Defining the Problem of Air Pollution in Metropolitan Birmingham, Alabama

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JEFFERSON COUNTY'S atmosphere has been studied extensively since 1956. The conclusion of these studies have been identical—Jefferson County, Ala., has an air pollution problem which should be controlled and which is probably caused primarily by industrial activities.

During the 1956 steel strike, a special air sampling study was conducted during July and August to investigate the effect of the industry on suspended particulate levels (*1*). Sampling was done both during and after the strike at three locations in the Birmingham area—central Birmingham, Bessemer, and at the western health center. Average levels of suspended particulates increased significantly when the steel industry resumed production. Furthermore, the maximum values of suspended particulate levels increased after the strike to almost three times the corresponding maximum values during the strike.

In 1957, at the request of local officials, a survey of air pollution in Birmingham and Jefferson County was made by the Community Air Pollution Program of the Public Health Service (*2*). This survey was limited to collection and review of existing data, interviews, and personal observations of the investigators.

The survey report indicated that meteorologic conditions in Jones Valley are often favorable to the accumulation of pollution emissions from fuel combustion, industrial activity, and waste incineration. It also indicated that there had been a rapid decrease in the use of coal for domestic purposes, but an increase in the amount used for steel manufacturing (*2*).

The Birmingham area is a manufacturing center and has many sources of industrial emissions. The heavy metals industry, particularly the steel industry, is undoubtedly the major source of industrial pollution. Air pollution in Birmingham has a significant effect on visibility which can be observed on those days when the atmosphere is unable to disperse the pollutants effectively. Difficulty in growing certain plants and damage to foliage were reported by local nurserymen who believed that air pollution was responsible. The damaging effects of atmospheric pollutants on clothing, surface coatings, and construction materials were not measured specifically in this study, but on the basis of present knowledge and of the conditions noted, it is reasonable to assume that they exist in the Birmingham area.

In 1961, the City of Birmingham and Jefferson County, with the assistance of the Public Health Service, conducted a two-season air quality study (*3*). The study was carried out in two 3-week parts, June 15–July 4 and November 20–December 19, 1961.

The results of the sampling during this study indicated that concentrations of gaseous pollutants were generally low. Particulate pollutants, notably dustfall, smoke, and total suspended particulates, were high, particularly during the fall. All pollutant concentrations might have been higher if ideal dispersion conditions had not existed during the study period.

Agencies conducting three previous studies

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recommended developing a countywide program of study, surveillance, prevention, and control of air pollution, including an inventory of air pollution sources and emissions, a meteorologic study, sampling of the ambient air for particulate and gaseous pollutants to determine trends and control needs, laboratory services for sample analyses and investigative activities, and the abatement of the causes of justified public complaints. The agencies also suggested instituting an air pollution control program aimed at minimizing emissions of particulate matter into the atmosphere, establishing limits for stack emissions of particulate matter, and conducting an informational program to acquaint citizens with the causes and effects of air pollution and methods of control.

In 1962, the Alabama air pollution and respiratory disease study was initiated by the Public Health Service (*4*). Sampling in the Birmingham area was resumed on a limited basis until the fall of 1963 when a 21-station sampling network was set up with seven stations located within Birmingham and 14 stations located in seven principal municipalities surrounding it. Intensive sampling was carried on from November 1963 through February 1965 for atmospheric particulate matter and the gaseous pollutants SO_2, NO_2, and aldehydes (*5*). The most significant specific pollutants were dustfall, suspended particulate matter, and nitrogen dioxide.

The Jefferson County Department of Health began its own air pollution study and continued atmospheric sampling at 10 of the original stations and at nine semimobile stations in 1965. Since the initiation of the Jefferson County Air Pollution Program, all previously mentioned recommendations have been carried out except those pertaining to control. At present, no State or county agency in Alabama has the legal authority to initiate an emission control program. The most logical solution to the control problem is State legislation authorizing an air pollution control agency and giving it sufficient authority to operate.

Air Quality and Climatology

Samples from these 19 stations were still being collected and analyzed when this report was written in 1967, resulting in 3½ years of continuous air monitoring in Jefferson County. A total of 6,628 suspended particulate, 5,191 sulfur dioxide, 6,884 nitrogen dioxide, 5,445 aldehyde, 433 dustfall, 405 sulfation, and more than 2,400 pollen and spore samples have been collected and analyzed by personnel of either the Public Health Service or the Jefferson County Health Department. In addition, more than 40,000 2-hour soiling samples have been collected and partially analyzed, and oxidants, oxides of nitrogen, and numerous other pollutants have been continuously monitored. Meteorologic data from the weather bureau were evaluated with regard to air pollution levels.

Suspended particulates. Results of suspended particulate matter sampling are reported in micrograms of particulates per cubic meter of air. The range of annual averages in the 10-station sampling network varied from 72 to 281 μg. per m.^{3} with a combined areawide average of 151 μg. per m.^{3} (table 1). In addition, 20 percent of the time the suspended particulate matter in Jefferson County exceeds 265 μg. per m.^{3}, which is about 10 times the background or natural level in less polluted areas of Alabama (*6*). Seasonal variations of suspended particulate matter were small, indicating year-round sources of pollution in Jefferson County.

Furthermore, there are specific areas in Jefferson County where levels of suspended particulates are always more than 200 μg. per m.^{3} and levels exceeding 500 μg. per m.^{3} are not uncommon.

Since 1957, the Public Health Service has operated the national air sampling network in cities throughout the country. Network data indicate a national urban average of only 104 μg. per m.^{3}. While we cannot compare our results with this average, we can say that Jefferson County's average level of suspended particulates is higher than 70 percent of all 14,494 samples collected by the national network in the years 1957–61 (*6*) and higher than 80 percent of all 12,607 samples collected in 1964 and 1965 (*7*).

