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PURE AIR FOR PENNSYLVANIA - A JOINT STUDY OF THE EXTENT AND NATURE OF AIR POLLUTION IN PENNSYLVANIA

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Cincinnati, Ohio

November 1961

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A joint study
of the extent
and nature of
air pollution in
Pennsylvania

by the
Pennsylvania Department of Health
and the
Public Health Service, U. S. Department of
Health, Education and Welfare

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"To maintain our industrial and scientific progress without impairing the purity of the air we breathe is of primary concern to the Nation. Government, industry, and individual citizens have mutual responsibility in this vital area."

Dwight D. Eisenhower, 1958

"Air pollution is a serious community problem brought about through industrial expansion and increasing population; soot, smoke flyash and noxious fumes and gases promise to become a greater hazard to the health and welfare of the people of Pennsylvania, as well as a source of grave economic waste."

David L. Lawrence, 1959

". . . . . the atmosphere over our growing metropolitan areas—where more than half the people live—has only limited capacity to dilute and disperse the contaminants now being increasingly discharged from homes, factories, vehicles, and many other sources."

John F. Kennedy 1961.

Pure Air for Pennsylvania

A joint study of the extent and nature of air pollution in Pennsylvania

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Details of illustrations in this
document may be better studied
on microfiche.

Pennsylvania Department of Health
and the
Public Health Service, U. S. Department of
Health, Education and Welfare
November 1961

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- Allegheny County Health Department
- Philadelphia Department of Public Health
- Bucks County Health Department
- Pennsylvania State University, Department of Meteorology

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Introduction

Form of This Report

This report is presented in such a way that the reader may rapidly obtain a concise idea of the pertinent results of this survey. Each chapter is prefaced with a short abstract printed on a blue background. Thus the reader may obtain a summary of the main points of the study by reading these pages. Each chapter is divided into two main sections: a general discussion of the chapter topic—"General"; followed by the specific findings for the State on the subject—"Pennsylvania." Thus, the first sections of each chapter taken together constitute a short monograph on air pollution. The second sections of each chapter constitute findings of the survey for Pennsylvania.

Study History

This report is the culmination of a joint study effort of the Pennsylvania Department of Health and the U.S. Public Health Service. In July, 1958, the Pennsylvania Department of Health, Division of Occupation Health, requested the Division of Air Pollution of the Public Health Service to assist in the conduct of a Statewide appraisal of air pollution problems. Public Health Service assistance was made available under provisions of Public Law 159, 84th Congress.

The study began in March 1959 with assignment by the Public Health Service of a full-time resident engineer who, serving as Project Director, was responsible for planning and conduct of the survey. Administrative supervision of the study was the responsibility of the Director, Division of Occupational Health, Pennsylvania Department of Health. Field work and technical phases of the study ended in November, 1959.

Field work was conducted primarily by the Pennsylvania Department of Health regional industrial hygiene staff. Overall direction of this field work, technical aspects of the study, and preparation of this report were the primary contributions of the Project Director. Some field work was also performed by personnel from the Philadelphia Department of Public Health, the Allegheny County Department of Health, and the Bucks County Department of Health.

Study Purpose

According to the Cooperative Project Agreement signed by representatives of the Pennsylvania Department of Health and the Public Health Service, this survey was to provide a "comprehensive evaluation of the air pollution problems in Pennsylvania and a compilation of technical information with which the Pennsylvania Department of Health could determine the need for future constructive planning and action in terms of State and local enabling legislation, regulations, and budgets."

Study Methods

Basically the study consisted of an analysis of all available air pollution data and opinion and the development of pertinent new data short of an actual air sampling program.

The main sources of information concerning community problems were personal visits and interviews with local officials. During each visit an interview form (Appendix A) was completed. Answers on these forms were tabulated according to community population group. This tabulation was the basis for the community findings presented in this report. Tables 1 and 2 summarize the characteristics of communities surveyed in this manner. More than 80 percent of the State's population was covered. These communities were all those over 2500 in

TABLE 1. COMMUNITIES SURVEYED FOR AIR POLLUTION PROBLEMS

County	Communities Surveyed	1950 Population		Percent Population Surveyed
		Surveyed	Total	
Adams	4	12,600	44,197	28.5
Allegheny	90	1,443,759	1,515,237	95.3
Armstrong	11	46,008	80,842	57.0
Beaver	20	140,090	175,192	80.0
Bedford	4	11,645	40,775	28.5
Berks	23	190,745	255,740	74.6
Blair	11	122,955	139,514	88.2
Bradford	3	16,234	51,722	31.4
Bucks	25	109,536	144,620	75.8
Butler	11	50,915	97,320	52.3
Cambria	30	176,203	209,541	84.3
Cameron	1	3,646	7,023	51.9
Carbon	10	48,849	57,558	84.7
Centre	5	55,173	65,922	83.7
Chester	19	102,611	159,141	64.3
Clarion	3	6,926	38,344	18.1
Clearfield	12	52,375	85,957	61.0
Clinton	2	15,132	36,532	41.5
Columbia	3	26,121	53,460	49.0
Crawford	6	38,988	78,948	49.4
Cumberland	11	65,963	94,457	69.9
Dauphin	14	173,780	197,784	87.7
Delaware	40	397,605	414,234	96.0
Elk	5	24,966	34,503	72.4
Erie	9	182,032	219,388	83.1
Fayette	23	165,793	189,899	87.2
Forest	1	728	4,944	14.8
Franklin	10	60,440	75,927	79.6
Fulton	1	1,126	10,387	10.8
Greene	7	29,641	45,394	65.5
Huntington	2	12,020	40,872	29.5
Indiana	13	53,323	77,106	69.1
Jefferson	5	20,983	49,147	42.7
Juniata	1	1,013	15,243	6.6
Lackawanna	15	233,255	257,396	90.6
Lancaster	33	196,556	234,717	83.8
Lawrence	10	86,751	105,120	82.5
Lebanon	7	53,963	81,683	66.0
Lehigh	17	176,110	198,207	88.9
Luzerne	36	350,715	392,241	91.0
Lycoming	8	73,744	101,249	72.7
McKean	7	40,097	56,607	70.9
Mercer	9	76,551	111,954	68.5
Mifflin	5	31,111	43,691	71.7
Monroe	3	17,144	33,773	50.8
Montgomery	39	317,268	353,068	89.9
Montour	2	11,457	16,001	71.6
Northampton	20	160,668	185,243	86.6
Northumberland	11	94,336	117,115	80.3
Perry	1	1,098	24,782	4.4
Philadelphia	1	2,071,605	2,071,605	100.0
Pike	1	1,111	8,425	13.2
Potter	1	3,210	16,810	19.1
Schuylkill	23	145,183	200,577	70.8
Snyder	4	8,042	22,912	35.1
Somerset	8	38,966	81,813	47.7
Sullivan	1	199	6,745	3.0
Susquehanna	4	9,288	31,970	29.1
Tioga	2	6,872	35,474	19.4
Union	3	10,251	23,150	44.3
Venango	7	48,412	65,328	74.1
Warren	3	23,363	42,698	54.6
Washington	26	156,569	209,628	74.3
Wayne	1	5,662	28,478	19.9
Westmoreland	34	282,714	313,179	90.4
Wyoming	1	2,170	16,766	12.9
York	20	148,458	202,737	73.2
67 Counties	801	8,742,823	10,498,012	83.3

TABLE 2. TYPES AND SIZES OF COMMUNITIES SURVEYED

Community Type	Number Surveyed	State Total	Community Size (population)	Number Surveyed	State Total
First Class City	1	1	less than 2,500	71	1,821
Second Class City	2	2	2,500-5,000	345	345
Third Class City	47	47	5,001-7,500	169	169
Borough	371	940	7,501-10,000	65	65
First Class Township	68	75	10,001-15,000	63	63
Second Class Township	306	1,493	15,001-20,000	39	39
Town	1	1	20,001-25,000	12	12
Unincorporated Area	5	-	25,001-50,000	20	20
			50,001-100,000	11	11
			greater than 100,000	6	6
Totals	801	2,559		801	2,559

population, based on the 1950 Census of Population[1] and special census reports through February, 1958.[2,3] In addition, several communities less than 2500 in population were surveyed. These latter areas were chosen to include at least one community in each county as well as several smaller communities known to have major air pollution problems.

Officials interviewed in community surveys are listed in Table 3. The air pollution control officer or the health officer, if any, were the preferred officials for interviewing. In the absence of these officials a member of the governing body of the community was contacted. It was frequently necessary, especially in small communities, to interview other officials such as members of the police department, municipal engineers, or others. Only eight smoke or air pollution control officials were available for interview. All 67 county agricultural agents were contacted concerning agricultural problems related to air pollution. A completed questionnaire (Appendix A) was returned by 62 of these agents.

TABLE 3. OFFICIALS INTERVIEWED IN COMMUNITY SURVEYS

Community Official	Number Interviewed
Chief Exec. Officer (Mayor, Burgess, Twp. Mgr., etc.)	84
Member, Governing Body (Borough Council, Twp. Bd. Supervisors)	139
Secretary, Clerk, Governing Body	289
Health Officer (Secretary Bd. of Health, Health Officer, etc.)	155
Smoke or Air Pollution Control Officer	8
Sanitation Officer	7
Director of Public Safety	3
Chief, Police Department	61
Other, Police Department	16
Chief, Fire Department	2
Engineer (including Bldg. and Plumbing Inspectors, etc.)	10
Other Officials	27
Total	801

All manufacturing industries and public utilities in Pennsylvania employing 100 or more persons were contacted by letter to ascertain industrial air pollution control activities in the State. The letter (Appendix A) was designed to elicit a personal response to obtain the viewpoints and attitudes of major industry groups. In all, 1779 letters were sent and 862 replies were received, a 48.5 percent response. There are approximately 18,000 manufacturing establishments in Pennsylvania (1959) but nearly 90 percent of these employ less than 100 persons.

All available air quality data were assembled and tabulated as concisely as possible. Data on local control activities received special emphasis. Certain technical methods were developed, which are self-explanatory in the body of this report. Photographs were obtained to illustrate some of the more severe problems. Finally, personal contacts with many individuals, other than those contacted in the community surveys, helped broaden the scope of the study and added to the continuity of this final report.

Chapter I

What Is in the Air?—Pollutants

Abstract

Polluted outdoor air contains foreign substances, generally originating from man's activities, in concentrations sufficient to interfere with man's comfort, safety, health, or with the full use and enjoyment of his property. Pollutants can exist as suspended particles or as gases or vapors. Particulate matter in the air varies in size from about 200 microns (about 1/100th of an inch) in diameter down to the size of large gas molecules, and includes dusts, smokes, fumes, mists, and fogs. The most important properties of suspended particulates are size, concentration, composition, density, solubility, electrical charge, and vapor pressure. Pollutant gases and vapors vary in composition and concentration. Their action, especially when breathed by man, depends primarily on their concentration, chemical nature, and solubility. Very often, particulate and gaseous pollutants occur simultaneously.

In Pennsylvania, this survey has shown that there are at least 476 communities (1959) where, according to local officials, one or more air pollutants are found in objectionable amounts. These communities represent about three-fifths of the 801 communities surveyed. Put another way, about 83 percent of the population of the State is exposed to objectionable air pollution from time to time. About half of all communities with less than 10,000 population are included. This fraction increases with community size to the point where *all* communities of greater than 100,000 population are affected. Personal opinion of interviewed officials is the basis of these findings and, therefore, the actual number of communities is subject to some bias. The over-all result and trend, however, are unchallengeable.

Nearly one hundred communities have major problems, in the opinions of officials seen. Over half of these are due, at least in part, to pollution sources outside the jurisdiction of the affected area. Local control action, unless area-wide, is therefore often unsatisfactory. Areas with major problems include all size groups, from 15 communities with less than 2,500 population to four with greater than 100,000.

The major types of pollutants cited were:

POLLUTANTS	COMMUNITIES REPORTING
Particulate Matter	
Fuel smoke and/or flyash	310
Refuse smoke	222
Industrial dusts	192
Metal fumes	45
Acid mists	6
Miscellaneous dusts	52
Gases and Vapors	
Unspecified industrial gases (odors)	174
Refuse odors	66
Sulfur gases	54
Sewage odors	49
Miscellaneous odors	28

Chapter I

What Is in the Air?—Pollutants

General

A distinction should be made between contaminated indoor air and outdoor air pollution. In this report "air pollution" refers only to the outdoor environment. A precise definition is difficult. Paraphrasing a commonly used one, a polluted atmosphere contains substances, generally originating from man's activities, in concentrations sufficient to interfere directly or indirectly with man's comfort, safety, or health, or with the full use and enjoyment of his property. Not all these manifestations must occur simultaneously. This definition is based on effects rather than arbitrary limits of concentration. Such effects, however, may or may not be immediately discernible.

Two types of air pollution occur. One is the complaint-arousing, intense, local-area problem which usually affects only a small percentage of the population. The other is the often-overlooked, lower level, community-wide problem which can affect the entire community population. A survey of the type presented here can overemphasize the first type since personal interviews most often bring out only obviously visible or offensive problems. Consequently an attempt has been made to assess certain community-wide problems by estimating total pollutant emissions for several communities (Chapters II and IV).

Pollutants are conveniently grouped into particulate matter and gases-vapors. Particulate matter dispersed in air forms an aerosol. Gases and vapors mix with air in much the same way that oxygen and nitrogen mix to form the air itself. The atmosphere acts as a carrier to transport pollutants from their source to their site of action, the exposed population or its property.

Particulate matter, as it occurs in the atmosphere, may be composed of solid or liquid particles in several forms. Particle diameters vary from about 200 microns (about one-hundreth of an inch) down to diameters of the order of large gas molecules, hundredths or thousandths of a micron. *Dusts* consist of solid particles formed as a result of the mechanical disintegration of matter. *Smokes* are dispersions of fine particles formed during combustion, chemical reaction, or condensation. *Fumes* are a class of solid smoke particles resulting from combustion or condensation of metals. *Mists* consist of liquid droplets formed by condensation of vapors upon suitable nuclei or by the atomization of liquids. A *fog* is a mist of sufficient concentration to reduce visibility. "*Smog*" is a term of a thousand meanings and has no exact definition. It may refer to a combination of fog and smoke or, in the popular mind, to any visible atmospheric pollution. Los Angeles "smog" is not normally associated with fog but rather is a complex mixture of gases and fine particles formed in part by photochemical reactions in the atmosphere.

The behavior of particulate matter in the atmosphere is determined by physical properties of the particles, most notably their effective size. Dusts and mists have very broad size ranges and may occur as large particulates as great as 200 microns or more in diameter, or as fine particulates one micron in diameter or smaller. Their size distribution depends on their method of generation. On the other hand, smokes and fumes usually occur as particles less than one micron in diameter. Other properties of aerosols which are of importance are concentration, chemical composition, solubility, specific gravity, shape, electrostatic charge, and (for liquid droplets) vapor pressure. More details of aerosol properties and behavior are available in three excellent sources.[4,5,6]

The distinction between gases and vapors depends on the form the pure substance takes at room conditions. Pure sulfur dioxide, for example, is a gas at room conditions. Carbon tetrachloride, on the other hand, will condense to a liquid at room conditions and, therefore, is called a vapor when it occurs in the gaseous state. For our purposes both gases and vapors may be considered gaseous since, in the atmosphere, contaminant vapors rarely reach condensable concentrations (dew point).

Gaseous contaminants are often classified according to physiological behavior, e.g., irritant gases or asphyxiants. Gases also exert chemical effects (corrosion, etc.) and may be classified according to physical and chemical properties. A thorough description of the properties and behavior of noxious gases is available.[7]

Some pollutants are often grouped separately. Among such miscellaneous contaminants are included pollens and other aero-allergens, certain odors, and radioactive materials (both gaseous and particulate).

Pennsylvania

Areas With Objectionable Pollution

The personal interviews described in the Introduction of this report indicate that, according to local officials, 476 of the 801 communities surveyed, or about 60 percent, have objectionable air pollution (Table 4). All communities in the State of over 2500 population were covered. Among communities with less than 2500 population, only 71 out of about 1800 were surveyed (3.9 percent). Prorating for the smaller communities and using actual findings for the rest, these results indicate that about 83 percent of the population of the State lives in communities where objectionable air pollution has been reported. The results show that even in the smallest communities, objectionable pollution occurs as often as in areas with populations of as much as 10,000 and that above a certain size community, which appears to be between 10

Officials of 801 Pennsylvania communities were interviewed.

TABLE 4. SIZE DISTRIBUTION OF COMMUNITIES WITH OBJECTIONABLE POLLUTION

Population Range	No. Surveyed	Number Reporting Objectionable Pollution			Percent Reporting Objectionable Pollution	Pollution Source		
		Major Problems	Minor Problems	Total Problems		Local	Outside Political Jurisdiction	Combination of both
less than 2,500	71	15	29	44	62	28	9	7
2,501-5,000	345	27	163	190	55	86	55	49
5,001-7,500	169	15	89	104	62	39	32	33
7,501-10,000	65	8	28	36	55	20	8	8
10,001-15,000	63	6	27	33	52	11	3	19
15,001-20,000	39	9	21	30	77	16	4	10
20,001-25,000	12	1	7	8	67	6	1	1
25,001-50,000	20	4	11	15	75	5	3	7
50,001-100,000	11	2	8	10	91	5	0	5
greater than 100,000	6	4	2	6	100	2	0	4
Total	801	91	385	476	59	218	115	143

and 20 thousand, the incidence of air pollution problems increases with increasing population. This is reasonable since prevalance of sources of pollution may be expected to increase as population becomes larger and the extent of human activities expands. This confirms similar results in other areas of the United States which show that the more highly urban an area becomes, the more likely (and more severe) will air pollution problems be.[9] An important new finding is that frequency of occurrence of objectionable pollution remains fairly constant for communities of less than 10,000 people. In communities having from one to ten thousand population, this frequency varies irregularly but only between 55 and 62 percent.

The majority of problems for each community size class are minor ones. However, major problems were reported in 91 communities, about one-fifth of the total with problems. The survey data indicate that the smaller communities have less severe problems than larger areas. In communities with less than 10,000 population, 65 out of 374 areas with problems (17 percent) considered their problem to be major. In the larger communities, 26 out of 102 (about 26 percent) considered air pollution to be a major problem.

A finding of considerable importance, and which is reasonably objective, is the indication that over half (56 percent) of the problem areas are partially (143 communities) or completely (115 communities) the result of pollution sources outside the jurisdiction of the local area government. This would reduce the improvement that could be achieved by strictly local control action.

It should be remembered that the results presented are based on personal opinions of officials interviewed. Some bias is bound to occur in this response. Thus the data should be considered as indicative of trends only.

Objectionable Pollutant Types

The most frequently cited problem is smoke and flyash from incomplete or ineffectively controlled combustion of fuels (Table 5). Nearly two-thirds of the problem areas have experienced these pollutants in objectionable amounts. Fuel smoke refers to a combination of fine carbon particles and liquid tar droplets. Flyash refers to larger air-borne particles of mineral ash and unburned fuel. It tends to settle out of the air fairly rapidly. Smoke and flyash occur in combination with sulfur dioxide and hydrogen sulfide. Sulfur gases, however, were specifically named as problems in only 54 communities. In some of these communities, sulfur gases arise from sources other than fuel combustion. This indicates that the sulfur gas problem in the State may be more severe than indicated by results shown in Table 5.

Refuse smoke was named as an offender in 222 communities. This type of smoke is different from fuel smoke, being composed of large percentages of resinous, non-carbonaceous particles. Industrial dusts of various types were considered objectionable in 192 communities. These dusts vary greatly in composition, depending on the source, and are of a wide size range. Fine metal fumes were next in order of occurrence (45 communities); acid mists, primarily sulfuric acid mist, were specifically cited in six communities; and a group of miscellaneous dusts including road dust, agricultural insecticides, fertilizer dusts and unspecified non-industrial dusts complete the list of particulate pollutants (52 communities).

The most frequently named gaseous pollutants, odorous industrial gases, were cited in 174 communities, 37 percent of the problem areas. Hydrocarbon vapors and ammonia were the gases identified most frequently. Refuse odors were the source of objectionable conditions in 66 communities. Open dumps and poorly operating incinerators were responsible in most cases. Although such odors are not easily analyzed, the predominating gases released from putrescent refuse are mercaptans and alkaloids. Sewage odors were cited in 49 areas. These odors come from open sewers, sewage disposal plants, and domestic septic tanks and cesspools. The most ob-

TABLE 5. TYPES OF AIR POLLUTION REPORTED

Type of Pollutant	Total	Population Range									
		<2,500	2,500-5,000	5,001-7,500	7,501-10,000	10,001-15,000	15,001-20,000	20,001-25,000	25,001-50,000	50,001-100,000	>100,000
Particulates											
Smoke; Flyash	310	31	116	66	18	27	21	6	11	8	6
Refuse Smoke	222	27	67	58	17	19	14	4	7	6	3
Industrial Dusts	192	19	77	43	17	12	12	2	5	3	2
Metal Fumes	45	5	5	14	3	2	2	–	7	4	3
Acid Mists	6	3	1	–	–	–	1	–	1	–	–
Miscellaneous Dust	52	9	21	12	–	6	–	–	2	–	2
Gases											
Industrial Gases	174	12	67	37	9	16	11	4	9	5	4
Refuse Odors	66	5	31	12	4	4	3	–	–	4	2
Sulfur Gases	54	9	9	8	8	11	2	–	2	3	2
Sewage Odors	49	1	21	12	4	8	1	1	–	–	1
Miscellaneous Odors	28	6	11	3	2	2	–	2	–	1	1

jectionable gases arising from excreta and other sewage wastes are hydrogen sulfide, mercaptans, and amines, especially trimethylamine.[8] Miscellaneous odors, including fertilizer odors (primarily ammonia) and rendering odors (amines), produced objectionable conditions in 28 communities.

The similarity of pollution sources causing problems in large and small communities is apparent (Table 6). The frequency that each type was cited does not vary greatly except in the cases of industrial and sulfur gases and metal fumes. These pollutants as a group, occur nearly twice as often in larger communities. This is to be expected since they arise from activities which are more prevalent in the larger areas. The similarity in the other pollutant groups illustrates an important point. Smaller communities are confronted as often as larger areas with the necessity of air pollution control action. These smaller communities are often unable, or in some cases, unwilling to undertake this action.

Major Problem Areas

Table 7 lists the 91 communities which are considered by local officials to be subject to an air pollution problem of major proportions (1959). The list is complete for communities over 2500 in population and includes those with lesser population which were surveyed and found to be major problem areas. The principal objectionable pollutants are shown and location of the sources is given. An attempt has been made to be specific in the pollutant list. Thus mercaptans are listed rather than paper mill odors and $CaCO_3$

TABLE 6. COMPARISON OF POLLUTANTS REPORTED IN LARGE AND SMALL COMMUNITIES

Pollutant	374 Communities with less than 10,000 population		104 Communities with more than 10,000 population	
	No. Reporting	Percent	No. Reporting	Percent
Particulate				
Smoke and Flyash	231	62	79	78
Refuse Smoke	169	45	53	52
Industrial Dusts	156	42	36	35
Metal Fumes	37	10	18	18
Acid Mists	4	1	2	2
Miscellaneous Dusts	42	11	10	10
Gaseous				
Industrial Gases	125	33	49	48
Refuse Odors	52	14	13	13
Sulfur Gases	34	9	20	20
Sewage Odors	38	10	11	11
Miscellaneous Odors	22	6	6	6

TABLE 7

Major Problem Areas and Pollutants
(According to Local Officials)

County	Community	Major Pollutants		Source Location
		Gaseous	Particulate	
Class I (Less than 2500 population) (Incomplete)				
Berks	Temple Borough	SO_2, amines	Metal dust, smoke (a)	L (c)
Cambria	Franklin Borough	SO_2	Fe_2O_3, smoke	L and NL (d)
Clarion	Sligo Borough	SO_2, H_2S	–	L and NL
Clearfield	Goshen Township	SO_2	Flyash (b)	NL
Delaware	Folcroft Borough	–	Smoke	L and NL
Delaware	Trainer Borough	SO_2	–	L
Indiana	Clymer Borough	SO_2, H_2S	–	NL
Indiana	E. Wheatfield Twp.	SO_2, H_2S	–	L
Lancaster	Marietta Borough	–	$AlCl_3$	L and NL
Montgomery	W. Conshohocken Boro.	SO_2	$CaCo_3$, smoke	L
Northampton	Bath Borough	–	$CaCo_3$	L and NL
Northampton	Lower Mt. Bethel Twp.	–	$CaCo_3$	L
Northampton	Stockerton Borough	–	$CaCo_3$	L
Westmoreland	Seward Borough	SO_2	Flyash	NL
Snyder	Shamokin Dam Borough	SO_2	Flyash	L
Class II (2500-5000 population) (Complete)				
Allegheny	W. Homestead Borough	SO_2	Flyash, smoke	L and NL
Allegheny	Springdale Borough	SO_2	Flyash	L and NL
Armstrong	Apollo Borough	SO_2, H_2S	–	NL
Beaver	Baden Borough	SO_2	Flyash	NL
Beaver	Harmony Township	SO_2	Flyash	NL
Berks	Hamburg Borough	–	Metal fume, smoke	L
Berks	Laureldale Borough	SO_2, amines	Metal dusts, smoke	L
Berks	Longswamp Township	S-gases	Smoke	L
Blair	Roaring Spring Borough	Mercaptans	$CaCo_3$	L and NL
Blair	Snyder Township	Mercaptans	Wood dust	L
Chester	Downington Borough	–	Flyash, smoke	L
Clearfield	Morris Township	SO_2, H_2S	Resins	L
Dauphin	Highspire Borough	SO_2	Flyash	L and NL
Delaware	E. Lansdowne Borough	–	Smoke, SiO_2	L and NL
Delaware	Marcus Hook Borough	SO_2, hydrocarbons	Flyash, Al_2O_3	L and NL
Elk	Benzinger Township	–	Carbon	L and NL
Franklin	Antrim Township	Animes	–	L and NL
Lancaster	E. Donegal Township	SO_2	Metal dusts, smoke	L
Lehigh	Catasauqua Borough	–	$CaCO_3$	L and NL
Lehigh	Coplay Borough	–	$CaCO_3$	L and NL
Mifflin	Granville Township	Mercaptans	–	L
Montgomery	Upper Providence Township	Chlorides, hydrocarbons	Smoke, flyash	L and NL
Northampton	Forks Township	–	$CaCO_3$	NL
Venango	Cornplanter Township	–	Flyash, Al_2O_3	L
Venango	Polk Borough	Amines, mercaptans	–	L
Washington	Carroll Township	H_2S, other	Flyash, Fe_2O_2	L and NL
York	Dover Township	Mercaptans, amines	–	L and NL
Class III (5001-7500 population) (Complete)				
Allegheny	Avalon Borough	H_2S	Flyash, smoke	NL
Allegheny	Brackenridge Borough	SO_2	Flyash, Fe	NL
Allegheny	Port Vue Borough	SO_2	Flyash, Fe	NL
Allegheny	Rankin Borough	SO_2	Fe_2O_3, smoke	L
Beaver	Monaca Borough	SO_2	Flyash	L and NL
Berks	W. Reading Borough	SO_2	Flyash	L and NL
Bucks	Doylestown Borough	NH_3, amines	–	L
Elk	Ridgway Borough	–	Flyash, smoke	L
Lackawanna	Olyphant Borough	SO_2, H_2S	–	L and NL
Lebanon	Palmyra Borough	–	$CaCO_3$	L and NL
Lehigh	S. Whitehall Township	Amines, others	–	L and NL
Northampton	Nazareth Borough	–	$CaCO_3$	L
Washington	Smith Township	SO_2, amines	–	L
York	W. Manchester Township	–	$CaCO_3$	L
York	West York Borough	Mercaptans	$CaCO_3$, $CaSO_4$	L and NL

Class IV (7501-10,000 population) (Complete)

Beaver	New Brighton Borough	H_2S, amines	–	NL
Blair	Tyrone Borough	Mercaptans	–	L and NL
Cambria	Richland Township	Amines	–	L
Cumberland	Lower Allen Township	SO_2	$CaCO_3$, carbon	L
Lackawanna	Dickson City Borough	SO_2, H_2S	–	NL
Northampton	Northampton Borough	–	$CaCO_3$	L
Washington	Cecil Township	Glycerides	–	L
York	Spring Garden Township	–	Flyash, rock dust	L

Class V (10,001-15,000 population) (Complete)

Allegheny	Homestead Borough	SO_2	Flyash, smoke	L and NL
Allegheny	N. Braddock Borough	SO_2	Flyash, Fe	L
Berks	Muhlenberg Township	SO_2, amines	Metal dusts, smoke	L
Delaware	Yeadon Borough	–	Flyash, smoke	L
Lehigh	Whitehall Township	–	$CaCO_3$	L and NL
Montgomery	Upper Merion Township	–	$CaCO_3$, Fe_2O_3	L and NL

Class VI (15,001-20,000 population) (Complete)

Allegheny	Braddock Borough	SO_2	Flyash, smoke	NL
Allegheny	Clairton City	SO_2	Flyash, smoke	L
Allegheny	Munhall Borough	SO_2	Flyash, smoke	L and NL
Allegheny	Swissvale Borough	SO_2	Fe_2O_3, carbon	L and NL
Beaver	Ambridge Borough	SO_2	Flyash	NL
Chester	Coatesville City	–	Fe, smoke	L and NL
Franklin	Chambersburg Borough	SO_2	Flyash	L
Luzerne	Hanover Township	SO_2, H_2S	–	L and NL
Westmoreland	Monessen City	H_2S, other	Flyash, Fe_2O_3	L

Class VII (20,001-25,000 population) (Complete)

Washington	Washington City	SO_2	Smoke	L and NL

Class VIII (25,001-50,000 population) (Complete)

Allegheny	Penn Hills Township	–	$CaCO_3$	L
Allegheny	W. Mifflin Borough	H_2S, SO_2	Fe_2O_3, carbon	L and NL
Beaver	Aliquippa Borough	SO_2	Flyash	L
Lebanon	Lebanon City	–	Metal dusts, flyash	L and NL

Class IX (50,000-100,000 population) (Complete)

Cambria	Johnstown City	SO_2, others	Flyash, others	L
Lancaster	Lancaster City	–	Flyash, metal dusts	L and NL

Class X (over 100,000 population) (Complete)

Allegheny	Pittsburgh City	SO_2, others	Flyash, others	L and NL
Berks	Reading City	SO_2, others	Metal dusts, others	L and NL
Lehigh	Allentown City	Amines, others	Flyash, smoke	L
Philadelphia	Philadelphia City	SO_2, others	Flyash, others	L and NL

(a) Smoke - refers to carbon and tars from incomplete fuel combustion
(b) Flyash - refers to entrained fuel ash and unburned fuel
(c) L - Local; pollution sources within jurisdiction of local government
(d) NL - Non-local; pollution sources located outside jurisdiction of local government

rather than cement dust. It is noted again that these are major problem areas according to the subjective opinions of local officials. Objective study, including air sampling, will doubtless remove some of these communities from the list and add others. A discussion of the sources, effects, and control of the pollutants listed will be found in succeeding chapters of this report.

Of the 91 communities listed, 51 (56 percent) were found to have objectionable pollution due partially or completely to non-local sources. This emphasizes the necessity for area-wide control action in many parts of the State. Local control by all affected communities will also produce the same results, but this is a more difficult way and has less chance of being successful.

Chapter II

Where Does It Come from?—Sources

Abstract

The major sources of air pollutants are combustion operations, industrial processes, and, to a lesser degree, agricultural activities and natural phenomena. A large percentage, greater than 80 percent in some areas, of the total weight of pollutants discharged to the atmosphere over a community results from fuel combustion. These fuels are burned in domestic, commercial, industrial, and transportation activities. The remainder of airborne wastes results primarily from non combustion type industrial processes.

As an example of the discharges during fuel combustion, for every ton of coal burned in Pennsylvania, on the average 70 pounds of sulfur dioxide, 20 pounds of hydrocarbons, up to 20 pounds of oxides of nitrogen, and up to 200 pounds of carbon and ash are emitted to the atmosphere. Similar types of discharges, but of different amounts, occur during the burning of fuel oil, natural gas, gasoline, and refuse.

In 1957, the last full year of record, over half the potential energy from fuels consumed in Pennsylvania came from coal. Fuel oil and gas accounted for about one-third of the total and gasoline the remainder. Over three-fourths of the coal was burned by electric utilities and coke and gas plants. The manufacturing industries and domestic users, however, are gradually changing from coal to fuel oil and gas—a prime factor in the dramatic improvement in the atmosphere of several of Pennsylvania's cities during the last 10 to 15 years. The major problem from fuel combustion is changing from one of soot and visibility-obscuring smoke to dust fall from flyash emitted by large-scale coal burning facilities such as electric power plants and central heating stations. In addition, the problem of gaseous emissions is increasing as the total quantity of all fuels burned rises.

Separate fuel use inventories were made in eleven Pennsylvania communities, of differing population, industrial activity, and topography. The total quantities, types, and proportions of major fuels consumed were highly variable. Coal, for example, produced only 4 percent of the combustion energy in the Borough of Media but 53 percent of the energy in Pittsburgh. Fuel oil use varied from 3 percent of the energy in North Charleroi to 44 percent in Harrisburg. The problems created by combustion operations are, therefore, quite different from one community to another.

Using these fuel use inventories, combustion emissions to the atmosphere over these eleven communities were estimated and tabulated according to major source. The total quantities emitted average about 10 percent particulate and 90 percent gaseous. The emissions are for a whole year, prorated to a daily basis. The major particulate emissions are smoke and flyash from coal combustion and organic aerosols from gasoline engines. The major gaseous discharges are sulfur dioxide from the use of coal and fuel oil, hydrocarbons from gasoline engines, and oxides of nitrogen from coal, fuel oil, and gasoline combustion.

In addition to these source inventories, which present the total problem from combustion, it was possible to use local official's interviews to determine areas in the State where combustion emissions created localized and readily discernible problems. In 263 of the 801 communities surveyed, smoke, flyash, and/or sulfur gases from industrial fuel usage were cited as objectionable in localized parts of the communities affected. Electric utilities were responsible in 37 of these areas. Home heating or automobiles and railroads were named as localized problem sources, primarily because of smoke, in 61 areas. Localized smoke and

Estimated Daily Discharges of Objectionable Combustion Products, Eleven Communities, 1958

Community	Daily discharges	Sources		
		Industry and commerce	Domestic activities	Transportation
	Tons	Percent	Percent	Percent
Philadelphia	1975	56	11	33
Pittsburgh	592	51	7	42
Reading	109	33	19	48
Harrisburg	98	30	16	54
Lebanon	58	52	12	36
Williamsport	54	22	25	53
Meadville	47	80	2	18
Lewistown	40	79	6	15
Swoyersville	4	2	37	61
Media	4	5	18	77
N. Charleroi	2	15	25	60
Average		39	17	44

odor problems from domestic waste burning were cited in 135 communities. Municipal waste disposal practices produced objectionable amounts of smoke and flyash in 73 areas. Industrial waste burning, primarily accidental combustion of coal refuse piles, created sulfur gas and smoke problems in 63 communities. At the time of survey 49* culm fires were active in the State.

By far the leading industrial activity in Pennsylvania is manufacturing with the metals and metal products industries accounting for over half of all the value added by manufacture. The other major groups are textiles and textile products, food and kindred products, chemicals and allied products, paper and printing industries, and stone, clay, and glass products. Each of these major industries uses processes, which, when uncontrolled or poorly operated can discharge objectionable materials to the air. Among these are dusts, mists, fumes and gases from steelmaking, metal fabricating, and machinery manufacturing; odors from the food products and paper manufacturing industries; gases, vapors and dusts from chemicals manufacturing and petroleum refining; and dusts from cement making.

The local officials' interviews reveal that process emissions from the manufacturing industries are major problems in many areas of the State, independent of community size. Major industry sources and the number and types of problems they produce are summarized below. The leading problem is industrial gases (odors), creating 185 community problems. Dusts, however, are responsible in 149 communities and it should be noted that these reportedly are the most serious problems. Metal fumes and acid mists produce problems in 13 communities.

Other non-combustion sources of air pollution were cited in local interviews. Agricultural practices created problems, mostly from field and fertilizer dusts, in 51 communities. Milling of mined rock and ore, at the mine, produced objectionable dust problems in 30 areas. Five communities were affected by dust from road construction. Dust from sanded or unpaved roads was cited in 26 communities.

Sewage or refuse odor problems from municipally operated sewerage systems and sewage disposal plants or from open dumps or poorly operated incinerators were cited in 81 communities. Domestic refuse piles and poorly maintained cesspools or septic tanks caused odor problems in 24 areas. Fourteen communities complained of natural sources such as airborne pollens or odorous swamps.

Radioactive sources were not cited. However, 440 users of radioactive materials are registered in the State. Disposal of wastes from these sources can create major problems if not carefully controlled.

Communities Affected by Process Emissions from Manufacturing Industries (Exclusive of Combustion Products)

Industry Group	Total Number of Communities Affected	Major Problem		
		Dust	Gas	Other
Primary Metals	62	43	19	–
Fabricated Metals and machinery Mfg.	57	34	15	8
Petroleum Refining	46	5	36	5
Chemical Products	37	5	32	–
Stone, Clay, and Glass (incl. Cement) Industries	37	28	9	–
Food and Kindred Products	36	5	31	–
Rubber and Leather Products	26	2	24	–
Lumber	19	19	–	–
Paper, Pulp, and Products	11	4	7	–
Other	16	4	12	–
Total	–	149	185	13

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*A recent survey by the Pennsylvania Department of Mines and Mineral Industries has indicated that there are approximately two hundred actively burning culm piles in the state.

Chapter II

Where Does It Come from?—Sources

General

The sources of air pollutants are many and varied. They may, however, be conveniently grouped into three main categories: combustion operations, industrial processes, and a special group including agricultural activities, natural sources, and others.

Combustion Emissions

All fuels can be burned efficiently and completely so that the only materials emitted to the atmosphere are carbon dioxide, water vapor, and, depending on fuel composition and firing methods, oxides of sulfur, oxides of nitrogen, and other minor constituents. The sulfur and nitrogen oxides are classed as air pollutants. Carbon dioxide, unless in very high concentrations which are found rarely in outdoor air, and water vapor are not true air pollutants. Unfortunately it very often happens that fuels are not burned properly and other pollutants may be emitted. These include particulate matter (smoke and flyash) and gases such as carbon monoxide, hydrocarbons, aldehydes, organic acids, and others.

It has been found in other studies [10,11] that a large percentage, greater than 80 percent in some areas, of the total weight of pollutants discharged from the atmosphere over a community result from fuel combustion. These fuels are burned in domestic, commercial, industrial, and transportation activities. The remainder of the air-borne wastes result primarily from industrial processes.

Combustion operations have been studied extensively to determine quantities of various pollutants discharged. Tables 8 through 13 are summaries of the best available factors available at this time (1959) for estimating quantities of pollutants released from combustion of various fuels. These factors have an accuracy of about ±50 percent for any one operation but their reliability is increased by applying them to many similar operations such as to several thousand domestic furnaces or to several hundred industrial fires. By such a method an estimate of total weight of various combustion pollutants can be made for a whole community, the total estimate being, in most cases, within 20 percent of actual amounts discharged. A discussion of methods used for obtaining the factors in Tables 8 through 13 is given in Appendix B.* This estimating technique has been used for eleven Pennsylvania communities.

Industrial Process Emissions

During many industrial operations, pollutants of several types are generated and emitted, either intentionally or unintentionally, to the atmosphere. The many industrial processes involved cannot be described in detail here. However, to give some indication of the problems encountered several of the most important industries in Pennsylvania and their operations with air pollution potential will be described.

Primary metals (ferrous): "During the production of 100 million tons of steel from raw materials to finished products, there will be used at steel plants more than 1 billion tons of air which must, of

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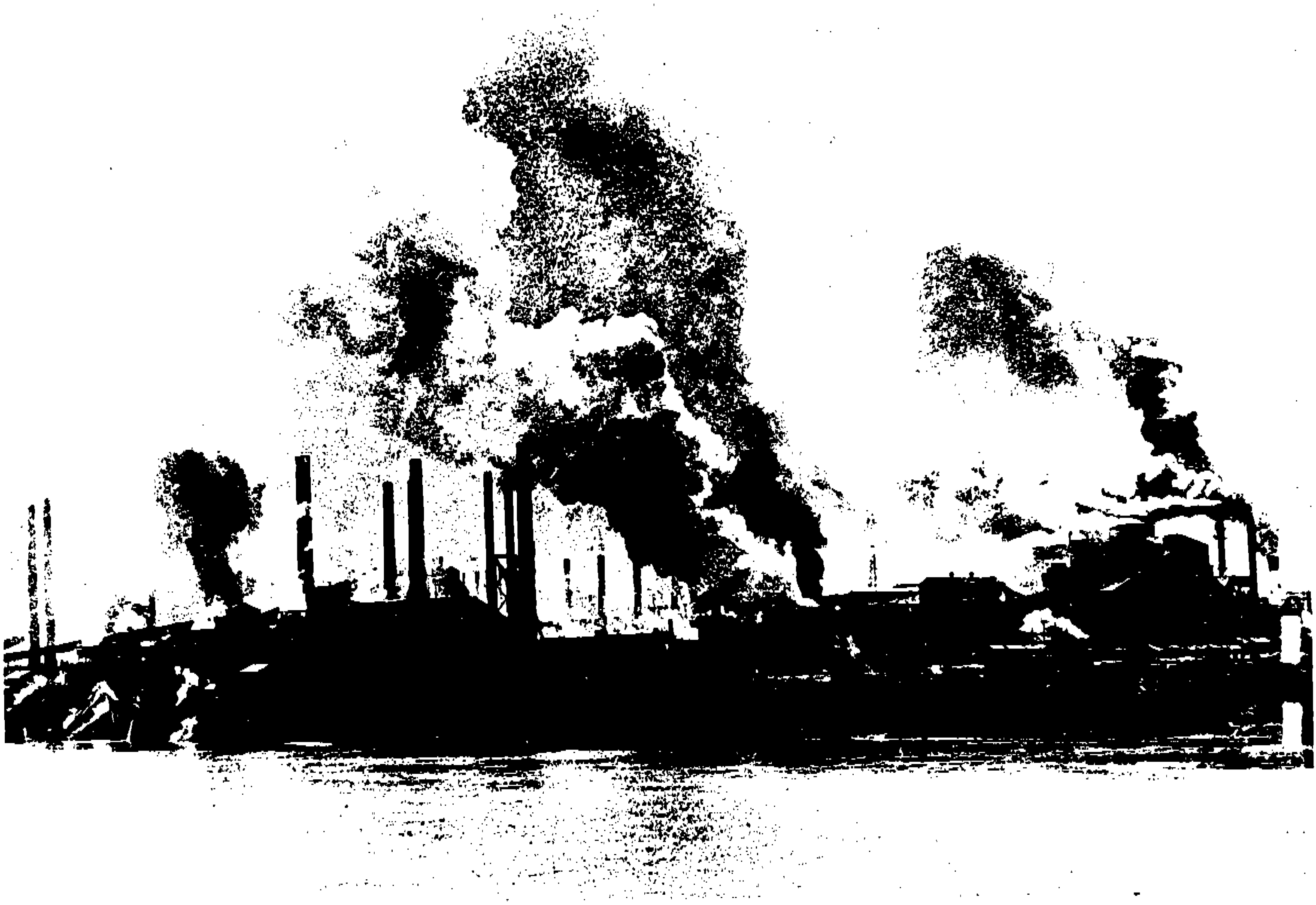
*Estimates of emission rates from various sources are being revised continually as new data become available. Revision is necessary due to modifications of fuel and fuel burning procedures as well as improvements in source sampling and analytical techniques. No doubt at the time this report is published, better estimating factors will be available. Nevertheless, the general method is valid and results are sufficiently accurate for purposes of this report.



More than one billion tons of air are used during the production of 100 million tons of steel.

course, be returned to the atmosphere. In many cases it contains both coarse and fine particles. These particles originate in the mechanical and chemical reactions of hot gases in the in-process materials inside sinter machines, coke ovens, blast furnaces, melting furnaces, convertors, or soaking pits, or on scarfing beds; from the chemical reactions and agitation in the molten bath; and from the combustion fuels."[12] The specific pollutants of major importance are smoke and sulfur gases from coke ovens, dust from blast furnaces (especially during "slips"), and probably the largest single problem, fumes from open hearth furnaces. Other problem areas in steel making processes include the basic oxygen process (fumes), electric furnaces (dusts and fumes), boilers (smoke and flyash), raw material handling (dusts), slag quenching (sulfur gases), sintering (dusts and sulfur gases), and scarfing operations (dusts).

