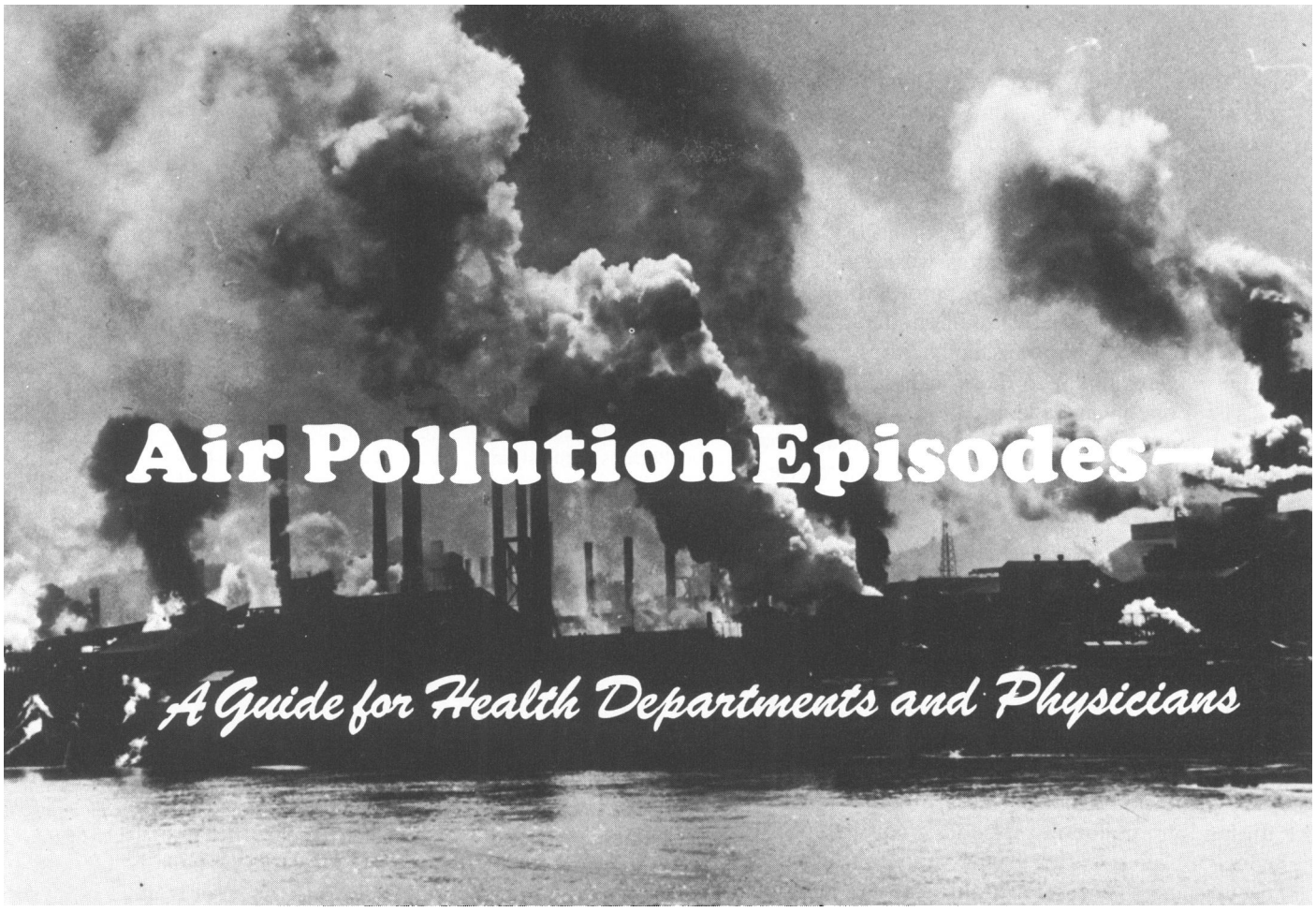

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THE EFFECTS of air pollution on health and comfort have recently been receiving popular and scientific concern. In Belgium in 1930 (*1, 2*), in Donora, Pa., in 1948 (*3–6*), and in London in 1952 (*7–10*), periods of excessive air pollution occurred. Episodes of extremely high pollution lasting several days still occur occasionally, especially in larger cities. They cause some deaths, speed others, and make many of those exposed ill or uncomfortable. In these episodes, the local health department and the practicing physician have important roles to play.

Effects of Air Pollution Episodes

The episode of air pollution that occurred in Belgium in 1930 (*1, 2*) was the first one to be closely studied. The major symptoms observed were cough, dyspnea, wheezing, chest and rib pain, nausea and vomiting and, in the most severely affected, shock and death. Autopsies revealed extensive irritation and inflammation of mucous membranes, especially in the lungs, and frequent evidence of heart failure.