North and central Birmingham and the Tarrant City areas consistently reported the highest levels of suspended particulates; the southside and Bessemer areas also had relatively high levels. This is due primarily to the proximity of large industrial complexes and to the fact that

Table 1. Annual pollution levels by sampling station location, Jefferson County, Ala.

Location	Suspended [1] particulate (μg. per m.³)		Dustfall [1] (tons per mi.² per month)		Sulfation [2] (mg. SO_3 per 100 cm.² per day)		Sulfur dioxide [2] (parts per 100 million)		Nitrogen dioxide [2] (parts per 100 million)		Aldehyde [2] (parts per 100 million)	
	Mean	20 percent [3]	Mean	20 percent	Mean	20 percent	Mean	20 percent	Mean	20 percent	Mean	20 percent
Bessemer	176	270	20	25	0.20	0.30	0.2	0.4	8.3	12.0	1.4	2.2
Fairfield	126	205	20	23	.31	.47	.3	.8	7.4	12.0	1.4	2.6
West end	124	200	21	27	.14	.19	.2	.4	7.9	12.0	1.3	2.2
North Birmingham	281	440	88	124	.55	1.00	.4	1.3	10.3	15.0	1.4	2.1
Central Birmingham	197	300	22	26	.32	.50	.4	1.3	9.7	13.5	1.5	2.2
Southside	179	276	20	25	.33	.52	.3	.9	8.6	12.8	1.8	2.7
Woodlawn	139	220	24	30	.07	.18	.1	.3	8.3	12.0	1.4	2.2
Tarrant	219	362	53	70	.13	.22	.2	.4	7.9	10.5	1.3	2.0
Irondale	115	180	15	18	.12	.18	.2	.6	7.2	10.6	1.5	2.3
Mountain Brook	72	115	10	13	.08	.19	.2	.4	7.1	10.8	1.3	2.0
All stations	151	265	29	38	.23	.38	.3	.7	8.3	12.1	1.4	2.3

[1] Jefferson County Air Pollution Program data.
[2] Reference 5.
[3] Levels occur 20 percent of the time or slightly more than 2 months per year.

NOTE: Geometric means or averages are used throughout this paper for all pollutants.

these stations are in the central part of Jones Valley, where pollutants tend to concentrate. The stations recording the lowest particulate levels are either to the south over Red Mountain or to the northeast in strictly residential areas.

Dustfall. Dustfall sample results are reported in tons of dustfall per square mile per month (*8*). The annual average dustfall ranges from 10 tons per mi.² per month in Mountain Brook to 88 tons per mi.² per month in north Birmingham (table 1). The stations reporting the highest levels of dustfall are those having the highest levels of suspended particulate matter. However, there are fewer stations with extremely high levels of dustfall than with excessive levels of suspended particulates. The sampling stations may be close enough to an industrial source to be affected by the lighter suspended particulate matter but far enough away so that a large portion of the heavier material settles out before reaching the sampling area.

Gaseous pollutants. The sulfation rate (commonly known as lead candle) is a monthly measurement of sulfur compounds in the air in milligrams of sulfur trioxide per 100 square centimeters per day (table 1).

Sulfation levels are generally low in Jefferson County, but they follow a definite seasonal trend, with winter levels about twice as high as those of any other season. The Fairfield, north, central, and southside Birmingham stations usually report the highest levels of sulfation for probably the same reasons that suspended particulates are excessive.

Sulfur dioxide, nitrogen dioxide, and aldehydes are measured every 24 hours at all 10 stations in the sampling network. Sulfur dioxide levels, consistent with sulfation, are generally low year round, with the highest concentrations in winter. Ninety percent of all sulfur dioxide samples were below 1.0 part per 100 million.

Nitrogen dioxide was the only gaseous pollutant found in significant quantities, the range of daily levels being 0.7 to 62.7 parts per 100 million. Nitrogen dioxide levels were highest in areas of industrial activity where dustfall, suspended particulates, and sulfation rate were also at the maximum.

Daily aldehyde levels ranged from 0 to 4.0 parts per 100 million. No geographic or source relationship to aldehydes like that with suspended particulates, dustfall, sulfation, and nitrogen dioxide is obvious (table 1).

Special sampling results. Sampling for suspended particulates at nine locations (other than the 10 fixed stations) was conducted during the fall and spring (fig. 1). The monthly mean for each of these nine stations ranged from

48 to 180 μg. per m.^{3}, the highest levels being in the southwest area. The city of Homewood had four of the mobile sampling stations located within its limits and, with one exception, they showed little variation in suspended particulate levels. In general, the levels of suspended particulates found at these mobile stations was somewhat lower than those found at the majority of the 10 fixed stations.

Continuous sampling with special instrumentation was begun for oxidants and total oxides of nitrogen in mid-August 1966. Since then, the highest levels of oxidants recorded have been about 4 parts per 100 million, while the background levels appear to be approximately 1.5 parts per 100 million. For total oxides of nitrogen, the peak value has been 17 parts per 100 million, with a background of approximately 6 parts per 100 million. The rather low levels of oxidants indicates an absence of photochemical smog from heavy automobile pollution.

From the beginning of the study, a limited number of samples have been analyzed for metal content. Metals found in the particulate matter of the atmosphere usually indicate a nearby source of pollution. Results of these analyses indicate a high metal content, especially iron, and relatively high concentrations of manganese, lead, and zinc.

Meteorology and air pollution. The topography of the Birmingham area is irregular, with ridges and intervening valleys. The city is in a valley between a series of low ridges that extend from northeast to west and Red Mountain, which extends from east to southwest, approaching a height of 600 feet above valley level.

The main climatic effects of the topography are extreme temperature inversions and rather low minimum temperatures during the winter and a marked reduction in visibility during the early morning and late afternoon caused by airborne particulate matter and, to some extent, by fog.

