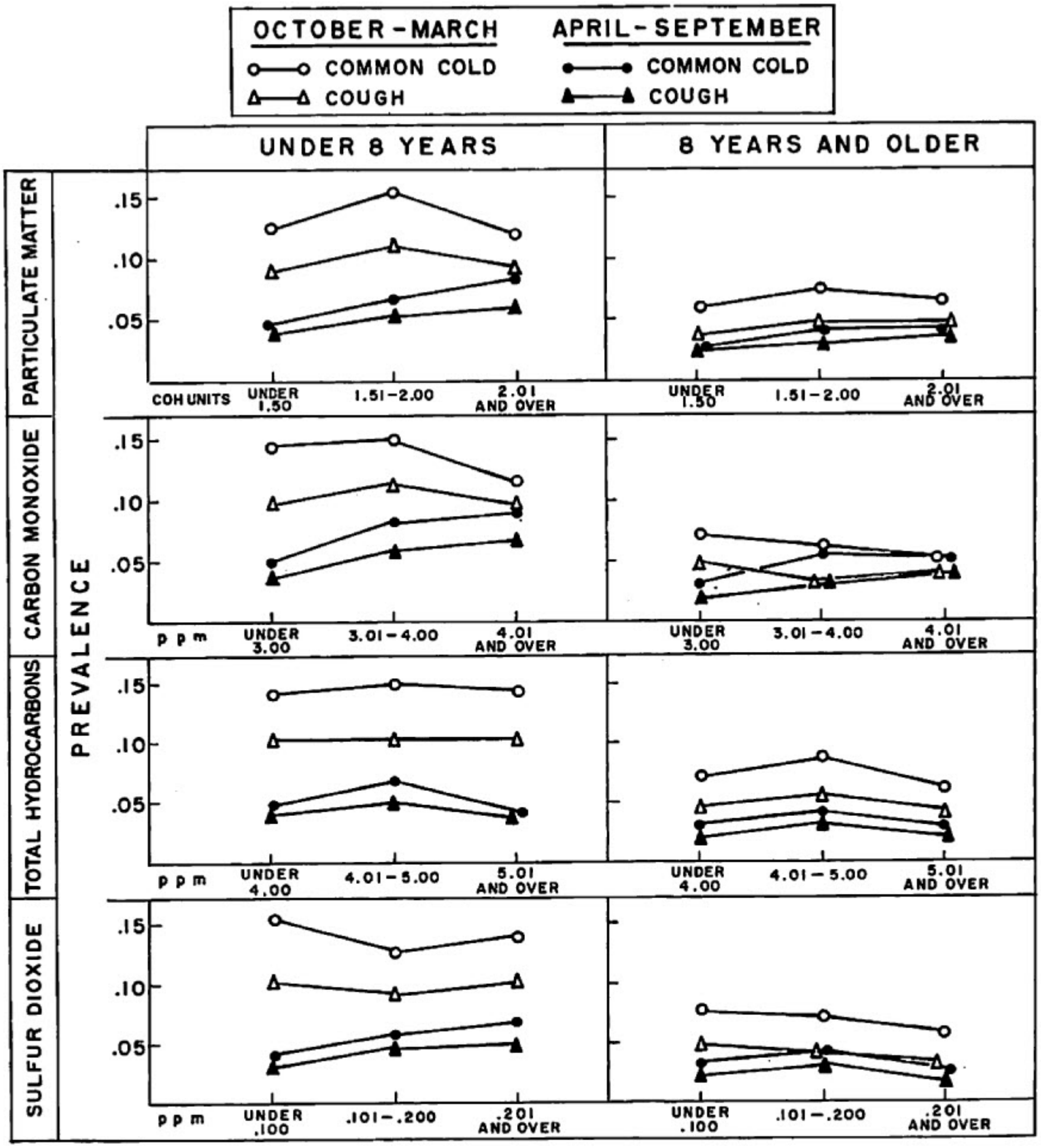

Fig 3.—Prevalence of respiratory symptoms in young vs older individuals associated with level of four pollutants; comparison by year-halves.