During the 5-day episode in Donora (*3–6*), 20 persons died, although only one or two deaths would have been expected during that interval. More than 40 percent of the general population (more than 5,900 persons) had symptoms, often on the very first day of the smog. If the same mortality and morbidity rates were applied to a city the size of New York, more than 10,000 deaths and more than 3 million illnesses would have occurred. Symptoms and autopsy results in Donora were similar to those in Belgium.

The London episode of 1952 (*7–10*) caused 4,000 more deaths than would normally have been expected. The mortality rate began to rise on the first day of the smog.

Studies of several subsequent episodes in London and in New York City clearly demonstrate that air pollution episodes lasting several days are accompanied by increases in mortality, in symptoms, or in frequency of clinic visits among certain groups of susceptible patients, especially those with cardiovascular or respiratory disease.

In short, information from clinical, autopsy, and mortality studies demonstrates that (*a*) there is excess mortality and cardiorespiratory morbidity during air pollution episodes, (*b*) the health effects of air pollution begin as soon as the smog occurs, and (*c*) certain groups are far more susceptible than others to the effects of these episodes.

Susceptible Groups

During or after each major episode in Donora (*3–6*), London (*7–12*), and New York (*13–17*), mortality records were tabulated by age, cause of death, and contributing illness. In Donora, one-third of the city's population was personally interviewed. After certain episodes, emergency room records, clinic records, and diaries of symptoms were scrutinized. The conclusions of these studies were that persons with the following characteristics or diseases were most at risk.

The elderly. During the Donora episode, a disproportionate number of residents over 65 became ill. Morbidity in selected groups in Donora during the air pollution episode of 1948 was as follows:

Population at risk	*Percent affected*
Total population	42.7
Mildly affected	15.5
Moderately affected	16.8
Severely affected	10.4
Persons with asthma	88.0
Severely affected	50.1
Persons with bronchitis	78.9
Persons over 65 years	60.0
Patients with cardiac disease	77.2

Asthma, bronchitis, or emphysema. In Donora, persons with asthma and chronic bronchitis became ill twice as frequently and severely ill five times as frequently as the general population. During the London episode, the death rate from bronchitis was up by 638 percent; that for pneumonia was up by 300 percent.

Coronary artery and other cardiac disease. In Donora, patients with cardiac disease became ill almost twice as frequently as previously healthy persons. In London, the death rate for myocardial infarction during the 1952 episode was up by 73 percent. In Donora, all of those hospitalized and most of those who died had antecedent pulmonary or cardiac disease.

Other groups. Increased risk from air pollution has been suggested, but not proved, for premature infants, newborn infants, postoperative patients, patients with cancer, patients with congenital heart disease, and persons with anemia. Clearly, preventive and protective measures should be directed especially toward these groups.

Guide for the Health Department

The health department's responsibilities in air pollution crises are four:

1. Defining a "crisis" and knowing when one is imminent or occurring
2. Maintaining effective lines of communication with hospitals, local practitioners, and the public and assuring that pertinent advice is available
3. Coordinating studies of health effects during and after the episode
4. Helping local governments to devise and implement a plan for abatement when episodes occur.