Fabricated metal products and machinery manufacture: These industries are involved in fabricating ferrous and nonferrous products such as cans, tinware, tools, hardware, structural metal products, and in manufacturing engines and turbines, farm machinery, construction, mining and materials handling equipment,

TABLE 8

Estimates of Products of Combustion from Industrial Fuel Burning Operations

(Emissions in Lbs./Lb. Fuel Fired)

Pollutant	Fuel				
	Coal	Fuel Oil	Natural Gas	Wood	Combust. Wastes
Sulfur dioxide	1.7 × S*	1.8 × S	1.8 × S	0.00008	0.0010
Sulfur trioxide	0.2 × S	0.2 × S	0.2 × S	n.a.**	n.a.
Hydrogen sulfide	0.004 × S	n.a.	n.a.	n.a.	n.a.
Oxides of nitrogen (as NO_2)	0.010	0.013	0.005	0.0006	0.0012
Total hydrocarbons	0.010	0.005	0.0015	0.010	0.0007
Inorganic chlorides (as HCl)	0.002	n.a.	n.a.	n.a.	n.a.
Fluorides (as HF)	0.0002	n.a.	n.a.	0.000003	n.a.
Organic acids (as CH_3COOH)	n.a.	0.015	0.0012	0.0002	0.0003
Aldehydes (as CH_3CHO)	n.a.	0.0018	0.0004	0.0009	0.0006
Ammonia	n.a.	0.000006	0.000006	n.a.	0.00015
Particulates	See Table 9	0.00025	n.a.	0.0013	0.004

*S = lbs. sulfur/lb. fuel
**not available
Source: Appendix B, except for Combustible Wastes which represents a selection of values from references 34, 42, 119, 135 and 136.

TABLE 9

Estimates of Particulate Emissions From Industrial Coal Burning

(Emissions in lbs./lb. fuel fired)

Firing Method	Solid Emission
Underfeed stoker	0.15 × A
Travelling grate	0.15 × A
Cyclone Furnace	0.15 × A
Spreader Stoker—dust reinjection	1.00 × A
Spreader Stoker—no dust reinjection	0.60 × A
Pulverized coal	0.75 × A

*A = Ash content from fuel analysis, lbs. ash lb. fuel
Source: Appendix B

TABLE 10

Estimates of Products of Combustion From Domestic Fuel Burning Operations

(Emissions in lbs./lb. fuel fired)

POLLUTANT	FUEL		
	Coal	Natural Gas	Combust. Wastes
Sulfur dioxide	1.8 × S*	1.8 × S	0.0004
Sulfur trioxide	0.04 × S	0.2 × S	n.a.
Hydrogen sulfide	0.004 × S	n.a.	n.a.
Oxides of nitrogen (as NO_2)	0.0002	0.004	0.00025
Total hydrocarbons	0.010	0.0015	0.12
Inorganic chlorides (as HCl)	0.0002	n.a.	n.a.

TABLE 10 (cont.)

POLLUTANT	FUEL		
	Coal	Natural Gas	Combust. Wastes
Fluorides (as HF)	0.0002	n.a.	n.a.
Organic acids (as acetic)	n.a.**	0.0012	0.0008
Aldehydes (as CH_3CHO)	n.a.	0.0006	0.002
Ammonia	n.a.	0.000006	0.0009
Particulates	see Table 11	n.a.	0.012

NOTE: See Table 8 for fuel oil and wood combustion
*S = lbs. Sulfur/lb. coal
**n.a. = not available
Source: Appendix B, except for Combustible Wastes which represents a selection of values from references 34, 42, 119, 135, and 136.

TABLE 11

Estimates of Particulate Emissions From Domestic Coal Burning

(Emissions in lbs./lb. fuel)

Firing Method	Carbon & Tars (< 1μ diameter)	Carbon & Tars (> 1μ diameter)	Ash (> 1μ diameter)
Hand-fired furnaces	0.006	0.004	0.002
Stoker-fired furnaces or stoves	0.0025	0.0015	0.0015
Hand-fired stoves	0.014	0.010	0.003

Source: Appendix B

TABLE 12

Size Characteristics of Particulates Produced in Fuel Combustion

Fuel	Firing Method	Mass Median Dia. (microns)	Standard Geometric Deviation	Percent by Weight Less Than 1 Micron
Coal, Industrial	Underfeed stoker	20	3.9	3
	Travelling grate	75	2.0	0.01
	Cyclone Furnace	5	3.7	12
	Spreader Stoker	57	4.1	0.2
	Pulverized Coal	20	2.5	0.1
Coal, Domestic	All Methods:			
	Suspended carbon and tars	0.3	2	95
	All carbon and tars	–	–	60
	All ash	> 1	–	0
Fuel Oil	Industrial and Domestic burners	> 1	–	100
Waste wood	Silo incinerators	16	3	0.7

Source: Appendix B

TABLE 13

Estimates of Emissions From Internal Combustion Engines*

(Emissions in lbs./gal. fuel burned)

Pollutant	Fuel: Gasoline (Automobiles, City Driving)	Fuel: Diesel Fuel (Buses, City Driving & R.R. Loco's.)
Gases		
Oxides of Sulfur (as SO_2)	12 × S**	14 × S
Oxides of Nitrogen (as NO_2)	0.056	0.222
Aldehydes (as CH_3CHO)	0.007	0.016
Organic Acids (as CH_3COOH)	0.004	0.031
Ammonia	0.002	n.a.
Hydrocarbons, Total	0.815	0.715
Paraffins, Total	0.365	
Olefins, Total	0.380	
Acetylene	0.038	
Aromatics, Total	0.032	
Particulates (all $<1\mu$)		
Carbon (non-ether sol.)	0.006	0.086
Tars (ether sol.)	0.008	n.a.
Oils (motor oil mist)	0.012	n.a.
Lead Compounds (as PbCl.Br)	0.0014 × TEL***	n.a.

*Tailpipe emissions only

**S = lbs. S/lb. fuel

***TEL = ml. tetraethyl lead/gal.

Source: Appendix B

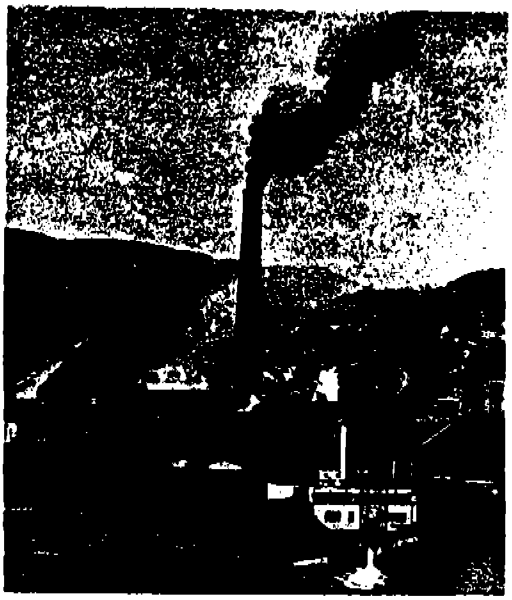
metalworking machinery, and general industrial machinery and equipment. The main sources of pollution in these industries are associated with the melting, casting, heat-treating, and finishing of metal and metal products. Many of these industries include foundry operations which produce dusts, gases, smoke and fumes.[13] Dusts from casting shakeout and grinding, gases and vapors from core baking ovens and oil quenching tanks, and dusts, smoke, and fumes from cupolas and melting furnaces are the major problem sources in foundry operations. In the non-foundry operations, major problem sources are smoke and flyash from heat-treating furnaces, dusts from grinding and sand-blasting areas, vapors and mists from pickling and dipping baths, and fumes from large-scale welding operations.

Mining industries: These industries include those establishments engaged in the extraction of naturally occurring minerals, such as coal, ores, natural gas, stone and clay. Besides the actual mining or quarrying operation, these industries are also engaged in crushing, screening, and washing of the mined materials. The most important air pollutant arising from these operations is dust from the milling of the mined material such as from coal cleaning operations and from the crushing and screening of limestone. A severe problem also arises from the uncontrolled disposal of coal refuse. Coal refuse piles (also called "gob," "bony," or "culm" piles) contain coal of various forms, sand, shale, clay, iron carbonate and iron sulfide.[14] About half of the discarded material is combustible. Spontaneous heating of bituminous piles, especially when wet, results in the formation of sulfur dioxide and sulfuric acid, and by secondary reaction hydrogen sulfide. Piles often reach several thousand feet in diameter and when burning can produce tons of sulfur gases daily.

Stone, clay, and glass products industries: This group includes industries engaged in manufacturing cement, structural clay products, pottery, concrete products, cut stone, abrasives, and glass products. In the operation of these establishments dust is the major air pollutant produced. Problem process areas are milling (crushing, grinding, screening), and heating (kilns). A major source is the rotary kiln in the cement industry which often produces high concentrations of limestone and silicate dusts. Smoke and odors from kiln fires are also important problems in these industries.

Petroleum refining: The major contaminants emitted to the atmosphere from petroleum refinery operations are hydrocarbons, oxides of nitrogen, particulate matter, sulfur compounds, aldehydes, and organic acids.[15] The major sources of hydrocarbons are storage tanks, catalytic cracking units, equipment leakage, and fuel combustion operations. These last sources, which include boilers, heaters, and internal combustion engines, are also responsible for large quantities of sulfur dioxide, nitrogen oxides, particulates, and other pollutants. Certain other processes may also create problems, such as waste water separators, vacuum jets and cooling towers (hydrocarbons), waste gas flares (smoke and sulfur dioxide), and blowdowns and turnarounds (hydrocarbons).

Chemicals and allied products: This group includes establishments producing basic inorganic and organic chemicals and those manufacturing products by chemical process, such as fibers, plastics, drugs, paints, and fertilizers. The chemical industry is often necessarily engaged in the use and manufacture of hazardous and toxic substances, and because of this, has instituted safety procedures as a basic part of their operations. Nevertheless emissions to the atmosphere of objectionable substances by this industry do occur. There are many different operations, depending on product type and unit process, where pollutants may be emitted. In basic chemicals, off-gases from reactor and scrubber vents, and from cooling towers and open tanks often give rise to odor and noxious gas problems. Paint and varnish manufacturing can produce dust problems from material handling, crushing and grinding operations, and odors from "cooking" processes. Fertilizer produc-



Industrial activity..........

tion often results in dusts from dryers and odors from cooling towers. Plastics and synthetic rubber making give rise to off-gas (vents) problems, and dusts from driers and rolling mills. Combustion products and entrained dusts from process heating are problems in many types of chemical industry.

Food and kindred products: In this group are included establishments manufacturing and/or processing foods and beverages, animal fats and oils, and prepared animal feeds. Meat packing, dairy products processing, canning and preserving fruits, vegetables, and sea foods, manufacture of grain mill products, and beverage production, are the major types in this group. Odors are the major pollutants arising from these industries and vary from offal and excreta odors in the meat products industry to the odors of wastes from the canning and malt beverage industries. Dusts can be a problem from grain mills and dehydrators.

Paper and allied products: In the manufacturing of paper from wood and other cellulose materials the most important air pollution problem is odors from digesters and black liquor recovery furnaces in the kraft pulping operation. A chemical smoke containing sodium sulfate particles is also given off. Wood dusts from the slashing, debarking, and grinding of logs may sometimes create a problem. Paperboard manufacturing can produce dust problems from cutting and milling operations.

waste disposal..........

and domestic activity, contribute to community air pollution.

Miscellaneous Emissions

Although practically every major source of air pollution can be classified as arising from either a combustion operation or industrial process, there are a few which cannot be so classified. Certain agricultural practices such as insecticide spraying, fertilizing, and some planting and harvesting operations can, at times, produce objectional dusts and odors. Natural sources such as pollens from weeds, road dusts, and occasionally, smoke from forest fires can also create objectionable situations. Commercial and municipal activities can cause problems arising from combustion operations such as electric power plants, burning dumps, and poorly designed or inefficiently operated incinerators. Odors from raw sewage or improperly operating sewage disposal plants can also produce unpleasant problems.

Pennsylvania

Combustion Emissions

Fuel use and trends: Table 14 summarizes the total quantities of various fuels consumed in Pennsylvania in 1957. Coal is still the major fuel used despite trends toward the use of other fuels. Over three-fourths of the coal is used by electric utilities and coke and gas plants (Table 15). Manufacturing industries and domestic users are gradually switching from coal to fuel oil and gas (Table 16). Although data for 1959 were not available for the State when these tables were compiled, the community fuel use information presented below confirms that this trend is continuing.

The meaning of these trends is very important. Smaller coal burning installations (domestic and small industrial furnaces) produce by far the largest amounts of smoke per pound of coal used (Tables 9 and 11). The dramatic change in the atmospheres of several of Pennsylvania's cities during the last 10 or 15 years is due in great measure to the changeover of these smaller plants to other fuels which cause less smoke. The enormous quantities of coal used by electric utilities, central heating stations, and large industries are today burned practically without smoke. However, in these operations, firing rates and therefore the combustion air increase. These high air rates, and other factors, cause large quantities of flyash to be entrained and, unless controlled, emitted, and eventually deposited as dustfall. This problem, although it does not cause reduced visibility, is nevertheless important because of the dirtying and damaging properties of flyash.

Fuel oil use is increasing as is the use of gas (Table 16). Although these fuels

TABLE 14

Fuel Consumption in Pennsylvania, 1957

Fuel	Quantity (1,000,000's)	Potential Energy (a) Trillion BTU	Percent Energy
Coal[16,17]			51
Bituminous (b)	41.5 tons	1120	
Anthracite (c)	9.7 tons	262	
Fuel Oil[18]			19
Distillate (d) (e)	45.7 bbls.	270	
Residual (d)	44.5 bbls.	252	
Gas[19]			16
Natural	314,000 cu. ft.	314	
Manufactured	26,000 cu. ft.	13	
Mixed	109,000 cu. ft.	98	
Gasoline[20]	3,170 gals.	380	14
Liquefied Petroleum Gas[21]	120 gals.	12	<1
Total		2721	100

(a) Assuming 100 percent combustion efficiency
(b) Based on first 9 months of 1958
(c) Based on Apr. 1957 through March 1958
(d) Including all company use (fuel not sold)
(e) Including diesel fuel, kerosene, and range oil

TABLE 15

Fuel Distribution by Consumer, (a) 1957

Fuel	Type	Consumer	Percent Used
Coal	Bituminous	Coke and gas plants	46
		Electric Utilities	32
		Retail Dealers	3
		Others (b)	19
	Anthracite	All users	100 (c)
Fuel Oil	Distillate	Heating—all users	65
		Industry (d)	16
		Railroads and vessels	14
		Others (e)	5
	Residual	Industry (d)	67
		Railroads and vessels	16
		Heating—all users	9
		Gas & Electric utilities	5
		Others (e)	3
Gas	All types	Domestic users	50
		Industry	37
		Commerce	10
		Others (f)	3
Gasoline	All grades	All users	100 (c)
Liquefied Petroleum Gas	All types	Industry	51
		Domestic users & commerce	42
		Others (g)	7

(a) Source: References given in Table 14
(b) Includes all others except railroads and vessels
(c) Distribution not available
(d) Including all company use
(e) Includes military and other uses
(f) Includes public consumers and utilities
(g) Includes internal combustion engines and other uses

TABLE 16

Trends in Fuel Usage By Major Consumers

Manufacturing Industries[22]

Fuel	1947		1954	
	Potential Energy Trillion BTU	Percent	Potential Energy Trillion BTU	Percent
Gas (nat'l. & mfg.)	923	43	1112	54
Coke	533	24	392	19
Coal (Bit. & Anth.)	517	24	344	16
Fuel Oil (Dist & Resid)	124	6	144	7
Other	64	3	77	4

Home Heating[23,24]

Fuel	1940		1950	
	Dwelling Units	Percent Using Fuel	Dwelling Units	Percent Using Fuel
Coal or Coke	2,122,309	86	1,726,860	60
Fuel Oil	137,387	6	424,325	15
Gas	108,075	4	592,700	21
Wood	72,720	3	47,910	2
Other or none	21,806	1	45,280	2
Total	2,462,297	100	2,337,075	100

Automotive Fuel[20,25,26]

Year	Registered Motor Vehicles			Fuel Consumption	
	Passenger	Commercial	Other	Gasoline Million Gal.	Diesel Fuel Million Gal.
1950	2,575,219	484,549	153,387	—	—
1953	2,915,296	536,530	173,679	2584	26
1957	3,426,391	572,926	—	3095	72

can be burned smokelessly, particulate emission (flyash and soot) during large scale burning of fuel oil, such as in electric power plants, can be a problem. A growing problem, however, arises from invisible gaseous emissions. The gases generated during the burning of liquid fuels (including gasoline) can produce objectionable concentrations of noxious gases over some communities.

Use of automotive fuel has been increasing at the very significant rate of about 5 percent per year since 1950 (Table 16). This is beginning to and will continue to create gaseous air pollution problems in the State. Even now, "smog" of the Los Angeles variety forms occasionally in the larger cities of the State. This type of problem can be expected to increase in frequency and severity in the future.

Problems from fuel combustion will continue to increase as population increases. The State's population is climbing at about one percent per year (Table 17). By 1970 there will be another one and one-half million people living in this State. Fuel use will necessarily increase proportionally. Furthermore, it is expected that urban areas will become larger. This in turn will lead to more severe problems and a large exposed group. Not only will problems from fuel use increase but those from industrial processes will also become more prevalent.

TABLE 17

Population and Growth Trends for Pennsylvania[27]

Year	Population	Percent Increase per year	Percent Urban
1930	9,631,350	-	67.8
1940	9,900,180	0.3	66.5
1950	10,498,012	0.6	65.8*
1958 (Estimated)	11,101,000	0.8	-
1970 (Projected	12,508,000	1.2	-

*According to new urban definition, 1950, 70.5 percent

TABLE 18

Communities for Which Fuel-Use Inventories Were Made

Community	County	1950 Population	Major Industry	Topography	Prevailing Wind & Ave. Speed-MPH	Surveyed By
Cities						
Philadelphia	Philadelphia	2,071,605	Diversified	Coastal plain	SW 9.7	Phila. Dept. Pub. Health
Pittsburgh	Allegheny	676,806	Iron and steel products	Narrow valley & surrounding hills	S 10.3 (a) WSW 10.2 (b)	Alleg. Co. Dept. Public Health
Reading	Berks	109,320	Railroad repair, textiles	Rolling hills, mountains to S and E	NW 8.8	Pa. Dept. Health
Harrisburg	Dauphin	89,544	Steel plate, elec. machinery	Saucer-like bowl 8–10 mi. wide	WNW 7.6	"
Williamsport	Lycoming	45,047	Aircraft parts, steel wire	Deep narrow river valley	WSW 6.8 (c)	"
Lebanon	Lebanon	28,156	Steel hardware	Rolling hills	NW 8.8 (d)	"
Meadville	Crawford	18,972	Metal fasteners rayon yarn	Shallow valley	S 10.1 (e)	"
Boroughs						
Lewistown	Mifflin	13,894	Rayon yarn	Flat valley 6 mi. wide	SW 6.8 (c)	"
Swoyersville	Luzerne	7,795	Anthracite mining	Deep river valley	SW 6.8 (c)	"
Media	Delaware	5,726	None	Rolling hills	SW 9.7 (f)	"
N. Charleroi	Washington	2,554	None	Narrow river valley	S 10.3 (g)	"

(a) Allegheny County Municipal Airport
(b) Greater Pittsburgh Airport
(c) Using data for Scranton, corrected for valley orientation
(d) Using data for Reading
(e) Using average data for Erie and Pittsburgh
(f) Using Philadelphia data
(g) Using Pittsburgh data

Fuel use—community inventories: To assess air pollution arising from combustion sources, fuel-use inventories were made for eleven Pennsylvania communities (Table 18). Tables E-1 to E-11 (Appendix E) summarize the results of these surveys. The primary purpose of these inventories is to assess the overall combustion emissions to the atmosphere of a variety of communities and to use these emissions to calculate probable atmospheric concentrations of major contaminants.

The communities surveyed were representative of a wide population range and are spread throughout the State (Figure 1, Chapter III). The communities covered a range in population from about 2500 to over 2 million; in major industry from none to highly diversified; in topography from narrow valleys to open rolling plains; and cover all major physiographic areas in the State. Refined estimates were made in many cases. For example, the collection efficiency, either measured or estimated, of air cleaning equipment was used when necessary to arrive at estimates of particulate discharges. Variations in fuel composition, firing method, and condition of the fuel burning equipment also were considered.

Table 19 summarizes the fuel-use inventory data. There is a 1000-fold variation in the total potential energy of the fuels burned, between the smallest and largest communities surveyed. The predominant fuel is variable. The six communities (Pittsburgh, Williamsport, Lebanon, Meadville, Lewistown, Swoyersville) where coal is the predominant fuel are all, with the exception of Lebanon, comparatively close to major coal producing regions. Fuel oil is the predominant fuel in Philadelphia, Reading, and Harrisburg, while natural gas predominates in North Charleroi. The variation in the percentage of gasoline energy is due, indirectly, to the predominance of or lack of industry in the area. In the very small communities where industrial activity is negligible gasoline combustion represents about one-third of all fuel combustion energy. Where industrial activity is greater than proportional for the community size gasoline energy amounts to only about 10 percent of the total (Meadville, Lewistown). Gasoline combustion in the remaining "typical" com-

TABLE 19

Summary of Fuel Consumption in Eleven Pennsylvania Communities, 1958

Community	Quantity Consumed				Equivalent Energy—Trillion BTU					Relative Fuel Consumption—Percent			
	Coal 1000 tons	Fuel Oil Million gallons	Gas Billion cu. ft.	Gasoline Million gallons	Coal	Fuel Oil	Gas	Gasoline	Total	Coal	Fuel Oil	Gas	Gasoline
Philadelphia	3,250	727	63.9	450	87.7	105	60.6	54.0	307	28	34	20	18
Pittsburgh	2,650	46.7	42.0	160	71.6	6.8	37.8	19.2	135	53	5	28	14
Reading	156	57.1	2.0	35.9	4.2	8.3	2.0	4.3	18.8	22	44	11	23
Harrisburg	171	49.2	2.7	36.8	4.6	7.1	2.7	4.4	18.8	25	38	14	23
Williamsport	114	15.0	0.2	19.3	3.1	2.2	0.2	2.3	7.8	40	28	3	29
Lebanon	141	17.3	0.6	14.4	3.8	2.5	0.6	1.7	8.6	44	29	7	20
Meadville	131	0.3	1.7	5.9	3.5	0.4	1.7	0.7	6.3	56	6	27	11
Lewistown	180	4.2	1.3	4.2	4.9	0.6	1.3	0.5	7.3	67	8	18	7
Swoyersville	16	0.4	<0.1	1.9	0.4	0.1	<0.1	0.2	0.7	60	8	negl	32
Media	1	1.4	0.1	2.1	<0.1	0.2	0.1	0.2	0.5	4	36	17	43
N. Charleroi	2	0.1	0.1	0.7	0.1	<0.1	0.1	0.1	0.3	26	3	39	32

*Coal—Includes bituminous and anthracite coal and coke.
Fuel Oil—Includes residual and distillate fuel oils, residue tar (Pittsburgh), LPG (Swoyersville), and diesel fuel.
Gas—Includes natural, mixed, and coke oven (Pittsburgh) gas.
Gasoline—All grades of motor gasolines.

munities accounts for 20 to 30 percent of all combustion energy.

The effects of these fuel usage patterns on air pollution problems is illustrated in the emission estimates presented in Tables E-12 through E-22 (Appendix E). These tables show in detail the mean daily emissions (averaged over a year) of the major gaseous and particulate pollutants according to fuel burned and major user. In every community the major gaseous emissions are sulfur dioxide, hydrocarbons, and oxides of nitrogen. The major coarse particulate emission is flyash while the fine particulates are primarily coal smoke and aerosols from gasoline engines. Table 20 summarizes the emission data for all eleven communities. Total discharges vary about 1000-fold from the smallest to the largest community. On the average, invisible gaseous pollution accounts for about 91 percent of the total discharges. This emphasizes the magnitude of sources which often are overlooked—the community-wide, individually small, contributors to gaseous and fine particulate air pollution.

For these communities, industrial and transportation sources are responsible for about equal fractions of the total pollutant discharges from combustion operations, about 40 percent in each case. Variations among communities are great, however. For example, the industrial contribution varies from 2 to 80 percent while vehicular emissions vary from 15 to 77 percent. Domestic sources contribute the balance of emissions, averaging about 17 percent.

Gaseous pollutant discharges generally are similar to total discharges in major source. Particulate emissions, however, are extremely variable. Industry is responsible for from one to 92 percent, averaging about 50 percent. Domestic and vehicular sources each contribute about one-fourth of the particulate pollution, on the average.

The variations in major fuel source are quite wide. However, use of coal and automotive fuels each are responsible for about 40 percent of the total. Fuel oil usage contributes the bulk of the remaining emissions. Gas and combustible waste burning are of relatively minor importance in all areas.

Combustion emissions—problem areas: Interviews with local officials provided pollution data which have been categorized by source. Table 21 summarizes these data for the areas where combustion products were considered the major pollution source. In many areas more than one source of combustion products were named. The major source of complaint was inefficient or uncontrolled fuel burning by industry which was responsible for objectionable conditions in 263 communities, about one-third of those surveyed. Smoke, flyash, and sulfur gas odors were the causes of complaint. Electric utilities are listed separately

TABLE 20

Summary of Combustion Emission Estimates in Eleven Pennsylvania Communities, 1958*

Community	Emissions			Relative Contribution by Sources—Percent			Relative Contribution by Fuel—Percent				
	Type	Quantity tons/day	Percent	Indust-trial	Domestic	Vehicu-lar	Coal	Fuel oil	Gas	Combust. waste	Gaso-line**
Philadelphia	Total	1975	100	56	11	33	28	37	2	1	32
	Gaseous	1890	96	56	10	34	27	40	2	–	31
	Particulate	85	4	54	21	25	58	10	2	7	23
Pittsburgh	Total	592	100	51	7	42	50	3	3	2	42
	Gaseous	480	81	42	8	50	41	3	4	2	50
	Particulate	112	19	87	6	7	89	1	–	3	7
Reading	Total	109	100	33	19	48	19	32	1	–	48
	Gaseous	102	94	33	18	49	16	34	1	–	49
	Particulate	7	6	44	32	24	74	2	–	–	24
Harrisburg	Total	98	100	30	16	54	18	27	1	–	54
	Gaseous	94	96	31	14	55	15	28	2	–	55
	Particulate	4	4	17	46	37	60	3	–	–	37
Lebanon	Total	57.6	100	52	12	36	46	14	1	3	36
	Gaseous	52.5	91	50	12	38	42	16	1	3	38
	Particulate	5.1	9	77	12	11	84	2	–	3	11
Williamsport	Total	54.4	100	22	25	53	29	12	–	6	53
	Gaseous	48.2	89	18	25	57	23	14	–	6	57
	Particulate	6.2	11	59	27	14	80	–	–	6	14
Meadville	Total	47.4	100	80	2	18	80	–	2	–	18
	Gaseous	42.8	90	79	2	19	78	1	2	–	19
	Particulate	4.6	10	92	2	6	92	–	–	2	6
Lewistown	Total	39.9	100	79	6	15	79	4	2	–	15
	Gaseous	33.1	83	76	6	18	76	4	2	–	18
	Particulate	6.8	17	91	6	3	97	–	–	–	3
Swoyersville	Total	4.4	100	2	37	61	36	3	–	–	61
	Gaseous	4.0	91	2	33	65	32	3	–	–	65
	Particulate	0.4	9	5	75	20	80	–	–	–	20
Media	Total	3.7	100	5	18	77	2	20	1	–	77
	Gaseous	3.6	97	7	16	77	1	20	1	1	77
	Particulate	0.1	3	1	33	66	33	1	–	–	66
N. Charleroi	Total	2.0	100	15	25	60	18	–	2	20	60
	Gaseous	1.9	95	14	24	62	16	1	2	19	62
	Particulate	0.1	5	27	46	27	47	–	–	26	27
Average	Total	–	100	39	17	44	37	14	2	3	44
	Gaseous	–	91	38	15	47	35	13	2	3	47
	Particulate	–	9	50	28	22	72	2	–	4	22

*Emissions do not include carbon monoxide. See tables 8-13.
**Includes diesel fuel.

because of the tremendous quantities of fuel burned and, therefore, the magnitude of the problems created. In 37 communities flyash and in some cases sulfur gases were the source of objectionable conditions due to electric utilities.

Burning of trash by individual residents produced problems in 135 communities, 17 percent of those surveyed. Municipal burning of both domestic and industrial wastes was responsible for objectionable conditions in 73 communities. Industrial waste disposal, primarily uncontrolled culm bank fires, caused complaint in 63 areas. Forty-nine culm fires were reported. Domestic heating (42 communities) and transportation sources (19 areas) were cited in comparatively few communities.

It should be emphasized that these problem areas were so named primarily because of complaints due to smoke or flyash. Invisible gaseous pollution exists in many other areas not cited. Sulfur gases, especially from burning waste coal piles and large-scale electric utilities, are of special note in this regard. Gaseous and particulate discharges from

TABLE 21

Communities Reporting Combustion Products As A Major Pollutant

Population Range	Number Surveyed	Number Reporting Problems from Fuel Burning					Number Reporting Problems from Waste Burning				
		Industrial		Domestic	Transportation		Industrial*		Domestic	Municipal**	
		Utilities	All Others	Home Heating	Automobiles	Railroads	Coal Wastes	All Others	Open Burning	Dumps	Incinerators
Less than 2500	71	6	17	4	2	–	8	4	15	6	2
2500-5000	345	11	80	12	2	–	15	2	39	23	3
5001-7500	169	9	52	7	1	6	14	8	35	13	2
7501-10,000	65	2	11	3	1	–	2	–	11	4	2
10,001-15,000	63	5	27	3	1	2	4	–	15	4	–
15,001-20,000	39	–	12	6	–	–	5	–	9	1	4
20,001-25,000	12	1	6	1	2	–	–	–	2	1	1
25,001-50,000	20	2	11	3	–	–	–	–	5	2	–
50,001-100,000	11	1	4	2	1	1	–	–	4	2	–
Greater than 100,000	6	–	6	1	–	–	1	–	–	2	1
Total	801	37	226	42	10	9	49	14	135	58	15

*Including commercial establishments
**Public incineration of domestic and industrial wastes

transportation sources, although often overlooked (only 19 communities cited these sources), are nevertheless important sources as is shown in Table 20.

Industrial Process Emissions

Tables 22 and 23 summarize the latest available industrial statistics for Pennsylvania. Manufacturing is by far the most important industrial activity both from the standpoint of value of production and number of employees. The metals and metal products industries account for over half of all the value added by manufacture in Pennsylvania's manufacturing industry (Table 23). The other major groups are, in order, textiles and textile products, food and kindred products, chemicals and allied products, paper and printing industries, and stone, clay and glass products.

The results of interviews with local officials are presented in Table 24 as they pertain to the manufacturing industries. Primary metals (62 problem areas) and metal products (53 problem areas) lead as sources in numbers of communities affected by process emissions from manufacturing. The emissions are pri-

TABLE 22

Industrial Activity in Pennsylvania, 1957 (a)

Industry Group	Employment		Value of Production	Net Income
	Number	Percent	Billions of Dollars	
Agriculture	147,200	3.7	0.76	
Manufacturing	1,509,400	38.2	26.70	
Mining	88,500	2.2	0.82	
Construction	178,500	4.5	0.78	
Transportation	215,400	5.4		0.13 (b)
Public utilities	96,200	2.4		0.23 (c)
Trade	739,900	18.8		–
Finance, Insurance, & Real Estate	141,400	3.6		–
Service & Misc.	428,300	10.8		–
Government	409,300	10.4		–
	3,954,100	100.0		

(a) Sources: Tables 119, 128, 130, 133, 136, 145, 148, 156, 158, 160 of reference 27.
(b) Includes railroads, motor bus, and electric transportation only
(c) Includes water, electric, gas, and telephone utilities

TABLE 23

Manufacturing Industry Statistics, 1947 and 1957[27,31]

Industry	Employment—Thousands		Value Added by Manufacture Millions of Dollars		Percent of Value Added			
	1957	1947	1957	1947	1957		1947	
Metals and Metal Products					56.7		48.0	
Primary Metal Industries	271.2	263.5	2843.3	1219.0		22.6		17.5
Fabricated Metal Products	110.4	113.5	922.3	533.0		7.3		7.7
Machinery; Except Electrical	133.7	136.1	1228.5	665.4		9.7		9.6
Electrical Machinery	127.6	92.7	1282.5	509.1		10.2		7.3
Transportation Equipment	74.8	64.6	695.3	314.4		5.5		4.5
Instruments and Related Products	20.6	20.7	174.8	94.3		1.4		1.4
Textiles and Textile Products					8.7		15.1	
Textile Mill Products	92.2	138.7	501.6	621.4		4.0		8.9
Apparel and Related Products	161.4	140.8	595.8	433.7		4.7		6.2
Food and Kindred Products	120.1	103.3	1067.5	588.3	8.4		8.4	
Chemicals and Allied Products					7.9		8.1	
Chemicals and Products	46.6	43.6	716.9	312.0		5.7		4.5
Petroleum and Coal Products	18.8	29.7	277.1	246.9		2.2		3.6
Paper and Printing Industries					6.8		7.9	
Paper, Pulp and Products	41.3	35.3	385.2	205.0		3.0		3.0
Printing and Publishing	58.9	54.7	486.5	339.6		3.8		4.9
Stone, Clay and Glass Products	68.3	72.9	640.0	339.9	5.1		4.9	
Rubber and Leather Goods					2.5		3.0	
Rubber Products	13.5	15.1	166.6	81.5		1.3		1.2
Leather and Leather Goods	31.0	31.1	146.0	125.1		1.2		1.8
Lumber and its Remanufacture					1.6		1.7	
Lumber and Wood Products	13.9	15.4	69.1	49.4		0.5		0.7
Furniture and Fixtures	21.4	18.6	137.2	73.0		1.1		1.0
Miscellaneous Manufactures	34.3	30.1	200.7	131.3	1.6		1.9	
Tobacco Manufactures	13.3	19.4	85.9	66.3	0.7		1.0	
Total	1473.4	1439.5	12,622.9	6946.9	100.0		100.0	

marily metal dusts, although some areas cite odors (mostly sulfur gases) as the major problem. In a few communities, metal fumes or acid mists are the prime complaint.

Petroleum and related products industries are second (46 areas) as sources in total numbers of communities affected by manufacturing process emissions. The problems are predominantly gaseous (odors). The chemicals and chemical products industries are next; process emissions, mostly gaseous, affecting 37 communities. The stone, clay and glass products industries also produce objectionable conditions in 37 communities. These are mostly particulate problems. The food and kindred products industries are responsible for problems, mostly odors, in 36 areas.

From the standpoint of community size it is obvious that all community size groups are affected by industrial process emissions. The size group 2500 to 5000

Odors are the major pollutants arising from food processing plants.

TABLE 24

Number Of Communities Affected By Process Emissions From Manufacturing Industries

(Exclusive of Combustion Products)

Industry Group	Population Range										Total	Major Problem		
	< 2500	2501-5000	5001-7500	7501-10000	10001-15000	15001-20000	20001-25000	25001-50000	50001-100000	> 100000		Dust (a)	Gas (b)	Others (c)
Primary Metals Indus.	2	29	14	8	3	2	1	–	3	–	62	43	19	–
Petroleum & Coal Prods.	12	18	3	3	2	2	–	–	3	3	46	5	36	5
Chemicals & Products	5	8	9	1	2	3	1	6	–	2	37	5	32	–
Stone, Clay & Glass Prod.	7	12	8	6	4	–	–	–	–	–	37	28	9	–
Machinery Except Elect.	1	6	13	3	6	2	1	4	–	1	37	23	9	5
Food & Kindred Products	6	17	8	2	–	2	–	1	–	–	36	5	31	–
Rubber Products	–	6	3	1	3	2	1	–	–	–	16	1	15	–
Fabricated Metal Prods.	2	5	2	–	2	1	1	1	1	1	16	11	3	2
Lumber & Wood Products	1	8	3	–	1	1	–	1	–	–	15	15	–	–
Paper, Pulp & Products	1	4	5	–	1	–	–	–	–	–	11	4	7	–
Leather & Leather Goods	1	3	3	–	2	–	–	1	–	–	10	1	9	–
Tobacco Manufactures	–	5	2	–	1	–	–	–	1	–	9	2	7	–
Others	–	4	2	–	1	3	3	1	1	–	15	6	8	1
Total Number of Problems(d)	38	125	75	24	28	18	8	15	9	7	347	149	185	13

(a) Inclusive only of process dusts such as Fe_2O_3, $CaCO_3$, etc.
(b) Includes industrial gases and odors
(c) Includes acid mists, metal fumes, etc.
(d) This total is not equal to total number of affected areas because of duplication.

leads in total number of problems. This is due to the large number of communities in this group.

With respect to problem type, industrial gases (odors) lead, creating 185 community problems. Industrial dusts, however, are responsible in 149 communities. Metal fumes and acid mists produce problems in 13 communities.

Other Sources

Table 25 summarizes the results of interviews of local officials with respect to non-combustion sources other than the manufacturing industries. Fifty-one communities cited agricultural sources as a major problem. Most of these areas are in the group of 5000 population and less. About three-fourths of the problems were due to dusts such as wind-blown field dust, fertilizers, and grain chaff. The remainder was due to odors from fertilizer and manure piles.

As was discussed under combustion sources, the major air pollution problem in Pennsylvania from mining operations is gases from burning waste coal piles. However, in thirty areas dust from the milling of mined materials produced objectionable conditions. Most of these were from limestone quarries. In five communities dust from road building operations created objectionable problems. The problems were very localized and of minor degree in all cases. Twenty-six communities cited dust from unfinished roads

TABLE 25

Numbers of Communities Affected By Non-Manufacturing Industries And Other Sources

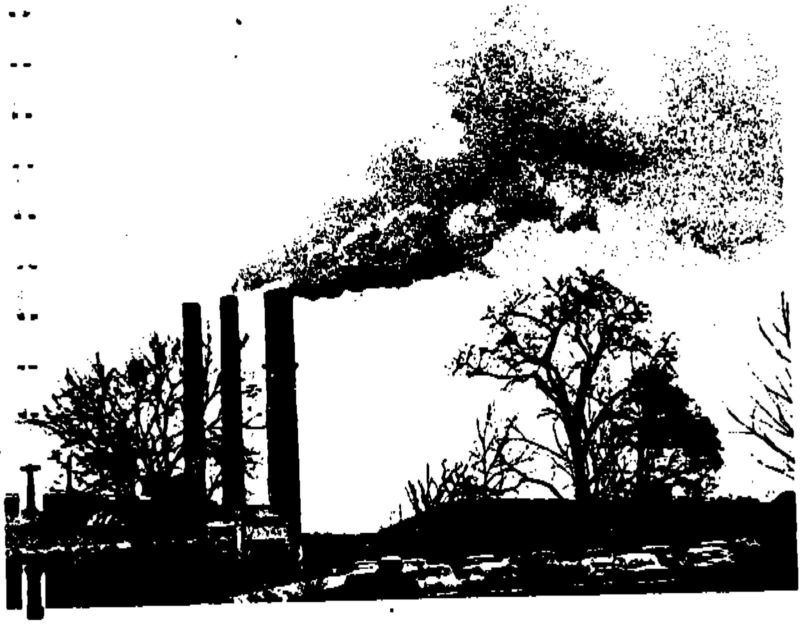
(Exclusive Of Combustion Products)

Source	Communities Reporting	Major Problem	
		Particulate(a)	Gaseous(b)
Agriculture	51	36	15
Mining	30	30	–
Construction	5	5	–
Transportation	26	26	–
Government	81	–	81
Domestic Activities	24	–	24
Natural Sources	14	2	12
Total Number of Problems (c)	231	99	132

(a) Includes dusts and pollens
(b) Includes fertilizer, refuse, and sewage odors
(c) This total is not equal to total number of affected areas because of duplication.

Burning coal refuse piles..........

Cement kilns..........



paper manufacturing plants..........

and coal burning electric power plants are some of the major sources of air pollution in Pennsylvania.

or from sanded road surfaces as creating problems. This dust is made air-borne by trucks and automobiles. The problems can be severe close to main transportation arteries.

Eighty-one areas blamed government operations for creating odor nuisances. These odors arose from improper sewage disposal practices including open sewers and poorly operated sewage treatment plants. In addition, open dumps, poorly operated and maintained incinerators, and inefficient sanitary landfills caused refuse odors in many of these communities. In 24 communities domestic activities created offensive odor problems. These odors came from backyard refuse piles and poorly operating cesspools and septic tanks. Fourteen communities cited problems from natural sources. These were air-borne pollens and odorous swamps.

Although radioactive waste sources have not created major problems to date they should be considered as possible serious air pollution sources. A recent survey of radiation registrations in the State[32] shows 503 users of radioactive material including 46 governmental agencies, 114 hospitals, 208 industries, 26 medical schools and universities, 98 physicians and surgeons, and 11 research institutions. The disposal of radioactive waste materials by these users can create serious air pollution problems, if uncontrolled, both by direct process emission or from incineration operations.

Chapter III

How Does It Behave?—Dynamics

Abstract

The dilution of a gaseous or fine particulate when emitted to the atmosphere depends upon the height at which it is discharged, the wind velocity and direction, and the turbulence or stability of the atmosphere. Rapid dilution is favored by tall stacks, high wind velocity, and turbulent, unstable air. Larger particulate pollutants, greater than about 10 microns in diameter, settle from the air at distances from the stack which depend on the wind speed, the size, shape and weight of the particles, the height at which they are discharged, and the temperature of the atmosphere. If flyash particles, for example, are discharged under certain typical conditions from a 100 foot stack, large (100 micron) particles will settle to the ground in about 100 yards while smaller (10 micron) particles will not be deposited until they travel about 7 miles. Other natural atmospheric cleansing processes operate over long periods to rid the atmosphere of pollutants. They include gas and vapor absorption in precipitation and fine particulate impaction caused by wind currents.

Although the atmosphere normally acts to dilute and disperse pollutants, situations arise when conditions are such that pollutants from an entire community's discharges can accumulate and concentrations increase. Such situations occur when stable air layers called inversions form either at the ground (nocturnal inversions) or several hundred feet or more above the ground (subsidence inversions). These stable air layers effectively prevent vertical mixing of pollutants and trap them either within or below the layer. Since wind velocity is usually low during inversion formation, natural ventilation is poor and pollutants accumulate rapidly. In areas such as narrow or bowl-shaped valleys, lateral diffusion of pollutants is retarded and pollution accumulation enhanced.

Atmospheric diffusion theory can be used to determine maximum permissible discharge rates from single sources such that the average concentration of the emitted pollutant in the surrounding area does not exceed a given value. A simple method using diffusion theory for the practical solution of this problem is presented in this Chapter.

Pennsylvania is located across the Appalachian Highland of the eastern U. S. and contains contrasting topography and climate. The southeastern corner is part of a coastal plain while the northwestern corner touches the Great Lakes and is part of the Lake Erie Plain. In between lies varied terrain including rolling hills in the southeast (Piedmont region), a ridge and valley area running from the south central to the northeastern parts of the State ending in the Pocono Mountains, and the Allegheny plateau which covers the remainder of the State and contains most of the narrow valleys. Pennsylvania has a humid continental climate modified in some areas by local topographical effects. The average annual temperature varies between 47 degrees F. in the north central mountains and 57 degrees F. in the extreme southeast. Precipitation is fairly evenly distributed, annual amounts ranging between 38 and 46 inches for the majority of places. Heavy fog formation, which can assist in prolonging inversion conditions, is most frequent in the coastal plain and in the Piedmont and southwest Allegheny plateaus.

In most of the State, ground inversions can be expected to form on about two-thirds of the nights of the year and last

for at least an hour. One-half of these will persist for at least six hours and one out of six for at least 12 hours. Their frequency is greatest in the autumn and least in the winter. During these nocturnal inversions, concentrations to which pollutants may be expected to accumulate depend on total emissions in the area affected, the wind speed, and the inversion height. Subsidence inversions, which form at about 2500 feet in most cases, can be expected to occur over Pennsylvania and persist for 24 hours or more about 16 times a year. They occur about twice a month in autumn but only twice a season in winter. Occasionally a subsidence inversion will persist for four days or longer. In Pennsylvania this can be expected once or twice a year, usually in late summer or early fall.

Data presented in this chapter are used in the next to estimate how high pollutant concentrations can be expected to rise under adverse meteorological conditions for several Pennsylvania communities.

Chapter III

How Does It Behave?—Dynamics

General

Pollution Dilution

The description of the behavior of an air pollutant during the period it remains in the atmosphere is a highly complex meteorological problem. The theory of atmospheric diffusion is often inapplicable to many situations or to certain geographical terrain. One contribution which meteorology can make to the study of air pollution lies in forecasting situations which will be conducive to pollution build-up or to pollution dilution. Certain simplified approaches to diffusion and dilution of contaminant plumes have definite and important uses such as estimating concentrations downwind of single sources or setting limits on discharge rates such that the concentration at a certain point will not exceed a given value.

The two situations most frequently encountered involve continuous point and line sources of pollution. The first represents a single stack and the second an array of stacks assumed to be more or less on a line perpendicular to the direction of the wind. The complete diffusion equations are complex but simplified solutions for certain special cases are available. Two of these for the isotropic case (i.e. diffusion rate is the same in all directions) are presented below:

These equations are limited to gases and vapors and to fine particulates less than about 5 to 10 microns in diameter.

Continuous Point Source	Continuous Infinite Crosswind Line Source
$d_{max} = \left(\frac{h^2}{C^2}\right)^{\frac{1}{2-n}}$	$d_{max} = \left(\frac{2h^2}{C^2}\right)^{\frac{1}{2-n}}$
$\chi_{max} = \frac{2Q}{e\pi \bar{u} h^2}$	$\chi_{max} = \frac{2Q}{(2e\pi)^{\frac{1}{2}} h \bar{u}}$

Symbols		Suggested Units
Q	= emission rate	grams per second
h	= stack height	meters
$\bar{u}$	= average wind speed	meters per second
C	= diffusion coefficient for isotropic turbulence	$(\text{meters})^{\frac{n}{2}}$
n	= lapse rate function (stability parameter)	dimensionless
d_{max}	= distance, downwind from the source, to maximum concentration	meters
χ_{max}	= maximum concentration at d_{max}	grams per cubic meter

The two situations most frequently encountered involve continuous point..........