Throughout the year visibility restricted to less than 6 miles and even to less than 1 mile occurs as a result of air pollution, but these occurrences are most frequent and intense during autumn and winter.

Pollution sources are located in industrial areas 4–8 miles southwest of the city, but the most heavily concentrated groups of known industrial sources extend from central to north and northeast Birmingham.

The greatest pollution levels at all stations for all measured pollutants occur on calm days with little or no wind movement. On days when there is significant wind movement, the highest levels of pollution generally occur at stations downwind from the industrialized north Birmingham-Tarrant area. This pattern is true for all pollutants except gaseous aldehydes, which show no consistent pattern in relation to wind directions. During 1964, days classified as calm by the weather bureau occurred 16.7 percent of the time, visibility was reduced below 6 miles 22.0 percent of the time, and significant quantities of smoke or haze, or both, existed at the airport 15.1 percent of the time.

Emission Inventory

In 1965, the Jefferson County Department of Health began a yearlong effort to obtain a comprehensive and complete inventory of the county's air pollutants. We learned that about 50 percent of the pollution is generated within the city limits of Birmingham and that the remaining 50 percent comes from the communities surrounding it.

In general, this air pollution comes from four main sources—domestic, transportation, commercial, and industrial. Information on domestic fuel, trash, and leaf burning was obtained by a random survey covering 7,200 households. The results were extrapolated to include all 188,000 households in the county.

Information on transportation sources of air pollution was obtained from tax records concerning fuel consumed in combustion engines. Airplanes and diesel-powered vehicles were included in this study, as well as buses, trucks, and automobiles.

Information on commercial sources was obtained from fuel use questionnaires, which were sent to 498 laundries, drycleaners, hospitals, rest homes, hotels, motels, schools, and shopping centers. An estimated 75 percent of all commercial establishments were sent questionnaires, and approximately 90 percent of the questionnaires were completed and returned. Therefore, the data on commercial emissions are based on ap-

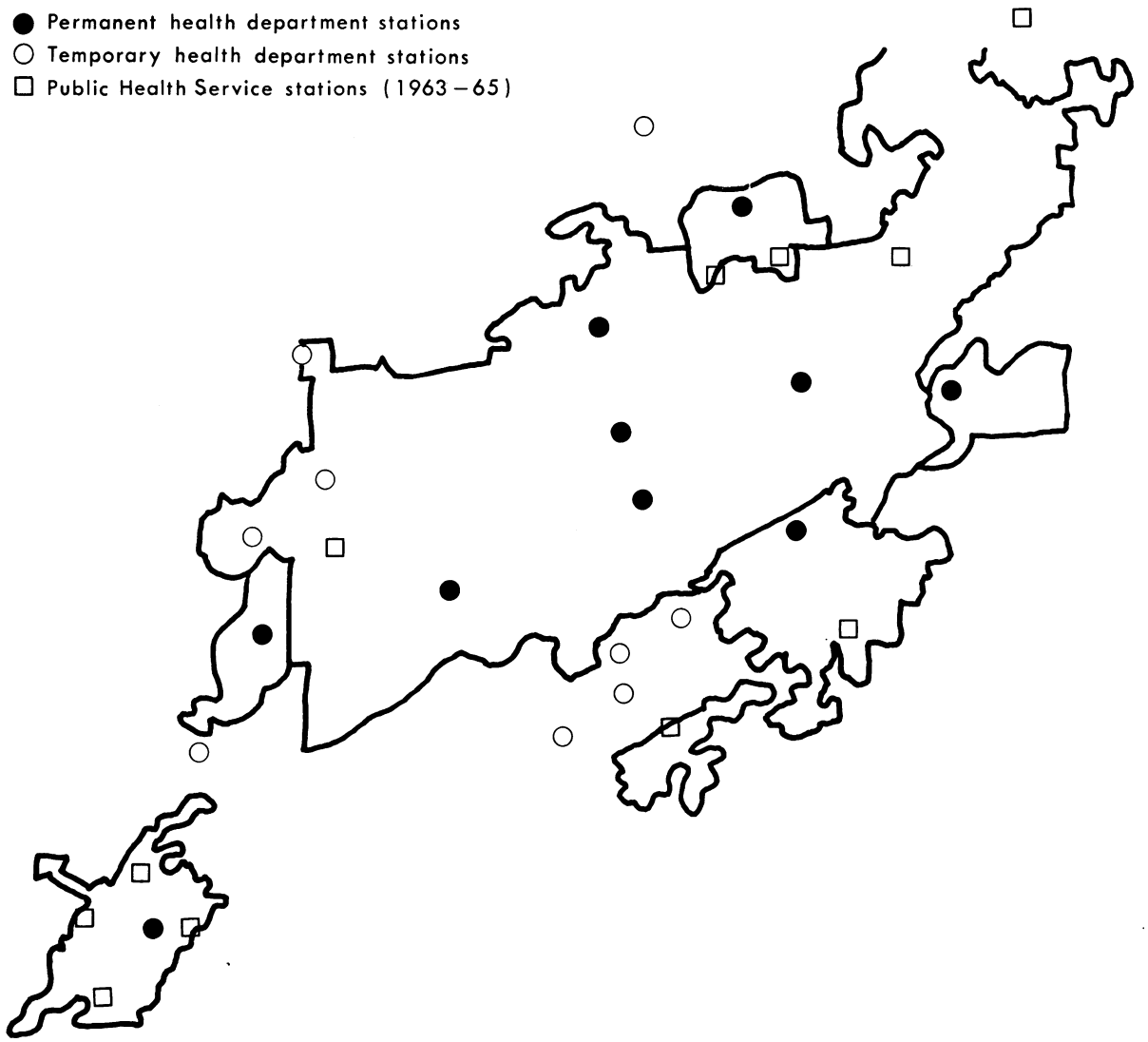


Figure 1. Birmingham area sampling network

proximately 68 percent of all the commercial establishments in Jefferson County.