Defining the Problem

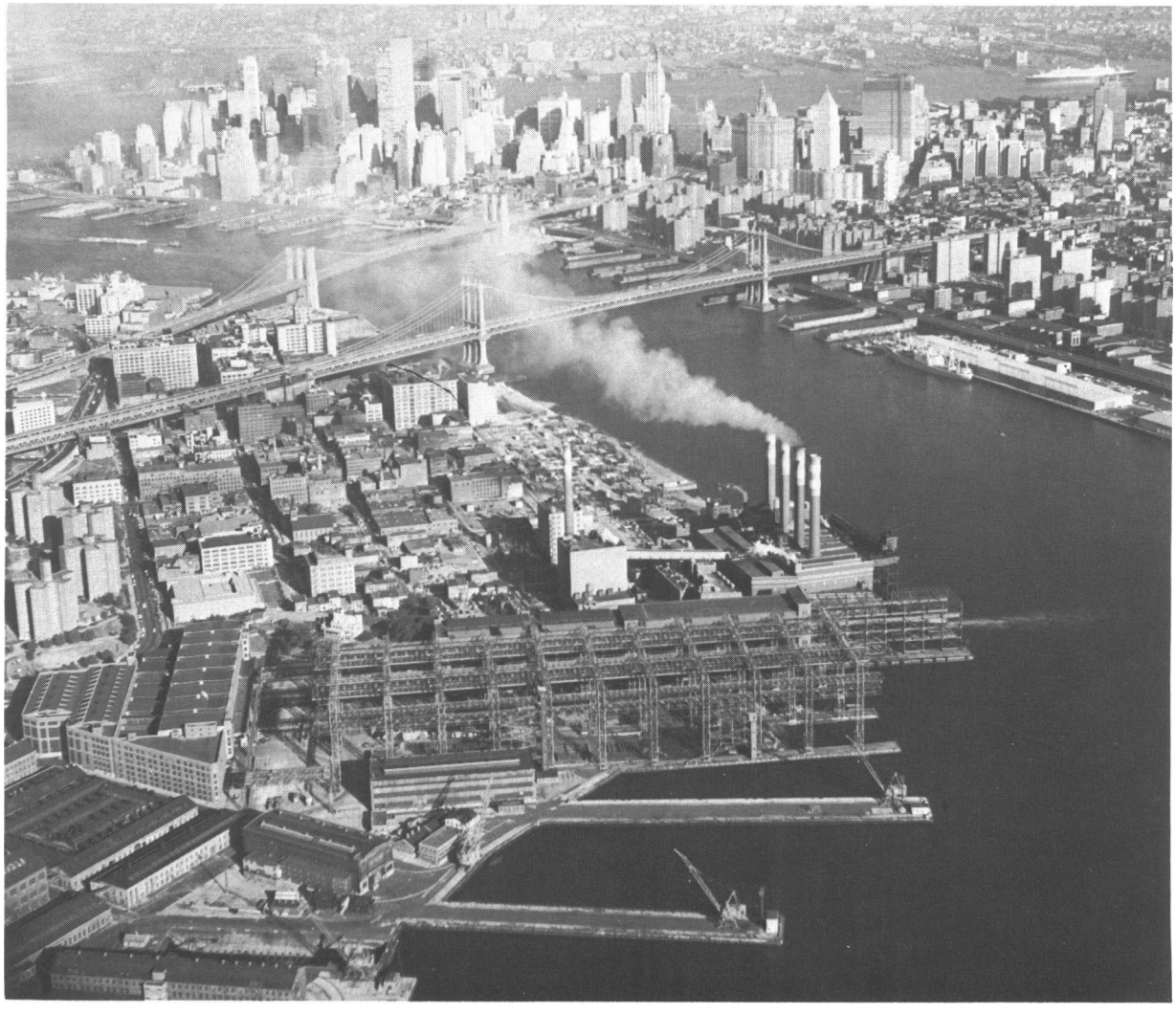
One definition of an air pollution crisis, drawn from the Air Quality Act of 1967 (*18*), is "a situation in which pollution presents an imminent and substantial endangerment to the health of per-

sons." Data currently available on the adverse effects of air pollution on health, however, do not pinpoint the offending pollutants, the pollutant concentration, or the duration of exposure at which "substantial endangerment" begins.

Although the direct irritant nature of air pollution during episodes is obvious, the specific chemical identity of the atmospheric pollutants responsible for the excess mortality has not yet been established. Sulfur dioxide, particulate matter, hydrocarbons, nitrogen oxides, and carbon monoxide are all commonly emitted in urban areas. When an episode occurs, the concentration of all pollutants generally rises so that it is impossible to be certain which pollutant or combination of pollutants is the prime offender.

British researchers (*11*) state that average values of 0.4 p.p.m. of SO_2 (sulfur dioxide) and 2 mg. per cubic meter of smoke for 24 hours are the minimum exposure-duration values responsible for excess mortality. Others, however, have shown changes in mortality rates at daily SO_2 averages of 0.2 p.p.m. or less, especially when cold waves coincided with periods of excessive pollution (*17*). Moreover, in certain susceptible populations (the elderly or persons with asthma, bronchitis, emphysema, or coronary artery disease), significant morbidity has been associated with pollution levels one-fifth to one-twentieth the magnitude cited by British workers as contributing to mortality (*19, 20*).

Also, in morbidity studies themselves, estimates of pollution thresholds for undesirable health effects vary widely. Zeidberg and associates, for example, found significantly more asthmatic episodes in their study population on days when the



New York City industrial pollution from Consolidated Edison smokestacks. View from Brooklyn, October 1966. *Photo, Sign X Labs, Inc., Essex, Conn.*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average daily SO_2 concentration exceeded approximately 0.01 p.p.m. (*19*). Cohen and associates found a significant increase in the number of asthmatic attacks only when the daily SO_2 averages reached 0.08 p.p.m. or greater (*20*). Schoettlin and co-workers found no association between the asthma attack rate and oxidant concentrations less than 0.25 p.p.m. (*21*). Greenberg and co-workers observed no increase in visits by patients with asthma to New York City hospital emergency rooms during an episode of high pollution in which SO_2 concentrations averaged at least 0.3 p.p.m. for 3 days (*14*).