shows a higher prevalence of all four symptoms among heavy smokers ($P < 0.001$). The observation that the prevalence of cough and of common cold is significantly greater among heavy than among nonsmokers is a striking result, especially when considering the fact that self-designated "chronic coughers" have been removed as respondents to questions about coughing. A rough estimate of the proportion of people who declared themselves "chronic coughers" can be made from Table 1. Thus, among the heavy smokers a denominator of 7,063 person-days (Mondays) in response to the question about common cold can be compared to 5,632 person-days in answer to the question about cough, a loss of about 0.375 of the group, presumably based largely on the elimination of the "chronic coughers." No such loss was observed among nonsmokers. It is recognized that by selecting the group by smoking habits of those 12 years of age and older, we are

Table 1.—Prevalence of Four Symptoms in Four Subpopulations

	Cough	Common Cold	Eye Irritation	Headache
Under 8 years of age	840/10,789 = 0.078	1,130/10,685 = 0.106	86/11,141 = 0.008	20/4,446 = 0.005*
8 years of age and older	1,538/41,883 = 0.037†	2,458/43,799 = 0.056	743/44,390 = 0.017	1,052/43,947 = 0.024
Heavy cigarette smokers‡	302/5,632 = 0.054†	529/7,063 = 0.075	178/7,154 = 0.025	232/7,093 = 0.033
Noncigarette smokers‡	557/19,440 = 0.029†	945/19,324 = 0.049	310/19,608 = 0.016	465/19,402 = 0.024

* Children 4 years of age (and under) were not included in these counts.
† Chronic coughers were not included in these counts.
‡ Among individuals 12 years of age and older, heavy cigarette smokers are those who smoke 20 or more cigarettes a day; nonsmokers are those who have never smoked.

including teenagers, some of whom would not admit to smoking. Although we attempted to get these baseline data from each individual, the mother was often present during the interview. Thus the "never-smoked cigarettes" group may be artifically loaded with those who "for the record" never had smoked.

Relation of Prevalence to Pollutant Level.—The analysis consisted of inspecting the concentration of a given pollutant for each day included, and ordering the days according to the concentrations of the pollutant, thus generating a frequency distribution. The days were then grouped according to pollutant concentration in such a way that the number of days in each of three level-groups was approximately equal. For the days within one level, a pooled prevalence was constructed from the ratio of symptom-days: person-days; that is, "Yes" answers: "Yes" plus "No" answers, for all Mondays at this level. By this means, the relationship of prevalence of symptoms to level of pollutant could be assessed. The necessary programs were written by one of us (I.M.M.) to carry out the analysis of this large mass of data with the aid of computers.

First, the entire three-year period was scanned. Later, seasonal adjustment was included in the analysis, by dividing the year into two halves centered on "winter" and "summer," October through March, and April through September, respectively.

Analysis.—*Four Subpopulations by Four Symptoms by Four Pollutants for Entire Period.*—In Table 2 has been tabulated for young children under 8 years of age vs all older individuals for the prevalence of the symptoms—cough, common cold, eye irritation, and headache—associated with three levels of each of the four pollutants—particulate matter, CO, total hydrocarbons, and SO_2—for the entire three-year period. For one of these pollutants, CO, the same data have been graphed in Fig 1. Most conspicuous is the well-known higher prevalence of coughs and colds in young children than in older individuals ($P < 0.001$). Furthermore, the relatively low prevalence of eye irritation and of headache (especially in young children) compared to that of the respiratory symptoms is striking. As for the pattern of relationship to pollutant level, clearly the prevalence of headache and of eye symptoms in both young children and older individuals is independent of the level of each pollutant. For cough, as well as common cold, the "hump" illustrated in Fig 1, with maximum prevalence corresponding to midlevels of pollutant concentration will be discussed in the light of the analysis following further breakdown.

Table 3 shows similarly for heavy and for noncigarette smokers the prevalence of symptoms associated with the three levels of each of the four pollutants. An example of the same data in association with CO has been graphed in Fig 2.