...and line sources of pollution.

For larger particles gravitional setting becomes an important factor. The distance a particle larger than about 10 microns will move before settling to earth depends upon its horizontal velocity (which may be assumed equal to the wind speed), its size, shape and density, the height at which it is emitted, and the temperature of the ambient air. The larger and heavier the particle, the closer to the source (stack) will it settle out of the air. For example, if flyash particles (specific gravity = 2.0) are being emitted into a five mph, 70 ° F. wind from a stack 100 feet high, 100 micron particles will settle to the ground at about 120 yards from the stack, while 10 micron particles will not be deposited until they travel about seven miles from the stack (theoretically).

Besides these two methods of dilution (diffusion and settling), the atmosphere is cleansed by other natural processes. Some gases and vapors are removed by rain and by diffusion into large bodies of water. Sulfur dioxide, for example, can be absorbed by raindrops and deposited as a dilute acid solution. Particulate matter which is too fine to settle may be removed by impaction on natural surfaces or by acting as nuclei for precipitation. Some "sweeping out" of fine particles by falling rain and snow also occurs.

Pollution Accumulation

The atmosphere normally acts in such a way that air pollutants are rapidly diluted or removed. Some situations arise, however, when conditions are such that pollutants accumulate and concentrations increase. There are two main types of such situations, both related to the formation of stable air layers. A stable layer is one in which the temperature decreases with altitude at a rate less than about 5 ° F. per 1000 ft. Air in such a layer has little vertical motion, mixing is poor, and winds are usually light. In some cases temperature may actually increase with height. Such a situation is very stable and is called an inversion.

The two types of inversions of importance in air pollution are ground layer inversions and subsidence inversions. The first is produced by a loss of heat from the earth's surface by radiation at a rate faster than by normal conduction and convection through the air. These inversions usually occur at night and are more common in late summer and early fall. They usually persist no longer than about 12 hours. In ground layer or nocturnal inversions, the temperature rises from the ground to the top of the layer then falls normally above the inversion. Mixing is very poor and pollution can build up in the layer with little lateral and practically no vertical diffusion.

The second type, the subsidence inversion, occurs much less frequently and is more complicated in origin. This type is associated with slow-moving or stagnated high pressure areas. Warm air at the center of the high settles to take the place of the outward blowing winds at the periphery of the high. As this air settles it becomes warmer by compression. The air at ground level, however, remains the same so that an intervening inversion layer is formed, warmer at the top than at the bottom. This type of inversion differs from the nocturnal type in that the base of the inversion occurs several hundred feet above and not at the ground. The subsidence type occurs most frequently in fall months and may persist for 4 days to a week. Below the inversion base the air is unstable with good mixing but the layer of stable air in the inversion above effectively puts a lid over this well-mixed air preventing further vertical diffusion. Pollution can build-up below the inversion and persist for days.

Climatological and Topographical Effects

The climate and topography of an area have direct effects on both pollution dilution and accumulation mechanisms. In an area characterized by fairly strong winds and open terrain, stack effluent dilution is enhanced. Lateral diffusion is unimpeded. On the other hand narrow valleys in areas where wind speed is low are conducive to pollution accumulation because of reduced lateral air motion and slow natural ventilation. However, both open areas and valleys are subject to pollution accumulation, especially during inversion conditions.

In any area the principal climatological elements which affect air pollution are wind speed and direction, turbulence, vertical stability, humidity, sunshine and precipitation. Wind speed affects the rate of dilution, as shown above, and also governs the rate of ventilation of an entire air mass such as that trapped in or below an inversion layer. The direction of the wind is important in determining the relation between a source of air pollution and a receptor. Turbulence increases the mixing processes in the atmosphere leading to rapid dilution of emissions. Vertical stability, which depends upon the temperature profile, is most important in its control of vertical transport of pollution. Finally, humidity and precipitation forms affect natural cleansing processes and, indirectly, in the case of fog, can aid in the persistence of stable air by limiting solar heating of air near the ground.

An Air Quality—Emission Standard Correlation

In the course of this survey, problems arose quite often in which a practical use of atmospheric diffusion theory was required. This is the case of determining a maximum permissible discharge rate from a single stack such that the average concentration of the emitted pollutant in the surrounding area will not exceed a given value. The following general method will assist in solution of this problem, making use of the continuous point source formulas presented previously.

For a given situation where the height of a particular emitting stack is known, if a wind speed is assumed, then

$$\chi_{max} = (\text{constant})(Q)$$

Similarly, assuming a diffusion coefficient (C) and lapse rate function (n) then

$$d_{max} = \text{constant}$$

The theoretical concentration, χ, at any point, d, has been related graphically to χ_{max} and d_{max} for several situations.[34] Thus a curve relating χ [i.e. χ = (constant) (Q)] to d for, say, 10 intervals of d_{max} (i.e. d = 10d_{max}) may be drawn. This curve can then be integrated graphically to give $\bar{\chi}$, the average pollutant concentration in the region between the stack and 10 times the distance of maximum concentration. (At this point, for most cases, the concentration is less than five percent of χ_{max}). The average concentration, $\bar{\chi}$, determined in this manner will be in terms of Q, i.e. $\bar{\chi}$ = (constant) (Q). The maximum permissible emission rate Q_{max} is therefore $\bar{\chi}$/(constant), where $\bar{\chi}$ is set equal to the atmospheric maximum allowable concentration (AMAC). An example of the solution will demonstrate use of this technique.

Suppose one desires to determine the maximum permissible discharge rate from a 50 foot stack of a substance whose AMAC is known, so that during an average poor condition for dilution this AMAC will not be exceeded when concentrations are averaged over the most highly affected area around the stack. For these conditions, h = 50 feet, and we may assume $\bar{u}$ = 2 mph, $C^2 = 0.007$ and n = 0.33 (for a moderate inversion[34]). Therefore

$$\chi_{max}\left(\frac{mg}{M^3}\right) = 0.001\ Q\left(\frac{mg}{sec.}\right)$$

and d_{max} = 500 meters. Plotting and solving graphically for $\bar{\chi}$ for the region up to d = 10d_{max} (5000 meters or about 3 miles), $\bar{\chi}$ = 0.0001 Q or Q_{max} = (10,000) ($\bar{\chi}$) = (10,000) (AMAC). If AMAC = 1 mg/M^3 then Q_{max} = 10,000 mg./sec. or about 1.0 ton per day. Similarly for a 100 foot stack and AMAC = 1 mg/M^3, Q_{max} = 4 tons/day.

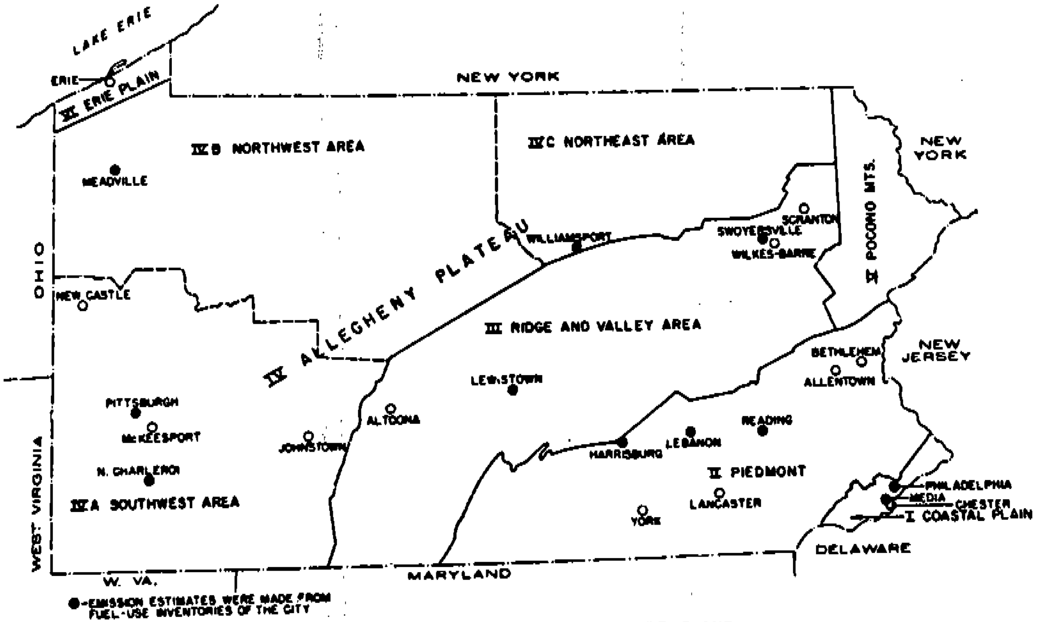
The method gives only an approximation and should be considered to give only an order of magnitude solution. Other constants may be used in the solution.

Pennsylvania

Topography and Climatology[35]

Pennsylvania is located in the Mid-Atlantic group of states between 39°43′ and 42° north latitude, bounded on the east by the Delaware River and on the west by the 80°30′ west longitudinal line. This 45,333 square mile rectangular area is set across the Appalachian Highland of the eastern United States and contains notable contrasts in topography, climate, and soils. The southeastern corner is reached by the Atlantic Ocean via the Delaware Estuary while the northwestern corner touches the Great Lakes. In between lies a variegated pattern of urban centers, forests, and cultivated land on terrain that ranges from almost flat in the extreme southeast to mountains interspersed with innumerable valleys in the remainder of the State. It is in these valleys that the majority of the industrial development exists and many of the 11 million people live. The most notable land forms include the Appalachian Mountain system composed of two ranges, the Blue Ridge and the Allegheny. These mountains divide the Commonwealth into three major topographical sections—the Piedmont, Ridge and Valley, and Allegheny Plateau. In addition, two plain areas and an upland glaciated area also exist—Coastal Plain, Lake Erie Plain, and Pocono Mountains; however, these areas are of relatively small size as shown by Figure 1.

The continental nature of the climate in Pennsylvania is due primarily to the prevailing westerly winds which move air masses west to east in this latitude. Air masses are modified somewhat by the Great Lakes and, to a larger extent, by the Atlantic Ocean through the addition of heat and moisture. This results in summers being warm and humid while winters are only moderately cold. Pacific maritime air masses, originally cool and moist, warm considerably and dry out somewhat before reaching Pennsylvania. However, the warm, humid air masses from the south and southeast reach the State with little change (most in eastern areas) and warm moist air from the Gulf of Mexico often reaches Pennsylvania



LOCATION OF MAJOR PHYSIOGRAPHIC AREAS AND SELECTED COMMUNITIES IN PENNSYLVANIA

Figure 1

with only a small loss in moisture content. Throughout the State, temperatures generally remain between zero and 100° F. with an annual average from 46 in the north central mountains to 56 in the extreme southeast.

Precipitation is fairly evenly distributed throughout the State and throughout the year. Annual amounts generally range between 34 and 52 inches while the majority of places receive 38 to 46 inches. Annual snowfall averages from about 20 inches in the extreme southeast to 90 inches in parts of McKean County. The most important meteorological data for all first-order weather stations are summarized in Table 26. These data are fairly typical of the State regions described below.

The coastal plain: This region is located in the southeastern corner of the State and is part of a larger area that extends into New Jersey, Delaware, and Maryland. It covers an area bounded on the east and southeast by the Delaware River extending about 10 miles to the northwest and is drained by the Delaware and Schuylkill Rivers and several small creeks. Philadelphia lies almost in the center of this area. The land is low, flat, and poorly drained in the immediate vicinity of the rivers. Elevations range from sea level to 50 ft. but farther to the west through northern sections in and around the city relatively hilly land prevails where elevations rise to nearly 400 ft. The topography of this area is such that there is little chance that extended widespread air parcel stagnation would create a serious problem. However, nocturnal stagnation occurs in localized areas, especially in the valleys of the Schuylkill River and Wissahickon Creek.

The Piedmont Plateau: This region borders the Coastal Plain and extends 60 to 80 miles northwest to the Blue Ridge. Elevations range from 100 to 1000 feet made up of rolling or undulating uplands and low hills and valleys. Ground level inversions are common especially in the autumn in the low elevations of this area. Subsidence inversions, when they occur, are mitigated somewhat by lateral diffusion which is unimpeded except near the Blue Ridge range.

The Ridge and Valley area: Just northwest of the Piedmont and between the Blue Ridge and Allegheny Mountains lies the Ridge and Valley region. The area is 80 to 100 miles wide and characterized by parallel ridges and valleys oriented in a Northeast-Southwest direction. The mountain ridges vary from 1300 to 1600 feet. above sea level with local relief 600 to 700 feet. Many water gaps and wind gaps break the continuity of the ridges.

Due to nocturnal radiation, cool air drains onto the valley floors from surrounding hillsides, resulting in minimum temperatures falling to lower levels than would otherwise occur. This air drainage can produce more extreme ground based inversion conditions. The ridges also serve as effective barriers of lateral air motion.

The Allegheny Plateau: This plateau lies north and west of the Ridge and Valley Region and extends to the Maryland, Ohio, West Virginia and New York borders. This is the largest natural division of the State and occupies more than half the area. It is crossed by many deep nar-

TABLE 26

Selected Meteorological Data For First-Order Stations In Pennsylvania

Station	State Physiographic Region	Temperature—°F			Normal Degree Days	Precipitation—Ins.		Relative Humidity—%		Wind		Percent of Possible Sunshine	Mean Number of Days		
		Normal Daily Max.	Normal Daily Min.	Normal Mean		Normal Total	Snow, sleet Mean Total	1:00 am	1:00 pm	Mean Speed MPH	Prevailing Direction		Clear	Partly Cloudy to Cloudy	Heavy Fog
Allentown	Piedmont Plateau	61.1	40.6	50.9	5880	42.2	28.4	82	57	9.4	WSW	-	89	275	32
Erie	Lake Erie Plain	57.1	39.4	48.3	6558	34.5	55.5	-	-	9.9	S	-	89	276	3
Harrisburg	Piedmont Plateau	62.2	43.8	53.0	5258	36.0	30.1	75	54	7.6	WNW	58	84	281	23
Philadelphia	Coastal Plain	64.0	44.6	54.3	4866	41.1	18.0	78	54	9.7	SW	58	90	275	32
Pittsburgh*	SW All. Plateau	61.0	42.7	51.9	5555	36.5	41.7	76	57	10.3	S	50	67	298	31
Reading	Piedmont Plateau	62.4	44.9	53.7	5060	40.0	29.6	-	50	8.8	NW	54	105	260	14
Scranton	Ridge & Valley	58.7	39.9	49.3	6284	40.5	41.5	-	57	6.9	SW	50	80	285	8
Williamsport	Ridge & Valley	60.9	40.5	50.7	5898	39.5	37.0	82	56	-	-	-	70	295	-

*Allegheny County Municipal Airport

row valleys and drained by the Susquehanna, Allegheny, Monongahela, and Ohio River systems. Elevations generally range between 1000 and 2000 feet above sea level, however, some mountain peaks extend up to 3000 feet. The area is heavily wooded and among the most rugged in the State.

Nocturnal cool air drainage lowers temperatures in the valleys below that of surrounding hillsides during all seasons and in so doing temperature inversions frequently form. When the moisture content of the air is high or temperatures low enough, early morning fog frequently forms. Generally such conditions will improve during the day as the sun heats the air in the valleys. Occasionally, however, stable atmospheric conditions prevail for several days at a time.

The Pocono Mountains: In northeastern Pennsylvania lies a high, well-forested land which is designated as the "Pocono Mountains." The area is not mountainous, but it does stand out from its surroundings as a highland that is, in places, nearly flat. Everywhere, however, it is of great enough elevation to be considerably cooler in summer and winter than nearby lowlands. Glaciation has left the upland poorly drained, dotted with lakes, and well supplied with clear, cold streams which alternately wander through swampy areas and over numerous waterfalls.

The Lake Erie Plain: This is a small region bordering Lake Erie. It is a narrow 40 mile strip of flat rich land 3 to 4 miles wide. The terrain is composed of a series of step-like terraces through which the streams have carved deep valleys. Although the Lake Erie Plain is of relatively small size it has a unique climate typical of the coastal areas surrounding much of the Great Lakes. The 500 ft. rise in elevation within the first 4 miles inland from the shore is sufficient to cause instability due to upslope motion of onshore winds. This results in less air stagnation and good natural ventilation.

Inversion and Stagnation Data

Pollution accumulation is directly related to the occurrence, persistence, and general properties of stagnating or slow moving inversion layers. Some limited data are available which allow prediction of the occurrence of these situations in Pennsylvania. From these data it is possible to estimate the potential community-wide problems of different areas in the State using, in addition, the local topography and microclimatology.

Ground level (nocturnal) inversion information is available for a western Pennsylvania site,[36] and with some modification is fairly representative of the State. The data of most direct use in air pollution work were taken from Figure 34 of this meteorological survey and summarized in Table 27. These data indicate that on about two-thirds of the nights of the year ground level inversions can be expected to form which last for at least an hour and that about one-half of these will persist for at least six hours and one out of six for at least 12 hours. Their frequency is greatest in the autumn when over 80 percent of the nights are affected

TABLE 27

Expected Occurrence and Persistence of Inversion Types in Pennsylvania[34,38]

Season	Number of Days of Occurrences					
	Case I No Inversions (all day)	Case II Nocturnal (Ground) Inversions			Case III Subsidence Inversions (without nocturnal inversion)	
		≥1 hr.	≥6 hrs.	≥12 hrs.	≥24 hrs.	≥96 hrs.
Winter	48	40	20	5	2	0
Spring	30	56	31	9	4	1/5
Summer	17	69	34	14	4	1
Autumn	9	75	37	15	6	1/2
Whole Year	104	240	122	43	16	2

and least in the winter when less than half of the nights have nocturnal inversions.

During these nocturnal inversions air pollution can be expected to accumulate, the concentrations reached depending upon total emissions in the area affected, the wind speed, and height of the inversions.[37] The average height of the top of ground level inversions varies only slightly between winter and summer. Data on average height of inversions are lacking for Pennsylvania but the averages for Portland, Maine and Nashville, Tennessee, which bracket the State do not differ significantly. For Portland, the average height is 247 meters and for Nashville, 245 meters. These values are probably fairly representative of conditions in Pennsylvania. The average height of inversion is about 800 feet.

The wind speed in the ground inversion was measured for the western Pennsylvania site.[36] Over a two-year period this ranged from 0.5 to 2.5 mph with most values in the range of 0.7 to 1.5 mph. A representative wind speed is, therefore, about 1.0 mph.

Information concerning subsidence inversion formation has been related to occurrence of stagnating high pressure systems in the eastern U. S.[38] These data have been presented in map form. Extrapolation and interpolation of these data yield the figures given in Table 27 for subsidence inversions for periods of 96 hours or longer. The data for periods of 24 hours or longer are from the Western Pennsylvania site.[36] These data apply only when no ground inversion exists since the lower level of the nocturnal inversion height effectively prevents vertical transport regardless of subsidence inversion formation. Subsidence inversion formation occurs infrequently with durations of 24 hours or more occurring only about 16 times a year. They occur about twice a month in the autumn and only twice a season in the winter. The long-term type which persist for 4 days or more occur once or twice a year, usually in the late summer or early fall.

The average height of the base of subsidence inversions varies between 813 meters for Portland and 772 meters for Nashville[37] with a fairly representative average for Pennsylvania of 792 meters or about 2600 feet. These are averages during periods with no ground inversion formation. According to Pennsylvania data[36] the average wind speed during subsidence inversions is about 1.0 mph.

The above data when combined show (Table 27) that only on about 100 days a year can no inversion formation be expected. Furthermore, these data indicate that ground based inversion formation is by far the most important type in producing conditions where pollution can accumulate. The calculated air quality data presented in the next chapter will show to what levels pollutant concentrations can be expected to rise during these inversions.

Chapter IV

How Much Is There?—Air Quality

Abstract

The quality of outdoor air is determined by sampling with various devices. Samples are analyzed by chemical procedures and by physical methods. Representative sampling depends on judicious selection of the number and location of sampling sites, the number of samples, and the time and frequency of sampling. Air quality data thus obtained are useful in determining the types and quantities of pollutants present, the location of sources, the degree of control action necessary, and the progress of an abatement program.

The table below summarizes certain information on measured pollutant concentrations in North American and European cities. These data are representative of concentrations during the past 10 years although higher values of some pollutants have been reported in recent years. The data serve as a comparison for results obtained in Pennsylvania.

Measurements of air quality have been made in Pennsylvania since 1912. Fourteen organizations have participated in sampling programs. The table below summarizes the most recent data for Pennsylvania.

Measured concentration data are comparatively sparse. Sulfur dioxide measurements (including some earlier data not shown above) indicate that concentrations in several Pennsylvania communi-

POLLUTANT CONCENTRATIONS FOUND IN URBAN ATMOSPHERES
(For gases: through 1955 - for particulates: through 1958)

Pollutant	Avg. Concentration	Maximum Reported
Sulfur Dioxide, parts per million	0.04–0.15	0.8–1.5
Oxides of Nitrogen, parts per million as NO_2	0.14–0.48	0.6–3.5
Hydrocarbons, parts per million as Hexane	0.29	3.0
Carbon Monoxide, parts per million	3.4–8.3	300
Oxidants, parts per million as O_3	0.03–0.07	0.33
Suspended Particulates, μg/cu. M.	100–190	2900
Settled Particulates, tons/sq. mi./mo.	16–72	184

POLLUTANT CONCENTRATIONS FOR SELECTED PENNSYLVANIA COMMUNITIES
1958–1959
Measured Concentrations

Community	Sulfur Dioxide (ppm)		Suspended Particulates (μg/cu. M.)		Settled Particulates T/sq. mi./mo.)	
	Avg.	Max.	Avg.	Max.	Avg.	Max.
Ambridge	0.25	—	176	290	94	134
Chester	—	—	—	—	65	94
Cooksburg	—	—	34	64	—	—
Egypt	—	—	—	—	237	372
Harrisburg	—	—	135	292	32	122
Lebanon	—	—	158	594	92	830
Middletown	—	—	104	170	125	231
Nazareth	—	—	—	—	74	128
Philadelphia	0.14	0.4	171	349	52	189
Pittsburgh	—	—	167	344	—	—
Reading	—	—	142	404	—	—
Seward	0.13	2.3	—	—	377	775
Wilkes-Barre	—	—	99	203	—	—

ties exceed those typical of North American-European urban areas. They include: Aliquippa, Ambridge, Baden, Beaver Falls, Midland, Monaca, Seward, Washington, and York. Average suspended particulate loadings are significantly greater than the U.S. average in Ambridge, Avalon, Chester, Harrisburg, Johnstown, Lebanon, Philadelphia, Pittsburgh, Scranton, and Williamsport. Total deposited particulate measurements indicate that the following communities have localized problems more severe than either New York (1953) or Chicago (1945): flyash—Ambridge, Lebanon, Middletown, and Seward; cement dust—Egypt, Fogelsville, Nazareth, Northampton, and Sandt's Eddy.

Estimates of pollutant concentrations are possible using data collected during this survey. The technical methods of making such estimates are presented in this chapter. These methods involve diffusion theory and a general atmospheric ventilation approach. The estimated concentrations presented above include only combustion sources of pollution. In Lebanon, Lewistown, and Meadville emissions are more than proportional to community size leading to higher estimated pollutant concentrations than would be expected from their size. Otherwise the trend is for increasing concentrations with increasing population.

The highest concentrations are to be expected during nocturnal (ground) inversions, although 96-hour subsidence inversions can, at times, produce more extreme conditions because of continuous exposure. An "adverse" level of sulfur dioxide concentration, when sensory irritation and vegetation damage are likely to occur, has been set (although not officially for Pennsylvania) at 0.3 ppm for 8 hours. This level may be expected to occur about 40 times a year in Philadelphia, Pittsburgh, and Meadville using the estimates above. Adverse levels for nitrogen oxides or hydrocarbons have not as yet been set. Both of these pollutants, however, are important contributors to possible photochemical smog formation.

ESTIMATED CONCENTRATIONS (Due to pollution from combustion sources only)

Community	Sulfur Dioxide-ppm		Oxides of Nitrogen-ppm NO_2		Hydrocarbons-ppm Hexane	
	Range (a)	Max. (b)	Range	Max.	Range	Max.
Harrisburg	0.02-0.1	0.1	0.03-0.1	0.2	0.07-0.3	0.4
Lebanon	0.07-0.2	0.2	0.04-0.1	0.1	0.07-0.2	0.2
Lewistown	0.1-0.3	0.3	0.08-0.2	0.2	0.08-0.2	0.2
Meadville	0.1-0.4	0.4	0.03-0.1	0.1	0.04-0.2	0.2
Philadelphia	0.06-0.6	1.0	0.04-0.4	0.6	0.05-0.6	1.0
Pittsburgh	0.03-0.2	0.4	0.02-0.2	0.3	0.04-0.4	0.6
Reading	0.03-0.2	0.2	0.03-0.2	0.2	0.06-0.3	0.4
Williamsport	0.02-0.06	0.07	0.02-0.07	0.09	0.06-0.2	0.3

(a) Expected about two-thirds of the time.
(b) Expected about one-tenth of the time.

Chapter IV

How Much Is There?—Air Quality

General

Air Pollution Measurement

In order to determine the quality of outdoor air in a given community, samples are taken and analyzed for various pollutants by several methods. The air quality data thus obtained are useful in determining the types and quantities of pollutants present, the location of the sources, the degree of control action necessary, possible effects of pollution and the progress of an abatement program.

Sampling methods: Gaseous contaminants are collected using methods based upon absorption, adsorption, condensation, or chemical reaction or by direct grab sampling. In absorption sampling the pollutant-air mixture is usually bubbled through a liquid which selectively absorbs the contaminant. In some cases the pollutant gas may be adsorbed on the surface of activated charcoal or silica gel. Volatile materials are often collected by condensing the vapors to a liquid in traps cooled by liquid nitrogen or dry ice. Occasionally the contaminant is reacted, such as by combustion, and the products of the reaction collected and analyzed. In some cases where concentrations are sufficiently high, evacuated flasks may be used to collect a grab sample of the air which subsequently is analyzed.

Particulates are collected by filtration, impaction, electrical or thermal precipitation, or by sedimentation. At times collection may not be necessary and the optical properties of the suspended particles may be measured directly. The most common method of sampling suspended particulates involves filtration with paper, cloth, ceramic, or glass media. Other sampling devices are impingers, electrostatic and thermal precipitators and dustfall jars.

Air samples are taken for various pollutants.

Certain techniques used in general atmospheric sampling are also applicable to the sampling of pollution sources. Special devices are necessary in source sampling, however, to insure the collection of representative samples. Representative sampling of the general atmosphere depends upon judicious selection of both the number and location of sampling stations, sampling times and the frequency of sampling. In general, the greater the number of sampling sites and the more frequent the sampling, the more reliable and representative are the results. The methods and devices most commonly used in both atmospheric and source sampling have been described in detail.[39 40]

Analytical methods: Both gaseous and particulate samples may be subjected to various chemical or physical analyses. Volumetric, gravimetric, and colorimetric analyses are the most common methods. Recently the use of chromatography for the separation of various gaseous pollutants has become more common. Air analyses are often made directly in the field in the sampling device, e.g., by determining the color change in an absorbent or by measurement of the conductivity of solution containing absorbed gases. Many analytical methods used in air sample analysis have been summarized.[39,41]

Ranges and Average Pollutant Concentrations Found in the Atmosphere

Gases and vapors: Over the past 50 years samples have been taken of the general atmosphere of many North American and European cities. The average analyses of some of these samples for certain pollutants are presented as a function of population in Table 28. In general, the larger the city the greater the reported concentration of contaminant. This is to be expected because of the increase in number of sources of pollution with increase in community size. This table serves as a basis of comparison for results obtained in Pennsylvania. Some of the values are based on very few samples and therefore should not be considered as truly representative in all cases.

Suspended particulates: The Public Health Service has, since 1953, conducted a nation-wide sampling program involving over 100 urban areas and many suburban and rural areas to determine the average and maximum concentrations of suspended particulate matter in the atmosphere (Table 29). In general, urban areas have three to five times the concentrations of rural areas, depending on size of the urban place. The mid-Atlantic (including Pennsylvania) and mid-western sections of the country have the highest average urban concentrations in the

TABLE 28

Summary of Some Measured Gaseous Air Pollutant Concentrations for Metropolitan Areas in North America and Europe[42]

Pollutant	Average Concentration—ppm			Average Maximum Concentration—ppm			Highest Concentration Reported—ppm		
	Population Range <½ million	½-2 million	>2 million	Population Range <½ million	½-2 million	>2 million	Population Range <½ million	½-2 million	>2 million
Sulfur Dioxide	0.04	0.05	0.15	0.21	0.36	0.72	0.8	0.75	1.5
Hydrogen Sulfide	0.01	-	0.10	-	-	0.61	-	-	-
Oxides of Nitrogen (as NO_2)	0.14	0.22	0.48	0.50	0.62	2.05	0.63	0.67	3.5
Ammonia	0.03	0.02	0.11	1.60	0.07	1.60	0.21	0.09	3.1
Aldehydes, (as HCHO)	0.04	0.07	0.24	0.37	0.70	0.89	0.6	1.8	0.92
Hydrocarbons	-	-	0.29	-	1.39	1.10	-	-	3.0
Chlorine	0.05	0.04	0.09	0.13	0.13	0.38	0.3	0.15	0.62
Carbon Monoxide	5.0	8.3	3.4	-	19	109	-	38	300
Ozone	0.03	0.03	0.07	0.15	0.08	0.17	0.33	-	0.33
Hydrogen Fluoride	0.005	0.006	0.008	0.031	0.027	0.027	0.032	0.05	-
Carbon Dioxide	-	370	330	430	460	980	-	530	2700

TABLE 29

Summary of Measured Suspended Particulate Concentrations for U.S.A. Communities, 1953 and Later*[43,44,45]

Region	Year	Number of Samples	Concentrations—μg/cu. M.		
			Min.	Max.	Avg.
Urban					
New England	1954-1957	669	11	472	118
New England	1957-1958	395	20	326	100
Mid Atlantic	1953-1957	2398	25	1011	191
Mid Atlantic	1957-1958	714	23	607	146
Mid East	1953-1957	623	28	793	170
Mid East	1957-1958	516	27	745	123
South East	1953-1957	758	15	644	129
South East	1957-1958	578	15	640	125
Mid West	1953-1957	1705	13	978	189
Mid West	1957-1958	967	11	978	158
Great Plains	1953-1957	879	12	800	152
Great Plains	1957-1958	503	22	722	136
Gulf South	1953-1957	883	10	2928	128
Gulf South	1957-1958	516	14	630	118
Rocky Mountain	1953-1957	358	15	1070	148
Rocky Mountain	1957-1958	247	15	466	99
Pacific Coast	1953-1957	1235	9	3112	153
Pacific Coast	1957-1958	704	11	639	136
U. S. A.	1953-1957	9508	9	3112	163
U. S. A.	1957-1958	5340	11	978	131
Suburban					
U. S. A.	1953-1956	723	3	748	69
Rural					
U. S. A.	1954-1957	511	3	460	40
U. S. A.	1957-1958	1252	1	460	39
Cities Only					
>1 million	1953-1957	-	-	-	~190
0.7 to 1 million	1953-1957	-	-	-	~150
all others	1953-1957	-	-	-	~110

*All measurements by high volume paper filtration.

country, approximately 190 micrograms per cubic meter for the 1953-1957 period.

Deposited particulates: The simplest, although not necessarily the most valuable, technique of air pollution measurement is "dustfall," the measurement of settled particulate matter. Results from this type of sampling are available for the last fifty years. Some results are summarized for the United States in Table 30. New York and Chicago have reported average settled solids of about 70

TABLE 30

Summary of Some Measurements of Deposited Particulate Matter for Selected Communities[42]

Community	Year	Total Deposited (tons/sq. mi./Mo.)		
		Min.	Max.	Avg.
Charleston, West Virginia	1948	20	98	-
Chicago, Illinois	1945	25	184	68
Cincinnati, Ohio	1950	-	-	29
Cleveland, Ohio	1950	-	-	36
Detroit, Michigan	1953	-	-	72
Holyoke, Massachusetts	1949	10	100	33
Los Angeles, California	1946	21	38	28
Louisville, Kentucky	1954	-	-	32
Milwaukee, Wisconsin	1952	12	35	23
New Haven, Connecticut	1952	7	27	16
New York, New York	1953	-	-	68
Seattle, Washington	1951	-	16	-
Wyandotte, Michigan	1952	20	47	33

tons per square mile per month. Smaller cities, such as Milwaukee and Cincinnati, average about 30 tons per square mile per month.

Optical density of suspended particulates: This measurement involves collection by filtration of a small amount of fine suspended particulate matter and measurement of the light obscuring power (optical density) of the resulting filter stain. Samples are usually taken automatically every hour or two giving a record of diurnal variations. The fundamental quantity of measurement is optical density per unit length, e.g., O.D./ 100,000 feet. Another term has been coined, the Coh or coefficient of haze. By definition one Coh per 1,000 feet is equivalent to O.D. = 0.01/1,000 feet or O.D. = 1.0/100,000 feet. Subjectively an optical density of 1.0 per 100,000 feet is a brilliantly clear day while an optical density of 10.0 per 100,000 feet is disagreeably smoky or hazy.[46]

Another use of optical density measurements is possible by relating them to weight concentrations. Work in England[47] with "general air pollution" can be used to relate optical density to weight concentration:

O.D. = 1.0 per 100,000 feet = conc. = 130µg/cu. M. (by calculation)

Thus an average density measurement of 2.0/100,000 feet is equivalent to a concentration of general suspended material of approximately 260 µg/cu. M. As a check on this correlation, data from Philadelphia for 1958[48] show an average O.D. = 1.6/100,000 feet which is equivalent to 210 µg/cu. M. using the above relation. The average measured particulate concentration was 260 µg/cu. M., a fair check. In order to use this procedure with accuracy, an empirical relationship should be developed for the particular community in which measurements are made.

Radioactivity of suspended particulates: Data taken as part of the National Air Sampling Network program are summarized in Table 31. The average gross beta radioactivity of suspended particulates for the United States for 1953-1957 is about 5 µµc/cu. M. (micro-microcuries per cubic meter). (One micro-microcurie of beta radiation is equivalent to 2.2 beta emissions per minute.) Except for the Rocky Mountain area regional variations are small. The rural-urban difference is also negligible. These facts indicate sources remote from the areas affected. It is therefore highly probable that most radioactivity (except for natural background) has arisen from the testing of nuclear weapons. The Rocky Mountain area was most highly affected because of its proximity to continental testing sites.

TABLE 31

Summary of Measured Radioactivity (Gross Beta Activity) of Suspended Particulates for U.S.A. Communities[43]

Region	Year	Number of Samples	Concentration (µµc/cu.M.)*		
			Min.	Max.	Avg.
A. Urban					
New England	1955–1957	279	–	58.8	3.3
Mid Atlantic	1953–1957	611	–	93.0	3.1
Mid East	1953–1957	406	–	82.6	2.6
South East	1953–1957	445	–	271.7	4.5
Mid West	1953–1957	991	–	117.9	2.7
Great Plains	1953–1957	453	–	324.0	4.4
Gulf South	1953–1957	637	–	193.1	4.9
Rocky Mountain	1953–1957	237	–	5435.0	33.9
Pacific Coast	1953–1957	788	–	731.9	4.3
U.S.A.	1953–1957	4845	–	5435.0	5.2
B. Suburban					
U.S.A.	1953–1956	474	0.1	2643.7	10.2
C. Rural					
U.S.A.	1955–1957	412	0.2	131.6	5.2

*Micro-microcuries per cubic meter.

Pennsylvania

Measured Pollutant Concentrations in Pennsylvania

Gases and vapors: Table 32 summarizes all available data on gaseous pollution measurements made in the State. Eight organizations have reported measurements since 1927. Sulfur dioxide measurements predominate. Pittsburgh and Philadelphia have been covered most extensively. Measurements since 1950 indicate that the following communities have had average concentrations of sulfur dioxide greater than the North American-European averages for communities of similar size: Aliquippa (5 times greater), Ambridge, (5 times greater), Baden (twice as great), Beaver Falls (twice as great), Midland (4 times greater), Monaca (5 times greater), Seward (3 times greater), Washington (4 times greater), and York (8 times greater). In California a recently adopted air quality standard sets 0.3 ppm sulfur dioxide for eight hours as an "adverse" level, a level at which sensory irritation and damage to vegetation is likely to occur.[49] Such "adverse" levels have been exceeded in most of the communities just named.

Hydrogen sulfide measurements have been limited. In Ashley recent tests show average concentrations about twice as high as that shown in Table 28 for communities of that size.

TABLE 32

Summary of Measured Atmospheric Concentrations of Gases and Vapors for Pennsylvania Communities

Community	Investigator[a]	Year	Season	No. of Stations	No. of Samples	Concentration—ppm Min.	Concentration—ppm Max.	Concentration—ppm Avg.	Ref.
Sulfur Dioxide									
Aliquippa	Pa. D H	1953	Nov-Dec	1	Cont.	0.02	1.07	0.19	50
Altoona	A H F	1936	Sept.	24	24	–	0.024	0.008	51
Ambridge	Pa. D H	1953	Nov	1	Cont.	0.05	0.87	0.22	50
Ambridge	Pa. D H	1958	Oct	1	Cont.	0.05	0.25	–	50
Baden	Pa. D H	1954	Jan	1	Cont.	0.01	0.46	0.10	50
Beaver Falls	Pa. D H	1954	Jan	1	Cont.	0.01	0.30	0.09	50
Charleroi	USPHS	1949	Apr	–	6	0.02	0.20	0.10	52
Donora	USPHS	1949	Feb-Apr	12	260	0.0	0.61	0.15	52
Harrisburg	A H F	1936	Sept	26	26	–	0.037	0.011	51
Johnstown	A H F	1936	Sept	13	13	–	0.038	0.014	51
Josephtown	Pa. D H	1953	Dec	1	Cont.	0.01	0.14	0.05	50
Midland	Pa. D H	1953	Feb-Mar	1	Cont.	0.05	2.0	0.14	50
Monaca	Pa. D H	1953	Dec	1	Cont.	0.02	0.93	0.21	50
Monessen	USPHS	1949	Apr	–	6	0.02	0.20	0.10	52
Monongahela	USPHS	1949	Apr	–	9	0.04	0.23	0.14	52
Philadelphia	A H F	1936-1937	Year	155	6899	0.0	0.42	0.025	53
Philadelphia	U C	1953-1954	–	–	50	–	0.22	0.09	54
Philadelphia	Ph.DPH	1956	Year	1	182	0.04	0.36	0.15	55
Philadelphia	Ph.DPH	1957	Year	1	249	0.04	0.48	0.17	56
Philadelphia	Ph.DPH	1958	Year	1	246	0.02	0.40	0.14	57
Pittsburgh	U S B M	1927-1928	Year	1	304	0.0	1.1	0.16	58
Pittsburgh	P T L	1931-1932	Year	1	607	0.0	2.5	0.30	59
Pittsburgh	M I	1932	Year	1	280	0.0	1.1	0.14	60
Pittsburgh	A H F	1936-1937	Year	125	7131	0.0	1.007	0.052	53
Seward	Pa. D H	1959	Feb-May	1	Cont.	0.03	2.3	0.13	50
Washington	Pa. D H	1951	June	1	Cont.	0.05	3.05	0.17	50
York	Pa. D H	1951	July	1	Cont.	0.05	4.7	0.27	50
Hydrogen Sulfide									
Ashley	Pa. D H	1959	Dec	1	392	0.0	0.230	0.023	50
Avalon	Pa. D H	1959	June	1	336	0.0	0.012	0.0014	50
Donora	USPHS	1949	Feb-Apr	–	–	0.0	0.0	0.0	52
Pittsburgh	M I	1954	Mar-Aug	1	–	0.0	0.010	0.0006	61
Carbon Monoxide									
Donora	USPHS	1949	Feb-Apr	–	–	0.0	0.0	0.0	52
Philadelphia	Ph.DPH	1956	Year	1	179	1.5	13.5	4.7	55
Philadelphia	Ph.DPH	1957	Year	1	246	1.5	13.5	5.1	56
Philadelphia	Ph.DPH	1958	Year	1	243	0.5	10.0	5.9	57
Oxidants (As Ozone)									
Philadelphia	U C	1953-1954	–	–	36	0.0	0.050	0.017	54
Oxides of Nitrogen (As NO_2)									
Donora	USPHS	1949	Feb-Apr	12	33	0.0	0.63	0.20	52

(a) Abbreviations:

Pa. D H	Pennsylvania Department of Health	A H F	Air Hygiene Foundation
USPHS	U. S. Public Health Service	U C	University of Cincinnati
Ph.DPH	Philadelphia Dept. of Public Health	P T L	Pittsburgh Testing Laboratory
M I	Mellon Institute	U S B M	U. S. Bureau of Mines

Carbon monoxide measurements have been made routinely only in Philadelphia; average concentrations are similar to those given in Table 28. The "adverse" level in California is taken as 30 ppm for 8 hours, a higher value than any reported in Philadelphia.

Other measurements are sparse. The oxident level (ozone) in Philadelphia for 1954 was only about one-fourth that reported in other cities (Table 28). "Adverse" conditions occur at 0.15 ppm for 1 hour,[49] while the maximum reported value for Philadelphia was 0.05 ppm. Nitrogen oxides measured in Donora in 1949 were above average for communities of that size.

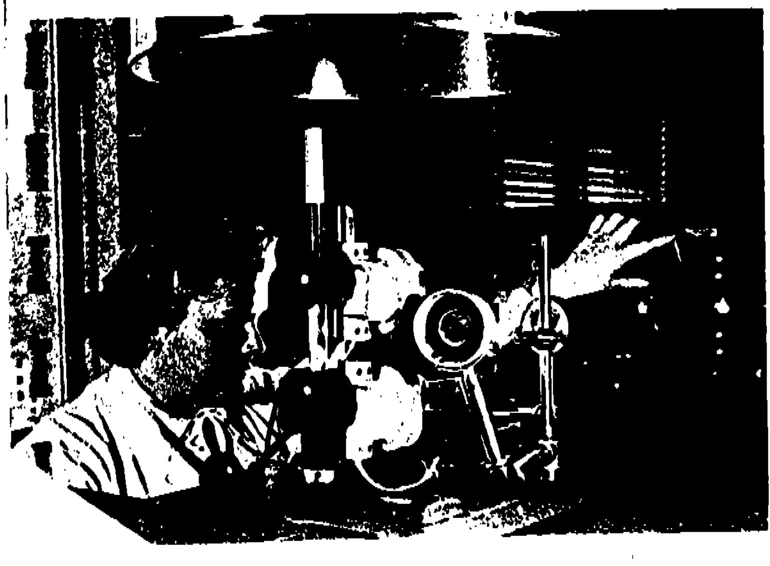
Suspended particulates: Table 33 summarizes all available measurements of suspended particulate concentrations for Pennsylvania communities. Six agencies have reported measurements since 1949. Sampling by paper filtration indicates that the following communities have had average particulate loadings significantly greater than the United States average for communities of that size (Table 29): Ambridge, Avalon, Chester, Harrisburg, Johnstown, Lebanon, Philadelphia, Scranton, and Williamsport. The average for all cities in the Mid-Atlantic region has been exceeded in Ambridge, Avalon, Johnstown, Lebanon, Philadelphia, Pittsburgh, Scranton, and Williamsport. Adverse levels for particulate concentrations have not been established.

Deposited particulates: Table 34 summarizes measurements of deposited particulate matter for Pennsylvania communities. Six organizations have made measurements since 1912. Measurements since 1950 show the following communities have had dustfall problems more severe than either New York (1953) or Chicago (1945) (Table 30): Ambridge, Egypt, Fogelsville, Lebanon, Middletown, Nazareth, Northampton, Sandt's Eddy, and Seward. In most the problems are local. Cement dust is the problem in Egypt, Fogelsville, Nazareth, Northampton, and Sandt's Eddy. Flyash (mainly from electric power plants) is the major problem in the other communities. Detailed analyses are available only for Pittsburgh, where insoluble material only was measured. The total quantity of insoluble deposit has not varied much since 1949 and the detailed analyses show that the composition is essentially the same today as it was years ago.

Optical density of suspended particulates: Table 35 summarizes measurements of the optical density of fine suspended particulates for Pennsylvania communities. Most communities have average optical densities between 1.6 and 2.4 per 100,000 feet of air. These levels are subjectively equivalent to a clear day. Objectionable maximum values, however, occur during some seasons in Ambridge, Avalon, Pittsburgh, and Sunbury (Optical density greater than 5.0 per 100,000 feet). Optical density measurements are of most value in determining diurnal, seasonal, and annual variations in particulate loading and indicating probable sources of pollution.

Radioactivity of suspended particulates: Table 36 summarizes measurements of the gross beta radioactivity of suspended

In the laboratories of the Pennsylvania Department of Health suspended particulate samples are subjected to spectrographic analysis and..........



deposited particulates are examined microscopically.