The "critical," or "trigger" pollution-stagnation value at which a crisis should be called should, of course, be substantially less than that at which increased mortality has been documented. The inconclusiveness of studies to date, however, contributes to the dilemma that appears when one must decide precisely how low the "alert" value is to be set. Establishing the "critical" value at the pollution level indicated by some researchers as contributing to illness would keep several major cities in a state of alert more often than out of it. The result would be protracted loss of those essential services curtailed during implementation of an abatement plan (for example, electric power production and garbage incineration).

A reasonable solution is to make the criterion of critical value a combination of weather and pollution conditions and to set the pollution trigger value well below the level of pollution known to cause an increase in mortality and as low as is practically possible, given the locality's need for the services whose delivery raises pollution levels. As further studies pinpoint the dose-response curve for common pollutants, the criteria can be updated and steps taken to assure that pollution levels do not frequently reach crisis proportions.

Two sample standards, one currently in use in New York City (*22*), the other recommended by the Air Pollution Control Office, Environmental Protection Agency, are presented here as guidelines (see next page). A "forecast" is called when it appears that highly stagnant weather conditions will obtain for at least 36 hours. The episode may then progress to an "alert," a "warning," or an "emergency," depending on the pollution levels reached. Sulfur dioxide (SO_2), carbon monoxide (CO), total oxidants (O_x), and particulate matter, measured as a coefficient of haze (COH) or in reflectance units of dirt shade (RUDS), are the indicator pollutants for these alert systems.

Heavy New York City traffic, 1964.
Photo Dan McCoy, Black Star

Once definitions are settled, provision must be made for the continuous collection and coordination of weather and pollution data so that crisis situations can be recognized as they begin to arise. In places without air surveillance programs, simple networks should be set up. In places where health departments and air pollution agencies are separate, close communication must be arranged.

Lines of Communication

During acute air pollution episodes many persons may become sick and some may become alarmed. The health department staff should be prepared to offer specific guidelines to physicians, hospitals, and the general population in a calm, informed fashion.

Before an episode occurs, arrangements should be made with the local news media and hospital officials for immediate transmission of information on worsening air quality. Publications detailing the measures to be taken should be made available to the news media and interested groups as well as to physicians and the general population. Such publications should emphasize the physicians' need to be aware of the added burden to their patients of a respiratory irritant so that they can vigorously treat and carefully observe the most susceptible ones. The publications should also make hospitals aware that during episodes an unusually large number of emergency admissions for respiratory disease is likely, so that some elective admissions might be held off and elective surgery delayed. The possible contribution to the patients' health of pollution-abatement devices in air conditioning systems should be mentioned.

In addition to facilitating optimal care for patients, close communication between the physician and the health department will prove helpful when cooperation is needed for studies of health effects.

Studies of Health Effects

The health department should be prepared to assess the health effects of an episode while it is in progress and do more complete studies afterward. Many kinds of studies have been tried with