Information on industrial sources was obtained from fuel use and process questionnaires sent to the 815 industrial establishments in the 1964 Industrial Directory of the Birmingham Area Chamber of Commerce. Only 368 were returned with usable information, and the data on industrial emissions are based on approximately 46 percent of the industries in Jefferson County. Most major industries, however, were included.

Emissions from stationary sources. Stationary sources include domestic, commercial, and industrial contributors to air pollution. In most communities, emissions from fuel burned for heat is one of the biggest sources of air pollution. In a large industrial area, however, the largest amount of fuel is consumed by industry for process heat, making emissions relatively constant year round.

Figure 2 illustrates the quantity ranges of particulate emissions and shows some known major industrial and commercial sources of air pollution. Figure 3 shows the emission breakdown in percentages for stationary sources in Jefferson County.

Industrial sources account for approximately 94 percent of the particulate emissions, 88 percent of the gaseous emissions, and 53 percent

of the hydrocarbon emissions from stationary sources (table 2). In addition, emissions are greatest in areas of concentrated industrial activities. The fairly large percentage of commercial hydrocarbon emissions comes mainly from burning dumps and drycleaning establishments. The small amount of emissions from domestic sources can be attributed primarily to the decline of coal as a source of space heating and cooking fuel.

Transportation emissions. Emissions from the transportation industry include those from automobiles, diesel vehicles, and aircraft. Calculations are based on fuel use data and airport flight information. Figure 4 shows the various types of pollutants emitted and their relative percentages.

In comparison with stationary sources, transportation contributes only slightly to the particulate matter in Jefferson County's air. Carbon monoxide emissions and a significant portion of the hydrocarbon emissions are primarily from the means of transportation (fig. 5).

It must be noted that the Federal Govern-

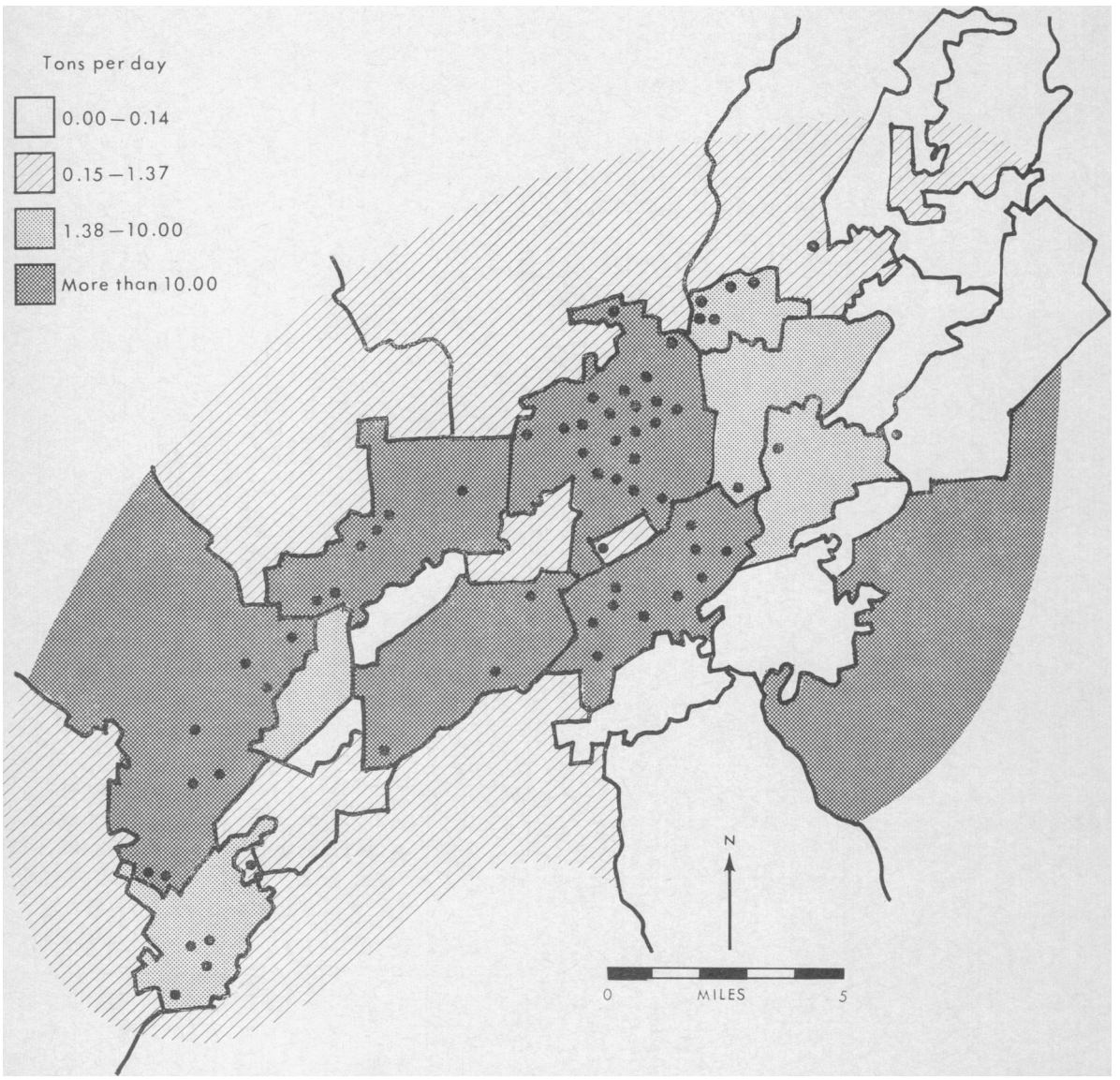
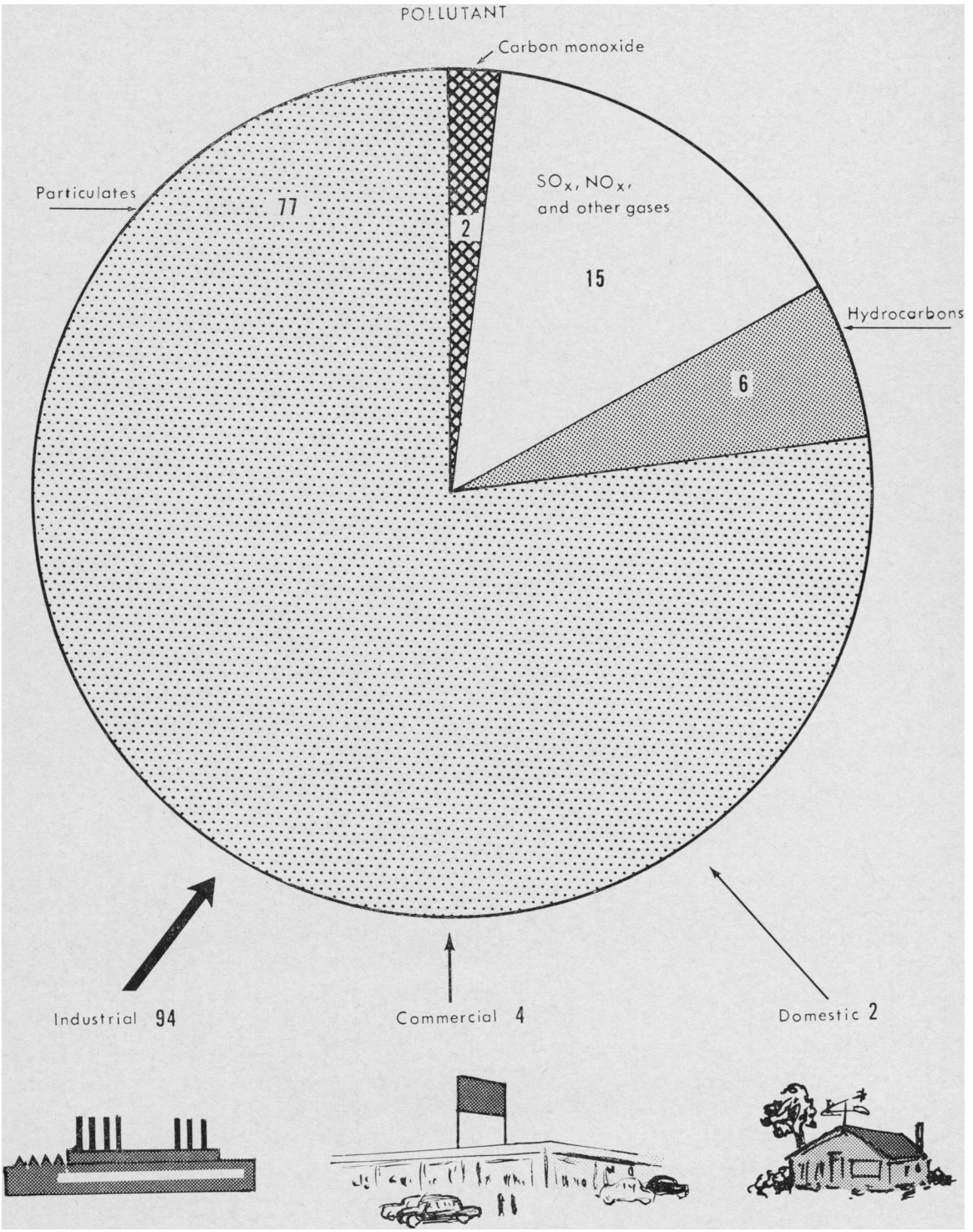