TABLE 33

Summary of Measured Suspended Particulate Concentrations for Pennsylvania Communities (a)

Community	Investigator (b)	Year	Season	Number of Stations	Number of Samples	Concentration—μg/cu.M.			Detailed analyses, if any (c) in percent	Ref.
						Min.	Max.	Avg.		
Allentown	USPHS—A H D	1957	Year	1	20	41	214	111	5.3% org. (benz. sol.)	43
Altoona	Pa. D H—USPHS	1955	Year	1	3	82	125	100	14.2% org. (benz. sol.)	43
Altoona	Pa. D H—USPHS	1956	Year	1	24	61	411	128	9.0% org. (benz. sol.), 6.0% Cu, 7.6% SO_4	43
Ambridge	Pa. D H	1958	Sept-Oct	1	8	117	290	176	-	50
Avalon	Pa. D H	1959	Feb-May	2	30	40	288	163	-	50
Bristol	USPHS—Pa.DH	1955	Year	1	31	27	229	96	6.6% org. (benz. sol.) 15.7% SO_4	43
Bristol	USPHS—Pa.D H	1956	Year	1	12	52	177	107	6.6% org. (benz. sol.), 15.7% SO_4	43
Charleroi (d)	USPHS	1949	Feb-Apr	1	5	284	718	458	2.8% Zn (see Monessen)	52
Chester	USPHS—Pa.D H	1955	Year	1	31	40	273	134	6.4% org. (benz. sol.), 7.6% SO_4	43
Chester	USPHS—Pa.D H	1956	Year	1	13	38	323	136	6.4% org. (benz. sol.), 7.6% SO_4	43
Cooksburg	USPHS—Pa.D H	1958	Year	1	21	15	64	34	-	44
Donora (d)	USPHS	1949	Feb-Apr	12	205	-	5720	706	11.4% Zn, 3.6% chlorides	52
Erie	USPHS—Pa.D H	1955	-	1	1	-	-	90	10.0% org. (benz. sol.)	43
Erie	USPHS—Pa.D H	1956	Year	1	49	25	550	80	5.8% org. (benz. sol.), 2.4% Fe, 10.3% SO_4	45
Harrisburg	USPHS—Pa.D H	1958	Year	1	25	46	292	135	-	44
Johnstown	USPHS—Pa.D H	1957	Year	1	11	33	268	165	6.5% org. (benz. sol.)	43
Lancaster	USPHS—Pa.D H	1957	Year	1	11	65	199	113	-	43
Lebanon	Pa. D H	1959	Apr-Aug	2	20	49	594	158	-	50
Monessen (d)	USPHS	1949	Feb-Apr	1	5	284	718	458	2.8% Zn, (see Charleroi)	52
Monongahela (d)	USPHS	1949	Feb-Apr	1	9	105	706	436	1.4% Zn	52
Middletown	Pa. D H	1959	July	2	10	84	170	104	-	50
Philadelphia	USPHS—Pa.D H	1953	-	2	14	71	414	224	16.5% org. (acet. sol.)	43
Philadelphia	USPHS—Pa.D H	1954	Year	3	107	29	760	203	14.5% org. (acet. sol.), 3.2% Fe, 1.6% Mg, 1.5% Pb, 1.1% NO_2, 12.8% SO_4	43
Philadelphia	Ph. D P H	1954	Year	3	170	-	-	189	-	55
Philadelphia	USPHS—Ph.DPH	1955	Year	7	391	44	621	215	6.5% org. (benz. sol.), 11.3% SO_4	43
Philadelphia	Ph. D P H	1955	Year	7	290	-	-	210	-	55
Philadelphia	USPHS—Ph.DPH	1956	Year	5	661	51	1011	239	6.4% org. (benz. sol.), 10.4% SO_4	43
Philadelphia	Ph. D P H	1956	Year	5	637	-	-	219	-	55
Philadelphia	USPHS—Ph.DPH	1957	Year	1	25	86	323	203	6.6% org. (benz. sol.), 10.8% SO_4	43
Philadelphia	Ph. D P H	1957	Year	5	789	-	-	201	-	56
Philadelphia	USPHS—Ph.DPH	1958	Year	1	24	61	349	171	-	44
Philadelphia	Ph. D P H	1958	Year	5	772	-	-	153	-	57
Pittsburgh (d)	Pg. D P H	1950	May-Dec	8	56	300	680	490	-	62
Pittsburgh (d)	Pg. D P H	1951	Year	12	144	200	700	490	79.9% comb., 8.1% Si, 9.2% free SiO_2, 2.3% Al, 1.4% Ca, 1.6% Fe, 1.2% Mn, 4.1% SO_4	62
Pittsburgh (d)	Pg. D P H	1953	Year	-	-	190	860	610	-	63
Pittsburgh	USPHS—ACHD—PaDH	1956	Year	1	71	43	311	134	8.7% org. (benz. sol.), 2.9% Cu, 2.6% Fe, 11.9% SO_4	43
Pittsburgh	USPHS—ACHD—PaDH	1957	Year	1	23	78	534	203	5.1% org. (benz. sol.)	43
Pittsburgh	USPHS—ACHD—PaDH	1958	Year	1	26	85	344	167	-	44
Reading	USPHS—Pa. DH	1958	Year	1	25	56	404	142	-	44
Scranton	USPHS—Pa. DH	1957	Year	1	26	62	466	176	7.0% org. (benz. sol.)	43
Wilkes-Barre	USPHS—Pa. DH	1958	Year	1	26	23	203	99	-	44
Williamsport	USPHS—Pa. DH	1955	Year	1	6	85	268	178	8.2% org. (benz. sol.), 1.0% Fe, 8.5% SO_4	43
Williamsport	USPHS—Pa. DH	1956	Year	1	40	74	515	213	-	43

(a) Unless otherwise noted all samples are by high volume paper filtration.

(b) Abbreviations: A H D Allentown Health Department
Pg. D P H Pittsburgh Department of Public Health
A C H D Allegheny County Health Department
(Others) See Table 32

(c) Analyses are averages based in some cases, on less than total number of samples; only components greater than 1% by weight included.

(d) Samples taken by portable electrostatic precipitators.

TABLE 35

Summary of Measured Optical Density of Suspended Particulates for Pennsylvania Communities

Community	Investigator (a)	Year	Season	Number of Stations	Number of Samples	Optical Density/100.00 feet (b) (c)			Ref.
						Min.	Max.	Avg.	
Ambridge	Pa. D H	1958	Sept-Oct	1	480	0.0	7.0	2.1	50
Avalon	Pa. D H	1959	Feb-Mar	1	612	0.2	7.6	2.1	50
Middletown	Pa. D H	1959	July	1	82	0.2	1.5	0.5	50
Philadelphia	Ph. D P H	1956	Year	1	304	0.6	6.5	1.7	55
Philadelphia	Ph. D P H	1957	Year	2	693	0.6	4.2	1.8	56
Philadelphia	Ph. D P H	1958	Year	2	697	0.2	4.0	1.6	57
Pittsburgh	M I	1953	Jan-July	1	2520	(2.2)	(3.9)	(2.7)	61
Pittsburgh	M I	1954	Jan-July	1	2520	(1.2)	(3.2)	(2.2)	61
Pittsburgh	A C D P H	1958	Year	1	304	0.6	6.5	1.7	72
Ridgway	Pa. D H	1959	Sept-Oct	1	396	0.0	4.0	1.2	50
Sunbury	P P L	1956	Year	1	–	0.0	7.4	–	71
Sunbury	P P L	1957	Year	1	–	0.0	8.0	–	71
Sunbury	P P L	1958	–	1	–	0.0	2.5	–	71
Washington	W J C	1952	May-Dec	1	2880	(1.4)	(2.8)	(2.1)	73
Washington	M I	1953	Nov	1	28	1.0	14.5	5.2	61
Washington	W J C	1953	Year	1	4320	(1.6)	(3.2)	(2.4)	73
Washington	W J C	1954	Year	1	4320	(1.1)	(3.7)	(2.2)	73
Washington	W J C	1955	Year	1	4320	(1.3)	(3.8)	(2.2)	73
Washington	W J C	1956	Year	1	4320	(0.9)	(3.2)	(2.0)	73
Washington	W J C	1957	Year	1	4320	(1.1)	(3.3)	(2.1)	73
Washington	W J C	1958	Year	1	4320	(0.8)	(3.5)	(2.1)	73
Washington	W J C	1959	Jan-Mar	1	1080	(2.6)	(2.8)	(2.7)	73

(a) Abbreviations: W J C Washington and Jefferson College
Others See Tables 32, 33, and 34
(b) Equivalent to Cohs/1,000 feet
(c) Values in parentheses refer to monthly averages.

particulates for Pennsylvania communities. Most community averages are well below the national average (Table 31). In 1957, however, Lancaster and Pittsburgh showed averages about twice the national average. According to Regulation 433 of the Commonwealth of Pennsylvania Department of Health, the maximum permissible concentration (MPC) of unspecified beta emitting radio-isotopes is 1000 μμc/cu. M. for a working environment and 100 μμc/cu. M. for the general atmosphere (whole year averages). None of the averages reported in Table 36 exceeds more than about 10 percent of this MPC.

TABLE 36

Summary of Measured Radioactivity (Gross Beta Activity) of Suspended Particulates for Pennsylvania Communities*

Community	Cooperating Agency	Year	Season	Number of Stations	Number of Samples	Radioactivity—μμC/cu.M. (a)			Reference
						Min.	Max.	Avg.	
Allentown	A H D	1957	May-Dec	1	18	0.4	7.9	1.9	43
Harrisburg	Pa. D H	1956	Jun-Sept	1	76	0.1	4.8	0.9	50
Harrisburg	Pa. D H	1957	May-Aug	1	89	0.4	26.6	4.0	50
Harrisburg	Pa. D H	1958	Year	1	289	0.1	17.3	3.1	50
Harrisburg	Pa. D H	1959	Year	1	240	0.0	24.2	3.4	50
Johnstown	Pa. D H	1957	May-Nov	1	10	0.4	12.7	4.3	43
Lancaster	Pa. D H	1957	May-Oct	1	10	0.9	46.8	10.0	43
Philadelphia	Ph. DPH	1953	–	1	14	–	1.3	0.3	43
Philadelphia	Ph. DPH	1954	Year	1	100	–	3.9	1.1	43
Philadelphia	Ph. DPH	1955	Year	1	129	0.1	91.2	2.5	43
Philadelphia	Ph. DPH	1956	–	1	2	0.4	1.6	1.0	43
Philadelphia	Ph. DPH	1957	May-Dec	1	14	1.3	22.3	1.9	43
Pittsburgh	ACHD—Pa. DH	1957	May-Dec	1	17	0.7	93.0	10.2	43
Scranton	Pa. D H	1957	May-Dec	1	16	0.8	18.8	4.7	43

*All measurements by U.S. Public Health Service: sampling by cooperating agency.
(a) μμC/cu.M.—micro-microcuries per cubic meter of air

Estimated Pollutant Concentrations in Pennsylvania

Methods of calculation: The combustion source pollution inventories presented in Chapter II and the meteorological information presented in Chapter III can be used as the basis for calculating estimated concentrations of pollutants from combustion sources. Two methods were used in making these calculations. For the case where no inversion exists to trap pollutants, atmospheric diffusion theory was used. For the cases where inversion "lids" effectively prevented vertical dispersion of pollutants, general industrial ventilation formulas were adapted to the large scale atmospheric ventilation situation.

Using the theory of diffusion from line sources of pollution (Chapter III), the following equation was derived for equally spaced multiple line sources all contributing to an equilibrium concentration, a reasonable model of the actual situation of multiple sources (Appendix C):

$$\bar{X}_{avg.} = \frac{2Q}{\pi^{1/2}\bar{u}CWL^{1/2}}\left[\frac{N - \sqrt{N-1}}{\sqrt{N} - \sqrt{N-1}}\right]$$

where Q is the total source strength of the community, $\bar{u}$ the average wind speed, C the diffusion constant (average value 0.22), W and L the community width and length perpendicular and parallel to the wind direction, respectively, and N is the number of line sources in the community (taken as 100 per mile-from 4 per block and 25 blocks per mile) all in consistent units. This equation was derived by integrating a simplified line source equation (Roberts),[33] and adding the resulting averaged concentration for N number of sources spaced equidistant in the wind direction.

For cases of inversion existence, the following general ventilation equation was derived (Appendix C) to predict the equilibrium concentration in a volume of air to which pollution is being added at a constant rate and from which air is escaping (due to wind) at a constant rate.

$$\bar{X} = 1.3\,\frac{Q}{WH\bar{u}}\left(1 - e^{\frac{-\bar{u}t}{L}}\right)$$

where H is the inversion height, t is the persistence time of the inversion, $\bar{u}$ is the average wind velocity during the inversion persistence time (see Chapter III), and Q, W and L are as above, all in consistent units. This equation is a modification of one used generally for ventilation work and assumes the initial concentration is zero.

Calculated results: The above two equations were used to calculate the probable concentrations of combustion pollutants for the eleven communities for which source inventories were made. The actual community areas were used in all cases. All areas were considered squares except for the valley communities of Lewistown (W = 0.5L) and Williamsport (W = 0.5L). The areas used in computing W and L were taken from the 1940 population census.[74] The other constants used in calculation were: C = 0.22, n = 100L, $\bar{u}$ = 1 mph, H = 800 feet and 2600 feet for ground and subsidence inversions, respectively, and t = 1, 6, 12, 24, and 96 hour periods. The average wind velocities ($\bar{u}$) for the diffusion calculations are given in Table 26. The source strength values (Q) were taken from Tables E-12 to E-22 (Appendix E). To the fine particulates total were added the sulfur trioxide emissions expressed as sulfuric acid mist, on the premise that sulfur trioxide will hydrolyze in the atmosphere. Coarse particulates deposition was calculated using the entire community area, a method which tends to minimize the results.

Table 37 presents the data calculated for the eleven communities. This table when used in conjunction with the information presented in Table 27 will give an indication of the estimated severity of the problem from the five pollutants listed. For example, for Philadelphia, average sulfur dioxide concentrations of at least 1 ppm can be expected to occur and persist for 12 hours on 43 nights of the year, on the basis of these calculations. It should be noted that these calculated con-

TABLE 37

Calculated Average Pollutant Concentrations From Products of Combustion.

(1958 Emission Estimates)

City	Case **	Pollutant Concentration				
		Sulfur Dioxide ppm	Hydrocarbons ppm (as Hexane)	Nitrogen Dioxide—ppm	Fine Particulates—μg/cuM	Course Particulates*
Philadelphia	1	0.065	0.053	0.037	32	11
	2a	0.12	0.12	0.068	59	
	2b	0.62	0.60	0.35	308	
	2c	1.00	0.97	0.97	496	
	3a	0.42	0.41	0.24	207	
	3b	0.48	0.47	0.27	237	
Pittsburgh	1	0.03	0.04	0.02	17	56
	2a	0.07	0.12	0.05	46	
	2b	0.24	0.40	0.18	153	
	2c	0.35	0.57	0.26	221	
	3a	0.13	0.21	0.10	82	
	3b	0.14	0.22	0.10	95	
Reading	1	0.03	0.06	0.03	26	11
	2a	0.06	0.10	0.05	44	
	2b	0.17	0.32	0.15	134	
	2c	0.20	0.37	0.18	157	
	3a	0.06	0.11	0.05	47	
	3b	0.06	0.11	0.05	47	
Harrisburg	1	0.023	0.068	0.031	20	5
	2a	0.032	0.10	0.044	28	
	2b	0.10	0.30	0.14	89	
	2c	0.12	0.35	0.16	102	
	3a	0.036	0.11	0.05	32	
	3b	0.036	0.11	0.05	32	
Williamsport	1	0.015	0.057	0.018	20	14
	2a	0.016	0.060	0.019	22	
	2b	0.06	0.22	0.070	80	
	2c	0.074	0.28	0.087	100	
	3a	0.024	0.090	0.028	32	
	3b	0.025	0.090	0.029	32	
Lebanon	1	0.057	0.069	0.035	32	29
	2a	0.079	0.094	0.048	44	
	2b	0.193	0.231	0.117	107	
	2c	0.203	0.243	0.124	112	
	3a	0.063	0.075	0.038	32	
	3b	0.062	0.075	0.038	32	
Meadville	1	0.12	0.044	0.033	52	56
	2a	0.20	0.074	0.056	92	
	2b	0.40	0.15	0.11	186	
	2c	0.41	0.15	0.12	190	
	3a	0.13	0.047	0.035	59	
	3b	0.13	0.047	0.035	59	
Lewistown	1	0.13	0.075	0.078	61	113
	2a	0.13	0.078	0.079	63	
	2b	0.30	0.18	0.18	145	
	2c	0.31	0.19	0.19	151	
	3a	0.13	0.076	0.078	61	
	3b	0.13	0.076	0.078	61	
Swoyersville	1	0.006	0.023	0.006	9	3
	2a	0.006	0.024	0.006	10	
	2b	0.011	0.044	0.011	17	
	2c	0.011	0.045	0.011	17	
	3a	0.006	0.023	0.006	9	
	3b	0.006	0.023	0.006	9	
Media	1	0.003	0.016	0.007	4	1
	2a	0.004	0.041	0.011	7	
	2b	0.006	0.061	0.016	10	
	2c	0.006	0.061	0.016	10	
	3a	0.003	0.016	0.007	4	
	3b	0.003	0.016	0.007	4	
North Charleroi	1	0.006	0.038	0.009	7	9
	2a	0.008	0.046	0.011	8	
	2b	0.009	0.055	0.013	10	
	2c	0.009	0.055	0.013	10	
	3a	0.006	0.038	0.009	7	
	3b	0.006	0.038	0.009	7	

*Dustfall independent of inversion condition (tons per square mile per month).

**Case 1 No inversion
2a Ground inversion—1 hour duration
2b Ground inversion—6 hours duration
2c Ground inversion—12 hours duration
3a Subsidence inversion—24 hours duration
3b Subsidence inversion—96 hours duration

centrations are only estimates and do not include all pollution sources. They are valuable, however, in assessing over-all community problems and the possible occurrence and frequency of objectionable conditions.

It is interesting to compare these calculated concentrations with the actual measured values. From Tables 37 and 27 a sulfur dioxide level of 0.06 to 0.62 ppm can be expected most of the time (226 days) in Philadelphia. The measured average (Table 32) is 0.14 ppm. The expected suspended particulate concentration (fines only) is between 32 and 308 µg/cu. M. The measured average (1958) is about 160 µg/cu. M.

Although ground inversions are in all cases responsible for higher equilibrium concentrations, subsidence inversions produce much longer lasting concentrations. It is under such extreme conditions that emergency measures may be necessary.

The data of Table 37 may be examined in detail for each community. The data indicate a general trend towards lower concentrations as the size of the community decreases. Lebanon, Meadville, and Lewistown are exceptions. In these communities emissions are greater than proportional to community size. This coupled with a smaller diffusion area leads to higher expected concentrations.

The maximum estimated concentrations occur during 12 hour or longer ground inversions, although the 96 hour subsidence inversion produces a longer and possibly more damaging exposure. Sulfur dioxide levels greater than the adverse 8 hour level of 0.3 ppm[49] may be expected to occur at least 40 times a year in Philadelphia, Pittsburgh, and Meadville. Suspended particulate loadings greater than the national average of about 150 µg/cu. M. will occur 40 times a year or more in Philadelphia, Pittsburgh, Reading, Meadville, and Lewistown. The smaller communities of Swoyersville, Media, and North Charleroi may be expected to be affected only to a minor degree from local sources of pollution.

Chapter V

What Does It Do?—Effects

Abstract

Air pollution can exert biological effects on man, vegetation, and animals and produce physical effects such as reduction in visibility, corrosion of metals, and soiling.

Gases, vapors, and particulates that pollute the air exert many as yet poorly understood effects upon man. So far as has been discovered, they act both locally upon the mucous membranes with which they have direct contact, and also generally upon many varied functions of the body through absorption into the blood stream. The local effects apparently result from both chemical and physical irritation, whereas the systemic, general effects, are primarily chemical in nature.

Air pollutants occasionally are able to cause dramatic, sudden epidemics of illness, which first drew attention to the importance of the health effects of air pollution. During a two-week period in 1952, for example, more than 4,000 deaths in London were attributed to very high concentrations of pollutants, of which sulfur dioxide and carbonaceous smoke seemed the most significant components. But even more dangerous than these dramatic epidemics are the long-term insidious effects of prolonged exposure to lower concentrations of pollutants. Such air pollution is probably playing an important role in such increasingly common and serious diseases as lung cancer, chronic bronchitis, emphysema, asthma, and certain other respiratory disorders.

Air pollution undoubtedly has other effects upon man as well, including annoying eye irritation and objectionable odors. The importance of the changes air pollution causes in the kinds of solar radiation we receive and the possible physiological significance of such changes is yet to be determined.

Vegetation can be affected by gaseous and particulate pollution. Injury can range from reduced growth and yield to complete plant destruction. Transfer to man and animals of pollutants concentrated in edible vegetation is also possible. Among the pollutants known to have caused vegetation damage are gases such as sulfur dioxide, ammonia, ethylene, ozone, and photochemical smog reaction products, and particulate matter such as sulfuric acid mist, carbonaceous smoke, and metal dusts. Livestock may be indirectly injured through acute or chronic poisoning from eating contaminated forage.

Reduced visibility due to suspended particulates is an important physical effect and depends on the composition, size, and concentration of the suspended particles. Not only does suspended matter directly reduce visual range but it can also promote fog formation and increase its persistence. Carbonaceous smoke, sulfuric acid mist, aerosols from automotive exhausts, and perhaps photochemical smog are the main contributors to visibility reduction.

Metal corrosion due to both gaseous and particulate pollution, particulate damage to stone and masonry, and gaseous injury to textiles, leather, and rubber goods are among the most important physical effects. Soiling is the most obvious of all air pollution effects. Coarse particles can mar or damage buildings, automobiles, and scenic attractions. Fine particles can infiltrate homes and businesses soiling walls, furniture, and decorations, and can reduce the value of saleable products, or interfere with fine products' manufacturing.

In Pennsylvania, 62 percent of 476 communities reporting objectionable air pollution concentrations also report personal discomfort effects—primarily up-

per respiratory or eye irritation. In addition to these survey results, vital statistics for the State suggest that air pollution in certain communities may be a contributing cause for an excess number of deaths. Comparative mortality studies in the U. S. show that in metropolitan areas, death rates from respiratory and digestive tract cancer and from heart disease are 10 to 20 percent greater than for the U. S. as a whole. Statistics for five Pennsylvania communities where air pollution levels—as indicated by suspended particulate concentrations—are higher than the U. S. average, in most cases corroborate these increased death rate findings. The excess deaths are due to factors not present in rural communities; air pollution is a possible contributory cause.

These comparative mortality studies are not conclusive with respect to respiratory cancer in Pennsylvania. Consequently a separate study of urban-rural differences in respiratory cancer death rates in Pennsylvania was made. In the eight highly urban counties in the State, this latter study shows that about 400 excess deaths due to respiratory cancer occur yearly. This cannot be explained by tobacco smoking habit differences or by expected urban-rural differences which occur for most diseases. Data are based on two separate multi-year studies. The corrected rates show that men in the urban counties are experiencing from 40 to 90 percent more cancer deaths, and women about 30 percent more, than their counterparts in 17 highly rural counties in the State. Again air pollution is suspected as a contributory factor for these differences.

Besides these long term effects, Pennsylvania need not look afield to find an example of acute biological air pollution effects. The Donora episode of 1948 is still fresh in mind. During a heavy and prolonged fog in late October a total of 5,910 or 42.7 percent of all persons in the Donora area, were affected to some degree by the smog. Twenty persons died. While no single pollutant was responsible for the episode, the action of two contaminants, most likely sulfur dioxide and particulate matter, probably produced the syndrome. A zinc plant and a steel and wire company were the major sources of these two pollutants. A follow-up study shows that during the ten years following the episode, persons who were reported ill during the smog episode subsequently had higher morbidity and mortality than other persons living in the community at that time.

Fifty-four communities in the State report vegetation damage due to air pollution. Eleven areas cited livestock injury as possibly the result of air pollution exposures. Over half the counties in the State are reported to have agricultural damage of some type due to pollution.

Visibility reduction was not specifically cited as a major problem in any Pennsylvania community. Remarkable progress indeed has been made in this area. For example, Pittsburgh has reduced moderate to heavy smoke from nearly 1000 hours per year in 1945 to about 60 hours in 1958. Still some visibility problems attributable to air pollution do occur in the State. Public acceptance of lowered visibility or the lack of knowledge of air pollution's part in its production account for the absence of specific complaints.

Property damage from air pollution was reported in about 30 percent (139 communities) of the communities affected by objectionable air pollution. Paint damage of personal property is the major complaint. Not determined, however, is the possibly enormous economic loss through damage to merchants' goods, valuable art pieces, or manufacturers' products. It is probable that the total economic loss due to property damage alone—and this neglects all direct and indirect effects on health and their related economic ramifications—is about three-quarters of a billion dollars annually in Pennsylvania.

Chapter V

What Does It Do?—Effects

General

Biological Effects

On Man: Respiratory effects are due primarily to the interactions of pollutants with the tissue of the lung passages. Effects in most instances seem to be similar to those caused by exposures in industrial environments except that air pollution exposures are usually for longer periods at lower concentrations. Thus accurate assessment of physiological damage is difficult since changes are very slow. Exceptions occur during short term exposures to comparatively high concentrations in the atmosphere which may occur during stagnant stable weather patterns.

Although there is overlap between categories, pollutant gases and vapors may be classified according to their physiological action as follows:[7]

(a) Irritants—injurious to air passages and lungs, inducing inflammation of the surfaces of the respiratory tract; e.g., ammonia, hydrochloric acid, sulfuric acid, formaldehyde, acetic acid, sulfur dioxide, chlorine, ozone, nitrogen dioxide.

(b) Asphyxiants—act either by mechanically excluding oxygen (simple) or by reacting with tissue or blood to prevent oxygen from reaching the tissues (chemical); e.g., simple asphyxiants—nitrogen, hydrogen, methane, nitrous oxide, ethylene; chemical asphyxiants—carbon monoxide, cyanogen.

(c) Drugs—act after being absorbed in blood and transported to body tissues producing intoxication and anesthesia of the nervous system and, for some gases, organic injury; e.g., anesthetics—aliphatic hydrocarbons, ethers and aldehydes; organic injury possible—carbon tetrachloride, chloroform, aromatic hydrocarbons, alcohols, and nitrites.

(d) Poisonous elements and compounds—exert a wide variety of toxic actions after absorption into the body; e.g., mercury vapor, tetraethyl lead, hydrogen sulfide.

Threshold limits of concentration of these and other substance have been established as guides in the control of industrial health hazards. They are based on a 40-hr. per week exposure of a healthy adult worker.[75] These values serve only as general guides in determining toxicity due to continuous exposure of the general population, which includes the chronically ill, the aged, and infants. "Adverse" levels of outdoor air pollution have recently been established in California for certain contaminants.[49] In Russia, maximum allowable daily average concentrations have been established for a number of materials.[76] Table 38 summarizes data on air quality criteria for the more common air pollutants. It should be emphasized that only the 40-hr. industrial exposure threshold limits are generally accepted in the U.S.A. "The relationship of existing or permissible manufacturing area concentrations to the general environment outside the factory is often in the relationship of 1 to 100 or less."[76] It may be noted from air quality data presented in Chapter IV that Russian maximum allowable outdoor concentrations have been exceeded in some Pennsylvania communities for sulfur dioxide, hydrogen sulfide, and carbon monoxide (see Table 32). The values also are exceeded in Russia.

The effects of particulate matter recently have been summarized.[77] Pneumoconiosis-producing dusts such as silica, asbestos, silicates, carbon, and beryllium act, after inhalation, by producing irreversible fibrotic changes and development of nodules in the lung. Certain

TABLE 38

Air Quality Criteria for Selected Air Pollutants

Pollutant	Industrial Exposure (40-hour/week Threshold Limit) (United States)[75]	Outdoor Daily Average Max. Allow. Conc. (Russia)[76]	Outdoor Adverse Level (California)(49)
Gases and Vapors (Parts per million by volume)			
Ammonia	100		
Carbon Dioxide	5,000		
Carbon Monoxide	100	2.0	30 (8 hrs.)
Chlorine	1.0		
Formaldehyde	5.0		
Gasoline (Hexane)	500		
Hydrogen Chloride	5.0		
Hydrogen Fluoride	3.0	0.015	
Hydrogen Sulfide	20	0.01	
Methyl Mercaptan (Tentative)	50		
Nitrogen Dioxide	5.0		
Ozone (or Oxidants)	0.1		0.15 (1 hr.)**
Sulfur Dioxide	5.0	0.1	0.3 (8 hrs.)
Dusts, Fumes, and Mists (Micrograms per cubic meter)			
Arsenic	500	3.0	
Beryllium	2.0	0.01*	
DDT	1,000		
Fluorides	2,500	10	
Iron Oxide Fume	15,000		
Lead	200	0.7	
Manganese	6,000	10	
Mercury	100	0.3	
Sulfuric Acid	1,000	100	

*United States value.[76]
**Oxidant index

inert dusts may also produce pulmonary change. Toxic aerosols (particulates) such as lead, radioactive matter, chromates, arsenic, cadmium, and fluorides can produce a variety of effects ranging from systemic poisoning to lung edema. Metal oxide fumes such as those of zinc, copper, and manganese, can cause a transient reaction, called "metal fume fever." Liquid particulates, too, can produce respiratory damage. Acid mists in particular can exert irritant effects in the lung, the site of action depending on solubility.

Aerosols produced during fuel combustion consist of carbon, tars, mineral ash, and acid mists. The organic portion has been shown to contain cancer-producing substances which may be deposited in the lungs and enhanced in activity by the action of irritant gases. Statistical studies link both tobacco smoking and air pollution to the incidence of lung cancer. In Britain one study concludes that about one-half of lung cancer deaths are associated with cigarette smoking and three-fourths of the remainder with a factor only slightly present in rural areas, presumably air pollution. A Russian estimate is more definite: "fifty cigarettes would have to be smoked in order to expose the smoker to as much 3,4-benzpyrene (a cancer-producing substance) as is inhaled daily in some industrial towns." This substance occurs in gasoline engine exhausts and in the combustion products of solid, liquid, and gaseous fuels.

Certain gases and particulates, acting together, are thought to be especially toxic. In the London fog episode of 1952, which was followed by an increase of some 4,000 deaths in a two-week period, the combination of carbonaceous smoke and sulfur dioxide gas has been suggested as the prime contributory cause, even though concentrations of each material, separately, were below proven damaging levels.

Long-term effects from exposure to low level concentrations of pollutants are also possible. Respiratory diseases, especially lung cancer, chronic bronchitis, emphysema, and asthma, have been frequently cited as correlating directly with air pollution levels. The U. S. Public Health Service and others are investigating possible long term chronic effects by statistical and field studies.

In addition to action through the respiratory system, gases and particulates can exert direct effects on other exposed parts of the body where mucous membranes are exposed. For example, eye, nose, and throat irritations arise from exposure to Los Angeles-type smog. The irritation is due to both the gaseous and particulate phase of the smog complex.

An indirect effect of suspended particulate pollution is reduction of sunlight and consequent loss of beneficial solar radiation. Total radiation intensity can be cut by one-fifth or more by suspended particulates. More important, nearly all of the beneficial ultraviolet radiation, the natural source of vitamin D, may be removed. Emotional health may also be affected by life in a darkened environment.

Gases and possibly some particulates in very minute concentrations can produce objectionable odor problems. Indeed, a large percent of all air pollution complaints is due to this cause. Although in most cases, their toxicity is nil, odorous substances may produce violent subjective psychological or physical reactions. Mercaptans and methylamines are the most commonly complained of odorous gases.

On Agriculture: Gases and particulates in community atmospheres exert effects on vegetation in several ways.[2] Gas injury to vegetation has been reported as being caused by sulfur dioxide, chlorine, ammonia, ethylene, fluorides, ozone, and others. Specific injury to plants has occurred from particulates such as sulfuric acid mist, fluorides, herbicides, "smog," carbonaceous smoke, and arsenic, zinc, and lead dusts. Effects range from reduced growth and yield or reduced photosynthesis to loss of leaf area or complete plant destruction. Field, flower, fruit, ornamental, and vegetable crops and even entire forests can be affected. An indirect hazard is the possible transfer to man and animals of toxic pollutants concentrated in edible vegetation, e.g., radioactive "fallout," metal fumes.

Farm animals may ingest vegetation contaminated by air pollutants. Arsenic, lead, and copper fumes have led to both chronic and acute poisoning of livestock. Fluorides when concentrated in forage and subsequently ingested by cattle can damage the animals' teeth and eventually lead to their death by self-imposed starvation. Radioactive pollutants, concentrated in forage, can produce increased radioactivity in milk products from cattle which graze in affected areas.

Air pollutants may damage vegetation causing loss of leaf area.

Physical Effects[77]

Reduction in Visibility: One of the most important effects of suspended particulates in the atmosphere is decreased visibility. The degree of lessened visibility depends on the physical properties of suspended material, its size distribution, and its concentration. It has been found that visual range is approximately inversely proportional to suspended particulate concentration. Visibility is directly dependent on the size of the suspended material, increasing with the size of particles. For example, with a fog at a concentration of water of 1.0 mg per cubic meter, visibility will be about four miles if the particles are seven microns in diameter but less than one-third mile if the particles are one-tenth that size.

Besides the direct effect of visibility reduction, fine suspended particulates act as condensation nuclei for fog formation. Not only does fog form more readily because of these particles but its persistence may increase because of the electrostatic charge of the particles.

Visibility criteria have been used as a qualitative measure of air pollution. For example, in one European city the average number of days of low visibility per year has doubled since 1800, during the same period in which this city has become markedly industrialized. Black smoke is not the only pollutant which contributes to reduced visibility. Others are sulfuric acid mist, automotive exhaust aerosols, fine inorganic dusts, metal fumes, and photochemical reaction products.

Damage to Exposed Surfaces: Corrosion of metal surfaces consists of slow chemical and electrochemical reactions between the metal and its environment. Air pollutants, both gaseous and particulate, can act individually or jointly to initiate corrosion. Corrosive gases attack metal surfaces directly at high concentration in the presence of water vapor. Usually, however, they act by adsorption followed by solution and often in the presence of particulate pollution which may act as the carrier or catalyst in their reactions. Deposited particulates can initiate corrosion depending on their water soluble components and the acidity or alkalinity of the resulting solutions. Particles of carbon and tars which settle on surfaces are especially important since they can promote corrosion either by adsorption of acid gases and water vapor or directly by the action of the tarry acids.

Carbonate building stone such as limestone often is affected by air pollution. Adhesive acid-bearing tar droplets convert the carbonates to sulfates, which are soluble in rainwater, and leave pitted surfaces. Other building materials can become covered with incrustations which may eventually break off, marring the surface. Textiles, leather, and rubber goods are especially vulnerable to gaseous pollution.

Soiling is the most obvious of atmospheric pollution effects. Coarse particles settle on horizontal surfaces such as streets and sidewalks, automobiles, porches, window sills, etc., rapidly covering them with unattractive films. Physical damage may occur when these materials are removed due to their abrasive action.

Fine particles are of a more insidious nature. They are carried easily by air currents through cracks around window frames into homes where they attach themselves to walls, draperies, upholstery, carpets, and clothing. Closing windows and doors is of no great help since, in the average well-constructed home, the air is changed many times a day through infiltration. Consequently, the housewife is continually fighting a battle against fine particulate pollution. Although these particles do not settle rapidly, they are deposited by thermal and electrostatic forces on nearly every exposed surface in the home. This problem is not peculiar to homes but is also important in certain industries (e.g., precision parts, paper, food, pharmaceutical, photographic films), in stores, office buildings, hospitals and hotels.

Economic Effects[77]

Atmospheric pollution produces an economic burden on individuals, industry, and communities. Reduction in visibility affects transportation operations, both ground, marine and air. Increased operational costs, passenger inconvenience, and additional safety hazards which can contribute to personal injury and property damage, result. The obstruction of natural light results in an increased cost of electricity for artificial lighting of streets and buildings.

Corrosion and soiling of metals and building materials requires extra costs in protective coatings or in cleaning or replacement of exposed surfaces. Soiling of merchandise, household articles, and clothing results in direct or indirect losses. Frequent laundering and dry cleaning of exposed textiles is required which is costly in itself and results in a shorter usefulness of the article. Soiling of manufactured products can result in lowered product value or, in some cases, complete loss of product worth (e.g., precision machinery and photographic films). Expensive air filtration equipment becomes necessary not only to control effluents but also to filter supply air. (Equipment used primarily for air conditioning or heating is not usually designed to remove fine particulate aerosols efficiently.)

Farmers and florists suffer considerable losses due to pollution effects on vegetation and livestock. The scenic value and recreational facilities of communities are often impaired. Property devaluation in highly polluted areas represents an important economic loss. The health of the community is affected resulting in lessened human efficiency, absenteeism, and in personal discomfort arising from the physiological and psychological effects of air-borne material. In some acute cases, human life can be destroyed.

Several estimates of the costs of air pollution have been attempted. In most cases these estimates have been confined to detrimental effects measurable in terms of money. No account is taken of the direct and indirect effects on human health and well-being. Recent estimates place the cost of the ***non-medical*** effects of air pollution at from $10 to $65 per year per person in the U.S. for a total economic loss up to $10 billion per year (1950 population). This does not include the costs of control activity. Governmental control costs are usually very low, on the order of 10 to 20 cents per capita per year. Total industry control costs are currently on the order of $300 million annually.

Pennsylvania

Biological Effects

On Man: During the survey of 801 Pennsylvania communities it was determined whether pollution concentrations were sufficient to cause personal discomfort or inconvenience (Table 39). In about 62 percent of the communities with objectionable air pollution, personal discomfort is a source of complaint. In

TABLE 39

Personal Discomfort Reported Due to Air Pollution in Pennsylvania, 1959

Community Population	Number Surveyed	Number with Pollution Problems	Type of Discomfort Reported				
			Respiratory (a)	Mucous Membrane (b)	Offensive Odors	Unspecified	Total
Less than 2500	71	44	10	5	10	6	31
2500-5000	345	190	53	5	15	37	110
5001-7500	169	104	43	2	13	21	79
7501-10,000	65	36	6	–	2	7	15
10,001-15,000	63	33	11	2	4	8	25
15,001-20,000	39	30	7	2	1	9	19
20,001-25,000	12	8	3	–	–	–	3
25,001-50,000	20	15	3	2	–	1	6
50,001-100,000	11	10	5	–	–	1	6
More than 100,000	6	6	2	–	1	1	4
TOTAL	801	476	143	18	46	91	298

(a) Respiratory symptoms—choking, coughing, throat pain
(b) Mucous membrane or eye irritation

roughly half of these cases upper respiratory symptoms such as choking, coughing, and throat irritation, are cited. Offensive odors produce discomfort in approximately one-fifth of these communities. Eye irritation occurs in about six percent of the affected areas. The remaining personal discomfort symptoms were unspecified.

A recent publication by the U.S. Public Health Service[78] tabulates comparative mortality data for 163 metropolitan areas of the United States listing 102 causes of death for the period 1949-1951. Certain causes of death in the metropolitan areas show rates appreciably higher than the national average. Air pollution is suspected as a possible causative factor on the premise that pollutant concentrations are greater in the metropolitan areas. Among those most frequently mentioned are cancer of the respiratory system and digestive tract and arteriosclerotic heart disease. Twelve metropolitan areas in Pennsylvania are listed. Of these twelve, five have higher than U.S.A. average suspended particulate concentrations: Philadelphia, Pittsburgh, Harrisburg, Johnstown, and Scranton (Tables 29 and 33). If suspended particulates are considered a good index of over-all air pollution levels and the deaths are related to air pollution, then death rates for these communities should be at least as high as the national average for metropolitan areas (Table 40).

In all cases except one the average ratios for the five highly polluted Pennsylvania communities equal or exceed the national ratios. The exception is cancer of the lung and bronchus, among men. The average ratio for the five Pennsylvania communities indicates no excess over the total U.S. Multiple listing of respiratory cancer causes may account for this exception, i.e., not all deaths from respiratory cancer are included in "Cancer of lung and bronchus, unspecified."

The ratios shown in Table 40 indicate that for 163 metropolitan areas in the U.S., death rates from the three causes listed are between 10 and 20 percent greater than for the U.S. as a whole. The results for the Pennsylvania communities listed corroborate this finding. It cannot be concluded categorically that the indicated excess deaths are due to air pollution These excess rates may be due to one or more factors peculiar to urbanized areas; air pollution is a possible contributory cause.

Since respiratory cancer is often linked to air pollution and since the above data are inconclusive with respect to this particular cause for Pennsylvania communities, a special study of mortality statistics in the State was made as part of this survey. Mortality data are available in the State on a county-wide basis. In order to test the hypothesis that urban areas are more conducive to development of cancer of the respiratory tract (possibly because of higher general air pollution), data were divided into two groups, urban and rural. Arbitrarily, those counties in

TABLE 40

Ratio of Mortality Rates of Urban Areas to the United States Average Due to Certain Diseases

(age adjusted, white population, 1949-1951)

Areas	Cancer of Lung and Bronchus, unspecified		Cancer of Lower Intestine (except rectum)		Arteriosclerotic Heart Disease (including coronary disease)	
	male	female	male	female	male	female
163 United States Metropolitan Areas	1.2	1.1	1.2	1.1	1.1	1.1
Philadelphia	1.2	1.1	1.4	1.3	1.1	1.1
Pittsburgh	1.2	1.2	1.2	1.2	1.2	1.4
Harrisburg	0.8	1.0	1.0	1.1	1.1	1.2
Johnstown	0.7	0.8	1.1	1.2	0.9	0.9
Scranton	0.9	1.3	1.5	1.9	1.1	1.2
Avg. Ratios—Pa.	1.0	1.1	1.2	1.3	1.1	1.2

TABLE 41

Deaths Due to Cancer of the Chest Cavity or Respiratory Tract—Pennsylvania*

	8 Urban Counties		17 Rural Counties		8 Urban plus 17 Rural Counties	
	male	female	male	female	male	female
			1946–1950			
Population—Millions**	12.97	13.37	1.26	1.29	14.23	14.66
Deaths—Cancer of Chest Cavity	3,844	855	162	51	4,006	906
Chest Cancer Rate—per 100,000	29.6	6.40	12.9	3.96	28.2	6.19
Deaths—All Other Cancer	17,219	20,219	1,562	1,690	18,761	21,909
Other Cancer Rate—per 100,000	133	152	124	131	132	149
			1956–1958			
Population—Millions**	8.10	8.34	0.734	0.755	8.83	9.10
Deaths—Cancer of Resp. Tract	3,682	576	202	33	3,884	609
Resp. Cancer Rate—per 100,000	45.5	6.91	27.5	4.38	44.0	6.69
Deaths—All Other Cancer	12,350	13,533	1,064	1,062	13,414	14,595
Other Cancer Rate—per 100,000	152	162	145	141	152	160

*Resident Mortality data

**Population at risk:

1946–1950 taken as five times 1950 population

1956–1958 taken as estimated population for the three years

which 75 percent or more of the population resided in urban areas (defined as places of more than 2500 population) were considered urban counties. According to the 1958 State statistical abstract,[79] eight counties are in this category: Allegheny, Dauphin, Delaware, Erie, Lackawanna, Lehigh, Luzerne, and Philadelphia. Those counties in which 25 percent or less of the population resided in urban areas were considered rural counties. The following 17 counties are in this category: Bedford, Clarion, Forest, Fulton, Greene, Indiana, Juniata, Perry, Pike, Potter, Snyder, Somerset, Sullivan, Susquehanna, Warren, Wayne, and Wyoming.

In order to obtain sufficient data for statistical reliability, mortality data for a five-year period, 1946-1950 and a three-year period, 1956-1958, were used. Data for the former period were taken from a Department of Health cancer mortality study[80] and included deaths from all cancer of the chest cavity (specific site not given). The 1956-1958 data were assembled from records of resident mortality of the Cancer Control Section of the Department of Health and included deaths from respiratory system cancer (causes 160-163 of the International Statistical Classification of Causes of Death) (Table 41).[81] These figures are *resident* mortality statistics, i.e., the place of death listed is the last place of residence prior to death and not necessarily the actual location of the hospital, home, etc., where death occurred.

Table 42 presents ratios of the calculated death rates for the urban counties to rural county rates. The differences in these rates shown in Table 41 were tested for statistical significance using Student's "t" test. The combined rates (Column 3, Table 41) were used as the true mean in these tests. In all cases the rate differences were significant at the 95 percent confidence limit. Indeed, in most cases the significance tests produced t-values of greater than three, indicating 98 percent confidence limit significance. These

TABLE 42

Ratio of Mortality Rates of Urban to Rural Counties Due to Cancer of the Chest Cavity or Respiratory Tract—Pennsylvania

Cause	Urban Rate/Rural Rate	
	1946–1950	
	male	female
Cancer of Chest Cavity	2.30	1.62
All Other Cancer	1.08	1.15
Predicted Difference—due to smoking habits	1.13	1.15
Chest Cancer Ratio, corrected	1.90	1.25
	1956-1958	
Cancer of Resp. Tract	1.66	1.58
All Other Cancer	1.05	1.15
Predicted Difference—due to smoking habits	1.13	1.15
Resp. Cancer Ratio, corrected	1.41	1.21

tests mean that the chances are less than one in twenty that the differences found in Table 41 would occur by chance alone. The ratios of Table 42 indicate that death rates from chest cavity cancer during 1946-1950, were over twice as high for men and over 60 percent higher for women in the urban counties compared to the rural counties. Similarly, in 1956-1958 death rates from respiratory tract cancer, for both men and women, were about 60 percent greater in the urban than the rural counties.