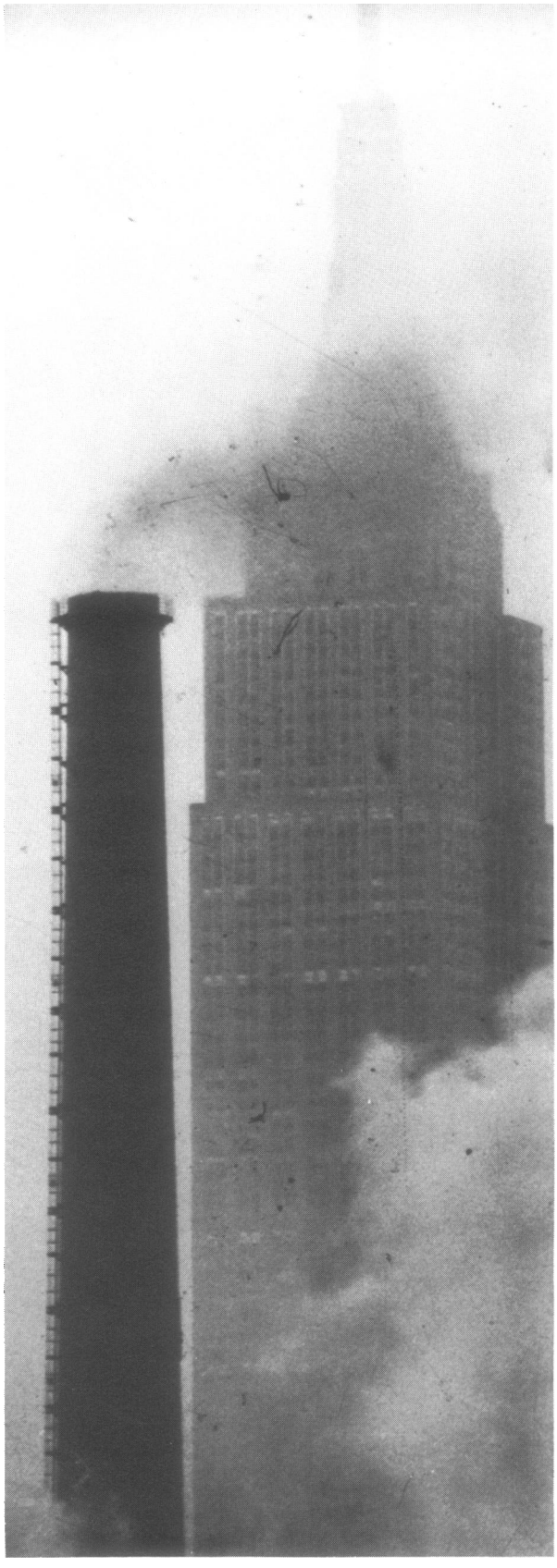
COMPARISON OF CRITERIA FOR AN AIR POLLUTION EPISODE, AIR POLLUTION CONTROL OFFICE AND NEW YORK CITY

STAGE	CONDITION	
	AIR POLLUTION CONTROL OFFICE	**NEW YORK CITY**
FORECAST	Likelihood that highly stagnant weather conditions will be present for at least 36 hours	Likelihood that highly stagnant weather conditions will be present for at least 36 hours
ALERT	Adverse weather conditions likely to continue for 12 hours ***and*** 1 or more of the following: 24 hr. $SO_2 > 0.3$ p.p.m. 24 hr. COH > 3.0 COH 24 hr. COH $\times$ 24 hr. $SO_2 > 0.2$ 8 hr. CO > 15 p.p.m. 1 hr. $O_x > 0.1$ p.p.m.	Adverse weather conditions likely to continue for 12 hours ***and*** 1 or more of the following: 6 hr. $SO_2 > 0.33$ p.p.m. with 6 hr. RUDS > 4.25 RUDS per 1,000 ft. 6 hr. CO > 30 p.p.m. 24 hr. $SO_2 > 0.25$ p.p.m. with 24 hr. RUDS > 4.05 RUDS per 1,000 ft.
WARNING	Adverse weather conditions likely to continue for 12 more hours ***and*** 1 or more of the following: 24 hr. $SO_2 > 0.6$ p.p.m. 24 hr. COH > 6 COH 24 hr. COH $\times$ 24 hr. $SO_2 > 1.0$ 8 hr. CO > 30 p.p.m. 1 hr. $O_x > 0.4$ p.p.m.	Adverse weather conditions likely to continue for 12 more hours ***and*** 1 or more of the following: 6 hr. $SO_2 > 0.5$ p.p.m. with 6 hr. RUDS > 4.25 RUDS per 1,000 ft. 6 hr. CO > 50 p.p.m. 24 hr. $SO_2 > 0.375$ p.p.m. with 24 hr. RUDS > 4.05 RUDS per 1,000 ft.
EMERGENCY	Adverse weather conditions likely to continue for 12 more hours ***and*** 1 or more of the following: 24 hr. $SO_2 > 1.0$ p.p.m. 24 hr. COH > 10 COH 24 hr. $SO_2 \times$ 24 hr. COH > 2.4 8 hr. CO > 50 p.p.m. 4 hr. CO > 75 p.p.m. 1 hr. CO > 125 p.p.m. 4 hr. $O_x > 0.4$ p.p.m. 2 hr. $O_x > 0.6$ p.p.m. 1 hr. $O_x > 0.7$ p.p.m.	Adverse weather conditions likely to continue for 12 more hours ***and*** 24 hr. $SO_2 > 0.625$ p.p.m. with 24 hr. RUDS > 9.1 RUDS per 1,000 ft.