Among the four subpopulations (Tables 2 and 3), prevalence of headache and eye irritation appeared in most cases to be independent of level of pollutant. The prevalence of these two symptoms was relatively low, usually 1% to 2%, in the majority of the subpopulations, although among heavy smokers, a prevalence of headache of more than 3% was found scattered in association with various levels of the four pollutants. A prevalence of eye irritation of more than 3%

Table 2.—*Prevalence of Four Symptoms in Young Children and Older Individuals Associated With Levels of Four Pollutants*

		Under 8 Years of Age				8 Years of Age and Older			
Pollutant	Concentration	Cough†	Common Cold	Eye Irritation	Headache*	Cough†	Common Cold	Eye Irritation	Headache
Particulate	Under 1.50	0.053	0.071	0.008	0.005	0.027	0.042	0.019	0.024
matter	1.51 to 2.00	0.102	0.141	0.008	0.003	0.042	0.069	0.016	0.025
(COH units)	2.01 and over	0.087	0.116	0.008	0.006	0.042	0.062	0.015	0.024
	Under 3.00	0.074	0.109	0.006	0.002	0.036	0.055	0.016	0.020
Co (ppm)	3.01 to 4.00	0.103	0.138	0.008	0.009	0.035	0.060	0.015	0.024
	4.01 and over	0.087	0.109	0.012	0.005	0.040	0.059	0.020	0.025
Total	Under 4.00	0.095	0.124	0.009	0.005	0.041	0.065	0.017	0.025
hydrocarbons	4.01 to 5.00	0.073	0.102	0.009	0.001	0.042	0.060	0.019	0.024
(ppm)	5.01 and over	0.069	0.088	0.005	0.006	0.031	0.046	0.017	0.022
	Under 0.100	0.068	0.096	0.010	0.005	0.035	0.052	0.018	0.025
So_2 (ppm)	0.101 to 0.200	0.080	0.106	0.006	0.003	0.039	0.063	0.016	0.023
	0.201 and over	0.088	0.120	0.008	0.005	0.035	0.052	0.016	0.023

* Children 4 years of age and under were not included in these counts.
† Chronic coughers were not included in these counts.

was found only among heavy smokers, associated with the highest levels of CO. The exceptions to independence were found among heavy smokers: the prevalence of headache and eye irritation bore a true linear relationship to the level of CO. Although the range of prevalence was not great, the slope of each line was significant ($P < 0.05$). These relationships and others among heavy and nonsmokers are represented graphically in Fig 2 with respect to CO.

These results for the entire period served to give perspective as to which variables might be pursued most profitably. The next step in the analysis consisted in modifying the program to compare the results after separation into two halves of the year. Since prevalence of eye irritation was low, any further subdivision of this symptom was not considered worthwhile. Also, further analysis by seasonal breakdown of the relatively small subpopulations by smoking habit was discontinued.

Young Children vs Older Individuals by Two Symptoms by Four Pollutants by Two Half Years.—The prevalence of cough and common cold in children under 8 years of age vs all older individuals was analyzed according to levels of pollutant concentration. Each half year centered on winter or summer, as defined above. Figure 3 depicts the outcome of analysis for young children and for the older group, respectively. The pattern of cough was similar to that of common cold in relation to pollutant. However, the prevalence of common cold was consistently, and proportionately, greater than that of cough. Outstanding in the comparison between winter and summer are the all-too-familiar winter cold and cough in young children. Furthermore, the pattern of association differs between winter and summer. Among the pollutants, the more striking results occur in association with particulate matter and with CO which are similar. (*1*) In summer, a direct linear relationship with significant slope obtains. This relationship, present but not marked for the older group, was more striking and highly significant for young children ($P < 0.01$). (*2*) In winter, for young children, a "hump" in the line indicates a peak of prevalence in the midlevel of pollutant. For the older group, no consistent relationship holds, prevalence being essentially independent of pollutant level although a "hump" was observed at midlevel of particulate matter associated with maximum prevalence of common colds. The greater association of particulate matter with colds than SO_2 with colds in adults is consistent with the findings of Angel et al.[7] Greenberg et al[8] also reported significantly increased clinic visits for upper respiratory illness in hospitals in New York city during the November 1953 pollution episode when smoke shade and SO_2 levels rose sharply. For the other two pollutants, total hydrocarbons and SO_2, no simple pattern is descriptive. Essentially, there is little relationship between pollutant level and prevalence in