The rates for all other forms of cancer, excluding in one case chest cavity cancer and in the other respiratory tract cancer, are between five and eight percent for men and 15 percent for women, respectively, higher in the urban than in the rural counties (Tables 41 and 42). This follows a pattern seen in many diseases: death rates are higher in urban areas than in rural areas, primarily due to the migration of the ill to better equipped hospitals in metropolitan areas.

Since tobacco smoking has often been incriminated as a causal factor in lung cancer and since tobacco smoking habits vary between urban and rural areas, this influence must be considered. According to Haenszel and Shimkin of the National Cancer Institute,[82] the predicted urban-rural ratios of lung cancer rates for those 35 years and over (which includes nearly all lung-cancer deaths) are those shown in Table 42. These predicted ratios are based on studies of smoking habits and the epidemiology of lung cancer in the United States, and in effect, standardize the smoking patterns. This correction also does not account for enough excess deaths to explain the total observed differences of Table 42.

When the observed ratios are corrected for both the migration factor (all other cancer death rate difference) and for smoking habit differences, the resulting ratios still indicate nearly twice as high a chest cavity cancer death rate among men for the urban counties when compared to the rural counties during the period 1946-1950. Similarly, for the same period, the female rate is about 25 percent higher. For the 1956-1958 data the corrected respiratory tract cancer rates are about 40 percent higher for men and 20 percent higher for women, when the urban counties are compared to the rural ones.

Both the 1946-1950 and 1956-1958 periods show that about 400 excess deaths from chest or respiratory cancer occur yearly in the eight highly urbanized counties of Pennsylvania (Table 43). The causes of these excess deaths are possibly environmental factors not present in rural areas. Air pollution is suspect as one of these factors.

To illustrate the acute effects of air pollution on man, three or four classic episodes of severe exposure with resulting death are usually cited. These epi-

TABLE 43

Reported And Expected Deaths, Due To Cancer Of The Chest Cavity Or Respiratory Tract*

	Cancer of Chest Cavity 1946–1950		Cancer of Respiratory Tract 1956–1958	
	Male	Female	Male	Female
1. Urban deaths	3844	855	3682	576
2. Urban deaths at rural rate	1673	528	2227	365
3. Actual excess urban deaths (1-2)**	2171	327	1455	211
4. Expected excess urban deaths				
5. Due to migration, better diagnosis, etc.	134	79	111	55
6. Smoking habit difference	217	79	289	55
7. Corrected excess urban deaths (3-5-6)	1820	169	1055	101
8. Expected urban deaths (Corrected) (2 + 5 + 6)	2024	686	2627	475
9. Percent excess (7 + 8)	90	25	40	21
10. Excess urban deaths per year (7 + 5 yrs. and 7 + 3 yrs.)	364	34	352	34
11. Total urban excess deaths per year	398		386	

*Corrected for normal urban-rural difference and difference due to smoking habits.
**Numbers in parentheses refer to line numbers.

sodes range from an accidental release of hydrogen sulfide gas in a Mexican city in 1949 which was reportedly responsible for 22 deaths, to the famous lethal London Fog of 1952 when 4,000 deaths were attributed to the smoke-sulfur dioxide mixture which built up to over ten times normal concentrations.

However, it is not necessary to leave Pennsylvania to find an example of the acute effects of air pollution on man. The following quotes from the U.S. Public Health Service report of its investigations of the Donora incident[52] summarize the cause and effects of the disaster.

"During the last week of October 1948 a heavy smog settled down over the area surrounding Donora, Pa. Weather men described it as a temperature inversion and anticyclonic condition characterized by little or no air movement, prevailing over a wide area encompassing western Pennsylvania, eastern Ohio, and parts of Maryland, and Virginia. This prolonged stable atmospheric condition was accompanied by fog and permitted the accumulation of atmospheric contaminants resulting in dense smog, particularly in highly industrialized areas." "During the smog of October, 1948 a total of 5,918 persons, or 42.7 percent of all persons in the Donora area, were affected to some degree by Smog. The affection was essentially an irritation of the respiratory tract and other exposed mucous membranes, and varied in degree from mild to severe. Cough was the predominant single symptom during the illness." "Twenty persons died in the Donora area during or shortly after the smog of October 1948." "Only in the degree of severity and in the outcome were the fatal cases different clinically from the severely ill persons who did not die. Preexisting disease of the cardiorespiratory system appeared as a single significant factor among the fatally ill . . ." "Mortality records showed that crises have occurred in Donora creating, occasionally, higher death rates due to cardiovascular disease. These crises probably are related to atmospheric conditions."

"It seems reasonable to state . . . that while no *single* substance was responsible for the October 1948 episode, the syndrome could have been produced by a combination, or summation of the action, of two or more of the contaminants. Sulfur dioxide and its oxidation products, together with particulate matter are considered significant contaminants."

Atmospheric studies showed that major sources of particulate matter were: the local zinc plant's smelters and waste heat boiler stacks, and the local steel and wire plant's blast furnace. The major sources of sulfur dioxide were: the zinc plant's waste heat boiler stacks and sintering operation, and the steel and wire plant's blooming mill and steel mill boiler stacks. The distribution of sulfur dioxide concentrations in the general atmosphere was the most uniform of all pollutants indicating the wide distribution of sources. Total particulate matter showed uniform distribution with the exception of the areas closest to the zinc plant, which were higher. A definite relationship was found to exist between the concentration of contaminants and atmospheric stability.

The study of the Donora incident did not end in 1949 with the Public Health Service's report. A special follow-up study of the mortality and morbidity through 1957 among persons residing in Donora during the smog episode of October 1948 has recently been published.[83] This study shows "that the group of persons who complained of being ill during the October, 1948 smog episode in Donora (5,910 persons) have had a subsequent morbidity and mortality history that is clearly distinguishable from those persons 'not affected' during the episode." "For the largest single cause of death, arteriosclerotic heart disease, the 'affected' males have an age-adjusted rate more than twice that of the 'not affected' males." "The essential finding . . . is that persons who were reported ill in 1948 at the time of the smog episode have demonstrated subsequently higher mortality and prevalence of illness than the other persons living in the community at that time. Furthermore, persons who complained of more severe illness in 1948 demonstrate greater subsequent morbidity and mortality than persons with mild complaints. This greater morbidity and

TABLE 44

Agricultural Damage Reported Due To Air Pollution In Pennsylvania, 1959

Community Population	Number Surveyed	Number with Pollution Problems	Number Reporting Vegetation Damage — Injury Type: Total	Burning	Spotting	Kill	Other	Number Reporting Animal Injury—Unspecified Type
Less than 2500	71	44	13	6	5	–	2	2
2500-5000	345	190	15	6	3	1	5	4
5001-7500	169	104	17	8	4	1	4	5
7501-10,000	65	36	1	–	–	–	1	–
10,001-15,000	63	33	1	1	–	–	–	–
15,001-20,000	39	30	3	1	–	1	1	–
20,001-25,000	12	8	–	–	–	–	–	–
25,001-50,000	20	15	–	–	–	–	–	–
50,001-100,000	11	10	2	1	1	–	–	–
More than 100,000	6	6	2	1	–	1	–	–
Total	801	476	54	24	13	4	13	11

mortality is apparently related to the cardiorespiratory system." "It would seem that subsequent health experience is to a great extent related to the complaints first arising during the episode."

On Agriculture: In the community surveys, air pollution concentrations were reported to be sufficient to cause vegetation damage and/or animal injury in 54 communities in the State, i.e., in about one-tenth of the communities reporting objectionable air pollution (Table 44). Most of the reported damage occurred in and around communities of 7500 population or less, which is to be expected since agriculture is a more important industry to these communities. The vegetation damage reportedly was due primarily to gaseous attack; over two-thirds of the affected areas reported the "burning" or spotting of vegetation. In four communities air pollution resulted in plant kills. Other less severe problems such as settled dust were cited in 13 communities. In 11 areas livestock was reported to be affected by air-borne pollution. In most cases, however, the local official was not specific on this point.

Questionnaires completed by county agricultural agents indicate that in over half the counties air pollution causes agricultural damage (Table 45). Vegetation damage was specifically cited in half of the affected counties. Animal injury, unspecified, occurred in five counties. In most of the unspecified cases, the agent assumed damage existed but had no specific complaints. In 14 of the 35 affected counties some remedial control action was being contemplated.

Physical Effects

Visibility Reduction: There were no specific complaints concerning reduced visibility due to air pollution reported during the survey. This is not to say that the communities in the State are unaffected by air pollution in this respect. Rather it indicates an acceptance by the public or, in some cases, the lack of knowledge, of the causes of reduced visibility. Certainly not all reduced sunshine or lowered visual range occurrences may be attributed to suspended particulate

TABLE 45

Summary Of Findings From County Agricultural Agents' Questionnaires

	Number	Percent
Questionnaires sent	67	100
Questionnaires returned	62	92
Counties with known or reported agricultural damage due to air pollution	35	56
Type of agricultural problem		
Vegetation damage	18	51
Animal injury (possible)	5	14
Unspecified damage	17	48
Major Problem pollutants and sources		
Gases	13	37
Industrial, unspecified	7	
Culm fires, sulfur gases	4	
Dump fires, sulfur gases	2	
Particulates	15	43
Industrial dusts	13	
Combustion, unspecified	2	
Unknown or unspecified	7	20
Control action planned	14	40
By local Government	4	
By industry	10	

TABLE 46

U. S. Weather Bureau Smoke Observations In Pittsburgh From 1945 Through 1958[84]

Year	Number of Hours Per Year		
	Light Smoke	Moderate Smoke	Heavy Smoke
1945	4964	653	208
1946	5017	665	298
1947	5205	401	234
1948	4778	373	132
1949	3719	427	162
1950	3327	393	58
1951	3241	257	51
1952	3286	260	23
1953	3543	303	16
1954	3794	141	4
1955	3781	103	10
1956	3495	122	0
1957	3328	122	0
1958	3130	60	0

pollutants. Natural phenomena, primarily fog or other forms of condensed water vapor, are responsible in the majority of cases for the reduced visibility which occurs frequently in some Pennsylvania communities. However, pollution forms, such as suspended carbonaceous matter, sulfuric acid mist, and a growing problem—petrochemical smog—are responsible, partially or completely for many occurrences of reduced visibility in the State.

It is rare today for a community to be affected to the extent of Pittsburgh's lowered visibility problem of 15 years ago. The remarkable progress made in abating the suspended particulates there, since 1945, can be seen by examining the records of the U.S. Weather Bureau Station in Pittsburgh where smoke observations have been made since 1945 (Table 46). During the past fourteen years the number of hours of light smoke have been cut from about 5000 to 3000; the hours of moderate smoke from over 600 to 60; and the hours of heavy smoke from nearly 300 to zero. This reduction has been due mainly to a change to "smokeless" fuels and a campaign for better fuel firing practices.

Damage to Property: Property damage was reported in 139 communities, about 30 percent of the 476 reporting air pollution problems (Table 47). Paint damage, primarily discoloration or spotting, was cited in 106 of these affected communities (about 75 percent). Other types of damage, such as the corrosion of metal surfaces, were cited in the remaining 33 areas. Other forms of possible air pollution damage, such as to merchant's products, clothing, valuable art pieces or manufacturers' goods, were not determined. Such damage undoubtedly is considerable. The effects of deposited material and the required extra cleaning of homes and places of business were not cited. This presumably is because people accept air-borne dirt as a cost of living in urbanized society.

Economic Effects

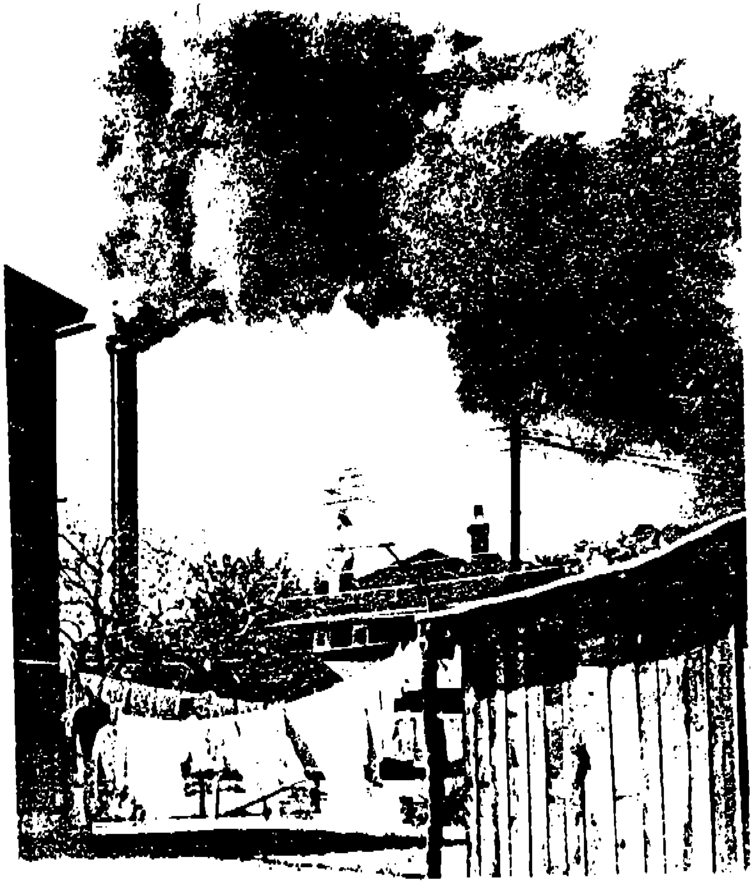
It is practically impossible to accurately assess the costs to Pennsylvanians of the effects of air pollution. In the course of this survey many individual examples of the economic burden of dirty air were found: the State Capitol Building recently required cleaning of its exterior at a cost of $200,000; an irate citizen complained that he had to repaint his home *every year* because of air pollution damage; one woman claimed all her flowers had been killed overnight by exposure

TABLE 47

Property Damage Reported Due To Air Pollution In Pennsylvania, 1959

Community Population	Number Surveyed	Number with Pollution Probs.	Number Reporting Property Damage		
			Total	Paint Damage	Other
Less than 2500	71	44	19	15	4
2500-5000	345	190	46	32	14
5001-7,500	169	104	38	31	7
7501-10,000	65	36	6	5	1
10,001-15,000	63	33	10	9	1
15,001-20,000	39	30	6	3	3
20,001-25,000	12	8	1	1	-
25,001-50,000	20	15	6	6	-
50,001-100,000	11	10	4	3	1
More than 100,000	6	6	3	1	2
TOTAL	801	476	139	106	33

to gaseous pollution; recently a fatal head-on collision on U. S. Route 22 was cited as due to reduced visibility in a highly polluted section of road. The examples are innumerable. If we neglect the many possible direct and indirect effects on health and well-being and their related economic ramifications, and consider only effects on property—cleaning, painting, laundering and damage to merchandise and buildings—the total cost to Pennsylvania at $65 per capita is about three-quarters of a billion dollars per year.



Soiling of laundry can be caused by air pollutants.

Air pollutants cause soiling and other damage to building exteriors.

Chapter VI

What Is Being Done About It?— Control

Abstract

In general, air pollution control can be accomplished through engineering methods which include process changes, effluent treatment, and effluent dispersion. Domestic sources are best controlled by process changes; industrial sources may require all forms of engineering control; and transportation sources may require effluent treatment. The cost of control depends on the method of control and other factors. For minimum cost, a thorough economic analysis should be made. Effluent treatment is usually the most expensive method.

Governmental programs function in six main areas: education, voluntary action, legal enforcement, community planning and zoning, technical assistance and research. Levels of possible action range from single or regional groups of communities to state, interstate, and federal levels. Local programs historically have been the major area of regulatory action. State and federal activity is today becoming more necessary because of the increased complexity and cost of air pollution problems and solutions. Governmental control can cost anywhere from $0.05 to more than $0.60 per capita per year at the local level with supporting and independent state and federal activity costing $0.01 to $0.05 per capita per year each.

In Pennsylvania, of the 862 industries replying to an inquiry concerning engineering control of their air pollution problems, 174 or 20 percent report one or more air pollution control installations. The chemical and petroleum industries have the highest percent of establishments with control applications. Costs of these installations can be very high. For example, a paper manufacturer reports a current annual cost of nearly three-quarters of a million dollars for air pollution control equipment and a Pennsylvania cement company reports a recent purchase of an electrostatic precipitator as part of a two million dollar dust suppression program.

Public control activities, at the local level, are limited in Pennsylvania. Twenty-eight communities report existence of a smoke or air pollution control ordinance but only six of these have full-time programs. The two major local control agencies are in Philadelphia and Allegheny County, each with an annual budget of over $100,000. Other local activity in the field is limited to answering nuisance complaints by police or other local authorities.

In addition to air pollution or smoke ordinances, Pennsylvania communities can act in two ways to reduce air pollution problems: by enforcement or enactment of restrictive zoning regulations; and by prohibition of open burning of public and industrial wastes. Unfortunately there are some 1500 open burning public dumps in the State and only about 200 sanitary landfills. Zoning is practiced more extensively but there are still 33 counties where less than 25 percent of the population is governed by zoning regulation and only 19 counties where more than half the population is so-regulated.

On the State level, recently enacted legislation has changed the character and extent of the Health Department's activity in air Pollution control. This is discussed in Chapter VII.

Chapter VI

What Is Being Done About It?— Control

General

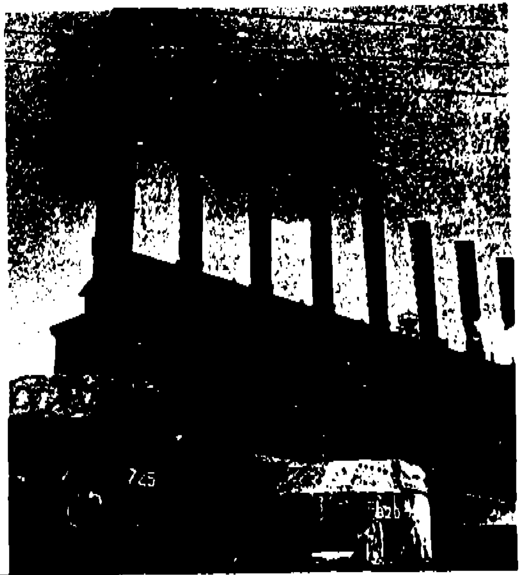
Private Control Activities

Engineering Control Methods: Of all methods available for control of atmospheric discharges the most basic is process change. By this method, polluting processes or materials are changed in such a way as to reduce or eliminate pollutants generated. Examples of process changes are: by industry—a change from a dry to a wet process in the milling of ore and stone; by government—a change from open burning dumps to sanitary landfill operations; by the public—a change from one heating fuel to another more "smokeless" type.

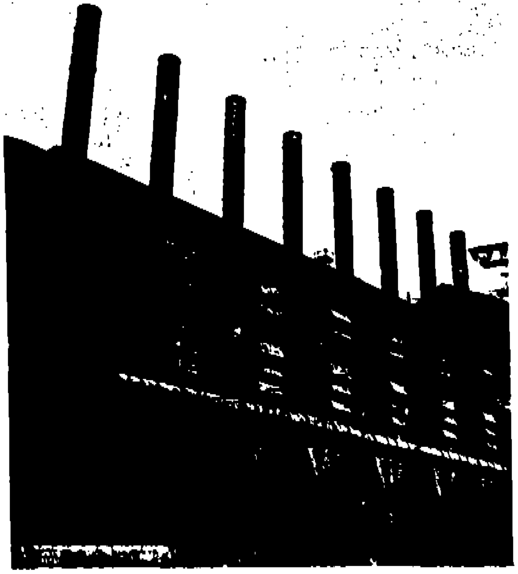
Many times, especially when industrial processes are concerned, process changes are not economically or technically feasible. In these cases effluent treatment becomes the necessary control technique. Methods of treating effluents to reduce or eliminate atmospheric discharges can be classified in two categories. For pollutant gases and vapors the major techniques available are: absorption, adsorption, combustion, and chemical treatment. For particulate emissions the main air cleaning methods are: settling chambers, cyclones and other inertial separators, packed media—including fiber filters, cloth collectors, scrubbers, and electrostatic precipitators. The proper choice of methods or devices depends on engineering evaluation of the problem. Among the factors to be considered are: the concentration of contaminants in the effluent stream; chemical nature and/or particle-size of the contaminant; the volume of discharge air to be handled; required degree of pollution reduction (i.e., the collection efficiency); and a number of other considerations such as product recovery, process variations, and special construction problems.

A third general control method, that of dilution and dispersion of contaminants by the use of tall stacks, is also available. This method is not to be recommended except when neither source control nor effluent treatment is possible or practical. Vagaries in micrometeorology are such that adequate contaminant dilution is not always possible or predictable. At times stack emissions can be affected by wind and turbulence, or by stable atmospheric conditions, such that stack concentrations are not materially reduced before reaching and affecting

BEFORE the addition of an efficient air cleaning device. *Photo courtesy U. S. Steel.*



AFTER. *Photo courtesy U. S. Steel.*



exposed populations and property. In the few cases when the use of tall stacks is the only control method available, detailed analysis of local micrometeorology and terrain should be made so that uncontrolled discharges will only be allowed under conditions conducive to adequate dispersion.'

Application of Control Techniques: Process change is the primary method which can be employed in the control of the major domestic emissions: smoke from heating fuel and wastes burning. The heating fuel can be changed to a "smokeless" type or firing methods or equipment can be improved so that any fuel can be burned efficiently without the production of smoke. The problem of burning domestic wastes should be assumed by municipal authorities. Instead of multiple, small, inefficient fires, all domestic wastes can be incinerated in a few well-designed, properly operated municipal incinerators. A better method is disposal of wastes in well-functioning sanitary landfill operations. This is often the cheaper and by far the more foolproof method. The problem of odor from domestic sewage disposal systems can be largely eliminated by proper design and operation of the systems.

Most combustion emissions from industry can be reduced considerably by proper process changes including correct fuel preparation, use of fuel suitable to the furnace, proper firing, or, at times, a change in fuel. Two industrial combustion problems are particularly important and require special note. Sulfur gases liberated in large-scale fuel burning operations, especially by electric power plants, can be reduced partially by judicious selection of low-sulfur fuels and prior treatment of the fuel. Large quantities of sulfur gases are still apt to be released, however. To control this problem the best available techniques are proper plant site selection and the use of tall stacks. Research on treatment of effluents for sulfur gas removal has been conducted and is continuing; however, at present, no economically reasonable treatment method is available. The other major industrial combustion problem is sulfur gas emissions from burning coal waste piles. Preventive control should be practiced by proper initial establishment of these waste piles and by prohibiting addition of wastes to piles already burning.

Industrial process emissions can be controlled by many methods, but, in practice, are most often reduced by effluent treatment. The following control methods are available for the emission problems of particular industries.

Primary Metals and Metal Products Industries—Blast, open hearth and electric furnaces can be equipped with wet washers, electrostatic precipitators or high temperature filters to reduce dust and fume problems. Wet or dry mechanical separators can be used at sinter plants to reduce dust emissions. Source control such as by coal washing, improved equipment design, and better firing procedures can improve the operation and reduce emissions from coke ovens. Dusts and fumes from foundry and milling operations can be controlled by bag filters (castings' shakeout and grinding), cyclones (grinding and sand blasting), and scrubbers (quenching tanks and dipping baths).

Petroleum and Related Products Industries—Hydrocarbon emissions from storage tanks can be reduced by a change in tank construction. Proper maintenance can reduce losses through equipment leakage. Waste water separators can be covered eliminating an evaporation loss. Gaseous discharges from boilers and process heaters can be reduced by limited use of waste products as fuel. Finally solid emissions from catalyst regenerator stacks can be reduced using mechanical collectors and/or electrostatic precipitators.

Chemicals and Allied Products Industries—Losses of toxic gases and vapors by leakage from reactors and other equipment can be reduced by proper maintenance. Scrubbers can be installed on vents from all reactors, holding tanks and cooling towers. Dusts from driers and milling operations can be controlled by a variety of methods including most types of particulate control devices.

Stone, Clay and Glass Products Industries—The major problem, dusts from rotary kilns, can be reduced using inertial pre-cleaning devices followed by high temperature cloth collectors or electrostatic precipitators. Milling operations can be controlled as described above in Primary Metals industries.

Other Industries—Odors from the food industry can be combatted by complete combustion to nonoffensive products and in some cases by the use of scrubbers. Mercaptan odors from paper manufacturing can be reduced by combustion and scrubbing with oxidized black liquor. Flyash from electric power generating plants can be controlled with mechanical collectors and/or electrostatic precipitators.

The exhausts from internal combustion engines may, under certain circumstances, require control. Several methods are possible for controlling exhaust pipe emissions, but none has been widely used. Combustion, either catalytically or by direct burning, of unburned hydrocarbons to carbon dioxide and water vapor is the most frequently suggested technique. Changes in fuel composition, especially the reduction in olefins content, is also suggested as a possible means. Emissions from crankcase breather pipes (caused by engine "blowby") may be reduced by venting the crankcase into the engine intake manifold. Several means have been suggested for controlling evaporation from carburetors and vehicle fuel tanks but none have yet gained general acceptance.

Cost of Private Control: The costs entailed in making process changes or substitutions vary. In some cases process changes will be less expensive than effluent control, in others, more expensive. Economic balances are necessary before making the decision as to which type of control to be used.

Effluent treatment methods and equipment vary in cost depending on the type used and other factors. When product reclamation is involved, the costs may be partially or completely recovered. For example, a large smelter, which originally treated sulfur gas emissions because of their toxic and nuisance aspects, is now reported to make a large percentage of its profit from these gases which are collected and eventually converted to saleable fertilizer. Generalizations about the cost of gas and vapor treatment systems are not possible. Installations are usually tailor-made for a particular problem. Particulate collection equipment, however, is in such wide use that certain generalizations as to initial and operating costs can be made. The cost estimates are made on the basis of the volume of effluent air to be cleaned, i.e., cost per cubic foot of air handled per minute or dollars per cfm. The unit cost usually decreases as the capacity increases. For a 50,000 cfm installation the most commonly used devices would have the following approximate initial costs (1953 dollars):[85] electrostatic precipitators, $0.75—$1.00 per cfm; fabric collectors, $0.30—$0.60 per cfm; wet collectors, $0.20—$0.40 per cfm; high efficiency mechanical collectors, $0.10—$0.30 per cfm; and low pressure cyclones, $0.10 per cfm. Today's costs are considerably higher. With some variation due to the characteristics of the particulates to be collected, the collector cost is proportional to the collection efficiency required.

Public Control Programs

Available Control Procedures: Public regulatory agencies can function in four main areas: education, voluntary action, legal enforcement, and community planning and zoning. In some cases local, state, and federal agencies can also contribute directly or indirectly in research programs aimed at finding out more about sources, effects, and control of air pollution.

The educational program of a control agency should be designed to adequately and effectively inform the general public, industry, and other groups about the causes and effects of air pollution. Proper education can and should lead to action. The public can take action by making complaints to the proper agency and by controlling its own emissions. Industry can act more effectively, when informed, to alleviate conditions for which it is responsible. It is in this regard that

A major function of governmental agencies is education. The Secretary of the Pennsylvania Department of Health addresses a seminar on air pollution.

education will sometimes lead to voluntary control action since good community relations are considered a necessary adjunct to any industrial activity. Voluntary action to promote good will often results from proper education of the affected public and those responsible for offending sources—industry or the public itself.

Legal enforcement of emission standards is undoubtedly necessary in some cases. Before rules and regulations for an area are written, however, the number and density of sources, atmospheric dilution capabilities, and economics should be considered. Regulatory control on a regional basis, is, therefore, often appropriate. The severity of control regulations should depend on present and future total pollution potential of the region. In the absence of specific emission standards, the most effective, economically practical control method should be the criterion.

Air pollution agencies can offer special help in the development of community planning and zoning programs. In new communities many potential air pollution problems can be avoided by proper control of the location of industrial activities, commercial establishments, and private dwellings. In older communities, non-conforming establishments can be gradually eliminated to eventually reach the desired zoning standards. Strict standards on all new construction, with air pollution potential considered together with all other requirements, is the most effective way to integrate the functions of zoning and air pollution control.

Levels of Action: Control action by public regulatory agencies can be at any level from single communities or regional groups of communities to the state and interstate levels. In some states, control is left primarily to local authorities. In others, state-wide enforcement of laws and regulations is provided, while not excluding local action. In large states, regional control may be set up in the framework of a state-wide program. The state may act directly in areas too small or unwilling to set up local control programs or act in an advisory capacity for local areas large enough to support an independent control program.

Local programs have historically carried the major burden of control action. The degree of local control can be small, such as use of punitive smoke control ordinances, or large-scale with establishment of regulatory ordinances and enforcement groups. The technology of air pollution control is growing at such a rate that today it is usually only the very large communities, over 100,000 population, that can afford self-sufficient and comprehensive control programs. State-level activity is, therefore, becoming increasingly more necessary to provide technical assistance to local governments.

Federal action in air pollution control is limited to education, research, and technical assistance to states and communities (Public Law 159 (1955)). Regulatory police powers are reserved to state and local agencies. However, if the states are unable or fail to control air pollution, federal enactments may become necessary to control the menace to public welfare.[86] The Public Health Service administers the federal activity, both medical and engineering, in this area. Training programs in air pollution are available at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. In addition, independent and sponsored research and university training is supported. Technical assistance is made available upon request.

Cost of Public Control: Adequate public control activity varies in total administrative and operating costs. Existing local governmental control activities today cost about $0.10 per capita per year with extreme cases of more than $0.60 per capita per year. State level control costs vary, depending on the amount of actual control work performed—an estimate of the average amount is $0.01—$0.05 per capita per year. Federal participation in air pollution research, training, and technical assistance now costs about $0.04 per capita per year. The severity of regional problems governs the cost of providing adequate control, so that the above averages are guides only.

Research: Air pollution science is in its infancy. The knowledge available today is far from adequate in most areas to allow complete understanding of causes, effects, and control. Research is necessary in the areas of sampling and analysis of contaminants, source control, and especially, in the effects of air pollution on health. The Federal government is now spending over five million dollars annually on government and contracted research and for research grants. State (notably California) and local agencies also engage in limited amounts of research. Research by the major polluting industries is also underway. All these areas of research activity are necessary and are to be encouraged. Continued and expanded research by public, private, and industrial groups is the main hope in eventually bringing under control present and future problems in this field.

Pennsylvania

Private Control Activities—Industry

Applications of Control Devices: The letter mailed to all manufacturing industries of 100 employees or more (Appendix A) produced replies which are summarized in Table 48. About 20 percent of the industries responding report one or more air pollution control installations. Mechanical collectors (wet or dry) are the most commonly used devices for particulate problems. Cloth collectors, scrubbers, and electrostatic precipitators are also used. Smoke alarms and other miscellaneous combustion control devices were reported in use by some industries. The chemical and petroleum industries have the highest percentage of control applications. In comparing these percentages it should be emphasized that for many industrial processes, control devices are not necessary. A low application percentage, therefore, is only a partial measure of the degree of control required in that industry. A total of 201 installations of effluent control equipment

Research is needed to determine the nature, effects and extent of various contaminants in our community atmospheres.

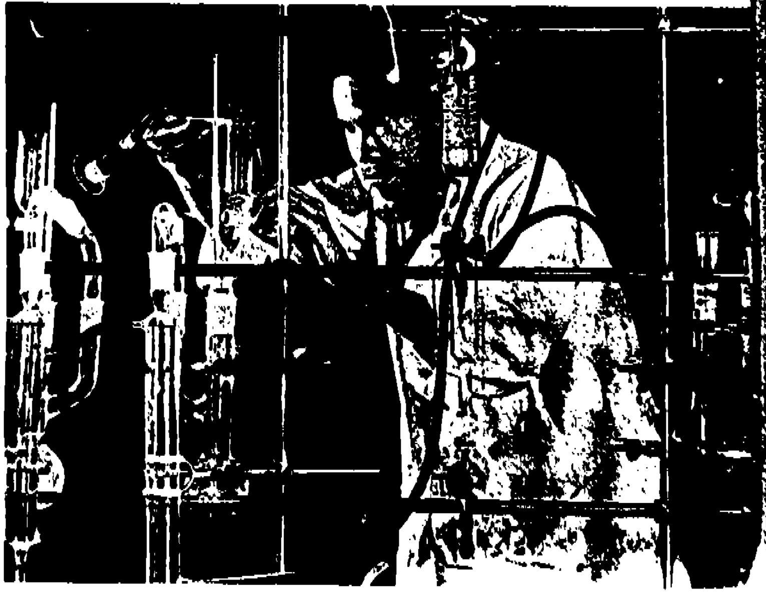


TABLE 48

Air Pollution Control Activities Of Manufacturing And Other Pennsylvania Industries*, 1959

Industry	Letters Sent	Replies Received	Using Controls		Type of Control Device Used**					Miscellaneous
			Number	Percent	Smoke Alarms	Mechanical Collectors	Cloth Collectors	Scrubbers	Electrostatic Precipitators	
A. Manufacturing										
Food and Kindred Products	196	87	9	10	2	8	-	3	1	1
Tobacco Manufacture	26	11	4	36	-	-	4	-	-	-
Textile Mill Products	176	74	6	8	4	2	-	-	-	-
Apparel and Related Products	9	7	0	0	-	-	-	-	-	-
Lumber and Wood Products	14	7	0	0	-	-	-	-	-	-
Furniture and Fixtures	46	19	3	16	1	-	1	-	1	-
Paper, Pulp and Products	97	55	10	18	4	6	-	4	3	-
Printing and Publishing	8	4	0	0	-	-	-	-	-	-
Chemicals and Products	71	47	18	38	-	13	3	7	1	4
Petroleum and Coal Products	17	11	5	45	-	2	-	1	5	1
Rubber Products	33	14	5	36	-	6	14	1	2	2
Leather and Leather Goods	86	37	10	27	-	8	-	-	-	2
Stone, Clay and Glass Products	124	61	18	30	-	10	4	5	1	3
Primary Metal Industries	138	67	15	22	-	10	4	5	2	3
Fabricated Metal Products	358	175	20	19	-	18	2	4	1	1
Machinery, Except Electrical	87	36	8	22	1	4	-	1	1	1
Electrical Machinery	85	66	10	15	2	7	7	3	1	-
Transportation Equipment	32	13	4	31	1	11	-	1	1	-
Miscellaneous Manufactures	22	10	3	30	1	1	1	1	-	-
B. Other										
Electric Utilities	52	26	4	15	2	3	-	-	1	-
Gas Utilities	30	12	2	17	-	1	-	-	1	1
Railroads	28	9	1	11	-	1	-	-	-	-
Personal Services	44	14	5	36	1	1	-	1	-	2
Total	1779	862	160	19	19	112	40	37	22	21

*Industries with over 100 employees only.
**Many industries have multiple control installations

and 38 installations of smoke alarms or other combustion controls were reported by 862 industries replying. In this survey no attempt was made to assess source control by process and materials changes.

Cost of Control Devices: It is impossible, on the basis of these incomplete results (Table 48), to accurately assess the costs to Pennsylvania industry of air pollution control measures. Individual examples will serve to indicate the costs involved.

Textile Industry—One company reports the recent installation of a collector to remove flyash from flue gases, cost—$24,300.

Furniture Industry—Dust and carbonized wood particles from the power plant stacks of a cabinet manufacturer are now being controlled with a collector reported to have an initial cost of $21,000.

Paper Industry—Dust collectors recently installed on two boilers of a container manufacturer reportedly cost $70,000; a paper manufacturer reports a current annual cost of $748,000 for air pollution control equipment, installation costs for which have amounted to $2,140,000—these costs include scrubbers, mechanical collectors, and an electrostatic precipitator.

Stone and Clay Industries—A brick manufacturer reports having spent about $2,500,000 during the last ten years on dust collection equipment; a $2,000,000 dust suppression program, including the purchase of an electrostatic precipitator, is reported by a cement company.

Other industry in the State has spent and is spending millions of dollars on control equipment and methods. Actual cost figures were not volunteered, however.

Public Control Programs

By Communities: Of the 801 communities surveyed, 16 reported the existence of air pollution control ordinances and 12 reported smoke nuisance regulations (Table 49). Smoke ordinances are limited to the control of smoke from combustion operations, only. The degree of effectiveness of control programs varied from complete non-enforcement to highly active programs such as in Philadelphia and Allegheny County. The amount of time spent in enforcing existing ordinances ranged from zero to 300 man-months per year (Philadelphia). Seven communities have ordinances but no one to enforce them. Nine communities have part-time enforcement, primarily complaint investigation. Only six communities have full-time programs. In communities where no ordinance is in effect complaints are handled by the police department, township supervisors, borough secretary, or health department. Complaints in these cases are treated as nuisances.

The two major local programs in the State are in Philadelphia and Allegheny County. A brief resume of their activities is in order. For Philadelphia, excerpts from the report of February, 1957, will serve to outline the budget and personnel of the control agency.[87]

"The tables (50 and 51) show the number of personnel authorized for employment in Philadelphia Air Pollution Control activities for the years 1954 through 1957 and the actual expenditures for the same period. The year 1954 was the last year in which the Air Pollution Control Division operated separately from the Division of Environmental Sanitation.

"The table on actual expenditures shows an increase in expenditures in each of the years shown. The personnel costs decreased between 1954 and 1955, but have increased since 1955, even though the number of personnel has remained approximately the same. The increase in expenditures then is not due to additional personnel but is due primarily to increased salaries, with a particularly

TABLE 49

Local Air Pollution Control Agencies in Pennsylvania, 1959

Community	Ordinance Type	Program Director	Total Personnel	Approximate Annual Budget
Philadelphia	APC*	R. Smith, Dept. of Public Health	25	$116,000 (1957)
Allegheny County	APC	L. Schreibeis, Dept. of Health**	23	$100,000 (Est.)
Erie	Smoke	E. May, Bureau of Smoke Abatement***	1½	$ 10,000 (Est.)
Low. Mt. Bethel Twp. Nazareth Boro. Northampton Boro. Stockertown Boro. Whitehall Twp.	APC	R. E. Doherty, Lehigh Valley APC	1	$ 10,000 (Est.)
Lebanon	APC	E. Sherman, Bureau AP Region	1	$ 2,500
Williamsport	Smoke	R. Winkleman, Smoke Control Office	1	$ 1,500
Allentown	Smoke	G. H. Slenker, Smoke Inspector	1 (PT)	$ 1,000 (Est.)
Conshohocken Boro.	APC	Health Officer	1 (PT)	< $ 1,000 (Est.)
Emporium Boro.	Smoke	J. D. Johnston, Health Officer	1 (PT)	< $ 1,000 (Est.)
Lower Merion Twp.	APC	Supt. Bldg. Inspections	1 (PT)	< $ 1,000 (Est.)
Lower Moreland Twp.	APC	Health Officer	1 (PT)	< $ 1,000 (Est.)
Norristown Boro.	Smoke	S. C. Detwiler, Health Officer	1 (PT)	< $ 1,000 (Est.)
Plymouth Twp.	APC	F. S. McFarlane, Health Officer	1 (PT)	< $ 1,000 (Est.)
Springfield Twp.	APC	Health Officer	1 (PT)	< $ 1,000 (Est.)
Washington	Smoke	D. S. Nettle, Health Officer	1 (PT)	< $ 1,000 (Est.)
Royersford Boro.	APC	Sanitation Commission	-	N.R.
Upper Saucon Twp.	APC	Consulting Engineers	0	N.R.
Easton	Smoke	Smoke Inspector, Bureau of Inspection	0	< $ 1,000 (Est.)
Lewisburg	Smoke	Smoke Inspector	0	< $ 1,000 (Est.)
Harrisburg	Smoke	Chief, Bureau Smoke Reg.	0	< $ 1,000 (Est.)
Stroudsburg Boro.	APC	Director, Department of APC	0	< $ 1,000 (Est.)
Sunbury	Smoke	Chief, Bureau of Smoke Region	0	< $ 1,000 (Est.)
Wilkes-Barre	Smoke	Director, Smoke Prev., Dept. of Health	0	< $ 1,000 (Est.)
Yeadon Boro.	Smoke	Smoke Inspector	0	< $ 1,000 (Est.)

*Air Pollution Control, Incl. Smoke
**Present Director—H. Dunsmore (February 1961)
***Present Director—R. T. Holland (February 1961)
N. R. = Not Reported
PT = Part Time

TABLE 50

Authorized Positions of Philadelphia Air Pollution Control Division[87]

Types of Positions	Number of Authorized Positions			
	1954	1955	1956	1957
Engineers	5*	7	7	7
Inspectors	10	8	8	9
Clerical	5	3	2	2
Lab. Tech.	1	1	1	1
Total	21	19	18	19

*Includes Executive Director

The above table does not include generalized administrative, clerical, training and other personnel of the Division who may render some service to the Air Pollution Control Section. The seven engineers include 1 section chief, 3 unit supervisors, 1 plans engineer, and 2 field engineers.

TABLE 52

Summary of Violations of Philadelphia Air Pollution Control Ordinance, 1956-1958[88]

	Total Violations			Percent of Total		
	1956	1957	1958	1956	1957	1958
Smoke	235	340	329	47.7	42.0	48.2
Open Burning	36	76	145	7.3	10.0	21.2
Odors	27	31	29	5.5	4.0	4.3
Soot	18	35	42	3.7	4.7	6.1
Fumes	8	5	32	1.6	0.7	4.7
Auto Burning	28	59	*	5.7	7.7	–
Dust	16	29	22	3.3	3.8	3.2
Railroads	4	2	–	0.8	0.3	0.0
Dumps	108	182	59	21.9	23.8	8.7
Gas Vapors	2	1	2	0.4	0.2	0.3
Motor Vehicles	2	1	–	0.4	0.1	0.0
Flyash	10	17	17	2.1	2.2	2.5
Permits	–	4	5	–	0.5	0.8
Total	494	762	682	100.0	100.0	100.0

*Included in Open Burning

TABLE 51

Air Pollution Expenditures in Philadelphia[87]

Purpose	Actual Expenditures			
	1954	1955	1956	1957*
Personnel	81,021.88	80,453.92	86,653.05	102,750.00
Equipment	2,682.64	9,187.80	10,002.04	8,000.00
Supplies	1,005.62	4,027.20	4,196.45	3,500.00
Travel and contracts	1,374.38	531.95	1,602.23	1,500.00
Total	86,084.52	94,200.87	102,453.77	115,750.00
Per Capita	$0.039	$0.043	$0.047	$0.053

*Estimated

large increase in salaries at the beginning of 1957. Even with the increase in salaries it is questionable if the city is still at a level which will recruit engineering personnel in competition with other employers."

The violations of Philadelphia's air pollution control ordinance for the period 1956-1958 have been summarized (Table 52).[88]

The following activities by the Philadelphia Department of Public Health will give some indication of the extent of the program maintained in 1958 despite the above budgetary problems:

Rigorous enforcement of the open burning ban coupled with its gradual acceptance by industrial and commercial organizations decreased the number of complaints of air pollution from refuse disposal to approximately one-quarter of the number received in 1957.

As surveys of the petroleum refining industry and bulk storage depots neared completion, a survey of the metal smelting and refining industry was begun. Emphasis in 1958 was placed upon the evaluation of potential and actual sources of air pollution from the sixteen gray iron foundries.

Plans for fifteen major control installations were approved...... The unit's engineering services, furthermore, were utilized in the correction of twenty-four major smoke problems of a long standing nature.

The activities in Allegheny County have been summarized recently:[89]

"The Bureau (of Air Pollution Control, Allegheny County Health Department) as of August 17, 1959, has 23 persons serving in the following categories: administration and engineering—6, laboratory—3, field inspection—9, and stenographic-clerical—5.

"This staff provides services to the County, which includes 129 municipalities, covers 750 square miles, and serves approximately 1,680,000 people, as required by regulations and by planned programs.

"Activities that are required by Ordinance include:

1. Examination and approval of plans for the installation of new fuel-burning equipment, including incinerators.
2. Annual inspections of fuel-burning equipment, except domestic.
3. Actions necessary to insure compliance with emission limitations in the ordinance:
    a. Measurement of smoke or flyash emission rates according to prescribed methods.
    b. Field and office conferences to discuss problems.
    c. Sealing of equipment.
4. Development of procedural rules and bulletins in the enforcement of the ordinance.
5. Recommend prosecutions for violations of the ordinance.
6. Issue licenses and permits and collect fees.

"Services connected with answering complaints of air pollution nuisances are an important part of the field inspection program. There were approximately 2,000 complaints from citizens or Bureau personnel during 1958. These included complaints against smoke, flyash or dust, odors, open fires, coal deliveries, and gases. The complaints in 1959 were running at about the same rate or almost 1,000 in the first six months.

"The Bureau now has an expanded evaluation program which requires the services of laboratory and field personnel. Since 1948 a regular dustfall measurement program has been conducted. A private agency (Mellon Institute) had run dustfall tests during 1939 and 1940. Tests for carbon monoxide and hydrogen sulfide by bulb aspirated detectors were also made from time to time.