SUMMARY OF ABATEMENT PLAN OF NEW YORK CITY FOR AIR POLLUTION EPISODES

ACTION

City	*Industry*	*Citizens*
Decrease all garbage burning by 10-20 percent. Prepare to store garbage. Discontinue burning on barges. Examine fuel burners to assure optimum performance.	Prepare to convert to gas or fuels with sulfur content of 1 percent or less.	Prepare to store garbage.
Discontinue burning at 5 city incinerators. Discontinue incineration at all city departments.	Must use gas or fuels with sulfur content of 1 percent or less.	Stop all private incineration.
Discontinue burning at 4 more city incinerators. Prepare to discontinue use of all but essential motor vehicles.	Reduce industrial emissions 25-50 percent.	Prepare to discontinue use of nonessential motor vehicles.
Stop all city incineration. Prohibit all motor vehicular movement except for fire fighting, police, and medical purposes.	Reduce emissions 50-75 percent. Prepare to shut down.	Decrease nonessential use of electricity or heat. Prohibit motor vehicle use except for emergencies.



varying success. Following are some of the health indicators analyzed in past episodes.

Mortality rates. A substantial period after each studied episode, death certificates were examined for the period of excessive pollution as well as for control periods of low pollution (*9, 14, 16, 17*). Mortality rates during control periods were used to compute figures for "expected mortality," and the difference between the expected and observed mortality was called "excess mortality." All such studies in the literature are retrospective; "expected mortality," however, can be calculated for each day of the year before an air pollution episode occurs so that significant conclusions can be drawn from daily mortality figures during the crisis.

There are, however, three major drawbacks to using analyses of mortality. First, there is no standard method for calculating "excess mortality." For one episode in New York City in 1963 (*16*), the use of different control periods in calculating expected mortality produced "excess mortality" figures ranging from 195 to 809. Second, it is difficult to separate the effects of cold weather and infectious disease, particularly influenza epidemics, from those of air pollution; air pollution episodes generally occur in the late fall when cold weather is beginning and respiratory illness is frequent. Third, mortality is an insensitive indicator of the health effects of air pollution since many more persons become ill but survive. Nevertheless, mortality data are so important and so easy and inexpensive to gather that their collection and analysis are virtually mandatory for those wishing to do a complete study of an air pollution episode.

Emergency room or clinic records. Studies in New York (*14*) and London (*12*) showed an increase in visits to physicians when pollution was high enough to cause increased mortality, but no consistent increases at lower pollution levels. These studies, too, were retrospective. Emergency room and clinic records, however, could be analyzed before an episode and the expected rate of visits calculated. Daily reports from health facilities during the episode could then be interpreted immediately.

At present, records of visits to emergency

Left. Smokestacks smudging city skyline, 1965. Photo, Charles Steinacher, Black Star

OPPOSITE PAGE

Above. Pollution in Omaha, Nebr., 1969. Photo, Bob Paskoch, Omaha World-Herald

Below. Smokestacks lost in their own murk

Weed burning in Long Beach, Calif., June 1955. *Photo, Los Angeles County Air Pollution Control District*

rooms and clinics are insensitive measurements of the acute health effects of air pollution, probably because many persons who become ill do not visit physicians and many of those going to a physician visit their local practitioners rather than hospital facilities. This indicator may become more useful as more people begin to use hospitals as their primary source of care.

School absences. Expected values for school absences may be tabulated and compared with running tallies obtained during episodes of air pollution (*23*). Studies, however, only occasionally show an association between such absences and elevated pollution levels. It is difficult to obtain accurate raw data and to partition the absence rates by cause.

Reports by panels of susceptibles. Groups of elderly patients or patients with asthma or chronic obstructive pulmonary disease were asked to furnish daily reports on the frequency and severity of symptoms (*20,21,24*). The panels were enrolled and the control data taken before episodes occurred; symptom rates for high and low pollution levels were then compared.

In Greenberg's study of the New York City episode of 1962 (*13*), respiratory symptoms among elderly subjects were found to be a more sensitive indicator of health effects than mortality, emergency room or clinic visits, or physicians' visits, as measured by health insurance claims. Other studies have confirmed the fact that the elderly and persons with chronic pulmonary disease or asthma are highly susceptible to adverse health effects from air pollution. Studies in which such susceptibles are asked to report daily symptoms produce significant results. In addition to providing the health department with sensitive and immediately available measurements of pollution-

Air pollution from oil refineries in Baton Rouge, La., January 1961

induced illness, such studies make valuable additions to our knowledge of the dose-response curve for pollutants.

Telephone surveys. In one study using a telephone survey, the population at risk was geographically defined and households with telephones were randomly selected from this population (*25*). Several hundred households were telephoned each day, and the rates of daily illness were calculated and compared with control data collected after the episode.

Telephone surveys are relatively inexpensive and quick if preliminary sampling procedures are carried out before the episode. Such studies, however, exclude households that lack a functioning telephone and thus may exclude persons of low economic status among whom chronic diseases tend to be particularly prevalent.