Table 3.—Prevalence of Four Symptoms in Heavy and Noncigarette Smokers Associated With Levels of Four Pollutants

		Heavy Cigarette Smokers*				Noncigarette Smokers*			
Pollutant	Concentration	Cough†	Common Cold	Eye Irritation	Head-ache	Cough†	Common Cold	Eye Irritation	Head-ache
Particulate matter (COH units)	Under 1.50	0.043	0.060	0.024	0.030	0.023	0.038	0.021	0.027
	1.51 to 2.00	0.063	0.091	0.026	0.034	0.033	0.059	0.015	0.024
	2.01 and over	0.057	0.078	0.025	0.035	0.032	0.053	0.011	0.021
Co (ppm)	Under 3.00	0.055	0.074	0.020	0.025	0.028	0.049	0.017	0.022
	3.01 to 4.00	0.061	0.086	0.028	0.034	0.028	0.048	0.012	0.022
	4.01 and over	0.049	0.070	0.032	0.036	0.032	0.055	0.018	0.024
Total hydrocarbons (ppm)	Under 4.00	0.056	0.080	0.025	0.034	0.035	0.061	0.017	0.024
	4.01 to 5.00	0.058	0.069	0.025	0.030	0.034	0.058	0.020	0.029
	5.01 and over	0.040	0.053	0.025	0.026	0.024	0.039	0.018	0.024
SO_2 (ppm)	Under 0.100	0.043	0.061	0.026	0.036	0.027	0.044	0.018	0.027
	0.101 to 2.00	0.071	0.092	0.020	0.025	0.029	0.057	0.016	0.026
	0.201 and over	0.052	0.071	0.027	0.037	0.029	0.045	0.014	0.020

* Among individuals 12 years of age and older, heavy cigarette smokers are those who smoke 20 or more cigarettes per day; noncigarette smokers are those who have never smoked cigarettes.

† Chronic coughers were not included in these counts.

young children and in the older group. For the older group in winter, a linear relationship is obtained with SO_2, but increasing levels of pollutant are associated with decreasing prevalence!

Comment

A variety of patterns of association of prevalence with level of pollutant emerges from this study. Of least interest are those in which prevalence appears to be independent of level of pollutant; of greater interest are the clear-cut patterns found in the association, ie, for young children in summer, between prevalence of cough (and of common cold) and level of each of the two pollutants, particulate matter and CO. At this ebb tide of respiratory symptoms, a direct linear relation holds (prevalence rises as pollutant level increases). At the flow tide in winter for young children, however, the relationship is far more important since the number of coughs and colds reported is far more numerous, ranging from 3.2 to 3.6 times as many as in summer. For this half of the year, a "hump" in the line occurs, prevalence rises as pollutant rises from lower third to midlevel, but again declining to its lower value as the highest third level of pollutant is reached. An interpretation of this pattern might be that the prevalence of respiratory symptoms in young children is associated with level of each of these two pollutants, among other factors. Thus the prevalence rises as the level of the pollutant increases up to a point, but not beyond the midrange for the pollutant level. In light of this nonlinear outcome, application of a transformation (such as angular, logit, or probit) might prove valuable. Beyond the midpoint of pollutant level, perhaps another environmental factor, or factors, becomes important, such as another pollutant, or ambient air temperature which is known to influence respiratory symptoms, especially in winter.[9] Dohan[10] demonstrated a highly significant correlation between the levels of particulate sulfates among five cities and the incidence of respiratory disease of more than seven days duration in working women. Zeidberg et al[11] found significant correlations between total morbidity and levels of soiling index and 24-hour SO_2 level, most marked among housekeeping white women over 55 years of age. In children (averaging about 5 years of age) in Great Britain, Lunn et al[12] observed a very strong association with levels of smoke shade and SO_2.