Figure 2. Estimated particulate emissions by neighborhood area and major industrial and commercial sources

Figure 3. Estimated percent of contributions by pollutant from stationary sources



ment has passed legislation partially controlling motor vehicle emissions. All new vehicles now have crankcase blowby devices which control up to 30 percent of their total emissions. This factor was not considered when the estimated emissions were calculated.

Legitimate comparisons of emissions between various communities are difficult to make because of the inherent incompleteness of any such survey. However, some comparisons might give insight into the extent of Jefferson County's air pollution problem.

In Nashville, Tenn., total particulate emissions (including those from transportation sources) were estimated at 42 million pounds per year (*9*), which is only one-tenth of those in Jefferson County. Gaseous emissions including hydrocarbons were estimated to be 172 million pounds per year, while Jefferson County's total gaseous emissions are approximately 753 million pounds per year.

In Chattanooga, Tenn., total particulate emissions were estimated at 204 million pounds per year (*10*), approximately half the amount in Jefferson County.

Public Opinion Survey

More than 300 complaints regarding air pollution have been received and investigated by the Jefferson County health department since its air pollution program began in 1965. In addition, during the summer of 1965, persons in

Figure 4. Estimated percent of contributions by pollutant from transportation sources

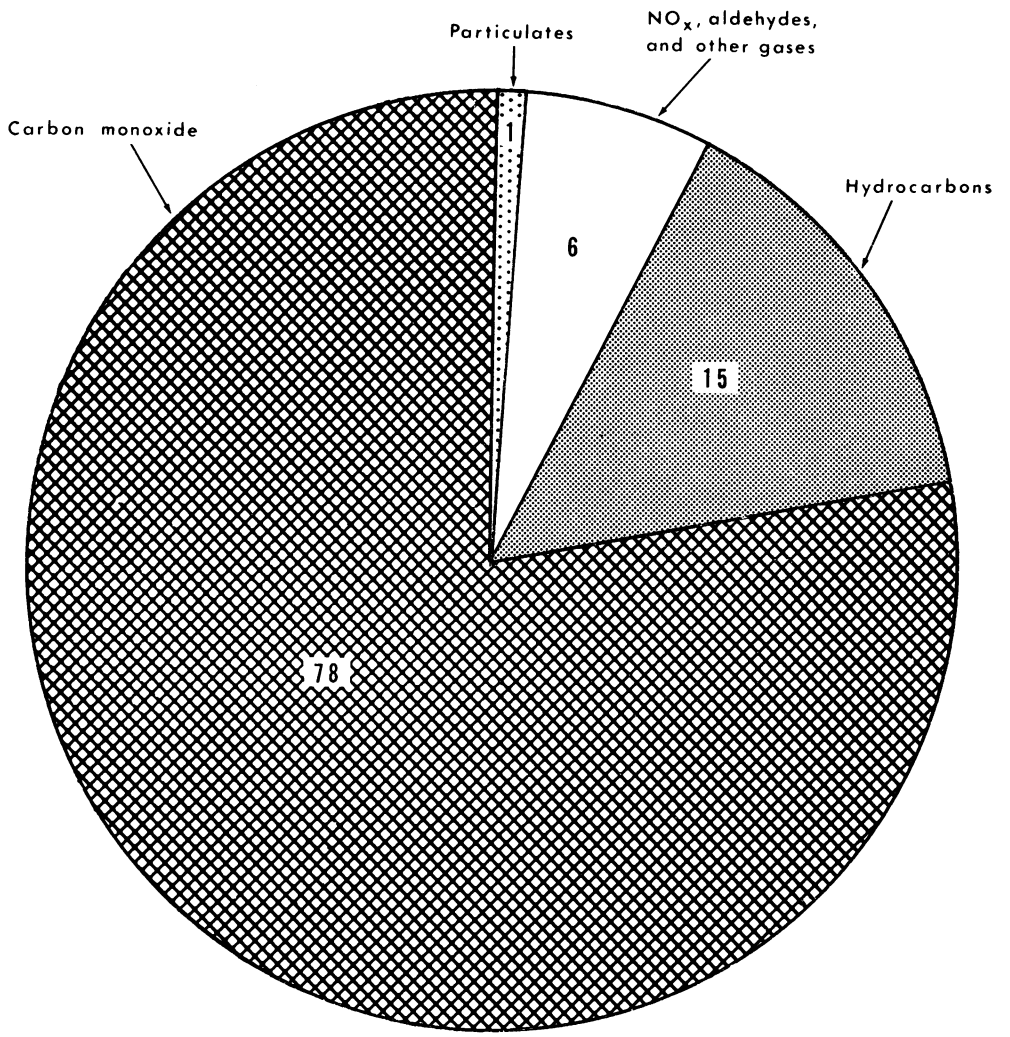


Table 2. Estimated emissions by pollutant (tons per year) and source, Jefferson County, Ala., 1965

Source	Particulates	Carbon monoxide	Hydrocarbon organic acids	Sulfur oxides	Nitrogen oxides	Aldehydes	Ammonia
Industrial fuel use	7, 130	191	411	7, 263	6, 922	41	[2]
Commercial fuel use	1, 796	961	[1] 1, 420	605	210	[3]	[2]
Residential fuel use	1, 261	1, 357	583	1, 047	801	[3]	[2]
Industrial processes	189, 420	1, 000	5, 857	22, 785	1, 616	[2]	[2]
Municipal incinerator	156	9	26	25	27	14	4
Municipal dumps	664	[2]	3, 949	17	8	57	33
Industrial refuse	143	136	761	3	2	33	5
Commercial refuse	13	127	72	[3]	[3]	21	[3]
Residential refuse	55	249	134	4	6	14	[3]
Gasoline (automobiles and trucks)	881	233, 195	42, 311	721	9, 055	320	160
Diesel (automobiles and trucks)	2, 938	1, 602	5, 636	1, 068	5, 930	106	[2]
Airplanes	258	13, 898	2, 791	[3]	956	54	[2]
Total	204, 715	252, 725	63, 951	33, 538	25, 533	660	202

[1] Includes 1,200 tons per year from dry cleaners.
[2] Not available.
[3] Negligible amount.

Table 3. Effects of air pollution on population, public opinion survey, Jefferson County, Ala.

City	Percent of households adversely affected				
	Total	General nuisance response	Health effects response	Material damage response	Odor response
Birmingham	54	33	18	19	23
Bessemer	35	17	11	8	20
Fairfield	66	60	3	0	19
Tarrant	87	74	53	9	68
Center Point	36	16	7	0	7
Irondale	23	12	9	2	4
Mountain Brook	22	12	16	0	2
Vestavia	24	15	24	0	3

approximately 7,200 households were interviewed by health department personnel in an extensive public opinion survey.

The household public opinion survey was conducted at random, and instructions on making random selections were issued to the interviewers. Only adults were interviewed. On the average, interviews were held in one home in 26. The survey showed that 54 percent of the people living within Birmingham and an average of 42 percent of the people living outside the city limits were annoyed or affected adversely in some way by air pollution. The actual percentage of people affected in the various communities ranged from 22 to 87 percent (table 3).

It was concluded that 33 percent of the people are adversely affected when suspended particulate levels exceed 150 μg. per m.^{3} of air and that 33 percent are adversely affected when dustfall levels exceed 30 tons per square mile per month (*11*). These are levels of pollution that frequently are exceeded in Jefferson County. One-third of the people is a significant number of persons.

The relation between public opinion in the communities and gaseous pollutants was not significant in most of the instances studied. However, it should be noted that gaseous concentrations were in most instances very low.