Physicians' visits. In Donora, physicians affiliated with the city health department visited households in which symptoms had been reported, performed physical examinations, took detailed histories, and ordered selected laboratory tests (white blood count, pulmonary function, and chest X-ray). These visits served to validate the survey of symptoms on the basis of which the households were chosen for visits by physicians, as well as to provide objective measurements of respiratory dysfunction.

Physicians' visits, however, require personnel and funds generally beyond the means of local health departments, and they do not as a rule add crucial information.

Household interviews. Several months after the Donora episode, approximately one-third of all households in the town were visited by public health nurses who administered questionnaires about symptoms (*3*).

Such household interviews, like physicians' visits, also require more money and personnel than local health departments can usually muster, but they can provide valuable information characterizing the sick and the well populations.

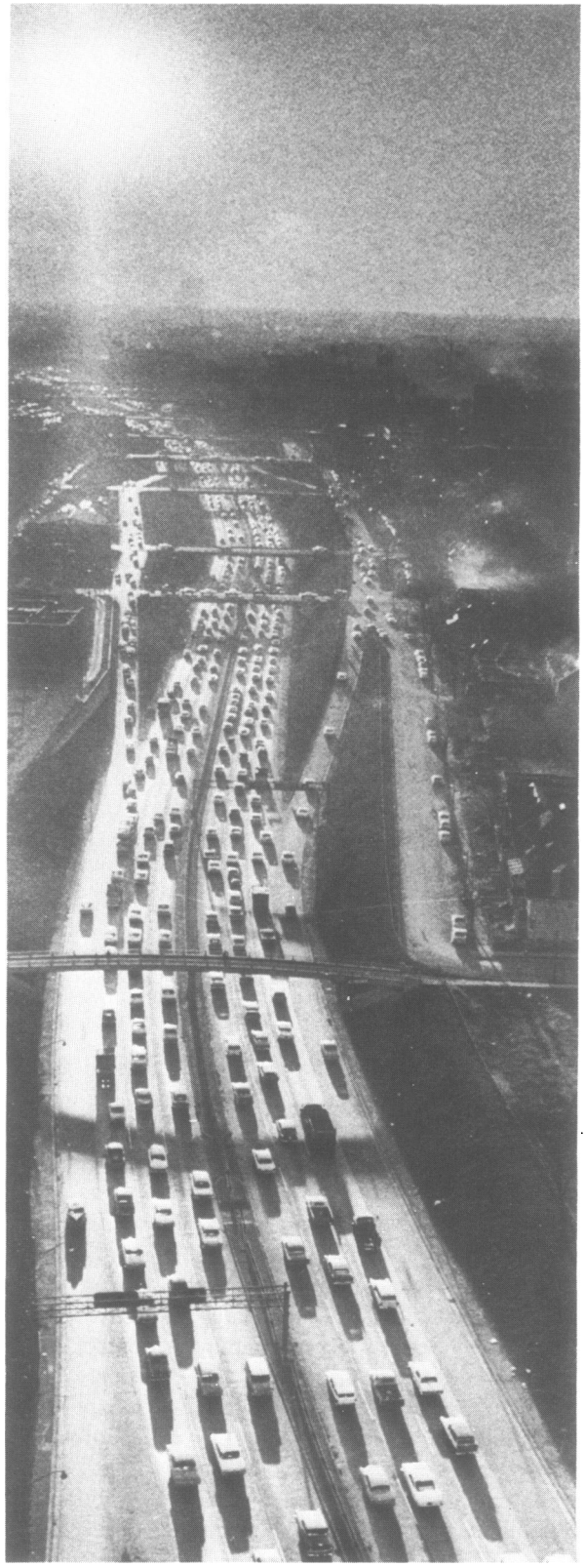
Recommendations for future studies. Programs for studies of health effects should include plans to study both mortality and morbidity. Panel studies, using reports from patients with bronchitis, emphysema, or asthma, appear to be the most sensitive of the relatively inexpensive studies.

Studies of health effects should be planned and begun before an air pollution episode occurs. During the crisis, neither time nor energy is available for detailed analyses of study designs. Furthermore, if data are first collected during an episode, their interpretation must remain uncertain until well after the episode, after control data are collected. If "expected" figures have been calculated before an episode, data taken during the episode will be meaningful immediately. The Air Pollution Control Office has had experience with both mortality and panel studies and is available as a consultant to health departments wishing to establish such study programs.

Immediate institution of appropriate systems for monitoring weather and air pollution is of the utmost importance in all such studies. Several major studies have been of limited usefulness because there was little or no objective measurement of pollution. Most large towns presently have some sort of monitoring system, which might be supplemented in times of emergency with equipment capable of giving hourly or continuous readings. The Air Pollution Control Office is available for consultation in devising and setting up local monitoring systems, a job which requires evaluation of local topography, meteorology, sources of emission, rational placement of sampling stations, and budgeting for costs of equipment and personnel.