"In 1958 the Bureau began measuring

TABLE 53

Population Governed By Zoning Ordinances in Pennsylvania Counties[91]

(Indicates rank according to percent of population governed by a zoning ordinance as of March, 1959)

Rank	County	Percent	County Population	Number of Zoning Ordinances
1	Philadelphia	100.0	2,071,605	1
2	Delaware	97.5	414,234	45
3	Montgomery	87.0	353,068	41
4	Allegheny	78.5	1,515,237	60
5	Bucks	77.2	144,620	32
6	Erie	77.2	219,388	8
7	Lycoming	72.2	101,249	9
8	Berks	68.1	255,740	20
9	Lawrence	68.0	105,120	7
10	Northampton	65.8	185,243	12
11	Lackawanna	64.7	257,396	6
12	Mercer	62.8	111,954	7
13	Lehigh	61.7	198,207	4
14	Blair	59.9	139,514	2
15	Dauphin	59.5	197,784	7
16	Beaver	52.2	175,192	14
17	Cameron	51.9	7,023	1
18	Cumberland	50.7	94,457	8
19	Chester	50.3	159,141	23
20	Montour	43.7	16,001	1
21	Lancaster	42.8	234,717	8
22	Crawford	41.4	78,948	3
23	Lebanon	40.8	81,683	3
24	Elk	40.8	34,503	2
25	York	39.3	202,737	5
26	Cambria	35.6	209,541	5
27	Centre	34.7	65,922	2
28	Warren	34.7	42,698	
29	Bradford	34.0	51,722	4
30	Union	32.5	23,150	2
31	Mifflin	31.8	43,691	1
32	Clinton	31.1	36,532	1
33	Venango	29.9	65,328	1
34	Luzerne	25.9	392,241	8
35	Northumberland	24.5	117,115	5
36	Columbia	24.1	53,460	2
37	Carbon	22.9	57,558	2
38	Franklin	22.6	75,927	1
39	Westmoreland	22.4	313,179	5
40	Snyder	20.9	22,912	2
41	Fayette	18.3	189,899	3
42	Washington	13.1	209,628	5
43	Pike	13.1	8,425	1
44	Butler	12.4	97,320	1
45	Huntingdon	11.4	40,872	1
46	Clearfield	10.8	85,957	1
47	Bedford	8.6	40,775	1
48	Somerset	7.2	81,813	1
49	Sullivan	2.3	6,745	1
50	Armstrong	0.6	80,842	1
51	Adams	0	44,197	
	Clarion	0	38,344	
	Forest	0	4,944	
	Fulton	0	10,387	
	Greene	0	45,394	
	Indiana	0	77,106	
	Jefferson	0	49,147	
	Juniata	0	15,243	
	McKean	0	56,607	
	Monroe	0	33,773	
	Perry	0	24,782	
	Potter	0	16,810	
	Schuylkill	0	200,577	
	Susquehanna	0	31,970	
	Tioga	0	35,474	
	Wayne	0	28,478	
	Wyoming	0	16,766	

fine particulates in several locations by the A.I.S.I. smoke sampler. Cooperation with the U. S. Public Health Service's National Air Sampling Network since 1956 is also part of the measurement program. A pollen survey is run from May to October each year.

"Sulfur dioxide was measured for about six months in 1958 with the Thomas Autometer (loaned from Pennsylvania State Health Department). The lead peroxide candle method, as published by the British, is used in four locations to measure atmospheric sulfur oxides over a one-month period. A program of measurement of volatile sulfur compounds by alkaline absorption was started in 1959.

"Hydrogen sulfide measurements by impregnated (lead acetate) filter paper on a continuous basis near a blast furnace are made. Other locations have also been chosen for special studies. For example, a new lagoon for sewage treatment was included in a special air pollution study. Also, a new multi-million dollar sewage treatment plant for Pittsburgh was studied in this manner. Several other industrial operations have been evaluated for hydrogen sulfide air pollution.

"The measurement of oxidant (ozone) by the 'Rubber Cracking' Method is in limited use and this program will be expanded. Other pollutants of significance in Allegheny County will be evaluated when necessary."

Besides direct control action through local control ordinances, communities can act in other ways to reduce their air pollution problems. The two most noteworthy steps which communities can take are by enforcement or enactment of zoning regulations which prohibit residential building in industrial areas, and vice versa, and by the prohibition of open burning of wastes by the public and by industry.

In Pennsylvania, over 95 percent of the communities still allow open trash burning.[90] There are only 39 municipalities where municipal incinerators are in operation. Of the 1700 refuse disposal sites in the State, wastes are burned in the open in about 1500 of them. Sanitary landfill procedures are employed in only about 150-200 refuse disposal areas. Obviously, there is much room for improvement in this area.

Zoning is practiced extensively in Pennsylvania (Table 53). However, there is room for improvement. The practice of good community planning can obviate new air pollution problems and reduce those already existing.

By the State: The program of air pollution control administered through the Health Department of the Commonwealth has recently been changed through the enactment of new legislation, the new program is described in the next chapter.

Chapter VII

What More Can Be Done in Pennsylvania?

Abstract

The responsibility for obtaining and maintaining clean air rests with state and local government, industry and the public. Cooperative efforts and exchanges of information between these groups is an effective tool for air pollution control.

Future efforts at the state level will be based upon the Pennsylvania Air Pollution Control Act. The adoption of local ordinances and the performance of a number of community air pollution studies demonstrate the interest of local government in this problem.

Industry and the public play an important role in guaranteeing that an effective and practical approach is taken towards the abatement and prevention of air pollution.

The Pennsylvania Air Pollution Commission meets in Harrisburg to consider air pollution control regulations. The Air Pollution Commission will provide the basis for future action at the state level.

Chapter VII

What More Can Be Done in Pennsylvania?

By Government

State Level

The authority of the Department of Health to control air pollution was augmented when, on January 8, 1960, the Pennsylvania Air Pollution Control Act (Act 787 of 1959) was signed into law.

Specific and directed air pollution control activities were instituted in the Department of Health in 1948, as a result of investigation of the Donora incident. Until January 8, 1960 the Department's control efforts were based solely on the General Health Law. This law provides, in part, that the Department of Health shall have the power and duty to order nuisances, detrimental to the public health, or the causes of disease and mortality, to be abated and removed. There are few standards available for evaluating the "health" effects associated with atmospheric contamination. The need for an effective control program, based upon realistic standards, became evident and Act 787 was promulgated. The Act defines air pollution as "The presence in the outdoor atmosphere of one or more air contaminants in sufficient quantity and of such characteristics and duration which is injurious to human, plant or animal life, or to property, or which unreasonably interfers with the comfortable enjoyment of life and property throughout the Commonwealth........" This definition recognizes the fact that air pollution manifests itself as an insult to public health—and public well being.

A copy of the Pennsylvania Air Pollution Control Act is contained in Appendix D of this report. Procedures are detailed in the Act and basically provide that it is "the policy of the Commonwealth of Pennsylvania to maintain such a reasonable degree of purity of the air resources of the Commonwealth as shall be technically feasible, economically reasonable, and necessary for the protection of the normal health, the general welfare and the property of the people of the Commonwealth."

The Act creates an eleven-member Air Pollution Commission in the Department of Health. The Commission establishes air pollution control "Regions" throughout the Commonwealth and adopts rules and regulations for the control of air pollution in these "Regions." The Commission makes determinations on complaints involving violations of its regulations and issues orders for the control of air pollution sources.

The Department's air pollution control

Public hearings are held before regulations are adopted for the control of air pollution.

program is administered by the Division of Air Pollution Control. The functions of the Division include: inspection and investigation of sources of atmospheric contamination; receipt and initiation of complaints; holding public hearings for the Commission; enforcing orders for compliance with the Commission's rules and regulations; plan examination; conducting studies, community and area air pollution surveys, stack emission tests, air monitoring programs, source evaluations, etc.; working with local authorities by providing technical information and operating a public information program.

In each region designated by the Commission, a Regional Air Pollution Control Association is established. The Association reviews and comments upon proposed regulations which will affect their Region. The Association attempts to abate air pollution problems within their Region through conference, conciliation, and persuasion.

Under the Air Pollution Control Act, complaints regarding air pollution, originating from the Department (after inspection) or private citizens, are referred to the proper Regional Association. If the Association fails in its efforts to achieve abatement, the complaint is referred to the Commission. The Commission may issue an order for control. These orders may be appealed to the Commission and the courts. If the orders are sustained or not appealed, they are enforced by the Department.

Local Level

Allegheny County and Philadelphia operate air pollution control programs through their respective County Health Departments and are excluded from the provision of the Pennsylvania Air Pollution Control Act. Liaison has been established between these units and the State unit. Cooperative survey and sampling programs have been conducted and the State unit has cooperated in controlling inter-county problems. Municipalities may enact local air pollution control ordinances providing they do not conflict with the provisions of the Air Pollution Control Act or rules and regulations of the Commission. The Division of Air Pollution Control assists municipalities in conducting community and area air pollution studies and in enforcing local ordinances.

The Allegheny County Department of Health has recently revised and consolidated its "Smoke and Air Pollution Control, Rules and Regulations." The new regulations specify emission (performance) standards for specific operations and processes and create an Air Pollution Control Advisory Committee. The Committee is to study the Allegheny County air pollution problem and recommended to the County Board of Health "appropriate means of air pollution abatement, including needed additions to or revisions of the rules and regulations." This modernization of the Allegheny County regulations should increase the effectiveness of a continuing program that has demonstrated significant successes in the past.

The operation of the Philadelphia air pollution control program, based upon the regulations of the Air Pollution Control Board, has resulted in the abatement of many significant sources of atmospheric contamination. The Air Pollution Control Section of the Philadelphia Department of Public Health is at present conducting studies of atmospheric emissions associated with various types of industry (petroleum manufacturing, metal smelting, etc.). As in other urban communities, the problem of atmospheric contamination from motor vehicles is receiving increased attention.

Air pollution studies conducted by the Pennsylvania Department of Health in cooperation with municipal officials have, to some extent, resulted in the revision and adoption of local ordinances, locally sponsored and conducted studies, and increased public interest.

By Industry

Industry has recognized that even though it is not the sole contributor to air pollution, it does have a responsibility in

The technical services of governmental agencies are available to aid in determining the extent and nature of air pollution problems or..........

this field. The formation of air pollution committees in industrial groups and the assignment of managerial personnel to the air pollution control phase of plant operation have indicated increased awareness of this problem by industry. There are as many industrial air pollution problems as there are industrial operations. There are, though, a number of common approaches which should be taken by any plant having an air pollution problem.

1. Recognize the fact that an air pollution problem exists and accept responsibility for its control. Responsibility may not end in complying with applicable codes, rules or regulations. Rules and regulations are based upon standards which should be considered as guides rather than absolutes.
2. Work closely with the State or local air pollution control agency. The technical services of the State and major local agencies are available, and can be valuable in providing information on air pollution control.
3. Contribute to air pollution research and exchange information on common problems.
4. Institute a public information and public relations program. This is an important part of being a good neighbor. It is also an important part of the actual control program since many air pollution control problems cannot be solved "overnight."
5. Provide for air pollution control in the design and preconstruction phases of new plants and processes. It is often much more expensive to

the effectiveness of air cleaning devices (engineers of the Pennsylvania Department of Health, Division of Air Pollution Control conduct field evaluations.)

attempt to add control devices after the plant or process is in operation.

6. Consider air pollution control devices as an integral part of the plant rather than as an unproductive appendage. This approach may lead to the discovery of possible uses of material removed from process emissions. It certainly will aid in developing a proper attitude towards the maintenance of air pollution control equipment and the necessity of providing for air pollution control prior to the plant construction.

By the Public

A primary purpose of an air pollution control program is the protection of the health, property and well-being of the public. The public, though, has responsibilities in insuring that the control program is operated in an effective and reasonable manner. It should be realized that many air pollution problems result from domestic sources such as home-heating units and refuse disposal. It is also necessary to understand the complexity and cost involved in controlling atmospheric contamination from industrial operations. Many air pollution problems require time and study before they are solved.

The Pennsylvania Air Pollution Control Act provides for public hearings "before any rules or regulations with regard to the control, abatement, prevention or reduction of air pollution are adopted." Public attitude and interest will have a significant effect upon the Commonwealth's air pollution program. State and local air pollution control units, and many industrial groups and industrial plants, operate public information programs. The services of these information programs should be utilized by those citizens and citizens' groups interested in community air pollution problems.

Appendix A

Survey Forms

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HEALTH
Air Pollution Control Section

AIR POLLUTION APPRAISAL PERSONAL INTERVIEW FORM

Region: __________ County: __________ Community: __________________ Class: __________

Population: ____________________ Chief industries: ______________________________

Person interviewed: ______________________________ Title: ____________________

1. Do any operations within your jurisdictional area emit to the atmosphere objectionable amounts of smoke, fume, dust or odor? Yes _____ No _____
2. Do sources outside your jurisdiction create problems in your area? Yes _____ No _____
3. In your opinion, is your area's air pollution of major ( ), minor ( ), or negligible ( ) significance?
4. Which of the following are principal sources of your area's air pollution?
   a. Municipal activities (e.g., city dumps and incinerators) __________
   b. Domestic activities (backyard incineration, home heating, autos, etc.) __________
   c. Commercial activities (hotels, laundries, stores, etc.) __________
   d. Industrial activities (including utilities) __________
   e. Agricultural practices __________
   f. Natural sources __________
   g. Other (describe) ______________________________
5. Do you consider air-pollutant concentrations sufficient to cause:
   a. Discomfort or inconvenience to residents? Yes _____ No _____
   b. Damage to property? Yes _____ No _____
   c. Damage to vegetation? Yes _____ No _____
   d. Injury to animals? Yes _____ No _____
6. a. Have you received air pollution complaints in the past five years? Yes _____ No _____
   b. Approximate number of complaints per year: _______
   c. At what time or under what conditions are complaints most numerous? ______________________________
   ____
   d. What department or agency investigates complaints? ______________________________
   e. Time spent on air pollution activities: __________ man-months per year.
7. What local ordinances, exclusive of general nusiance regulations, are there for controlling air pollution? _____
   ____
8. What steps have been taken to assess the local air pollution situation? (Surveys, inspections, sampling, etc.)
   ____
9. What plans do you know of that might have an effect, favorable or adverse, on your area's air pollution? _____
   ____
10. What other organizations or individuals might furnish additional information regarding your area's air pollution?
   ____

Date: ______________ Interviewer: ______________________ Title: ______________

NOTE: Use reverse side, if necessary, identifying answers by question number.

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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HEALTH
P. O. BOX 90
HARRISBURG

Dear Mr. ________________________:

An appraisal of the extent and nature of the air pollution problems of Pennsylvania is now being made as a joint project of the Pennsylvania Department of Health and the U. S. Public Health Service. Your function as state agricultural agent puts you in a unique position to assess the problems, if any, created by air pollution with regard to agricultural operations in your county.

The enclosed questionnaire has been designed to obtain general information concerning possible problems in your area of jurisdiction. All information provided by you will be kept in confidence as to names of sources or complainants.

Your cooperation in completing and returning this questionnaire will be of great value.

Sincerely yours,

David M. Anderson, Ph. D.
Resident Engineer
United States Public Health Service

DMA:jmh
Ag/100

PENNSYLVANIA DEPARTMENT OF HEALTH

Division of Occupational Health

County Agricultural Agent's Pollution Appraisal Questionnaire

	YES	NO
1. Are there any operations (municipal, domestic, industrial, agricultural) in your area of jurisdiction that emit objectionable amounts of smoke, fumes, gases, dust or odors to the atmosphere?	( )	( )
2. In your opinion are these pollutants present in sufficient concentration to cause damage or injury to:		
(a) Vegetation (including interference with natural growth)	( )	( )
(b) Animal life	( )	( )
3. Has your office received complaints concerning air pollution damage to plant or animal life during the past two years?	( )	( )

4. Please describe briefly any air pollution problems in your jurisdiction. Give sources, type of damage and severity of the problem.

____

____

____

____

____

____

	YES	NO
5. Have any steps been taken in your area of jurisdiction to control sources of air pollution? Describe.	( )	( )

____

____

____

Signed: ______________________________

DMA: jmh
Ag/100

County: ______________________________

COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF HEALTH
P. O. BOX 90
HARRISBURG

Dear Sir:

An appraisal of the extent and nature of the air pollution problems of Pennsylvania is now being made as a joint project of the Pennsylvania Department of Health and the U. S. Public Health Service. American industry spends millions of dollars annually on air pollution control measures and this fact should be considered in any attempt to appraise the problems of a highly industrialized state such as Pennsylvania.

In order that the role of industry may be presented in a proper perspective, we would like to obtain from you information such as the following for inclusion in a section, "Control Activities - industry:"

1. reports of air pollution control sections of your company, if any, or summary listings of control equipment used by you to reduce emissions;
2. published papers on your control activities;
3. general information on your products, raw materials, fuel consumption;
4. any other information or comments you wish to present.

We will provide you with copies of the final state-wide appraisal at your request. Information which you wish kept confidential will not be published.

Your cooperation in this study will be of great value.

Sincerely yours,

David M. Anderson, Ph. D.
Resident Engineer
United States Public Health Service

Appendix B

Sources Of Estimating Factors For Combustion Emissions

Sources Of Estimating Factors For Combustion Emissions

Coal Burning

Industrial

Gases

Sulfur dioxide and sulfur trioxide: Since the sulfur content of fuels is variable, the estimating factor is best expressed in terms of the sulfur content, S, pounds of sulfur per pound of fuel. An estimate such as made by Wohlers,[42] i.e., 0.020 pounds SO_2/pound coal, does not take this into account. In terms of the amount of sulfur burned to sulfur oxides, various estimates have been made ranging from 90%[94] to 100%.[92] An average value of 95% is probably reasonable. This checks experimental work by Crumley and Fletcher.[93] Johnstone[5] has shown that for all solid, liquid, and gaseous fuels burned industrially, the ratio of SO_2 to SO_3 remains close to 10:1 (by volume). Using this ratio and assuming 95% of the sulfur is burned to the oxides, the estimating factors were calculated:

SO_2 - 1.73S lbs. SO_2/lb. coal fired
SO_3 - 0.21S lbs. SO_3/lb. coal fired

Hydrogen Sulfide: This gas is probably produced by destructive distillation of coal (followed by incomplete combustion of the sulfides to sulfur oxides.) A general estimate of 0.001 lbs. H_2S/pound coal fired has been made.[42] Experimental results[93] however, related H_2S production to sulfur content:

H_2S - 0.004S lbs. H_2S/lb. coal fired

Oxides of nitrogen: The production of nitrogen oxides by high temperature oxidation of atmospheric nitrogen undoubtedly occurs in industrial coal burning. Unfortunately no experimental work has been yet reported on typical effluent concentrations. An estimate of these oxides has been made[42] but this is based on the combustion of other fuels. Orning[96] has presented some data based on the theoretical thermodynamic considerations of Myers, et al.[97] These data have direct application to the problem of nitrogen oxides production specifically from coal burning. If a temperature of 2000°F. is assumed to occur in the fire box an equilibrium concentration of 700 ppm NO will exist in the flue gas (at 50% excess air). Orning assumes that equilibrium may be maintained at this level by rapid gas cooling. Using Orning's data and a flue gas volume of 180 cubic feet (STP)/lb. coal (50% excess air, coal of 70% carbon), at this concentration it is equivalent to 0.016 lbs. NO_2/lb. coal fired. A similar calculation for 20% excess air (equilibrium NO concentration = 500 ppm at 2000°F.) shows an oxides of nitrogen production of 0.0086 lbs. NO_2/lb. coal fired. Since most industrial coal burning facilities operate in this excess air range an intermediate value is probably applicable. Considering that fire box temperatures may be lower than 2000°F. at excess air quantities greater than 20%, the average was weighted in favor of the lower concentration:

Oxides of nitrogen (as NO_2) - 0.010 lbs. NO_2/lb. coal fired

This value, incidentally, agrees fairly well with factors determined experimentally for the combustion of gaseous and liquid fuels.

Total hydrocarbons: Hydrocarbons may be emitted as the result of incomplete combustion and volatile matter of coal. Their type can vary from simple aliphatic compounds released during the initial distillation of the coal to more complex polymers and polycyclic products formed, in part, by gaseous phase reactions. Although, in general, industrial coal combustion is characterized by high efficiency burning, nevertheless, some gaseous hydrocarbons are often emitted. Flue gas analyses made on effluents from coal burning operations have not been as detailed as those on other combustion effluents. Consequently, a breakdown of hydrocarbon types is not possible. Total hydrocarbons are usually expressed as methane. Concentrations during continuous operation have been reported.[93,98] They range from 300 ppm (average, as CH_4) to 700 ppm (average, as CH_4). Based on the original data these concentrations when expressed in terms of fuel weight fired vary from 0.013 to 0.007 lbs. hydrocarbons (as CH_4) per pound coal fired, respectively. An average value was used:

Total hydrocarbons - 0.010 lbs./lb. coal fired

This value is of the same order of magnitude as that reported from the combustion of other fuels.

Inorganic chlorides: Chlorides are emitted in small quantities from coal combustion processes, probably in the form of hydrogen chloride gas. Measurements of flue gas concentrations from coal burning operations have not been made. An estimate of the magnitude of this emission has been made by Meetham,[92] however, based on the average chlorine content of coal: 0.002 lbs. HCl/lb. coal fired. Information from the Coal Manual for Industry[99] indicates a chloride emission (as NH_4Cl) of 3.55 lbs/ton 0.1% Cl coal fired. This is equivalent to 0.0023 lbs. HCl/lb. coal fired for a 0.2% Cl coal. The chlorine content is variable and frequently not reported in coal analyses. A U.S. variation of 0.1 to 1.0% with an average of about 0.2% is reported.[99] On the basis of the above data an approximate factor for chloride emission was used:

Inorganic chlorides (as (HCl) - 0.002 lbs./lb. coal fired

Fluorides: Fluorides also must be estimated on the basis of coal composition since effluent analyses are not available. An approximate average fluorine content is 0.02% by weight.[92] This content will produce an emission rate of (assuming 100% liberation):

Fluorides (as HF) - 0.0002 lbs./lb. coal fired

Other gaseous products: Other pollutant gaseous products of combustion are probably emitted in coal burning operations. In the combustion of fuel oil and gas effluent analyses show the presence of significant quantities of aldehydes, organic acids, ammonia, and even hydrogen cyanide. These compounds are formed through incomplete combustion of initial distillation products or by gaseous phase chemical reactions at high temperature. Reliable estimates of the magnitude of such emissions cannot be made for coal burning either on the basis of thermodynamic considerations (as, for example, NO_2) or by the use of fuel analyses (as in the case of the halogens). It would not be valid and could possibly be highly erroneous to use estimates based on the combustion of other fuels, as has been suggested.[42] Estimation of these other gases will require experimental work.

Solids

Total weight and composition: Coal is fired industrially by several methods. Nearly all such methods are characterized by high combustion efficiency. Consequently the production of carbonaceous and tarry particulate matter ("smoke") is, with one exception, insignificant except under conditions of initial firing. On the other hand, industrial coal firing operations are characterized by comparatively high gas velocities through the fuel bed and in the stack. This fact together with the use of fine or pulverized coal results in the entrainment of large quantities of the ash residue. This residue is composed of SiO_2, Al_2O_3, carbon, Fe_2O_3, and other oxides.[106] The amount of ash entrained and subsequently discharged as "flyash" can vary widely depending on the firing method. A review of the literature indicates that the ash emission can be conveniently expressed in terms of A, the ash content of the fuel (lbs. ash/lb. fuel):

Underfeed stokers—Estimates of ash emission from this firing method vary. In terms of pounds ash emitted per pound coal fired Swengel[100] suggests 0.10A; Kaiser[101] lists < 0.15A; Marks and Kaiser[102] present data showing 1.3 pounds dust per 1000 lbs. flue gas (at 50% excess air) which can be converted to approximately 0.19A; Miller's data[103] can be similarly converted to 0.45A. The last estimate is probably high. An approximate average value was used:

Solids (ash) - 0.15A lbs./lb. coal fired

Travelling grate—Ash emission estimates for this firing procedure are more uniform: 0.15A,[100] 0.15A[101] and (by calculation) 0.09A.[102] The most common estimate was used:

Solids (ash) - 0.15A lbs./lb. coal fired

Cyclone furnace—This firing method is used in a comparatively small number of installations. Only one estimate of ash emission from this firing method appears to have been made:[100]

Solids (ash) - 0.15A lbs./lb. coal fired

Pulverized coal burning—A large quantity of the ash content of the coal is discharged in this firing method because of the technique of burning the coal in a suspended state. Among estimates which have been made are 0.75A[100] and > 0.50A.[101] The former is probably reasonably accurate:

Solids (ash) - 0.75A lbs./lb. coal fired

Spreader stokers—This method is quite popular in this country and in England where it is called "sprinkler" firing. The use of estimating factors here is complicated by variations in firing method such as the use of overfire jets and dust reinjection. A further complication arises since, contrary to most mechanical firing methods used industrially, spreader stoker firing is often characterized by the emission of unburned carbon as well as ash. Consequently, reinjection of collected flue gas solids or injection of overfire air is sometimes used to improve combustion efficiency. General estimates of total solids emission have been made in terms of ash content, however. The following estimates do *not* take into account dust reinjection or overfire jet operations: TOTAL SOLIDS—0.50A (as ash 0.30A, as carbon 0.20A);[100] TOTAL SOLIDS—0.70A[104] (by calculation); TOTAL SOLIDS—0.4A to 0.8A (as ash 0.2A to 0.4A, as carbon 0.2A to 0.4A);[101] TOTAL SOLIDS—0.47A[102] (by calculation); TOTAL SOLIDS—0.62A[103] (by calculation). The consensus of opinion seems to indicate a general average of: TOTAL SOLIDS—0.6A, which is about half ash and half carbon. It should be noted that this carbon is *not* the carbonaceous material of which coal "smoke" is usually considered to be composed. Rather, it is unburned fuel particles, as opposed to condensed or cracked hydrocarbon gases.

One team of investigators[105] has studied the effects of dust reinjection and the use of overfire jets in relation to total solids emission from spreader stoker operations. The combinations of reinjection with and without overfire jets, and vice versa, were studied, the results being expressed in terms of dust loading in the furnace breaching. These data when converted to pounds of total solids per pound coal fired show:

Overfire Jets	Dust Reinjection	Pounds Total Solids per Pound Coal Fired
No	No	0.11 = 0.66A
No	Yes	0.17 = 1.00A
Yes	No	0.09 = 0.63A
Yes	Yes	0.11 = 0.66A

The weight of total solids emitted has been expressed in terms of ash content by the use of the ash content of the fuel fired and assuming 60% of the dust loading at the breaching eventually escapes into the atmosphere.[102] Examination of these data shows that the only important variable is dust reinjection, i.e. when expressed in terms of ash content total solids emitted are approximately 0.6A without dust reinjection and 1.0A with reinjection The former figure agrees well with the consensus of opinion of other investigators (see above). With dust reinjection, however, total solids discharge increases. This is due to the recycling of collected particles containing carbon which are then reburned yielding smaller sizes of ash which can be carried out with the flue gas.

On the basis of these data the following estimates were chosen for spreader stoker operation:

WITHOUT DUST REINJECTION, TOTAL SOLIDS (ash and unburned carbon) - 0.6A lbs./lb. coal fired

WITH DUST REINJECTION, TOTAL SOLIDS (ash and unburned carbon) - 1.0A lbs./lb. coal fired

Particle size: Kaiser[101] has presented in a general summary form typical size frequency analyses of the emitted solids from various industrial coal firing methods. His size frequency distributions, when plotted on log-probability paper, yield good straight line approximations. Consequently, these data may be expressed in terms of two variables, Mg', the mass median (geometric mean) and $\sigma g'$, the standard geometric deviation:

Firing Method	Mg' microns	$\sigma g'$	Percent by weight less than 1 micron
Underfeed stoker	20	3.9	3.0
Travelling grate	75	2.0	0.01
Cyclone furnace	5.0	3.7	12.0
Spreader stoker	57	4.1	0.2
Pulverized coal	20	2.5	0.1

Using one micron as an arbitrary dividing point between coarse and fine solids, it can be seen that fines production is distinctly related to firing method, cyclone firing producing the greatest proportion of fines and the use of travelling grates, the least. These data apply only to the size distribution *before* any dust collection. Estimates of size distribution of effluents from dust collectors must be based on data such as the above *and* collector performance.

Domestic

Gases

Sulfur dioxide, sulfur trioxide, and hydrogen sulfide: Sulfur oxides production in domestic coal burning operations is slightly different than in industrial combustion. This is due primarily to lower fuel bed temperatures and, often, incomplete combustion. A very thorough survey of sulfur gas production in domestic furnaces was made several years ago.[107] It showed that approximately 90% of the sulfur in the coal was liberated during combustion. Recent tests[93] show that this is predominantly as SO_2, with about 1.5% of the sulfur liberated in the form of SO_3 and 0.4% as H_2S. These data when converted to estimating factors in terms of S, the sulfur content, yield:

SO_2 - 1.8S lbs./lb. coal fired
SO_3 - 0.04S lbs./lb. coal fired
H_2S - 0.004S lbs./lb. coal fired

Oxides of nitrogen: Nitrogen oxides production is also affected by the lower temperatures in domestic coal burning. The difference between industrial and domestic production of these oxides is very significant. In recent tests[93] equilibrium nitrogen oxides concentrations of 0.9 ppm in the flue gas were measured. Using the gas volume and fuel consumption data of these tests, total oxides of nitrogen production when expressed in terms of fuel weight yield the following factor:

Oxides of nitrogen (as NO_2) - 0.0002 lbs./lb. coal fired

Total hydrocarbons: Because of lower combustion efficiency usually encountered in domestic coal burning, the total gaseous hydrocarbon production is probably greater than with industrial combustion of coal (see references 93, 98). Undoubtedly, more total hydrocarbons are produced in inefficient combustion. These, however, partially condense, are cracked, or polymerize to form solids such as carbon chains and tarry hydrocarbons. Estimates of these solids are presented elsewhere in the appendix. In the absence of data to the contrary the estimate used for gaseous hydrocarbons was taken as the same as that for industrial coal burning:

Total hydrocarbons - 0.010 lbs./lb. coal fired

Halides: These were estimated on the basis of coal composition as in the case of industrial coal burning. The same estimating factors were chosen.

Other Gaseous Products: As in the case of industrial coal combustion, other gaseous pollutants, besides those listed above, are probably emitted during domestic firing. Reliable estimates are not possible because of the lack of quantitative effluent analyses.

Solids

Total weight and composition: Coal is fired in domestic furnaces and stoves both by mechanical stokers and by hand. Since domestic coal smoke has been a problem for so many years, studies of solids emission from domestic fires were started many years ago. It was unfortunate in one respect, however, when the use of the Ringelmann chart became widespread (around the turn of the century) since smoke measurements were then, and still are, made on the basis of an optical property of smoke rather than its weight. Consequently, a very thorough literature search was required to find even approximate estimating factors for total solids emissions.

Hand-Fired Furnaces—Comprehensive tests of hand-fired low-pressure steam plants were made in Chicago several year's ago.[108] The results of these tests (from stack samples) indicate that 1.2 percent of the fuel weight is emitted in the form of solids. In spite of the comparatively long time period since these tests were made they are probably still representative of hand-fired operations. More recent surveys of the Coal Producers' Committee for Smoke Abatement and "Coal-Heat" magazine have shown that most hand-fired low pressure plants are still operated inefficiently and are of extremely old design.[109,110,111] The only other reported test of emissions from hand fired furnaces made in this country (on a weight basis) indicate that over the life of the fire 5.7% of the fuel weight becomes air-borne at the surface of the fuel bed (by graphical integration of the original data).[112] Most of these particulates are burned while suspended above the bed.

Studies have been made to determine the proportion of ash escaping from hand-fired coal burning furnaces by means of material balances.[113,114] Average values of ash emitted vary from 2.4 to 5.5%. Expressing these percentages in terms of fuel weight, ash emission averages about 0.2% of the fuel fired. Using the 1.2% figure above for total solids emission the remaining 1.0% must therefore be tars and carbon.

As a check on this, the analyses of stack samples and chimney deposits from hand-fired installations show 75 to 84% of the solids (averages) are carbon and tars.[108,115] Again using 1.2% of the fuel weight emitted as solids these analyses indicate 0.9 to 1.0 of the fuel fired will be emitted as tars and carbon. This is in good agreement with the figure obtained on the basis of ash balance.

The factors of estimation used for hand-fired furnaces were therefore:

Particulate (ash) - 0.002 lbs./lb. coal fired

Particulate (carbon and tars) - 0.010 lbs./lb. coal fired

Particulate (total) - 0.012 lbs./lb. coal fired

Stoker-Fired Furnaces—Stokers used in coal-fired home furnaces are either the underfeed or overfeed type. Stack samples of solids emissions from the former type[116] indicate that approximately 0.6% of the fuel weight is emitted. This is composed of about 70% carbon and tars and 30% ash. Ash balances on overfeed stokers[114] indicate that ash emission is about 0.1% of the fuel fired. Carbon and tars production from this type stoker is similar to that from underfeed stokers. Using the above data, estimating factors were determined for stoker-fired furnaces (average of under-fired and overfired types):

Particulate (ash) - 0.0015 lbs./lb. coal fired
Particulate (carbon and tars) - 0.004 lbs./lb. coal fired
Particulate (total) - 0.006 lbs./lb. coal fired

Coal-burning Stoves—A considerable portion of the coal burned domestically in this country is still burned in hand-fired or stoker-fired stoves (for space and water heating and for cooking). Particulates emission from the latter type is similar to that from stoker-fired furnaces. Particulates emission from hand-fired stoves, however, is considerably higher than from hand-fired furnaces. This is due to less efficient combustion and more frequent firing. No tests for the determination of particulates emission from this type of firing appear to have been made in this country. Combustion in hand-fired stoves may, however, be considered roughly comparable to the closeable-grate coal burning practices used in England. Many estimates have been made of particulates emissions from this combustion method. The latest estimates are 2.7% of fuel fired emitted as total particulates (0.3% and 2.4% of fuel fired as ash and carbon plus tars, respectively).

These figures were used directly for hand-fired coal stoves (U.S.):

Particulates (ash) - 0.003 lbs./lb. coal fired
Particulates (carbon and tars) - 0.024 lbs./lb. coal fired
Particulates (total) - 0.027 lbs./lb. coal fired

Particle Size: No determinations of particle size of particulates emissions from domestic coal firing processes have been reported. It is possible to determine, very approximately, the most probable size characteristics of these particulates from measurements of suspended smoke. According to Meetham[117] suspended smoke (from coal burning) has a median size by count of 0.075μ with 0.02% by number greater than 1μ and 0.001% by number greater than 2μ. These data when plotted on log-probability paper and converted to a weight basis show a mass median diameter of 0.32μ and $\sigma g' = 2.0$. Expressed another way, 95% of the weight of the suspended particles is due to sizes less than 1.0μ. Meetham also shows that of all combustibles (tars and carbon) emitted in coal burning operations, 63% remains suspended and can be considered "smoke." The remainder falls out of the atmosphere in a very short time. Using these data, 0.95 × 63 = 60% (by weight) of the carbon and tars emitted are as particles less than 1μ in diameter. If the ash particles emitted are considered >1μ, a safe assumption, then an approximate size analysis of particulate emissions from domestic coal firing is on the basis of 1 pound of coal fired:

Firing Method	Carbon and Tars (< 1μ)	Carbon and Tars (> 1μ)	Ash (> 1μ)
Hand-Fired Furnaces	0.006	0.004	0.002
Stoker-fired furnaces or stoves	0.0025	0.0015	0.0015
Hand-fired stoves	0.014	0.010	0.003

Fuel Oil Burning

Industrial

Gases

Sulfur dioxide and sulfur trioxide: Comprehensive effluent samplings from fuel oil burning operations have been made.[118,119] These tests indicate that all the sulfur in the fuel oil is burned to the oxides. Using the factors of Johnstone[95] the estimating factors were calculated as follows:

SO_2 = 1.8 S lbs./lb. fuel oil fired
SO_3 = 0.2 S lbs./lb. fuel oil fired

Oxides of nitrogen and other gases: The same tests have been established the following estimating factors for non-sulfur gases:

Oxides of nitrogen (as NO_2) = 0.013 lbs./lb. fuel oil fired
Total hydrocarbons = 0.005 lbs./lb. fuel oil fired
Organic acids (as acetic) = 0.015 lbs./lb. fuel oil fired

Aldehydes (as CH_3CHO) = 0.0018 lbs./lb. fuel oil fired

Ammonia = 0.000006 lbs./lb. fuel oil fired

It is possible that other gases such as halides, HCN, H_2S etc. may be emitted. Reliable sampling data are not however, available upon which to base estimating factors.

Particulates

Comprehensive testing in Los Angeles[118,119] has established the following factor:

Solids (total) = 0.00025 lbs./lb. fuel oil fired

The analysis of these particulates is probably similar to that of the particulates emitted in refinery fuel oil firing, i.e. fine carbon, tars, metallic oxides. Particle size information is not available. On the basis of Meetham's data,[117] and since no entrainment of fuel particles is possible as in the case of solid fuels, it is probably safe to assume that these solids are all less than 1µ in diameter.

Domestic

The Los Angeles tests[118,119] indicate that there is no significant difference between emissions from industrial and domestic fuel oil burning processes. The combustion of atomized fuel oil was reported to be similar in both cases.

Natural Gas

Industrial

Gases

Sulfur dioxide and sulfur trioxide: Data from the Los Angeles tests[118,119] indicate 0.000027 lbs. of sulfur oxides (as SO_2) emitted per lb. of fuel fired. Using the sulfur content of the fuel reported,[120] 0.4 grs./100 cu. ft., this shows 100% conversion of the sulfur in the fuel to sulfur oxides. As in the case of fuel oil burning, sulfur gas production, calculated on the basis of 100% conversion yields the following:

SO_2 = 1.8 S lbs./lb. gas fired
SO_3 = 0.2 S lbs./lb. gas fired

Oxides of Nitrogen: Estimates of nitrogen oxides production, based on effluent analyses, range from 0.007 lbs. (as NO_2) per lb. fuel fired[118,119] to 0.0035 lbs. (as NO_2) per lb. fuel fired.[120,121] The average value was used.

Oxides of nitrogen (as NO) = 0.005 lbs./lb. gas fired

Aldehydes: The estimate of 0.0015 lbs. (as CH_3CHO)/lb. gas fired from Los Angeles tests[118,119] appears to be too high on the basis of two independent estimates of 0.00037 lbs. (as CH_3CHO)/lb. gas fired.[120,121] The latter value was used, therefore:

Aldehydes = 0.0004 lbs. (as CH_3CHO)/lb. gas fired

Hydrocarbons and other gases: The Los Angeles tests[118,119] have established the following factors for other gaseous emissions from industrial natural gas firing:

Total hydrocarbons = 0.0015 lbs/lb. gas fired

Organic acids (as acetic) = 0.0012 lbs./lb. gas fired

Ammonia = 0.000006 lbs./lb. gas fired

Again, other gaseous emissions are possible, but reliable estimates are impossible due to incomplete information.

Particulates

It has been shown possible for particulates to be produced in natural gas combustion due to polymerization of gaseous combustion products at high temperatures.[122] It is as yet impossible, however, to estimate their emissions from typical gas burning processes.

Domestic

Gases

Oxides of nitrogen: Nitrogen oxides production from domestic natural gas burning operations is, in general, less than from industrial natural gas burning operations. This is due to lower combustion temperatures. A recent estimate, based on effluent sampling[123] indicates the following factor:

Oxides of nitrogen (as NO_2) = 0.004 lbs./lb. gas fired

Aldehydes: Aldehydes production is also significantly different in domestic gas burning processes. In this case aldehydes production is greater from domestic firing than from industrial firing. The explanation is that the lower combustion efficiency does not produce as complete a conversion of the adlehydes to CO_2 and water. Based on the data of Faith[120] and Hall[121] an average estimating factor for domestic natural gas burning is:

Aldehydes (as CH_3CHO) = 0.0006 lbs./lb. gas fired

Other gases: The production of other pollutant gases is not significantly different from industrial firing.[118,119] The estimating factors for industrial gas burning were used.

Particulates

See industrial natural gas burning. Appendix B.

Waste Wood Burning

Industrial, Commercial and Other

Gases

Sulfur Oxides, Nitrogen Oxides, Hydrocarbons, Organic Acids, Aldehydes: These gases have been sampled in the effluent from wood waste burning in a silo-type incinerator[118]. Estimating factors as determined from these data are:

Sulfur oxides (as SO_2) = 0.00008 lbs./lb. wood fired
Oxides of nitrogen (as NO_2) = 0.0006 lbs./lb. wood fired
Total hydrocarbons = 0.010 lbs./lb. wood fired
Organic acids (as acetic) = 0.0002 lbs./lb. wood fired
Aldehydes (as CH_3CHO) = 0.0009 lbs./lb. wood fired

Fluorides and Other Gases: Estimation of the emission of fluorides has been based on the fluoride content of the wood burned[124]. Using a fluorine content of 3 ppm (by weight)[125] the estimating factor for fluorides is:

Flourides (as HF) = 0.000003 lbs./lb. wood fired

Other gases, such as SO_3 H_2S, HCl, NH_3, etc., may be emitted in wood waste burning. Effluent analyses upon which to base estimating factors for these gases are not available.

Particulates

In waste wood burning operations[118] particulates emission from silo-type incinerators averages 2.06 lbs./ton wood fired, or:

Particulates = 0.0013 lbs./lb. wood fired

These particulates are composed of carbon, tars and fine particles with some coarse unburned fuel and inorganic ash particles[118]. Using data from the Los Angeles County Air Pollution Control District[126] a typical size frequency analysis shows a mass median diameter of 16 microns (σ g' = 3.0). From these figures it can be shown that approximately 0.7% by weight of these particles are less than 1.0 μ in diameter.

Internal Combustion Engines

Emission Rates From Automobiles, City Driving

Gases

Sulfur Oxides: According to Magill et. al.[127], a typical sulfur content of automotive gasoline is 0.25% by weight. On the basis of 100% conversion of this to sulfur oxides during combustion and an average gasoline density of 6.0 lbs./gal. (RVP = 9.4 lbs.), total sulfur oxides production is:

Oxides of Sulfur (as SO_2) - 0.030 lbs./gal. gasoline burned, or - 12S lbs./gal.

Oxides of Nitrogen: Nitrogen oxides production during gasoline combustion varies with the age of the automobile and type of driving conditions. For 1950 and 1951 cars nitrogen oxides production (as NO) varies from nil during idling to 0.065 lbs./gal. burned during steady driving[127] To obtain an estimate for normal city driving patterns the data of Magill, Hutchison and Stormes[127] were used: acceleration, 23% of gasoline consumed; steady driving, 53% of gasoline consumed; deceleration, 18% of gasoline consumed; and idling, 4% of gasoline consumed. On this basis a weighted average of nitrogen oxides production was determined as follows:

Oxides of Nitrogen (as NO_2) = 0.056 lbs./gal. gasoline burned

At the time of these tests the cars tested were only one or two years old. Newer models of automobiles may have different rates of emission.

Aldehydes: Aldehydes production is also related to driving conditions. The data of the Los Angeles County Air Pollution Control District[128] when weighted according to city driving conditions (as above) yield:

Aldehydes (as CH_3CHO) = 0.0073 lbs./gal. gasoline burned

Organic Acids: Similarly, the Los Angeles data[128] when weighted for city driving conditions yield:

Organic Acids (as CH_3COOH) = 0.0040 lbs./gal. gasoline burned

Ammonia: Magill and Benoliel[119] suggest an average emission factor, for city driving, of 0.7 lbs./ton gasoline. This is equivalent to:

Ammonia = 0.0021 lbs./gal. gasoline burned

Hydrocarbons: The analyses of hydrocarbon constituents of automobile exhaust gases have been very thorough[127] According to these data, and based on a city driving pattern, the emission factors are calculated to be:

methane	= 0.050 lbs./gal. gasoline burned
ethane	= 0.099 lbs./gal. gasoline burned
C_3-C_5 paraffins (M = 58)	= 0.104 lbs./gal. gasoline burned
C_6 + paraffins (M = 93)	= 0.112 lbs./gal. gasoline burned
ethene	= 0.111 lbs./gal. gasoline burned
C_5 olefins (M = 70)	= 0.076 lbs./gal. gasoline burned
C_6 olefins (M = 84)	= 0.093 lbs./gal. gasoline burned
C_7 olefins (M = 100)	= 0.100 lbs./gal. gasoline burned
acetylene	= 0.038 lbs./gal. gasoline burned
benzene	= 0.013 lbs./gal. gasoline burned
other aromatics (M = 92)	= 0.019 lbs./gal. gasoline burned

Particulates

Carbon and Tars: Los Angeles data[128] when weighted to city driving patterns [127] yield the following factors for carbon and tars:

Ether soluble aerosols (tars) = 0.0076 lbs./gal. gasoline burned

Non-ether soluble aerosols (carbon) = 0.0064 lbs./gal. gasoline burned

Oil Mist: These same data[128] indicate the following:

Oil Mist (motor oil) = 0.012 lbs./gal. gasoline burned

Lead Compounds: Hirschler et. al [129] indicate that about 40% of the lead in leaded gasolines is emitted as particulate matter in automobile exhaust gases under city-type driving conditions. The remainder is deposited in the engine and exhaust system. The most common composition of these particulates is as PbCl Br, the halides also being present in additives. Using an average gasoline lead content of 1.38 ml. tetraethyl lead (TEL) per gal[127]. These data were calculated to be:

Lead compounds (as PbCl Br) = 0.0020 lbs./gal. gasoline burned or = (0.0014 × TEL) lbs./gal. gasoline burned

The particulates emitted from automobile exhaust pipes (carbon, tars, lead compounds) have been studied[130] and the experimental data indicate that most aerosol particles are less than 1 μ in diameter, the mist emitted from engine blowby pipes may also be assumed to be less than 1 μ in diameter. It probably possesses size characteristics similar to the submicron oil smokes generated by the vaporization-condensation technique used for experimental purposes.[131]

Emission Rates From Diesel Engines

Gases

Sulfur Oxides: Typical average sulfur content of diesel fuel ranges from 0.11% (premium grade fuel) to 0.52% (regular grade fuel)[132]. On the basis of 100% conversion of the sulfur to the oxides during combustion and an average diesel fuel density of 6.8 lbs./gal., total sulfur oxides production is as follows:

Regular fuel, oxides of sulfur (as SO_2) = 0.071 lbs./gal. fuel burned,

Premium fuel, oxides of sulfur (as SO_2) = 0.015 lbs./gal. fuel burned, or

All fuels, oxides of sulfur (as SO_2) = (14 × S) lbs./gal. fuel burned

Oxides of Nitrogen - Aldehydes - Organic Acids: The production of these pollutant gases has been measured in the exhausts of cruising diesel buses[128].