Since we have not yet tested the effect of time lag, another possible interpretation remains. Ipsen in a related study (unpublished data) found that application of lag did not clarify a similar relationship. Further comprehensive analysis by Ipsen (unpublished data) explained why the effect of lag is not highly essential. The high prevalence associated with the midrange of pollutant level might be caused by the measuring of the shoulder of a prior peak of pollutant level which had occurred, perhaps two to three days earlier. We are aware that by simultaneously testing prevalence and level of pollutant, we are depending to some extent on the persistence of pollutant level preceding the symptom reported. The symptom, if associated temporally with pollutant, must have occurred at some time following an environmental effect, whether a peak, a sudden change, or an unusual accumulation of pollutant. Thus our method as carried out so far might reveal an association but could not maximize the time relationship. Furthermore, we are not telling the whole story unless the incubation period required by respiratory disease of infectious origin is recognized.[13] For this, we are once more dependent on persistence of pollutant level, if indeed an unusual pollutant event triggered the pathogenic process in an individual already infected. The introduction of time lag, beyond the scope of this paper, is essential to determine the condition of maximum association in time.

The problem still to be solved is which combination of multiple factors are most strongly associated with prevalence of these symptoms. The approach described here could be extended to at least two environmental factors simultaneously. For example, is the maximal prevalence associated with highest levels of particulate matter or of CO and lowest temperature? For a large number of variables, a multivariate analysis will be reported soon.

The analysis described here has been based on symptoms and pollutant data drawn from one day of the week (Monday). Two primary considerations prompted the choice of analysis by a single day rather than including all days of the week. First, a weekly periodicity is recognized for symptoms as well as for pollutants.[4-6] The periodicity of both variables is undoubtedly related to the weekly pattern of urban life. For example, at the end of the working week, many factory furnaces are shut down; automobile driving habits differ markedly from weekdays to weekends. But we do not know whether the prevalence cycle is dependent on the cyclic pollutant level or whether both cycles are based on other extraneous causes. In this study, the weekly periodicity which would tend to show association has been circumvented by using one day of the week only. This is a conservative approach, since we are then asking the question: "Is there an association over and beyond that attributable to the weekly cycle?" Second, by the nature of the persistence of a symptom, the observation for one day is not independent of that for the next day. But we have learned from studying the distribution of duration of symptoms in this study that, for example, a common cold as reported here seldom lasts more than six days. Similarly, minor pollutant episodes usually last not more than a few days. Thus observations at an interval of seven days can be considered essentially independent.

Conclusions

This analysis presents a statistical approach to assess the effect of each of several pollutants on health of urban families living in lower- and middle-income housing on the lower East Side of New York city.

First, prevalence of the four symptoms—cough, common cold, headache, and eye irritation—was evaluated in young children (under 8 years of age) compared to all individuals eight years of age and older; in heavy cigarette smokers compared to noncigarette smokers (among individuals 12 years of age and older).

In young children, respiratory symptoms were significantly more prevalent than in older individuals, but headache and eye irritation were more prevalent in the older group. In heavy smokers the prevalence of all four symptoms studied was significantly higher than in nonsmokers.

Next, the relationship of these prevalences to levels of four pollutants was analyzed. The pollutants were particulate matter, CO, total hydrocarbons, and SO_2. A notable relation at this point of the analysis was found among heavy cigarette smokers; prevalence of eye irritation and headache rose in a direct linear relation with increasing levels of CO. Any comment on this association would be speculation at this point, but this observation may provide a valuable lead. Are heavy cigarette smokers more prone to the effect of CO? Would they provide a "susceptible" group for further study?

Because of known seasonal effect, the year was broken into two halves, centering on winter (October through March) and summer (April through September). Prevalence of respiratory symptoms in young children and in older individuals were compared for the two year-halves. Although no single pattern appeared to represent an association between prevalence of each of the symptoms and level of each pollutant, several types of patterns emerged.