Plans for Abatement

Abatement actions must be based on a thorough inventory of major sources emitting pollution, including a designation of those sources practically amenable to regulation. In a major city, decreasing the burning of garbage in municipal incinerators for a short period presents few difficulties, but restriction of emissions of major industries raises legal and political questions. Also, keeping automobiles out of a city dependent for its commercial life on commuting workers and



Air pollution dims setting sun as commuters speed homeward. *Photo, Toni Spina*

customers imposes considerable hardship. Once abatement priorities have been decided, plans for emission restriction can then be legislated and implemented in stages as crisis levels of pollution are attained.

Local circumstances will dictate at what pollution levels the abatement plans are to be put into effect and the measures to be taken. A sample abatement plan now in use in New York City is shown on pages 542–543.

Guide for the Physician

The physician's role in air pollution episodes is threefold:

1. To be aware of the occurrence of air pollution alerts
2. To deliver advice and care to patients during episodes
3. To help the community study the health effects associated with episodes.

The physician should become familiar with local emergency air pollution programs by inquiring at community, city, or county health departments. Alert systems have been previously discussed in this paper.

Advice and Care of Patients

All patients should be advised to follow these instructions:

1. Try to avoid exposure to outdoor pollution by staying indoors, closing all windows, and making full use of any air-purifying device available, such as filters or air conditioners. The effectiveness of such devices varies considerably with the device and the pollutant. Particulate matter is best removed with an electrostatic precipitator; sulfur dioxide, by an activated charcoal filter. Other gaseous pollutants require special filtration procedures. Although these procedures are expensive, communities should consider installing efficiently filtered central air conditioning systems in hospitals, homes for the elderly, and apartment houses.
2. Minimize exposure to indoor pollution by not smoking, avoiding rooms where others are smoking, and by not engaging in activities that raise dust, like starting a furnace, using a fireplace, dusting furniture, or doing extensive vacuuming.
3. Do not subject the cardiorespiratory system to stress. Avoid unnecessary exertion, unnecessary exposure to cold, and exposure to substances that sometimes cause allergic reactions.
4. Respond early to symptoms. If you have chronic bronchitis or emphysema, begin taking your medicine at the first sign that your symptoms are getting worse. If you experience an asthmatic episode and cannot quickly bring it under control, go to your physician. In general, call your physician at the first sign of trouble and follow the recommendations of local health authorities.

In addition to giving this advice, the physician should be sure to observe closely early signs of illness and treat them aggressively. He should be aware of the added burden imposed on patients by the presence of a respiratory irritant and be more vigorous in responding to early signs of complications. Elective surgery might be delayed since the risks may be increased during an air pollution episode. Physicians should insist on immunization of chronically ill patients against influenza. Since air pollution episodes tend to occur in the fall and winter, when influenza epidemics strike, the effects of the two may be additive or worse.

Helping With Studies of Health Effects

Some communities may wish to obtain an objective measurement of the adverse effects on health of air pollution episodes. Such measurements might include the number of visits or calls made to physicians because of worsening symptoms or the number of patients admitted to hospitals because of cardiac or respiratory illness. Physicians can help by keeping track of these data during episodes.

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The responsibilities of the health department in air pollution episodes include knowing when an episode is imminent, maintaining effective lines of communication with physicians and laymen, coordinating studies of adverse health effects, and helping to devise and implement plans for pollution abatement.

An episode should be diagnosed when pollution levels become dangerously elevated and the weather forecast is for protracted stagnation of air. Episodes are associated with increased mortality and the onset of acute respiratory and cardiac illness. Hospitals should be notified that an unusual number of emergency admissions for respiratory illness is likely. Physicians should be reminded that the elderly and persons with asthma or chronic obstructive pulmonary disease must be followed with special care.

Studies of health effects should include analyses of mortality and morbidity; these studies need to be prepared well in advance of episodes.

The Air Pollution Control Office of the Environmental Protection Agency is available to assist local health departments in devising monitoring networks and abatement plans and developing health studies to assess the impact of air pollution episodes.

The practicing physician should instruct elderly patients and patients with heart or lung disease to minimize their exposure to indoor and outdoor pollution during episodes so that they will not strain their cardiovascular systems. He must also remind these susceptible persons to seek early treatment of acute illness.

Physicians should be alert to the possibility of air pollution emergencies, assure early and vigorous treatment of acute illness, and assist the community in studies of the health effects of air pollution.