Oxides of nitrogen (as NO_2) = 0.222 lbs./gal. fuel burned

Aldehydes (as CH_3CHO) = 0.016 lbs./gal. fuel furned

Organic acids (as CH_3COOH) = 0.031 lbs./gal. fuel burned

Hydrocarbons: Total hydrocarbon emission from diesel coaches has been measured as a function of driving conditions[133]. These data can be used to calculate average emission under city driving conditions using the data of Elliot[134]. The latter data show, for an average of experience, percentage of fuel consumed in idling, 30%; in acceleration, 17%; in cruising, 33%; and in deceleration, 20%. A weighted average emission rate for city driving is:

Total hydrocarbons = 0.715 lbs./gal. fuel burned

Particulates

Particulate emissions have been measured only in terms of the non-ether soluble component (carbon)[128]. These data indicate the following emission factor:

Non-ether soluble aerosols (carbon) - 0.086 lbs./gal. fuel burned

The particle size characteristics of these particulates may be assumed similar to those of aerosols found in gasoline engine exhausts[130], i.e. all particles less than 1.0μ in diameter.

Appendix C

Derivation of Equations For Calculating Atmospheric Pollution Levels

Derivation of Multiple Line Source - Average Concentration Equation:

Starting with Roberts' simplified line source equation (33):

$$\chi_{x,z} = \frac{Q_w}{2(\pi \bar{u} K \sqrt{x^2 + z^2})^{1/2}} \exp. -\left(\frac{\bar{u} z^2}{4 K \sqrt{x^2 + z^2}}\right)$$

for the case where $z = 0$, i.e. at ground level:

$$\chi_x = \frac{Q_w}{2(\pi \bar{u} K x)^{1/2}}$$

But $K = \frac{\bar{u} c^2}{4}$ (ref. 33 p. 114). Therefore

$$\chi_x = \frac{Q_w}{\bar{u} C \pi^{1/2} x^{1/2}}$$

The average concentration $\bar{\chi}_x$ from $x = 0$ to $x = x$ is:

$$\bar{\chi}_x = \frac{Q_w}{\bar{u} C \pi^{1/2} x} \int_0^x \frac{dx}{x^{1/2}} = \frac{2 Q_w}{\bar{u} C \pi^{1/2} x^{1/2}}$$

For 1 line source placed at $x = L/2$ where L is the city length in direction of wind, using $Q_w = Q/W$ and letting $A = 2Q/\bar{u} C \pi^{1/2}$

$$\bar{\chi}_{\mathrm{downwind}} = \frac{A}{W (L/2)^{1/2}}$$

For the whole city;

$$\bar{\chi} = \frac{\sqrt{2} A}{W L^{1/2}} \left(\frac{1}{2}\right) = \left(\frac{1}{\sqrt{2}}\right) \frac{A}{W L^{1/2}}$$

Similarly for 2 line sources placed at $x_1 = L/3$ and $x_2 = 2L/3$, for the whole city;

$$\bar{\chi} = \frac{A}{2 W (2L/3)^{1/2}} \left(\frac{2}{3}\right) + \frac{A}{2 W (L/3)^{1/2}} \left(\frac{1}{3}\right)$$

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For N line sources placed equidistantly over the city, perpendicular to the wind:

$$\bar{\chi} = \frac{A}{W L^{1/2}} \left[\frac{N^{1/2} + (N-1)^{1/2} + (N-2)^{1/2} + \ldots + (1)^{1/2}}{N(N+1)^{1/2}} \right]$$

The sum of the finite series in brackets is:

$$S = \frac{\dfrac{N}{\sqrt{N-1}} - 1}{\sqrt{\dfrac{N}{N-1}} - 1} = \frac{N - \sqrt{N-1}}{\sqrt{N} - \sqrt{N-1}}$$

Therefore for N (finite number only) line sources the weighted average concentration over the whole city is:

$$\bar{\chi}_{avg.} = \frac{2Q}{\bar{u} C \pi^{1/2} W L^{1/2}} \left[\frac{N - \sqrt{N-1}}{\sqrt{N} - \sqrt{N-1}} \right]$$

Symbols:

χ = pollutant concentration in air, gm./cu.M.

$\chi_{x,z}$ = pollutant concentration in air at position x, z, gm./cu.M.

Q_w = continuous line source strength, gm./sec.

$\bar{u}$ = average wind speed in x direction, M./sec.

z = height above ground, M.

x = distance from line source in direction of wind, M.

K = eddy diffusivity, M^2/sec.

C = virtual diffusion coefficient, $M^{1/2}$.

N = number of infinite line sources spaced equidistant along L and perpendicular to L.

L = length of city, in direction of wind, M.

W = width of city, across wind, M.

Q = total pollutant emissions, gm./sec.

Derivation of General Ventilation - Average Concentration Equation

The differential equation describing the addition of contaminants at a rate Q into a moving volume of air (WLH) moving at a rate of (WHū) is:

$$(WLH)\frac{d\chi}{dt} = Q - (WH\bar{u})\chi$$

The solution to this equation is:

$$\bar{\chi} = \frac{Q}{WH\bar{u}}\left(1 - e^{-\frac{\bar{u}t}{L}}\right)$$

The factor 1.3 is added to account for the efficiency of mixing, following accepted ventilation methods. Therefore:

$$\bar{\chi} = 1.3\,\frac{Q}{WH\bar{u}}\left(1 - e^{-\frac{\bar{u}t}{L}}\right)$$

Symbols:

W = width of volume of air, M.
H = height of volume of air from ground to top of inversion, M.
$\bar{u}$ = average wind speed, M./sec.
Q = rate of pollutant emission, gm./sec.
t = time, sec.
L = length of volume of air, M.
e = base of Naperian logarithms (2.718).
χ = concentration of pollutant in air, gm./cu.M.
All in consistent units.

Appendix D

Pennsylvania Air Pollution Control Act

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No. 787

AN ACT

To provide for the better protection of the health, general welfare and property of the people of the Commonwealth by the control, abatement, reduction and prevention of the pollution of the air by smokes, dusts, fumes, gases, odors, mists, vapors, pollens and similar matter, or any combination thereof; creating within the Department of Health an Air Pollution Commission and defining its powers; authorizing the Department of Health to enforce rules and regulations of the Commission as provided in this act; establishing Regional Air Pollution Control Associations and defining their powers; reserving powers to local political subdivisions, and defining the relationship between this act and the ordinances, resolutions and regulations of counties, cities, boroughs, towns and townships; imposing penalties for violation of this act; and providing for the power to enjoin violations of this act; and conferring upon persons aggrieved certain rights and remedies; and providing an appropriation therefor.

The General Assembly of the Commonwealth of Pennsylvania hereby enacts as follows:

Air Pollution Control Act

Section 1. Short Title.—This act shall be known and may be cited as the "Air Pollution Control Act."

Section 2. Declaration of Policy.—It is hereby determined and declared to be the policy of the Commonwealth of Pennsylvania to maintain such a reasonable degree of purity of the air resources of the Commonwealth as shall be technically feasible, economically reasonable, and necessary for the protection of the normal health, the general welfare and the property of the people of the Commonwealth. The measures for the accomplishment of this purpose shall not unreasonably obstruct the attraction, development and expansion of business, industry and commerce within the Commonwealth, but shall be technically feasible and economically reasonable. The program for the control of air pollution under this act shall be undertaken in a progressive manner, and each of its successive objectives shall be sought to be accomplished by a maximum of cooperation and conciliation among all the parties concerned. All powers herein conferred upon the Department of Health, the Air Pollution Commission, or any Regional Air Pollution Control Association, and all powers herein reserved to any political subdivision shall be exercised solely to effectuate the policy declared in this section.

Section 3. Definitions.—The following words and phrases, when used in this act, unless the context clearly indicates otherwise, shall have the meaning ascribed to them in this section:

(1) "Department." Department of Health of the Commonwealth of Pennsylvania.

(2) "Commission." The Air Pollution Commission.

(3) "Person." Any individual, public or private corporation for profit or not for profit, association, partnership, firm, trust, estate, department, board, bureau or agency of the Commonwealth, political *subdivision, municipality, district, authority or any other legal entity whatsoever which is recognized by law as the subject of rights and duties.

(4) "Air contaminant." Smoke, dust, fume, gas, odor, mist, vapor, pollen, or any combination thereof.

(5) "Air pollution." The presence in the outdoor atmosphere of one or more air contaminants in sufficient quantity and of such characteristics and duration which is injurious to human, plant or animal life, or to property, or which unreasonably interferes with the comfortable enjoyment of life and property throughout the Commonwealth or throughout such areas of the Commonwealth as shall be affected thereby.

(6) "Air contamination." The presence in the outdoor atmosphere of an air contaminant which contributes to any condition of air pollution.

(7) "Air contamination source." Any source at, from or by reason of which there is emitted into the outdoor atmosphere any air contaminant, regardless of who the person may be who owns or operates the building, premises or other property in or on which such source is located or the facility, equipment or other property by which the emission is caused or from which the emission comes. Without limiting the generality of the foregoing, this term includes all types of business, commercial and industrial plants, works, shops and stores, and heating and power plants and stations, buildings and other structures of all types, including single and multiple family residences, apartments, houses, office buildings, public buildings, hotels, restaurants, schools, hospitals, churches and other institutional buildings, automobiles, trucks, tractors, buses and other motor vehicles, garages and vending and service locations and stations, railroad locomotives, ships, boats and other water-borne craft, portable fuel-burning equipment, incinerators of all types, indoor and outdoor, refuse dumps and piles, and all stack and other chimney outlets from any of the foregoing.

(8) "Association." Any Regional Air Pollution Control Association provided for in this act.

(9) "Region." Any geographical subdivision of the Commonwealth whose boundaries shall be determined by the commission.

(10) "Subregion." Any geographical subdivision whose boundaries shall be determined by the Commission.

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* "subdivisions" in original.

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Section 4. Powers of the Department of Health.—In accordance with the policies of the Commission, the department shall have the power and its duty shall be to—

(1) Enter any building, property, premises or place and inspect any air contamination source for the purpose of investigating an actual or a suspected source of air *pollution or for the purpose of ascertaining the compliance or non-compliance with any rule or regulation which may have been adopted and promulgated by the Commission hereunder. Any information relating to secret processes or methods of manufacture or production obtained in the course of such inspection, investigation or determination shall be kept confidential and shall not be subject to subpoena by any court of the Commonwealth in any civil action or any other proceeding, except before the Commission as herein defined. If, in connection with such inspection or investigation, samples of air or air contaminants are taken for analysis, a duplicate of the analytical report shall be furnished promptly to the person who is suspected of causing such air pollution or air contamination.

(2) Have access to, and require the production of, books and papers pertinent to any matter under investigation.

(3) Receive and initiate complaints of air pollution in alleged violation of law or any rule or regulation promulgated under this act, and to submit such complaints to the Association of the air pollution control region in which such complaints arise: Provided, however, That where the source of air pollution is within one region and the effects thereof extend to another region or regions, as determined by appropriate surveys by the department, the said complaint shall be forwarded to the Commission.

(4) Investigate complaints, institute and conduct surveys and testing programs, conduct general atmospheric sampling programs, make observations of conditions which may or do cause air pollution, make tests or other determinations at air contamination sources, and assess the degree of abatement required.

(5) When directed by the Commission, institute or cause to be instituted in a court of competent jurisdiction proceedings to compel compliance with any order of the Commission from which there has been no appeal or which has been sustained on appeal.

(6) Act as the agent for the Commission in holding public hearings when so directed by the Commission.

(7) Enforce orders for compliance with rules and regulations of the Commission.

(8) Recommend the minimum job qualifications of personnel employed by county and municipal air pollution control agencies hereafter created.

(9 Accept, and at the request of the Commission require to be submitted to it, and consider for approval, plans and specifications of air pollution control equipment, devices or process changes, and inspect such installations or modifications to insure compliance with the plans which may have been so approved by it.

(10) Conduct or cause to be conducted studies and research with respect to air contaminants, their nature, causes and *effects, and with respect to the control, prevention, abatement and reduction of air pollution and air contamination.

(11) Determine by means of field studies and sampling the degree of air pollution existing in any part of the Commonwealth.

(12) Prepare and develop a general comprehensive plan for the control and abatement of existing air pollution and air contamination and for the abatement, control and prevention of any new air pollution and air contamination, recognizing varying requirements for the different areas of the Commonwealth, and to submit a comprehensive plan to the Commission for its consideration and approval.

(13) Encourage the formulation and execution of plans in conjunction with air pollution control agencies or civil associations of counties, cities, boroughs, towns and townships of the Commonwealth wherein any sources of air pollution or air contamination may be located, and enlist the cooperation of those who may be in control of such sources for the control, prevention and abatement of such air pollution and air contamination.

(14) Encourage voluntary efforts and cooperation by all persons concerned in controlling, preventing, abating and reducing air pollution and air contamination.

(15) Conduct and supervise educational programs with respect to the control, prevention, abatement and reduction of air pollution and air contamination, including the preparation and distribution of information relating to the means of controlling and preventing such air pollution and air contamination.

(16) Develop and conduct in cooperation with local communities demonstration programs relating to air contaminants, air pollution and air contamination and the control, prevention, abatement and reduction of air pollution and air contamination.

(17) Provide advisory technical consultative services to local communities and to the Regional Air Pollution

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* "pollition" in original.

* "affects" in original.

Control Associations for the control, prevention, abatement and reduction of air pollution and air contamination.

(18) Cooperate with the appropriate agencies of the United States or of other states or any interstate agencies with respect to the control, prevention, abatement and reduction of air pollution, and where appropriate formulate interstate air pollution control compacts or agreements for the submission thereof to the General Assembly.

(19) Serve as the agency of the Commonwealth for the receipt of *moneys from the Federal government or other public or private agencies, and expend such *moneys for studies and research with respect to air contaminants, air pollution and the control, prevention, abatement and reduction of air pollution.

(20) Do any and all other acts and things not inconsistent with any provision of this act, which it may deem necessary or proper for the effective enforcement of this act and the rules or regulations which have been promulgated thereunder.

Section 5. The Air Pollution Commission.—(a) There is hereby created in the department an Air Pollution Commission which shall consist of five governmental members and six public members. The public members shall be appointed by the Governor, by and with the advice and consent of two-thirds of all the members of the Senate.

(b) The governmental members shall be the Secretaries of the Department of Health, Department of Commerce, Department of Labor and Industry, Department of Mines and Mineral Industries, Department of Agriculture, or persons designated by them.

(c) Of the six public members, one shall be a member of the general public. Of the remaining five members, one member shall be an industrial toxicologist experienced and competent in the toxicology of air contaminants; three members shall be representative of industry and as such shall be employed by a manufacturer or a public utility carrying on a manufacturing or public utility business within the Commonwealth and shall be experienced and competent in matters of air pollution control, of which three members at least one member shall be a licensed professional engineer trained and experienced in matters of air pollution control; and the remaining one member shall be an additional licensed professional engineer trained and experienced in matters of air pollution control. All the public members of the Commission shall be residents of the Commonwealth.

(d) The term of each public member shall be four (4) years or until a successor is duly appointed. The members of the Commission, other than the governmental members, shall receive twenty-five dollars ($25.00) per diem while actually engaged in the work of the Commission and each of them shall be allowed the necessary and actual expense which he shall incur in the performance of his duties under this act.

(e) The Commission shall elect a chairman and vice chairman every two years: Provided, however, That the first chairman of the Commission shall be the Secretary of Health.

(f) The Commission shall have the power and its duty shall be to—

(1) Certify to the Governor as soon as is practicable the number and boundaries of regions and subregions as defined herein, and in the event that the number of regions or the boundaries thereof are subsequently changed, to certify such changes to the Governor, by resolution, at a subsequent meeting.

(2) Adopt rules and regulations for the control of air pollution in regions or parts thereof, after reviewing studies made by the department in those regions or parts thereof, and *after such suggested rules and regulations have been reviewed by the Association of the region affected: Provided, however, That if such rules and regulations are designed to correct an air pollution condition which affects more than one region, it shall be necessary for the Commission to submit such rules and regulations to the Associations affected. To carry out the purpose and intent of this act, all rules and regulations shall be adopted by the Commission in accordance with the provisions of the act of June 4, 1945 (P. L. 1388), known as the "Administrative Agency Law," and its amendments. In exercising its authority to adopt rules and regulations, the Commission may, and to the extent deemed desirable by it shall, consult with a council of technical advisers, properly qualified by education or experience in air pollution matters, appointed by the Commission and to serve at the pleasure of the Commission, to consist of such number of advisers as the Commission may appoint, but such technical advisers shall receive no compensation for their services to the Commission.

(3) Adopt rules and regulations for the orderly conduct of business before it.

(4) Hold meetings or hearings at the call of the Chairman, but in no event shall meetings be held less than six times per year.

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* "monies" in original.

* "after" not in original.

(5) Hear and determine all complaints of alleged violations of the rules and regulations of the Commission, which complaints have been referred to it by any Association or by the department as provided by section 4 (3) of this act. Any and all action by the Commission taken with reference to any complaint shall be in the form of an adjudication, and all such action shall be subject to the provisions of the Administrative Agency Law, the act of June 4, 1945 (P. L. 1388), as amended, insofar as the rights of any person aggrieved are concerned.

(6) * Prescribe and disseminate to Associations a form of complaint which such Associations shall make available to persons desiring to make a complaint.

(7) Require the necessary and proper steps to minimize the effect, hazard or nuisance from air pollution and issue appropriate orders for compliance with rules and regulations for the control, abatement, reduction and prevention of air pollution and stipulate in such orders a time by which compliance shall be made.

(8) Establish and publish maximum quantities of air contaminants that may be permitted under various conditions at the point of use from any air contaminant source in various areas of the Commonwealth so as to control air pollution.

(g) Any party aggrieved as defined in the act of June 4, 1945 (P. L. 1388), known as the "Administrative Agency Law," and its amendments, by any order, decision or determination of the Commission made pursuant to the provisions of this act, shall have the right to appeal such order, decision or determination in the manner provided for by, and subject to all the provisions of, the act of June 4, 1945 (P. L. 1388), known as the "Administrative Agency Law," and its amendments.

Section 6. Regional Air Pollution Control Associations.—(a) In each of the regions designated by the Commission there shall be established an Association consisting of a representative of industry, and of labor, and a county commissioner of one of the counties comprising the region. In addition thereto, each Association shall be comprised of a resident of each of the counties of the region concerned. All members of such Association, including the chairman, shall be appointed by the Governor and shall serve at his pleasure.

(b) Each Association shall have the power and its duty shall be to—

(1) Review and comment upon all proposed regulations of the Commission peculiar to the region within a period of ninety **(90) days. If the Commission shall

not have received comments from the Association within ninety days of their submission to the Association, such suggested rules and regulations shall be adopted by the Commission.

(2) Suggest to the Commission such regulations as may seem suitable to the conditions of that region.

(3) Consider complaints regarding air pollution within their respective regions. In the consideration of such complaints, an Association shall attempt through the use of maximum of conference, conciliation and persuasion to abate, control, reduce or prevent air pollution within the region pursuant to the rules and regulations of the Commission. Within six months of the receipt of any complaint, an Association shall report to the Commission regarding the disposition of the complaint. In the event that the efforts of an Association are unavailing with respect to the air pollution problem *or problems set forth in a complaint, an Association shall refer such complaint to the Commission for appropriate action. If within sixty (60) days after an Association has reported to the Commission a satisfactory disposition of a complaint, another complaint concerning the same problems or persons, whichever the case may be, is filed with an Association, this complaint shall be forthwith referred to the Commission for appropriate action.

(4) Cooperate with persons within the region to develop a program for the prevention, abatement, control and reduction of air pollution within the region.

(5) Avail itself of the services of the Department of Health for technical service or advice whenever it is necessary for a proper understanding of the problems within the region.

(6) Meet at the call of the chairman of the Association or of the chairman of the Commission, but in no event shall the Association meet less than four times a year.

(7) Submit to the Commission a copy of all complaints received by the Association and action taken thereon.

(8) Utilize such stenographic and clerical assistance of the department as is necessary for the conduct of the business of the Association.

(9) Enter into an agreement with the Department of Health for the reimbursement of all necessary expenses of the Association.

(10) Provide for convenient headquarters for the Association. In the absence of any cogent reason the headquarters of the Association shall be situated in the regional office of the Department of Health, and such

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* "To" in original.
** "(90)" not in original.

* "and" in original.

office shall be supplied by the department to the Association at no charge.

(c) Each Association shall be considered an autonomous body insofar as the conduct of its business is concerned, notwithstanding the fact that it may utilize such services of the department as are herein provided, and notwithstanding the fact that it must comply with subsection (b) (3) of this section.

Section 7. Public Hearings.—(a) Public hearings shall be held by the Commission or by the department, acting on behalf and at the direction or request of the Commission, in any region of the Commonwealth affected before any rules or regulations with regard to the control, abatement, prevention or reduction of air pollution are adopted for that region or subregion. In the case where it [*]becomes necessary to adopt rules and regulations for the control, abatement, prevention or reduction of air pollution for any area of the Commonwealth which encompasses more than one region or parts of more than one region, public hearings shall be held in the area concerned. Full stenographic transcripts shall be taken of all public hearings and shall be made available by the department to any party concerned with the subject matter of the hearing upon the payment of prevailing rates for such transcripts.

(b) In addition to the matters discussed at the public hearings, the Commission may, in its discretion, solicit the views, in writing, of persons who may be affected by, or interested in, proposed rules and regulations.

(c) Notice to the public of the time and place of any public hearing shall be given at least thirty (30) days prior to the scheduled date of the hearing by public advertisement in a newspaper or newspapers of general circulation in the region of the Commonwealth affected.

(d) The persons designated to conduct the hearing shall have the power to issue notices of hearings in the name of the Commission.

(e) Full opportunity to be heard with respect to the subject of the hearing shall be given to all persons in attendance, in addition to which persons, whether or not in attendance, may, within thirty (30) days, submit their views to the department, which the department shall transmit to the Commission with its report.

(f) No information relating to secret processes or methods of manufacture or production shall be disclosed at any public hearing or otherwise and all such information shall be kept confidential.

Section 8. Unlawful Conduct.—It shall be unlawful to refuse to comply with any rule or regulation or order

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[*] "become" in original.

of the Commission, or to assist in the violation of any of the provisions of this act or rules and regulations adopted hereunder, or to in any manner hinder, obstruct, delay, resist, prevent or in any way interfere or attempt to interfere with the department or its personnel in the performance of any duty hereunder, or refuse to permit such personnel to perform their duty by refusing them, after proper identification or presentation of a written order of the department, entrance at reasonable hours to any premises.

Section 9. Penalties.—(a) Summary offense. Any person as herein defined, except a department, board, bureau or agency of the Commonwealth, political subdivision, municipality, district or authority, engaging in unlawful conduct as set forth in section 8 of this act, shall, for each offense, upon conviction thereof in a summary proceeding before a magistrate, alderman or justice of the peace, be sentenced to pay the costs of prosecution and a fine of not less than thirty dollars ($30.00) nor more than three hundred [*]dollars ($300.00), and, in default thereof, to undergo imprisonment of not less than ten (10) days nor more than thirty (30) days.

(b) Misdemeanors. Any person as herein defined, except a department, board, bureau or agency of the Commonwealth, political subdivision, municipality, district or authority, convicted of a third or subsequent offense, shall be guilty of a misdemeanor and shall, upon conviction thereof, be sentenced to pay a fine of not less than five hundred dollars ($500.00) nor more than one thousand dollars ($1,000.00), or to undergo imprisonment not exceeding one year, or both, in the discretion of the court.

(c) For the purpose of this section, violations on separate days shall be considered separate offenses.

Section 10. Application for Injunctive Relief.—(a) In addition to any other remedies provided for in this act, the Commission may request the Attorney General to petition the court of common pleas in the county in which the defendant resides or has his place of business for an injunction to restrain all violations of this act.

(b) The penalties and remedies prescribed by this act shall be deemed concurrent and the existence of or exercise of any remedy shall not prevent the Commission from exercising any other remedy hereunder, at law or in equity.

Section 11. Powers Reserved to the Department under Existing Laws.—Nothing in this act shall limit the powers conferred upon the department to control and abate nuisances detrimental to the public health as

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[*] "dollars" omitted in original.

*are provided in section 2101 **of The Administrative Code of 1929, the act of April 9, 1929 (P. L. 177), as amended.

Section 12. Powers Reserved to Political Subdivisions.—Nothing in this act shall prevent counties, cities, towns, townships or boroughs from enacting ordinances with respect to air pollution which will not conflict with the provisions of this act or the rules and regulations promulgated pursuant to ***its provisions. This act shall not be construed to repeal existing ordinances, resolutions or regulations of the aforementioned political subdivisions existing at the time of the effective date of this act, except as they may conflict with the provisions of this act.

The provisions of this act shall not apply to any city or county which has an air pollution control agency, except in the case in which a source or suspected source of air pollution exists in such city or county the effects of which extend beyond the boundaries of the city or county concerned. Notwithstanding any other provision of this act (including the provisions of section 2 of this act) nothing in this act shall limit the powers conferred under existing laws upon counties of the first and second class to enact and enforce through the county health department or otherwise, ordinances or rules and regulations controlling and regulating air pollution or the emission of smoke.

Section 13. Appropriation.—There is hereby appropriated to the Department of Health the sum of fifty thousand dollars ($50,000.00), or as much thereof as is necessary, to carry out the provisions of this act. All moneys expended pursuant to the provisions of this act shall be expended consistent with the policies of the Commission.

Section 14. Severability.—The provisions of this act are severable and if any ****provision, sentence, clause, section or part thereof shall be held illegal, invalid, unconstitutional or inapplicable to any person or circumstances, such illegality, invalidity, unconstitutionality or inapplicablity shall not affect or impair any of the remaining provisions, sentences, clauses, sections or parts of the ordinance or their application to him or to other persons and circumstances. It is hereby declared to be the legislative intent that this act would have been adopted if such illegal, invalid or unconstitutional provision, sentence, clause, section or part had not been

included therein, and if the person or circumstances to which the ordinance or any part thereof is inapplicable had not specifically been exempted therefrom.

Section 15. Effective Date.—This act shall take effect immediately: Provided, however, That the rules and regulations promulgated pursuant to the provisions of this act shall be of no effect until one (1) year after the passage of this act.

Approved—Th. .h day of January, A. D. 1960.

DAVID L. LAWRENCE

The foregoing is a true and correct copy of Act of the General Assembly No. 787.

John S. Rice

Secretary of the Commonwealth.

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* "is" in original.
** "and" in original.
*** "ts" in original.
**** "provisions" in original.

Appendix E

Detailed Data On Fuel Use Inventory and Emission Estimates

TABLE E 1

Fuel Use Inventory—Philadelphia, Pa.—1958

Type of Consumer	Fuel	Analysis		Annual Consumption (1000's)	Equipment Type*	Reference
		Ash (%)	Sulfur (%)			
Industrial & Commercial	Coal—bituminous	7.9	2.25	2,150 tons	Boiler—pulverized coal *cyclones and electrostatic precipitators*	(a)
	Coal—bituminous	7.6	1.7	17.6 tons	Boiler—underfeed stoker	
					Cyclones	(f)
	Coal—bituminous	8	1.7	184.9 tons	Boiler—underfeed stoker	(b), (c), (d)
	Coal—bituminous	8	1.7	115 tons	Boiler—traveling grate	(b), (c), (d)
	Coal—bituminous	8	1.7	52.5 tons	Boiler—spreader stoker	(b), (c), (d)
	Coal—anthracite	13	1.5	330 tons	Boiler—55% stoker-fired 45% hand-fired	(b), (c), (d)
	Fuel Oil		2.7	34,000 gals.	*Cyclones*	(a), (f)
	Fuel Oil		2.7 (avg.)	77,000 gals.		(a), (f)
	Fuel Oil		2 (avg.)	139,000 gals.		(g)
	Fuel Oil		2.5 (avg.)	165,000 gals.		(h)
	Mixed Gas		0.0028	8,640,000 cu. ft.		(a)
	Natural Gas		0.0012 (avg.)	13,300,000 cu. ft.		(a)
	Mixed Refuse			145 tons	Municipal Incinerator	(i)
Domestic	Coal—anthracite	7-10	0.5-1.0	400 tons	94% hand-fired furnaces 5% stoker-fired furnaces 1% hand-fired stoves	(b), (e)
	Fuel Oil		1.0 (avg.)	250,000 gals.	Furnace	(b)
	Mixed Gas		0.0028	42,000,000 cu. ft.	Furnace	(a)
	Mixed Refuse			330 tons	Municipal Incinerator	
Vehicular	Gasoline (2.21 ml TEL/gal)		0.032	450,000 gals.	Autos, trucks, airplanes	(j), (k)
	Diesel Fuel		0.21	12,000 gals.	35% buses 33% trucks 31% locomotives	(a), (j), (l)
	Fuel Oil		2.0	50,000 gals.	Ships	(m)

(a) Industry Contacts
(b) Fuel dealer Contacts
(c) Questionnaire replies-prorated
(d) Questionnaire replies-avg. analysis
(e) Survey of firing methods—fuel dealers
(f) Stack tests by industry
(g) State-wide sales—prorated
(h) Unpublished report, Phila. Dept. Public Health, Air Pollution Control Section
(i) Philadelphia Department Streets
(j) Data supplied by Pa. Department of Revenue
(k) Ref. (28)
(l) Ref. (29)
(m) Estimate of Philadelphia port traffic

*Control equipment is underlined.

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TABLE E 2

Fuel Use Inventory—Pittsburgh, Pa.—1958

Type of Consumer	Fuel	Analysis		Annual Consumption (1000's)	Equipment Type*	Reference
		Ash (%)	Sulfur (%)			
Industrial, Commercial, and Public Utilities	Coal—bituminous	10.0	1.9	85.6 tons	Boiler pulverized, feed boiler *electrostatic precipitators*	(a)(b)
	Coal—bituminous	10.0	1.9	152 tons	Pulverized, feed boiler	(a)(b)
	Coal—bituminous	10.0	1.9	0.8 tons	Spreader stokers, *multiple cyclones*	(a)(b)
	Coal—bituminous	10.0	1.9	152 tons	Spreader stokers	(a)(b)
	Coal—bituminous	10.0	1.9	636 tons	Underfeed stokers	(a)(b)
	Coal—bituminous	10.0	1.9	98.6 tons	Traveling grates	(a)(b)
	Coal—bituminous	10.0	1.9	1.2 tons	Hand-fired	(b)
	Fuel Oil		1.0 (avg.)	2,416 gals.		(b)
	Residue tar		0.6	24,076 gals.		(a)
	Natural Gas		0.034	8,100,000 cu. ft.		(a)(b)
	Coke oven gas			9,500,000 cu. ft.		(a)
	Combust. wastes			41.2 tons	Commercial incinerators	(c)
Domestic	Coal—bituminous	7.9	2.1	124 tons	30% stoker-fired 70% hand-fired	(b)(d)
	Fuel oil		1.0 (avg.)	1,200 gals.		(b)
	Natural gas		0.034	24,400,000 cu. ft.		(b)
	Combust. wastes			200 tons	92% by Municipal incinerator 8% by Domestic incinerator	(c)(e)
Vehicular	Gasoline (2.46 ml TEL/gal)		0.032	160,000 gals.	Auto, bus, truck engines	(f)(g)
	Diesel Fuel		0.21	16,000 gals.	Bus (#1—8%), truck (#2—9%), locomotive engines (#3—83%)	(a)(g) (h)

(a) Industry contacts
(b) Fuel dealer contacts
(c) Survey by Pennsylvania Economy League, October, 1958
(d) Records of Allegheny County Dept. Health, Bureau of Air Pollution Control
(e) Records of City of Pittsburgh, Dept. Sanitation
(f) Ref. (28)
(g) Data supplied by Pa. Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(h) Ref. (29)
*Control equipment is underlined.

TABLE E 3

Fuel Use Inventory—Reading, Pennsylvania—1958

Type of Consumer	Fuel	Analysis		Annual Consumption**	Equipment Type*	Reference
		Ash (%)	Sulfur (%)			
Industrial, Commercial and Public Utilities	Coal-anthracite	13	1.6	20,400 tons	Hand-fired	(a)
	Coal-anthracite	9.3	0.84	6,800 tons	Hand-fired	(a) (b)
	Coal-bituminous	7.5	1.6	4,500 tons	Hand-fired	(a) (b)
	Coal-bituminous	7.5	1.6	15,500 tons	Underfeed stokers	(a) (b)
	Coal-anthracite	9.3	0.84	14,900 tons	Underfeed stokers	(a) (b)
	Coal-bituminous	7.5	1.6	16,000 tons	Spreader stoker, dust reinj. *multi-tube cyclone*	(a)
	Coal-anthracite	13	1.6	7,300 tons	Traveling grate, *baffles*	(a)
	Coal-anthracite	9.3	0.84	3,100 tons	Traveling grate, *baffles*	(a)
	Fuel oil (#2,4,5,6)		2.2	24,300,000 gals.	12% #4-5, 22% #2, 66% #6	(a) (b)
	Natural gas		0.035	1,220,000 MCF		(b)
	Combustible wastes				Not burned in Reading	
Domestic	Coal-anthracite	9.3	0.84	67,100 tons	65% Hand-fired, 30% stoker-fired, 5% stoves	(b) (c)
	Fuel oil (#2)		0.40	31,600,000 gals.		(b) (c)
	Natural Gas		0.035	795,000 MCF		(b) (c)
	Combustible wastes				Sanitary land-fill outside city	
Vehicular	Gasoline (2.21ml TEL/gal.)		0.035	35,900,000 gals.	Auto, bus, truck engines	(d) (e)
	Diesel Fuel		0.11	1,210,000 gals.	Bus (#1-66%), truck (#2-21%) and RR locomotive (#3-13%) engines	(a) (d)

(a) Industry contacts
(b) Fuel dealer contacts
(c) Based on 32,500 dwelling units, heated 44.9% by oil (1500 gals./dwell.), 29.5% by coal (7 tons/dwell.) and 25.6% by gas (gas usage supplied by fuel dealer)
(d) Data supplied by Pa. Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(e) Ref. (28)
* Control equipment is underlined
** MCF is thousand cubic feet

TABLE E 4

Fuel Use Inventory—Harrisburg, Pennsylvania—1958

Type of Consumer	Fuel	Analysis		Annual Consumption**	Equipment Type*	Reference
		Ash (%)	Sulfur (%)			
Industrial, Commercial and Public Utilities	Coal-anthracite	15	0.35	101,400 tons	Travel grate, *multiple 4" cyclones*	(a)
	Coal-anthracite	7	1.0	3,100 tons	Underfeed stokers	(a) (b)
	Coal-bituminous	8	1.1	450 tons	Underfeed stokers	(a)
	Coal-bituminous	8	1.1	580 tons	Hand-fired	(a)
	Fuel oil (#2, #4, #6)		1.2	30,000,000 gals	63% #6, 4% #4, 33% #2	(a) (c) (d)
	Natural gas		0.03	1,670,000 MCF		(c)
	Combustible wastes				Land fill, open dump (no burning)	
Domestic	Coal (90% anthracite, 10% bituminous)	7	1.0	65 ,500 tons	75% Hand-fired, 23% stoker-fired, 2% stoves	(c) (e) (f)
	Fuel oil (#2)		0.27	18,100,000 gals.		(d) (e) (f)
	Natural gas		0.036	990,000 MCF		(c)
	Combustible wastes			280 tons	Apartment house incinerators	(g)
Vehicular	Gasoline (2.21ml. TEL/gal.)		0.035	38,000,000 gals.	Auto, truck and bus engines	(h) (i)
	Diesel fuel		0.18	1,110,000 gals.	Bus (#1-33%), truck (#2-48%), RR locomotive (#3-19%) engines	(a) (h) (j)

(a) Industry contacts
(b) Railroad company contacts
(c) Fuel dealer contacts
(d) Ref. (30)
(e) Based on 28,200 dwelling units. 31% heated by coal (7.5 tons/dwelling), 53% by fuel oil (1200 gals./dwelling)
(f) Fuel dealer survey (1958) of 15,500 dwellings; heated 31% by coal, 53% by fuel oil, 11% by gas, 5% other
(g) Based on 1071 apt. house dwelling units (> 9 units), Ref. (24)
(h) Data supplied by Pa. Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles.
(i) Ref. (28)
(j) Ref. (29)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 5

Fuel Use Inventory—Williamsport, Pennsylvania—1958

Type of Consumer	Fuel	Analysis: Ash (%)	Analysis: Sulfur (%)	Annual Consumption**	Equipment Type*	Reference
Industrial & Commercial	Coal-anthracite	16	1.3	12,000 tons	Traveling grate, *9' cyclones (2)*	(a) (b)
	Coal-anthracite	16	1.3	2,700 tons	Hand-fired	(a) (b)
	Coal-bituminous	6.8	0.7	19,600 tons	Spreader stokers	(a) (b)
	Coal-bituminous	6.8	0.7	16,600 tons	Underfeed stokers	(a) (b)
	Coal-bituminous	6.8	0.7	3,000 tons	Pulverized	(a) (b)
	Coal-bituminous	6.8	0.7	9,200 tons	Hand-fired	(a) (b)
	Fuel oil (79% #2, 21% #5)		0.73 avg.	3,670,000 gals.		(a) (b)
	Natural Gas		0.034	107,000 MCF		(b)
	Combustible wates (Primarily wood)			5,400 tons	As furnace fuel	(a)
Domestic	Coal-anthracite	9.1	0.8	48,000 tons	36% stokers, 62% Hand-fired, 2% stoves	(b)
	Coal-bituminous	8.5	1.8	2,800 tons	Stoker-fired	(b)
	Fuel oil (#2)		0.6	10,300,000 gals		(b)
	Natural gas		0.034	142,000 MCF		(b)
	Combustible wastes			9,400 tons	80% back yard incinerator, 20% municipal incinerator	(c)
Vehicular	Gasoline (2.21ml TEL/gal)		0.035	19,300,000 gals	Auto, bus and truck engines	(d) (e)
	Diesel fuel		0.23 avg.	985,000 gals	Locomotive (#3-97%), bus (#1-1%) engines	(a) (f)

(a) Industry contacts
(b) Fuel dealer contacts
(c) Personal communication, Smoke Control Officer, Williamsport
(d) Calculated from data supplied by Pa. Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(e) Ref. (28)
(f) Ref. (29)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 6

Fuel Use Inventory—Lebanon, Pennsylvania—1958

Type of Consumer	Fuel	Analysis: Ash (%)	Analysis: Sulfur (%)	Annual Consumption**	Equipment Type*	Reference
Industrial, Commercial and Public Utilities	Coal-anthracite	15	2 (avg.)	73,000 tons	Pulverized, *elect. prec.*	(a)
	Coal-anthracite	10	2 (avg.)	38,400 tons	Pulverized, *Multiple-cyclones*	(a)
	Coal-bituminous	8	1.7	2,590 tons	Underfeed stoker	(a) (b)
	Coal-bituminous	8	1.7	12,940 tons	Hand-fired	(a) (b)
	Fuel oil					
	(67%—#5; 33%—#6)		0.64 (avg.)	6,650,200 gals.		(a) (c)
	(35%—#2; 65%—#4)			2,845,500 gals.		(a) (b) (c)
	Natural gas		0.035	337,500 MCF		(a) (b)
	Combustible wastes			875 tons	Open Burning	(e)
Domestic	Coal	8	2	14,300 tons	90% Hand-fired, 9% stoker, 1% stove	(b) (d)
	Fuel oil (80%—#2; 20%—#4)		0.38 (avg.)	7,480,000 gals.		(b) (c) (d)
	Natural gas		0.035	225,000 MCF		(b)
	Combustible wastes			3,650 tons	33%—Backyard incinerators	(e)
Vehicular	Gasoline (2.21ml TEL/gal.)		0.032	14,416,000 gals.	Auto, bus, and truck engines	(f) (g)
	Diesel fuel		0.21 (avg.)	324,000 gals.	Bus, truck, and locomotive engines	(f) (h)

(a) Industry Contacts
(b) Fuel dealer contacts
(c) Ref. (30)
(d) Based on 8,295 dwellings; heated 75% oil (1200 gal/dwelling), 23% coal (7.5 T/dwelling), and 2% gas (150,000 cu. ft/dwelling)
(e) Based on municipal contacts and sanitary land-fill information
(f) Calculated from data supplied by Pa. Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(g) Ref. (28)
(h) Ref. (29)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 7

Fuel Use Inventory—Meadville, Pennsylvania—1958

Type of Consumer	Fuel	Analysis Ash (%)	Analysis Sulfur (%)	Annual Consumption**	Equipment Type*	Reference
Industrial, Commercial and Public Utilities	Coal-bituminous	10.6	3.83	126,900 tons	Pulverized, *Aerodyne "C" collectors*	(a)
	Coal-bituminous	3.8	0.76	2,100 tons	Pulverized	(a)
	Coal-bituminous	3.8	0.76	900 tons	Spreader stoker, dust reinject.	(a)
	Fuel oil (#2)		0.27	30,000 gals.		(a) (b)
	Natural gas		0.035	620,000 MCF		(a) (c)
	Combustible wastes			1,100 tons	Commercial incinerators	(a) (d)
Domestic	Coal-bituminous	10.0	1.9	1,020 tons	Hand-fired, 9% in stoves, 91% in furnaces	(c)
	Fuel oil			Neglig.		(c)
	Natural gas		0.035	1,070,000 MCF	(97% of dwelling units, burn natural gas)	(c)
	Combustible wastes			5,000 tons	Municipal incinerator	(e)
Vehicular	Gasoline (2.46ml TEL/gal)		0.032	5,910,000 gals	Auto, bus, truck engines	(a) (f) (g)
	Diesel Fuel		0.2	238,000 gals	R.R. locomotive engines (all)	(a) (f)

(a) Industry contacts
(b) Ref. (30)
(c) Fuel dealer contacts
(d) About 50% of industrial waste (estimated at 270 lbs/yr/capita) is incinerated, remainder is collected for open dump.
(e) Based on 640 lbs/yr/capita, over 90% of which is burned in municipal incinerator.
(f) Calculated from data supplied by Pa. Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(g) Ref. (28)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 8

Fuel Use Inventory—Lewistown, Pennsylvania—1958

Type of Consumer	Fuel	Analysis Ash (%)	Analysis Sulfur (%)	Annual Consumption**	Equipment Type*	Reference
Industrial, Commercial and Public Utilities	Coal-bituminous	9.0	1.6	81,000 tons	Pulverized, *multiclones*	(a)
	Coal-bituminous	9.0	1.6	84,200 tons	Underfeed stokers	(a)
	Coal-bituminous	8.2	1.4	700 tons	Hand-fired	(a) (b)
	Coal-bituminous	8.2	1.4	820 tons	Spreader, stokers	(a) (b)
	Coal-bituminous	8.2	1.4	480 tons	Underfeed stokers	(a) (b)
	Fuel oil (15% #1, 85% #2)		0.24 (avg.)	1,520,000 gals.		(b) (c)
	Natural gas		0.034	1,270,000 MCF		
	Combustible wastes			NOT BURNED IN LEWISTOWN		(b)
Domestic	Coal (40% anthr., 60% bit.)		1.1 (avg.)	12,600 tons	90% hand-fired, 5% stoker-fired, 5% stoves	(b)
	Fuel oil (85% #2, 15% #1		0.24 (avg.)	2,620,000 gals.		(b) (c) (d)
	Natural gas		0.034	50,800 MCF		(b) (d)
	Combustible wastes			NOT BURNED IN LEWISTOWN		
Vehicular	Gasoline (2.21ml TEL/gal)		0.035	4,210,000 gals.	Auto, bus and truck engines	(e) (f)
	Diesel fuel (#1)		0.089	98,000 gals	Bus, truck engines	(f) (g)

(a) Industry contacts
(b) Fuel dealer contacts
(c) Ref. (30)
(d) Based on 4200 dwelling units, heated 40% by coal (7.5 tons/dwelling), 52% by fuel oil (1200 gals/dwelling), and 8% by natural gas (150,000 cu. ft./dwelling)
(e) Ref. (28)
(f) Data supplied by Pa. Department of Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(g) Ref. (29)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 9

Fuel Use Inventory—Swoyersville, Pennsylvania—1958

Type of Consumer	Fuel	Analysis		Annual Consumption**	Equipment Type*	Reference
		Ash (%)	Sulfur (%)			
Industrial, Commercial and Public Utilities	Coal-anthracite	11.0	0.69	443 tons	Underfeed stokers	(a) (b)
	Coal-anthracite	8.8	0.64	180 tons	Hand-fired	(a) (b)
	Fuel oil (#2)		0.50	53,187 gals.		(a) (b)
	Natural gas		0.034	323 MCF		(b)
	Propane gas		nil	23,568 lbs.		(a) (b)
	Combustible wastes				Not burned in Swoyersville	
Domestic	Coal-anthracite	8.8	0.64	9,800 tons	Hand-fired	(b)
	Coal-anthracite	11.0	0.69	5,400 tons	Stoker-fired	(b)
	Fuel oil (#2)		0.50	276,720 gals.		(b)
	Natural gas		0.034	3,130 MCF		(b)
	Propane gas		nil	120,000 lbs.		(b)
	Combustible wastes				Not burned in Swoyersville	
Vehicular	Gasoline (2.21ml TEL/gal.)		0.035	1,920,000 gals.	Auto, bus, truck engines	(c) (d)
	Diesel fuel (#2)		0.18	52,400 gals.	Bus, truck, locomotive engines	(b) (c)

(a) Industry contacts
(b) Fuel dealer contacts
(c) Calculated from data supplied by Pa., Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(d) Ref. (28)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 10

Fuel Use Inventory—Media, Pennsylvania—1958

Type of Consumer	Fuel	Analysis		Annual Consumption**	Equipment Type*	Reference
		Ash (%)	Sulfur (%)			
Industrial, Commercial and Public Utilities	Coal			neglig.		(a) (b)
	Fuel oil (88% #5, 12% #2)		1.8 (avg.)	308,500 gals.		(a) (b)
	Gas (mixed)		0.0006	10,300 MCF		(a)
	Combustible wastes				Not burned in Media	(c)
Domestic	Coal-anthracite	10.1	0.59	825 tons	70% hand-fired, 23% stoves 7% stoker-fired	(a)
	Fuel oil (#2)		0.33	1,120,000 gals.		(a) (d)
	Gas (mixed)		0.0006	104,000 MCF		(a)
	Combustible wastes			70 tons	Backyard incineration	(c) (e)
Vehicular	Gasoline (2.21ml TEL/gal.)		.035	2,100,000 gals.	Auto, bus, truck engines	(f) (g)
	Diesel fuel		0.24 (avg.)	11,900 gals.	Bus (#1-23%) & truck, (#2-77%) engines	(f) (h)

(a) Fuel dealer contacts
(b) Industry contacts
(c) Borough Engineer
(d) Based on 53% of homes (1745) heating by fuel oil (1200 gals./dwelling)
(e) Based on 5% of homes (and 0.8 tons/yr./dwelling) employing open burning.
(f) Data supplied by Pa. Dept. of Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles.
(g) Ref. (28)
(h) Ref. (29)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 11

Fuel Use Inventory—North Charleroi, Pennsylvania—1958

Type of Consumer	Fuel	Analysis Ash (%)	Analysis Sulfur (%)	Annual Consumption**	Equipment Type*	Reference
Industrial, Commercial and Public Utilities	Coal-bituminous	6.8	1.6	1,150 tons	Underfeed stoker	(a)
	Coal-bituminous	6.8	1.6	170 tons	Hand-fired	(a)
	Fuel oil			None		(a)
	Natural gas		0.035	25,000 MCF		(b)
	Combustible wastes			230 tons	Open pit burning	(a)
Domestic	Coal-bituminous	1.6	6.8	1,050 tons	Hand-fired	(c)
	Fuel oil (#2)		0.27	30,000 gals.		(c) (d)
	Natural gas		0.035	62,300 MCF		(b)
	Combustible wastes			820 tons	Open burning	(a)
Vehicular	Gasoline (2.46ml TEL/gal)		0.032	678,000 gals.	Auto, bus, truck engines	(f) (g)
	Diesel fuel		0.20 (avg.)	21,600 gals.	Bus (20% #1) and truck, (80% #2) engines	(a) (f) (h)

(a) Industry contacts
(b) Fuel dealer contacts
(c) Based on 25 homes burning 1200 gals./heating season, and 150 homes burning coal at 7.0 tons/heating season
(d) Ref. (30)
(e) Based on 640 lbs./yr/capita
(f) Data supplied by Pa. Dept. Revenue, Bureau of Liquid Fuels Tax, and Bureau of Motor Vehicles
(g) Ref. (28)
(h) Ref. (29)
* Control equipment is underlined.
** MCF means thousand cubic feet.