The number of complaints received regarding

air pollution over the past 2 years obviously reflects only a small percentage of the total population of Jefferson County. Since, to make a complaint a person has to telephone and identify himself, it is apparent that these complaints represent severe and specific problems resulting from localized sources of pollution. Two-thirds of all complaints received have been about health effects or property damage, in contrast to the public opinion survey in which most of the complaints concerned a general nuisance.

Two-thirds of the complaints are about dust, smoke, and flyash, and the source of two-thirds of this pollution is industrial (table 4).

In the absence of specific regulations and control legislation, investigations of the complaints are made to ascertain if the complaint is justified, to inspect the source, and to make appropriate recommendations for voluntary control.

Since the program began it has been possible to investigate about 75 percent of the complaints received. However, voluntary compliance in abating the sources of these complaints occurs in less than 5 percent of the cases, most involving small sources such as leaf and trash burning. Voluntary compliance has not reduced air pollution levels appreciably.

Table 4. Summary of air pollution complaints, Jefferson County, Ala.

Type of complaint	Number of complaints	Type of complaint	Number of complaints
Source of pollution	302	Visibility	28
Industrial	209	General nuisance	133
Domestic	33	Pollutant	[1] 396
Commercial	51	Dust	112
Transportation	9	Smoke	127
Effect	[1] 566	Flyash	45
Property damage	120	Gas	13
Health effect	178	Odor	99
Odor	107		

[1] Totals exceed the number of complaints received since more than one effect or type of pollution can be reported simultaneously.

Control of Air Pollution

There are many ways to approach air pollution control. The first and perhaps most obvious solution is to zone industry away and downwind from residential areas. This approach usually fails because of the rapid expansion of cities and the refusal of winds to always blow in the same direction.

We can avoid air pollution by more efficient combustion of fuels, using different fuels, or making modifications of the processes in use. These solutions are generally more applicable to domestic and commercial space heating and waste incineration than to large industrial processes. The control of automobile exhaust is a good example of control by modifications resulting in more efficient combustion. Federal law requires that all new automobiles (1968 models on) be modified or have factory-installed devices to reduce the amount of carbon monoxide and hydrocarbons emitted (*12*). These reductions will average 60–80 percent, depending on the vehicle and the conditions under which it is driven. These regulations will undoubtedly be tightened in 1970 and will probably include buses and diesel-powered vehicles.

Another widely used technique, especially in the power industry, is the erection of stacks 500 feet or higher. These stacks carry pollutants high into the atmosphere where they are dispersed relatively easily. This method of control is often satisfactory, but it offers no safeguard against downdrafts or prolonged stagnation periods. With Jefferson County's mountains and valleys, this method would be unsatisfactory.

Most industries and processes have methods and equipment to remove the bulk of pollutants from stack gases before they are discharged into the atmosphere. These methods or devices generally fall into four broad classifications.

The first group is mechanical and its most common device is the cyclone collector. Gas is forced into a swift spiral, and the centrifugal force created causes the solid particles to be thrown out of the gas stream and into a hopper. The cleaned gas then passes into the atmosphere.

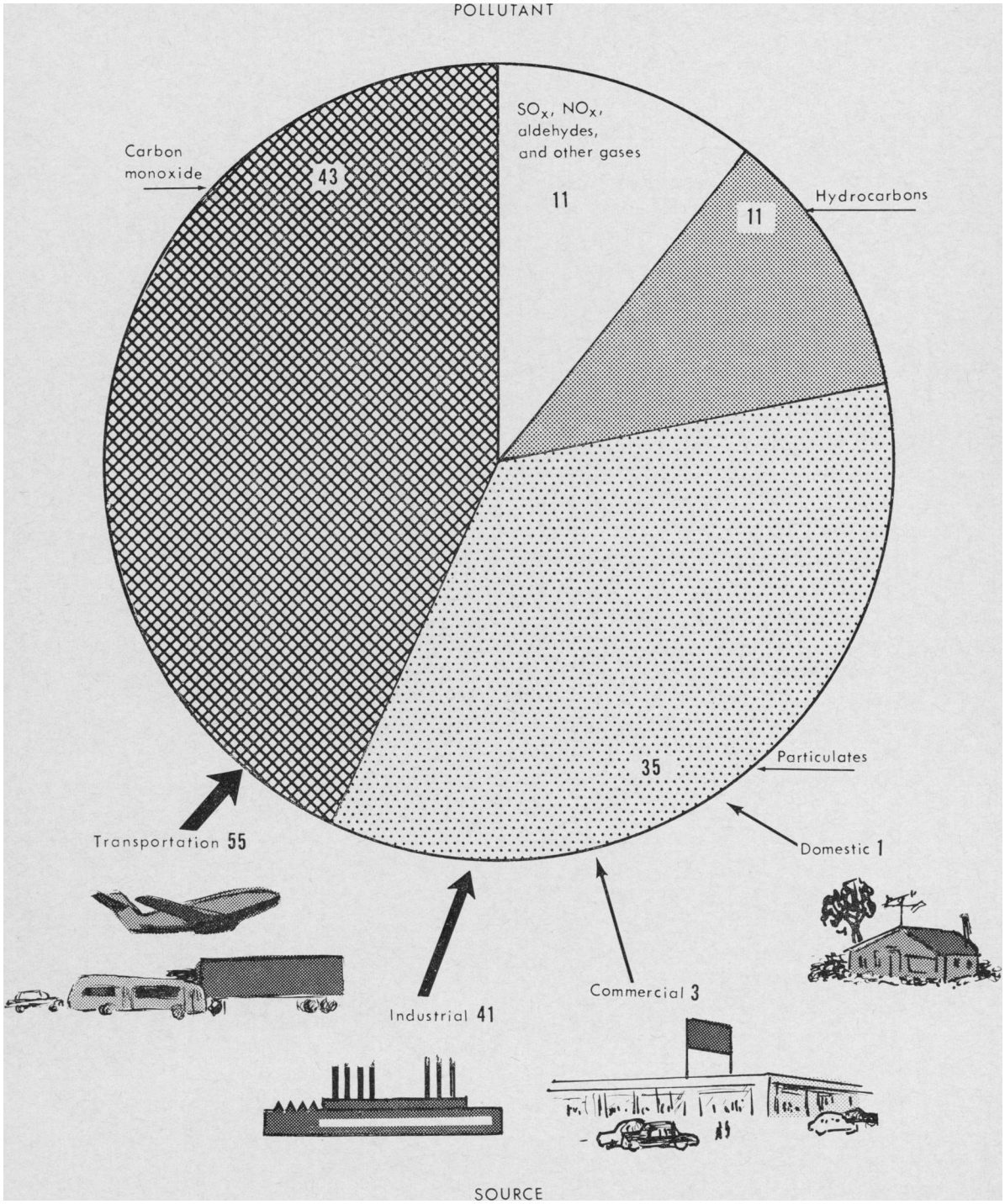
The second group is generally classified as wet collectors. Polluted gases are forced into intimate contact with finely divided liquid (usually water) droplets. This wetting causes many of the solid and gaseous pollutants to be trapped in the water. They are later recovered for disposal or reuse.