The summer pattern of prevalence of respiratory symptoms bore a linear relation to level of each of the two pollutants, particulate matter and CO. The prevalence increased as the pollutant level increased. Essentially true for the older group, the relationship was more striking for young children. For the winter half of the year, in the older group, the prevalence of respiratory symptoms showed no interesting or consistent relation to level of CO and of particulate matter. However, in young children a "hump" on the curves indicated an increased prevalence corresponding to increases in levels of the two pollutants from lowest to midlevels; but with further increase in pollutant levels, a return in prevalence to that associated with lowest levels of pollutant. Interpretation of the "hump" has been discussed.

For the other two pollutants, total hydrocarbons and sulfur dioxide, in both winter and summer halves of the year, prevalence of respiratory symptoms was independent of level of pollutant.

Although no unifying pattern emerges to describe the relation of prevalence of each symptom to level of pollutant, some prevailing patterns may serve as a guide to further analysis.

This study was supported by the Health Research Council of the City of New York, contract U-1155, and the Division of Air Pollution, Public Health Service grants AP-00547 and AP-00266. Mr. Joseph J. Troia assisted in the programming and data processing. Data on air pollution were provided for this study by William T. Ingram. The report in reference 6 can be obtained on request from the Department of Public Health and Preventive Medicine, University of Pennsylvania School of Medicine, Philadelphia.

References

1 McCarroll, J.R., et al: Health and the Urban Environment: I. Design for Study, *Arch Environ Health* 10:357-363 (Feb) 1965.

2. McCarroll, J.R., et al: Health and the Urban Environment: IV. Health Profiles Versus Environmental Pollutants, *Amer J Public Health* 56:266-275 (Feb) 1966.

3. Armitage, P.: Test for Linear Trends in Proportions and Frequencies, *Biometrics* 11:375-386 (Sept) 1955.

4. Sterling, T.D., et al: Urban Morbidity and Air Pollution, *Arch Environ Health* 13:158-170 (Aug) 1966.

5. McCarroll, J.R., et al: Air Pollution and Illness in a Normal Urban Population, read before the Air Pollution Medical Research Conference of the American Medical Association, Los Angeles, March 2 to 4, 1966.

6. Ipsen, J.: *Relationships of Acute Respiratory Disease to Measurements of Atmospheric Pollution and Local Meteorological Conditions,* Final Report, Contract PH 86-63-25, March 1965.

7. Angel, J.H., et al: Respiratory Illness in Factory and Office Workers, *Brit J Dis Chest* 59:66-80 (April) 1965.

8. Greenberg, L., et al: Air Pollution and Morbidity in New York City, *JAMA* 182:161-164 (Oct 13) 1962.

9. Lidwell, O.M.; Morgan, R.W.; and Williams, R.E.O.: The Epidemiology of the Common Cold: IV. The Effect of Weather, *J Hyg* 63:427-439 (Sept) 1965.

10. Dohan, F.C.: Air Pollution and Incidence of Respiratory Disease, *Arch Environ Health* 3:387-395 (Oct) 1961.

11. Zeidberg, L.D.; Prindle, R.A.; and Landau, E.: The Nashville Air Pollution Study: III. Morbidity in Relation to Air Pollution, *Amer J Public Health* 54:85-97 (Jan) 1964.

12. Lunn, J.E.; Knowelden, J.; and Handyside, A.J.: Patterns of Respiratory Illness in Sheffield Infant Schoolchildren, *Brit J Prev Soc Med* 21:7-16 (Jan) 1967.

13. Fox, J.P., et al: The Virus Watch Program: A Continuing Surveillance of Viral Infections in Metropolitan New York Families: I. Overall Plan, Methods of Collecting and Handling Information and a Summary Report of Specimens Collected and Illnesses Observed, *Amer J Epidem* 83:389-412 (May) 1966; II. Laboratory Methods and Preliminary Report on Infections Revealed by Virus Isolation, 83:413-435 (May) 1966; III. Preliminary Report on Association of Infections With Disease, 83:436-454 (May) 1966.

Printed and Published in the United States of America