The third group works on a principle similar to that of a vacuum cleaner. The dust-laden gases are passed through a large filter bag, where the solid matter is trapped in the fabric

of the filter. This type of collector is somewhat limited because the filters clog and because the temperatures of some industrial exhaust gases are too high for the filters.

The fourth type of control equipment is the electrostatic precipitator. Electrically charged dust is passed through tubes or between plates which have an opposite charge. The dust parti-

Figures 5 Estimated percent of contributions of all emissions from all sources



cles are attracted to the walls of the tube and mechanically removed.

These methods are all technically feasible and are presently being used either singly or in combinations by industry throughout the country.

The cost of air pollution control is high, but so is the cost of not controlling pollution. In Canada, air pollution excluding health effects costs $25 per person per year (*13*); in the United States the cost exceeds $65 per year (*14*).

The cost of cleaning our skies will vary from a few dollars per source to as high as $1 million for one stack, but the time has come when we can no longer afford not to clean our air. Air pollution costs much more in economic and health losses than it will cost to control.

Summary

In 3½ years of continuous air monitoring in Jefferson County, Ala., 6,628 suspended particulate, 5,191 sulfur dioxide, 6,884 nitrogen dioxide, 5,445 aldehyde, 433 dustfall, 405 sulfation, and more than 2,400 pollen and spore samples have been collected and analyzed by personnel of either the Public Health Service or the county health department.

The range of annual averages of suspended particulate matter varied from 72 to 281 μg. per m.^{3}, with a combined areawide average of 151 μg. per m.^{3}. Seasonal variations of suspended particulate matter were small, indicating year-round sources of pollution in the county.

The annual averages for dustfall ranged from 10 to 88 tons per mi.^{2} per month among various areas. Sulfation levels are generally low, but follow a definite seasonal trend, winter levels being about twice as high as those of any other season.

The greatest pollution levels at all stations for all measured pollutants occur on calm days with little or no wind movement.

In general, air pollution comes from four main sources—domestic, transportation, commercial, and industrial. The major sources of particulate emissions are stationary, and pollution control efforts in Jefferson County should be directed at these stationary sources, particularly industrial ones.

REFERENCES

(*1*) Tabor, E. C.: Effects of the 1956 steel strike on air pollution levels in several communities. Paper presented at the Air Pollution Control Association's annual meeting, Philadelphia, May 1958.

(*2*) Keagy, D. M., and Schueneman, J. J.: Air pollution in the Birmingham, Alabama, area. Technical Report A58–8. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, 1958.

(*3*) Hochheiser, S., Hortsman, S. W., and Tate, G. M.: A pilot study of air pollution in Birmingham, Alabama. Technical Report A62–22. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, 1962.

(*4*) Branscomb, B. V., et al.: Alabama respiratory disease and air pollution study. Arch Environ Health (Chicago) 12:15–22 (1966).

(*5*) Robison, C. B., Meadows, F. L., and Henderson, J. J.: Air pollution patterns in the greater Birmingham area. Arch Environ Health (Chicago) 15:703–727 (1967).

(*6*) U.S. Public Health Service: Air pollution measurements of the National Air Sampling Network, suspended particulates, 1957–1961. PHS Publication No. 978. U.S. Government Printing Office, Washington, D.C., 1962.

(*7*) U.S. Public Health Service: Air quality data from the National Air Sampling Network, 1964–1965. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, 1966.

(*8*) Committee on Air Pollution Measurements of the Air Pollution Control Association: Recommended standard method for continuing dustfall survey (APM 1-a). J Air Pollut Contr Assoc 5:176–181, November 1955.

(*9*) Schueneman, J. J., Williams, J. S., and Edmisten, N. G.: An air resource management plan for the Nashville metropolitan area. Paper presented at the 58th annual meeting, Air Pollution Control Association, Toronto, Canada, June 1965.

(*10*) Air Pollution Control Bureau, City of Chattanooga: Air quality management, emission inventory, Greater Chattanooga area. Chattanooga, Tenn., 1965.

(*11*) Stalker, W. W., and Robinson, C. B.: A method for using air pollution measurements and public opinion to establish ambient air quality standards. J Air Pollut Contr Assoc 17:142–144, March 1967.

(*12*) The Clean Air Act as Amended, October 20, 1965. Public Law 89–272.

(*13*) Air/Water Pollution Report. Business Publishers, Inc., Silver Spring, Md., February 1967, vol. 5, p. 59.

(*14*) Lewis, H. R.: With every breath you take. Crown Publishers, Inc., New York, 1965. ch. 10, pp. 114–115.