TABLE E 12

Emissions From Combustion Operations—Philadelphia, Pennsylvania, 1958

(Tons per day averaged over the year)

Pollutant	Total Emissions	Source and Amount of Emissions													
		Industrial & Commercial					Domestic					Vehicular			
		Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel	Fuel Oil
GASEOUS, Total	1890	1058	476	566	16	0	194	33	131	26	4	638	592	19	27
Sulfur Dioxide	667	585	270	315	0	0	64	20	43	0	1	18	2	1	15
Hydrocarbons	721	128	78	47	3	0	29	11	12	5	1	564	550	12	2
Oxides of nitrogen (as NO_2)	271	182	78	94	10	0	48	0	31	16	1	41	33	4	4
Sulfur trioxide	65	60	32	28	0	-	5	0	5	0	-	-	-	-	-
Inorganic chlorides (as HCl)	17	15	15	-	-	-	2	2	-	-	-	-	-	-	-
Organic acids (as CH_3COOH)	123	75	-	73	2	0	40	-	36	4	0	8	2	1	5
Aldehydes (as CH_3CHO)	22	10	-	9	1	0	6	-	4	1	1	6	4	1	1
Fluorides (as HF)	2	2	2	-	-	-	0	0	-	-	-	-	-	-	-
Hydrogen sulfide	1	1	1	-	-	-	0	0	-	-	-	-	-	-	-
Ammonia	1	0	-	0	0	0	0	-	0	0	0	1	1	0	0
COARSE PARTICULATES, Total	49	39	36	1	-	2	10	6	-	-	4	-	-	-	-
Silicon dioxide, metal oxides	39	37	36	1	-	-	2	2	-	-	-	-	-	-	-
Carbon, resins	10	2	-	-	-	2	8	4	-	-	4	-	-	-	-
FINE PARTICULATES, Total	36	7	1	5	1	0	8	6	1	1	0	21	18	2	1
Carbon, tars, oils	24	0	-	-	-	0	6	6	-	-	0	18	16	2	-
Silicon dioxide, metal oxides	10	7	1	5	1	-	2	-	1	1	-	1	-	-	1
Lead halide (PbCl-Br)	2	-	-	-	-	-	-	-	-	-	-	2	2	-	-
TOTAL	1975	1104	513	572	17	2	212	45	132	27	8	659	610	21	28

TABLE E 13

Emissions From Combustion Operations—Pittsburgh, Pennsylvania, 1958

(Tons Per Day Averaged Over The Year)

Pollutant	Total Emissions	Source And Amount Of Emissions												
		Industrial & Commercial					Domestic					Vehicular		
		Total	Coal (a)	Fuel Oil (b)	Gas (c)	Combust. Waste	Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel
GASEOUS, Total	480	203	180	16.2	5.8	0.45	36.7	17.3	0.64	11.6	7.2	240	218	22.4
Sulfur dioxide	120	104	99.8	3.9	0.29	0.11	14.4	12.8	0.21	0.88	0.52	1.5	0.84	0.64
Hydrocarbons	262	33.5	30.8	1.7	0.92	0.09	11.1	3.4	0.06	2.2	5.4	218	202	15.8
Oxides of nitrogen (as NO_2)	62.6	38.9	30.8	4.4	3.6	0.14	6.6	0.07	0.15	5.8	0.62	17.1	12.3	4.9
Sulfur trioxide	12.6	12.2	11.7	0.43	0.03	-	0.40	0.28	0.02	0.10	-	-	-	-
Inorganic chlorides (as HCl)	6.9	6.2	6.2	-	-	-	0.67	0.67	-	-	-	-	-	-
Organic acids (as CH_3COOH)	9.5	5.9	-	5.1	0.74	0.03	2.1	-	0.18	1.7	0.18	1.5	0.88	0.68
Aldehydes (as CH_3CHO)	3.9	0.93	-	0.62	0.25	0.06	1.2	-	0.02	0.86	0.35	1.8	1.5	0.35
Fluorides (as HF)	0.7	0.62	0.62	-	-	-	0.07	0.07	-	-	-	-	-	-
Hydrogen sulfide	0.3	0.23	0.23	-	-	-	0.03	0.03	-	-	-	-	-	-
Ammonia	0.6	0.04	-	0.002	0.02	0.02	0.12	-	0.00	0.01	0.11	0.44	0.44	-
COARSE PARTICULATES, Total	101	96.5	96.0	-	-	0.50	4.4	1.7	-	-	2.7	-	-	-
Silicon dioxide, metal oxides	96.6	96.0	96.0	-	-	-	0.62	0.62	-	-	-	-	-	-
Carbon, resins	4.3	0.51	0.01	-	-	0.50	3.8	1.1	-	-	2.7	-	-	-
FINE PARTICULATES, Total	11.0	1.0	0.95	0.09	-	0.004	1.7	1.7	0.003	-	0.02	8.3	6.4	1.9
Carbon, tars oils	9.3	0.02	0.02	-	-	0.004	1.7	1.7	-	-	0.02	-	-	1.9
Silicon dioxide, metal oxides	1.0	1.0	0.93	0.09	-	-	0.003	-	0.003	-	-	7.6	5.7	-
Lead halide (PbCl · Br)	0.7	-	-	-	-	-	-	-	-	-	-	0.67	0.67	-
TOTAL	592	300	277	16.3	5.8	1.0	42.8	20.7	0.6	11.6	9.9	248	224	24.3

(a) Does not include coke, which for purposes of these estimates, was not considered a fuel.
(b) Includes residue tar.
(c) Includes natural and coke oven gas.

TABLE E 14

Emissions From Combustion Operations—Reading, Pennsylvania, 1958

(Tons Per Day Averaged Over The Year)

Pollutant	Total Emissions	Source And Amount Of Emissions									
		Industrial & Commercial				Domestic				Vehicular		
		Total	Coal	Fuel Oil	Gas	Total	Coal	Fuel Oil	Gas	Total	Gasoline	Diesel Fuel
GASEOUS, Total	102	33.5	11.4	21.5	0.64	18.6	5.1	13.1	0.38	50.4	48.7	1.7
Sulfur dioxide	21.4	16.2	5.4	10.3	0.04	5.0	2.8	2.2	0.03	0.24	0.21	0.03
Hydrocarbons	53.6	3.9	2.4	1.4	0.11	3.4	1.8	1.5	0.07	46.3	45.1	1.2
Oxides of nitrogen (as NO_2)	13.7	6.3	2.4	3.5	0.36	4.2	0.04	4.0	0.19	3.2	2.8	0.38
Sulfur trioxide	2.1	1.8	0.64	1.2	0.005	0.31	0.06	0.25	0.003	-	-	-
Inorganic chlorides (as HCl)	0.85	0.48	0.48	-	-	0.37	0.37	-	-	-	-	-
Organic acids (as CH_3COOH)	9.2	4.2	-	4.1	0.09	4.7	-	4.6	0.06	0.25	0.20	0.05
Aldehydes (as CH_3CHO)	1.5	0.52	-	0.49	0.03	0.59	-	0.56	0.03	0.37	0.34	0.03
Fluorides (as HF)	0.09	0.05	0.05	-	-	0.04	0.04	-	-	-	-	-
Hydrogen sulfide	0.02	0.01	0.01	-	-	0.006	0.006	-	-	-	-	-
Ammonia	0.01	0.002	-	0.002	0.000	0.002	-	0.002	0.000	0.01	0.01	-
COARSE PARTICULATES, Total	3.2	2.2	2.2	-	-	1.0	1.0	-	-	-	-	-
Silicon dioxide, metal oxides	2.2	1.9	1.9	-	-	0.35	0.35	-	-	-	-	-
Carbon, resins	1.0	0.35	0.35	-	-	0.65	0.65	-	-	-	-	-
FINE PARTICULATES, Total	3.3	0.65	0.58	0.07	-	1.1	0.98	0.08	-	1.6	1.5	0.15
Carbon, tars, oils	2.9	0.52	0.52	-	-	0.98	0.98	-	-	1.4	1.3	0.15
Silicon dioxide, metal oxides	0.21	0.13	0.06	0.07	-	0.08	-	0.08	-	-	-	-
Lead halide (PbCl-Br)	0.15	-	-	-	-	-	-	-	-	0.15	0.15	-
TOTAL	109	36.4	14.2	21.6	0.64	20.7	7.1	13.2	0.38	52.0	50.2	1.8

TABLE E 15

Emissions From Combustion Operations—Harrisburg, Pennsylvania, 1958

(Tons Per Day Averaged Over The Year)

Pollutant	Total Emissions	Source And Amount Of Emissions											
		Industrial & Commercial				Domestic					Vehicular		
		Total	Coal	Fuel Oil	Gas	Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel
GASEOUS, Total	93.7	29.1	8.6	19.6	0.87	13.4	5.5	7.1	0.47	0.30	51.2	49.7	1.6
Sulfur dioxide	13.6	9.2	1.9	7.2	0.06	4.1	3.2	0.86	0.04	0.001	0.25	0.21	0.04
Hydrocarbons	54.8	4.7	2.9	1.7	0.15	3.0	1.8	0.88	0.09	0.29	47.1	46.0	1.1
Oxides of nitrogen (as NO$_2$)	13.4	7.7	2.9	4.3	0.49	2.6	0.04	2.3	0.23	0.001	3.1	2.8	0.34
Sulfur trioxide	1.2	1.0	0.21	0.80	0.007	0.17	0.07	0.10	0.004	-	-	-	-
Inorganic chlorides (as HCl)	0.94	0.58	0.58	-	-	0.36	0.36	-	-	-	-	-	-
Organic acids (as CH$_3$COOH)	8.0	5.1	-	5.0	0.12	2.7	-	2.6	0.07	0.002	0.25	0.20	0.05
Aldehydes (as CH$_3$CHO)	1.4	0.64	-	0.60	0.04	0.36	-	0.32	0.04	0.004	0.37	0.35	0.02
Fluorides (as HF)	0.10	0.06	0.06	-	-	0.04	0.04	-	-	-	-	-	-
Hydrogen sulfide	0.01	0.004	0.004	-	-	0.007	0.007	-	-	-	-	-	-
Ammonia	0.11	0.003	-	0.002	0.001	0.003	-	0.001	0.000	0.002	0.10	0.10	-
COARSE PARTICULATES, Total	1.6	0.64	0.64	-	-	1.0	0.98	-	-	0.03	-	-	-
Silicon dioxide, metal oxides	0.97	0.63	0.63	-	-	0.34	0.34	-	-	-	-	-	-
Carbon, resins	0.68	0.006	0.006	-	-	0.67	0.64	-	-	0.03	-	-	-
FINE PARTICULATES, Total	2.7	0.09	0.01	0.08	-	1.0	0.96	0.04	-	0.00	1.5	1.4	0.13
Carbon, tars, oils	2.4	0.01	0.01	-	-	0.96	0.96	-	-	0.000	1.4	1.3	0.13
Silicon dioxide, metal oxides	0.12	0.08	0.003	0.08	-	0.04	-	0.04	-	-	-	-	-
Lead halide (PbCl·Br)	0.15	-	-	-	-	-	-	-	-	-	0.15	0.15	-
TOTAL	98.0	29.8	9.2	19.7	0.9	15.4	7.5	7.1	0.5	0.33	52.8	51.1	1.7

TABLE E 16

Emissions From Combustion Operations—Williamsport, Pennsylvania, 1958

(Tons Per Day Averaged Over The Year)

Pollutant	Total Emissions	Source And Amount Of Emissions												
		Industrial & Commercial					Domestic					Vehicular		
		Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel
GASEOUS, Total	48.2	8.6	6.6	1.8	0.05	0.17	12.0	4.5	4.7	0.06	2.7	27.6	26.2	1.4
Sulfur dioxide	6.4	3.0	2.5	0.49	0.004	0.001	3.3	2.2	1.1	0.005	0.01	0.14	0.11	0.04
Hydrocarbons	31.8	2.0	1.7	0.19	0.009	0.15	4.5	1.4	0.50	0.01	2.6	25.3	24.3	0.97
Oxides of nitrogen (as NO$_2$)	5.4	2.2	1.7	0.49	0.03	0.01	1.4	0.03	1.3	0.03	0.01	1.8	1.5	0.30
Sulfur trioxide	0.95	0.35	0.30	0.05	0.000	-	0.60	0.48	0.12	0.001	-	-	-	-
Inorganic chlorides (as HCl)	0.63	0.35	0.35	-	-	-	0.28	0.28	-	-	-	-	-	-
Organic acids (as CH$_3$COOH)	2.2	0.57	-	0.56	0.008	0.003	1.5	-	1.5	0.01	0.02	0.15	0.11	0.04
Aldehydes (as CH$_3$CHO)	0.50	0.08	-	0.07	0.002	0.01	0.22	-	0.18	0.005	0.04	0.20	0.18	0.02
Fluorides (as HF)	0.07	0.04	0.04	-	-	0.000	0.03	0.03	-	-	-	-	-	-
Hydrogen sulfide	0.06	0.006	0.006	-	-	-	0.05	0.05	-	-	-	-	-	-
Ammonia	0.07	0.000	-	0.000	0.000	-	0.02	-	0.001	0.000	0.02	0.05	0.05	-
COARSE PARTICULATES, Total	4.4	3.4	3.4	-	-	0.02	1.0	0.69	-	-	0.33	-	-	-
Silicon dioxide, metal oxides	3.5	3.3	3.3	-	-	-	0.25	0.25	-	-	-	-	-	-
Carbon, resins	0.92	0.15	0.13	-	-	0.02	0.77	0.44	-	-	0.33	-	-	-
FINE PARTICULATES, Total	1.8	0.23	0.22	0.01	-	0.00	0.68	0.66	0.02	-	0.002	0.89	0.77	0.12
Carbon, tars, oils	1.7	0.20	0.20	-	-	0.000	0.66	0.66	-	-	0.002	0.81	0.69	0.12
Silicon dioxide, metal oxides	0.05	0.03	0.02	0.01	-	-	0.02	-	0.02	-	-	-	-	-
Lead halide (PbCl·Br)	0.08	-	-	-	-	-	-	-	-	-	-	0.08	0.08	-
TOTAL	54.4	12.2	10.2	1.8	0.05	0.19	13.7	5.9	4.7	0.06	3.0	28.5	27.0	1.5

TABLE E 17

Emissions From Combustion Operations—Lebanon, Pennsylvania, 1958

(Tons per day averaged over the year)

Pollutant	Total Emissions	Source and Amount of Emissions												
		Industrial & Commercial					Domestic					Vehicular		
		Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel
GASEOUS, Total	52.5	26.0	20.5	5.1	0.18	0.31	6.4	1.9	3.1	0.11	1.3	20.0	19.6	0.45
Sulfur dioxide	15.4	13.3	11.7	1.7	0.01	0.001	1.9	1.4	0.50	0.008	0.004	0.089	0.076	0.013
Hydrocarbons	24.8	4.3	3.5	0.46	0.030	0.30	2.0	0.39	0.37	0.020	1.25	18.4	18.1	0.31
Oxides of nitrogen (as NO_2)	6.7	4.5	3.22	1.2	0.099	0.001	1.0	0.008	0.95	0.053	0.002	1.20	1.1	0.098
Sulfur trioxide	1.6	1.5	1.3	0.19	0.001	–	0.09	0.03	0.06	0.0009	–	–	–	–
Inorganic chlorides (as HCl)	0.78	0.70	0.70	–	–	–	0.08	0.08	–	–	–	–	–	–
Organic acids (as CH_3COOH)	2.6	1.4	–	1.4	0.024	0.002	1.1	–	1.1	0.015	0.008	0.093	0.079	0.013
Aldehydes (as CH_3CHO)	0.48	0.18	–	0.17	0.008	0.004	0.16	–	0.13	0.008	0.018	0.14	0.14	0.0071
Fluorides (as HF)	0.08	0.07	0.07	–	–	–	0.01	0.008	–	–	–	–	–	–
Hydrogen sulfide	0.03	0.03	0.03	–	–	–	0.003	0.003	–	–	–	–	–	–
Ammonia	0.05	0.003	–	0.0005	0.0001	0.002	0.01	–	0.0004	0.000	0.009	0.04	0.04	–
COARSE PARTICULATES, Total	4.1	3.8	3.7	–	–	0.30	0.34	0.2	–	–	0.12	–	–	–
Silicon dioxide, metal oxides	3.7	3.6	3.6	–	–	–	0.07	0.07	–	–	–	–	–	–
Carbon, resins	0.40	0.13	0.10	–	–	0.029	0.27	0.14	–	–	0.12	–	–	–
FINE PARTICULATES, Total	1.0	0.22	0.19	0.02	–	0.0002	0.24	0.2	0.018	–	0.0008	0.59	0.55	0.038
Carbon, tars, oils	0.93	0.16	0.16	–	–	0.0002	0.22	0.22	–	–	0.0008	0.55	0.51	0.038
Silicon dioxide, metal oxides	0.08	0.06	0.03	0.02	–	–	0.02	0.02	0.018	–	–	–	–	–
Lead halide (PbCl·Br)	0.04	–	–	–	–	–	–	–	–	–	–	0.04	0.039	–
TOTAL	57.6	30.0	24.4	5.1	0.18	0.34	7.0	2.4	3.1	0.11	1.4	20.6	20.1	0.49

TABLE E 18

Emissions From Combustion Operations—Meadville, Pennsylvania

(Tons per day averaged over the year)

Pollutant	Total Emissions	Source and Amount of Emissions											
		Industrial & Commercial					Domestic				Vehicular		
		Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Coal	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel
GASEOUS, Total	42.8	33.8	33.4	0.01	0.32	0.01	0.69	0.14	0.50	0.05	8.3	8.0	0.32
Sulfur dioxide	22.9	22.7	22.7	0.001	0.02	0.003	0.15	0.10	0.04	0.01	0.04	0.03	0.01
Hydrocarbons	11.4	3.7	3.6	0.002	0.06	0.002	0.13	0.03	0.09	0.01	7.6	7.4	0.23
Oxides of nitrogen (as NO_2)	4.6	3.8	3.6	0.004	0.18	0.004	0.27	0.001	0.25	0.02	0.52	0.45	0.07
Sulfur trioxide	2.7	2.7	2.7	0.000	0.003	–	0.006	0.002	0.004	–	–	–	–
Inorganic chlorides (as HCl)	0.72	0.71	0.71	–	–	–	0.006	0.006	–	–	–	–	–
Organic acids (as CH_3COOH)	0.16	0.04	–	0.004	0.04	0.001	0.08	–	0.08	0.004	0.04	0.03	0.01
Aldehydes (as CH_3CHO)	0.13	0.02	–	0.001	0.02	0.002	0.05	–	0.04	0.008	0.06	0.06	0.005
Fluorides (as HF)	0.07	0.07	0.07	–	–	–	0.001	0.001	–	–	–	–	–
Hydrogen sulfide	0.05	0.05	0.05	–	–	–	0.000	0.000	–	–	–	–	–
Ammonia	0.02	0.000	–	0.000	0.000	0.000	0.002	–	0.000	0.002	0.02	0.02	–
COARSE PARTICULATES, Total	4.2	4.1	4.1	–	–	0.01	0.07	0.01	–	0.06	–	–	–
Silicon dioxide, metal oxides	4.1	4.1	4.1	–	–	–	0.006	0.006	–	–	–	–	–
Carbon, resins	0.07	0.01	–	–	–	0.01	0.06	0.004	–	0.06	–	–	–
FINE PARTICULATES, Total	0.36	0.08	0.08	0.000	–	0.000	0.02	0.02	–	0.000	0.26	0.23	0.03
Carbon, tars, oils	0.26	0.000	–	–	–	0.000	0.02	0.02	–	0.000	0.24	0.21	0.03
Silicon dioxide, metal oxides	0.08	0.08	0.08	0.000	–	–	–	–	–	–	–	–	–
Lead halide (PbCl·Br)	0.02	–	–	–	–	–	–	–	–	–	0.02	0.02	–
TOTAL	47.4	38.0	37.6	0.01	0.32	0.02	0.78	0.17	0.50	0.11	8.6	8.2	0.35

TABLE E 19

Emissions From Combustion Operations—Lewistown, Pennsylvania, 1958

(Tons per day averaged over the year)

Pollutant	Total Emissions	Source and Amount of Emissions										
		Industrial & Commercial				Domestic				Vehicular		
		Total	Coal	Fuel Oil	Gas	Total	Coal	Fuel Oil	Gas	Total	Gasoline	Diesel Fuel
GASEOUS, Total	33.1	25.2	24.0	0.58	0.66	2.1	1.1	1.0	0.02	5.8	5.7	0.14
Sulfur dioxide	13.3	12.5	12.4	0.06	0.05	0.79	0.68	0.11	0.002	0.02	0.02	0.002
Hydrocarbons	10.6	4.7	4.6	0.07	0.11	0.47	0.34	0.13	0.004	5.4	5.3	0.10
Oxides of nitrogen (as NO_2)	5.8	5.1	4.5	0.19	0.37	0.35	0.007	0.33	0.01	0.35	0.32	0.03
Sulfur trioxide	1.4	1.4	1.4	0.007	0.005	0.03	0.02	0.01	0.0002	–	–	–
Inorganic chlorides (as HCl)	0.98	0.91	0.91	–	–	0.07	0.07	–	–	–	–	–
Organic acids (as CH_3COOH)	0.71	0.31	–	0.22	0.09	0.38	–	0.38	0.004	0.02	0.02	0.004
Aldehydes (as CH_3CHO)	0.15	0.06	–	0.03	0.03	0.05	–	0.05	0.002	0.04	0.04	0.002
Fluorides (as HF)	0.10	0.09	0.09	–	–	0.007	0.007	–	–	–	–	–
Hydrogen sulfide	0.03	0.03	0.03	–	–	0.002	0.002	–	–	–	–	–
Ammonia	0.01	0.0005	–	0.0001	0.0004	0.0002	–	0.0002	0.0002	0.01	0.01	–
COARSE PARTICULATES, Total	6.3	6.1	6.1	–	–	0.22	0.22	–	–	–	–	–
Silicon dioxide, metal oxides	6.2	6.1	6.1	–	–	0.15	0.15	–	–	–	–	–
Carbon, resins	0.08	0.008	0.008	–	–	0.07	0.07	–	–	–	–	–
FINE PARTICULATES, Total	0.52	0.11	0.11	0.004	–	0.23	0.22	0.006	–	0.18	0.17	0.01
Carbon, tars, oils	0.39	0.01	0.01	–	–	0.22	0.22	–	–	0.16	0.15	0.01
Silicon dioxide, metal oxides	0.11	0.10	0.10	0.004	–	0.006	–	0.006	–	–	–	–
Lead halide (PbCl·Br)	0.02	–	–	–	–	–	–	–	–	0.02	0.02	–
TOTAL	39.9	31.4	30.2	0.58	0.66	2.5	1.5	1.0	0.02	6.0	5.9	0.15

TABLE E 20

Emissions From Combustion Operations—Swoyersville, Pennsylvania, 1958

(Tons per day averaged over the year)

Pollutant	Total Emissions	Source and Amount of Emissions										
		Industrial & Commercial				Domestic				Vehicular		
		Total	Coal	Fuel Oil	Gas	Total	Coal	Fuel Oil	Gas	Total	Gasoline	Diesel Fuel
GASEOUS, Total	4.0	0.008	0.06	0.02	0.000	1.3	1.2	0.12	0.01	2.6	2.5	0.08
Sulfur dioxide	0.53	0.02	0.02	0.005	0.000	0.50	0.48	0.02	0.000	0.01	0.01	0.002
Hydrocarbons	2.9	0.02	0.02	0.003	0.000	0.44	0.42	0.01	0.005	2.4	2.4	0.05
Oxides of nitrogen gen (as NO_2)	0.38	0.02	0.01	0.007	0.000	0.19	0.15	0.04	0.001	0.17	0.15	0.02
Sulfur trioxide	0.03	0.003	0.002	0.001	0.000	0.03	0.03	0.003	0.000	–	–	–
Inorganic chlorides (as HCl)	0.08	0.003	0.003	–	–	0.08	0.08	–	–	–	–	–
Organic acids (as CH_3COOH)	0.06	0.008	–	0.008	0.000	0.04	–	0.04	0.004	0.01	0.01	0.002
Aldehydes (as CH_3CHO)	0.03	0.001	–	0.001	0.000	0.005	–	0.005	0.000	0.02	0.02	0.001
Fluorides (as HF)	0.008	0.000	0.000	–	–	0.008	0.008	–	–	–	–	–
Hydrogen sulfide	0.001	0.000	0.000	–	–	0.001	0.001	–	–	–	–	–
Ammonia	0.005	0.000	–	0.000	0.000	0.000	–	0.000	0.000	0.005	0.005	–
COARSE PARTICULATES, Total	0.19	0.02	0.02	–	–	0.17	0.17	–	–	–	–	–
Silicon dioxide, metal oxides	0.09	0.02	0.02	–	–	0.07	0.07	–	–	–	–	–
Carbon, resins	0.10	0.002	0.002	–	–	0.10	0.10	–	–	–	–	–
FINE PARTICULATES, Total	0.25	0.004	0.004	0.000	–	0.16	0.16	0.001	–	0.09	0.08	0.006
Carbon, tars, oils	0.24	0.003	0.003	–	–	0.16	0.16	–	–	0.08	0.07	0.006
Silicon dioxide, metal oxides	0.002	0.001	0.001	0.000	–	0.001	–	0.001	–	–	–	–
Lead halide (PbCl·Br)	0.008	–	–	–	–	–	–	–	–	0.008	0.008	–
TOTAL	4.4	0.10	0.08	0.02	0.00	1.6	1.5	0.12	0.01	2.7	2.6	0.08

TABLE E 21

Emissions From Combustion Operations—Media, Pennsylvania, 1958

(Tons per day averaged over the year)

Pollutant	Total Emissions	Source and Amount of Emissions										
		Industrial & Commercial			Domestic					Vehicular		
		Total	Fuel Oil	Gas	Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel
GASEOUS, Total	3.6	0.24	0.24	0.005	0.61	0.04	0.51	0.04	0.02	2.8	2.8	0.02
Sulfur dioxide	0.21	0.11	0.11	0.000	0.09	0.02	0.07	0.000	0.000	0.01	0.01	0.001
Hydrocarbons	2.7	0.02	0.02	0.001	0.11	0.02	0.06	0.009	0.02	2.6	2.6	0.01
Oxides of nitrogen (as NO_2)	0.38	0.04	0.04	0.003	0.18	0.000	0.16	0.02	0.000	0.16	0.16	0.004
Sulfur trioxide	0.02	0.01	0.01	0.000	0.009	0.001	0.008	0.000	–	–	–	–
Inorganic chlorides (as HCl)	0.004	–	–	–	0.004	0.004	–	–	–	–	–	–
Organic acids (as CH_3COOH)	0.26	0.05	0.05	0.001	0.20	–	0.19	0.008	0.000	0.01	0.01	0.001
Aldehydes (as CH_3CHO)	0.05	0.006	0.006	0.000	0.02	–	0.02	0.004	0.000	0.02	0.02	0.000
Fluorides (as HF)	0.000	–	–	–	0.000	0.000	–	–	–	–	–	–
Hydrogen sulfide	0.000	–	–	–	0.000	0.000	–	–	–	–	–	–
Ammonia	0.006	0.000	0.000	0.000	0.000	–	0.000	0.000	0.000	0.006	0.006	–
COARSE PARTICULATES, Total	0.02	–	–	–	0.02	0.02	–	–	0.002	–	–	–
Silicon dioxide, metal oxides	0.005	–	–	–	0.005	0.005	–	–	–	–	–	–
Carbon, resins	0.01	–	–	–	0.01	0.01	–	–	0.002	–	–	–
FINE PARTICULATES, Total	0.10	0.001	0.001	–	0.02	0.02	0.003	–	0.000	0.08	0.08	0.001
Carbon, tars, oils	0.09	–	–	–	0.02	0.02	–	–	0.000	0.07	0.07	0.001
Silicon dioxide, metal oxides	0.004	0.001	0.001	–	0.003	–	0.003	–	–	–	–	–
Lead halide ($PbCl \cdot Br$)	0.009	–	–	–	–	–	–	–	–	0.009	0.009	–
TOTAL	3.7	0.24	0.24	0.005	0.65	0.08	0.51	0.04	0.02	2.9	2.9	0.02

TABLE E 22

Emissions From Combustion Operations—North Charleroi, Pennsylvania, 1958

(Tons per day averaged over the year)

Pollutant	Total Emissions	Source and Amount of Emissions											
		Industrial & Commercial					Domestic				Vehicular		
		Total	Coal	Gas	Combust. Waste	Total	Coal	Fuel Oil	Gas	Combust. Waste	Total	Gasoline	Diesel Fuel
GASEOUS, Total	1.9	0.28	0.19	0.01	0.08	0.46	0.12	0.01	0.03	0.29	1.2	0.93	0.30
Sulfur dioxide	0.19	0.10	0.10	0.001	0.000	0.08	0.08	0.001	0.002	0.001	0.01	0.004	0.008
Hydrocarbons	1.5	0.12	0.04	0.002	0.08	0.32	0.03	0.001	0.006	0.28	1.1	0.86	0.21
Oxides of nitrogen (as NO_2)	0.19	0.04	0.03	0.007	0.000	0.03	0.001	0.004	0.02	0.001	0.12	0.05	0.07
Sulfur trioxide	0.01	0.01	0.01	0.000	–	0.002	0.002	0.000	0.000	–	–	–	–
Inorganic chlorides (as HCl)	0.01	0.007	0.007	–	–	0.006	0.006	–	–	–	–	–	–
Organic acids (as CH_3COOH)	0.02	0.002	–	0.002	0.000	0.01	–	0.004	0.004	0.002	0.01	0.004	0.009
Aldehydes (as CH_3CHO)	0.02	0.002	–	0.001	0.001	0.007	–	0.001	0.002	0.004	0.01	0.006	0.005
Fluorides (as HF)	0.002	0.001	0.001	–	–	0.001	0.001	–	–	–	–	–	–
Hydrogen sulfide	0.000	0.000	0.000	–	–	0.000	0.000	–	–	–	–	–	–
Ammonia	0.005	0.001	–	0.000	0.001	0.002	–	0.000	0.000	0.002	0.002	0.002	–
COARSE PARTICULATES, Total	0.09	0.04	0.03	–	0.008	0.05	0.02	–	–	0.03	–	–	–
Sillicon dioxide, metal oxides	0.04	0.03	0.03	–	–	0.006	0.006	–	–	–	–	–	–
Carbon, resins	0.05	0.01	0.002	–	0.008	0.04	0.01	–	–	0.02	–	–	–
FINE PARTICULATES, Total	0.06	0.004	0.004	–	0.000	0.02	0.02	0.000	–	0.000	0.04	0.02	0.02
Carbon, tars, oils	0.06	0.003	0.003	–	0.000	0.02	0.02	–	–	0.000	0.04	0.02	0.02
Silicon dioxide, metal oxides	0.001	0.001	0.001	–	–	0.000	–	0.000	–	–	–	–	–
Lead halide (PbCl·Br)	0.003	–	–	–	–	–	–	–	–	–	0.003	0.003	–
TOTAL	2.0	0.32	0.22	0.01	0.09	0.53	0.16	0.01	0.03	0.32	1.2	0.95	0.32

Literature Cited

1. U. S. Bureau of the Census, "1950, Census of the Population." Volume II, Characteristics of the Population, Part 38, Pennsylvania, U. S. Government Printing Office, Washington, D.C., 1952.
2. "Pennsylvania Statistical Abstract, 1958," prepared by Pennsylvania Department of Internal Affairs.
3. "Pennsylvania Statistical Abstract, 1958," prepared by Pennsylvania Department of Internal Affairs (corrected for special consensus through February, 1958).
4. Drinker, P. and Hatch, T., "Industrial Dust," 2nd Ed., McGraw-Hill Book Co., Inc., New York, 1954.
5. Green, H. L. and Lane, W. R., "Particulate Clouds: Dusts, Smokes and Mists," E. & F. N. Spon Ltd., London, 1957.
6. Dallavalle, J. M., "Micromeritics," 2nd Ed., Pitman Publishing Corp., New York, 1948.
7. Henderson, Y. and Haggard, H. W., "Noxious Gases," Reinhold Publishing Corporation, New York, 1943.
8. McCord, C. P. and Witheridge, W. N., "Odors, Physiology and Control," 1st Ed., McGraw-Hill Book Co. Inc., New York, 1949.
9. Stern, A. C., "Changes in Identity and Quantity of Pollutants, Past and Future," Proc. National Conference on Air Pollution, pp. 86-93, Public Health Service Publication No. 654, U. S. Government Printing Office, Washington, D.C., 1959.
10. "The Air Over Louisville," Summary of a joint report by the Special Air Pollution Study of Louisville and Jefferson County, Kentucky, 1956-57, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, May, 1958, p. 30.
11. "Technical Report—The Air Over Louisville," Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio; in preparation (1960).
12. Howell, M. D., "Accomplishments in Air Pollution Control by the Steel Industry," Proc. National Conference on Air Pollution, pp. 53–57, Public Health Service Publication No. 654, U. S. Government Printing Office, Washington, D.C., 1959.
13. "Foundry Air Pollution Control Manual." American Foundrymen's Society, Inc., Des Plaines, Illinois, 1956.
14. Hebley, H. F., "The Control of Gob Pile Fires," *JAPCA*, **6**, 29, May, 1956.
15. "Emissions to the Atmosphere from Petroleum Refineries in Los Angeles County—Final Report No. 9," Joint District, Federal and State Project for the Evaluation of Refinery Emissions, Air-Pollution Control District, County of Los Angeles, 1958.
16. U. S. Bureau of Mines, "Bituminous Coal and Lignite Distribution Statistics," Mineral Market Report MMS 2853, Washington, D.C., 1954.
17. U. S. Bureau of Mines, "Anthracite Distribution Statistics," Mineral Market Report MMS 2834, Washington, D.C., 1954.
18. U. S. Bureau of Mines, "Sales of Fuel Oil and Kerosene in 1957" Mineral Market Report MMS 2800, Washington, D.C., July 7, 1958.
19. "Statistics for Gas Utilities in Pennsylvania, 1957 Census of Public Utilities in Pennsylvania," Department of Internal Affairs, October, 1958.
20. "Liquid Fuels Tax Accrual by Months and Calendar Year, January 1, 1957 to December 31, 1957." Pennsylvania Department of Revenue, Bureau of Liquid Fuels Tax, Feb. 13, 1958.
21. U. S. Bureau of Mines, "Sales of Liquefied Petroleum Gases in 1957" Mineral Market Report MMS 2816, Washington, D.C., August 6, 1958.
22. U. S. Bureau of the Census, "1954 Census of the Manufacturing Industries, Pennsylvania," U. S. Government Printing Office, Washington, D.C., 1956.

23. U. S. Bureau of the Census, "U. S. Census of Housing, 1940," U. S. Government Printing Office, Washington, D.C., 1942.

24. U. S. Bureau of the Census, "U. S. Census of Housing, 1950," U. S. Government Printing Office, Washington, D.C., 1952.

25. "Pennsylvania Statistical Abstract, 1958," Table #77, Number of Registered Motor Vehicles, Licensed Operators, 1906 to 1956, Pennsylvania Department of Internal Affairs.

26. "Approximate Statement of Receipts and Registrations, broken down by Counties, entire State, and a number of Key Cities." Pennsylvania Department of Revenue.

27. "Pennsylvania Statistical Abstracts, 1959," Pennsylvania Department of Internal Affairs. August, 1959.

28. "Motor Gasoline Fuel Survey, Summer of 1958," Bureau of Mines, U. S. Department of the Interior, U. S. Government Printing Office, Washington, D.C., March, 1959.

29. "Diesel Fuel Oil Survey, Summer of 1958," Bureau of Mines, U. S. Department of the Interior, U. S. Government Printing Office, Washington, D.C., March, 1959.

30. "Burner Fuel Oil Survey, Summer of 1958," Bureau of Mines, U. S. Department of the Interior, U. S. Government Printing Office, Washington, D.C., March, 1959.

31. U. S. Bureau of the Census, "1954 Census of Manufacturers, Pennsylvania," U. S. Government Printing Office, Washington, D.C. 1957.

32. "Summary of Radiation Registrations of Users of Equipment and Radioactive Materials," monthly reports from 12-31-58 to 6-30-60, Division of Occupational Health, Pennsylvania Depatment of Health.

33. U. S. Atomic Energy Commission, "Meteorology and Atomic Energy," U. S. Government Printing Office, Washington 25, D.C., July, 1955, p. 49.

34. Magill, P. L., Holden, F. R. and Ackley, C., ed's., "Air Pollution Handbook," McGraw-Hill Book Co., Inc., New York, 1956, p. 5—27.

35. This section of Chapter III prepared by Nelson M. Kauffman, State Climatologist, U. S. Weather Bureau, Harrisburg, Pennsylvania.

36. Special Projects Section, Office of Meteorological Research, "A Meteorological Survey of the PWR Site at Shippingport, Pennsylvania," U. S. Weather Bureau, Washington, D.C., December, 1957, p. 53.

37. Austin, J. M., et al., "Low-Level Inversions—Final Report, Quartermaster Research and Engineering Command, DA 19-129-QM-377, Project Number 7-83-05-003B," Massachusetts Institute of Technology, Cambridge, Massachusetts, September 30, 1957.

38. Korshover, J., "Synoptic Climatology of Stagnating Anticyclones East of the Rocky Mountains in the United States for the Period, 1936-1956," Office of Meteoroligical Research, U. S. Weather Bureau, Washington, D.C.

39. Silverman, L., "Industrial Air Sampling and Analysis," Industrial Hygiene Foundation, Pittsburgh, Pennsylvania, 1947.

40. Magill, P. L., et al., op. cit., Chapter 10.

41. ibid., Chapter 11.

42. Wohlers, H. C. and Bell, G. B., "Literature Review of Metropolitan Air Pollution Concentrations—Preparation, Sampling and Assay of Synthetic Atmospheres," Stanford Research Institute, Menlo Park, California, November 30, 1956.

43. "Air Pollution Measurements of the National Air Sampling Network," U. S. Public Health Service, R. A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio, 1958.

44. Zimmer, C. E., Tabor, E. C. and Stern, A. C., "Particulate Pollutants in the Air of the United States," *JAPCA*, 9, 136 (1959).

45. Stern, A. C., "Changes in Identity and Quantity of Pollutants, Past, Present, and Future," Proc. National Conference on Air Pollution, pp. 86-94;

Public Health Service Publication No. 654, U. S. Government Printing Office, Washington, D.C., 1959.

46. Hemeon, W. C. L., Haines, G. F., and Ide, H. M., "Determination of Haze and Smoke Concentrations by Filter Paper Samplers," *Air Repair 3*, 22-28, (August, 1953).

47. Hill, A. S. G., "Measurement of the Optical Densities of Smoke Stains on Filter Papers," *Trans. Far. Soc.*, *32*, 1125 (1936).

48. Annual Report of 1958, Air Pollution Control Section, Ray Smith, Chief, Philadelphia Department of Public Health, Philadelphia, Pennsylvania.

49. "California Standards for Ambient Air and Motor Vehicle Exhausts," Standards adapted by California State Board of Public Health—December 4, 1959.

50. Unpublished material, Files of Division of Air Pollution, Pennsylvania Department of Health, Harrisburg, Pennsylvania.

51. Burdick, L. R. and Barkley, J. F., "Concentration of Sulfur Compounds in City Air," U. S. Bureau of Mines Information Circ. 7066, Washington, D.C., 1939.

52. Schrenk, H. H., et al., "Air Pollution in Donora, Pennsylvania Epidemiology of the Unusual Smog Episode of October 1948, Preliminary Report," Public Health Bulletin No. 306, U. S. Public Health Service, Washington, D.C., 1949.

53. "Concentration of Volatile Sulfur Compounds in Atmospheric Air," Special Research Series Bulletin No. 1, parts I and II, Air Hygiene Foundation of America, Inc., Pittsburgh, Pennsylvania, September, 1937 and January, 1938.

54. Cholak, J., et al., "Air Pollution in a Number of American Cities," ***Arch. Industrial Health***, **11, 280 (1955).**

55. Annual Report of 1956 Air Pollution Control Section, Ray Smith, Chief, Philadelphia Department of Public Health, Philadelphia, Pennsylvania.

56. Annual Report of 1957 Air Pollution Control Section, Ray Smith, Chief, Philadelphia Department of Public Health, Philadelphia, Pennsylvania.

57. Annual Report of 1958 Air Pollution Control Section, Ray Smith, Chief, Philadelphia Department of Public Health, Philadelphia, Pa.

58. Meiter, E. G. and Traubert, C. E., "Sulfur Dioxide Concentrations in the Air at the Pittsburgh Experiment Station of the U. S. Bureau of Mines," Report of Investigations 3005, U. S. Bureau of Mines, Pittsburgh, Pennsylvania, 1930.

59. Betz, C. E., Holden, J. H. and Handy, J. O., "Sulfur Dioxide in the Air of an Industrial Community," *Ind. Eng. Chem.*, 25, 774 (1933).

60. Shade, C., "Sulfur Dioxide in Pittsburgh, Pennsylvania," *J. Ind. Hyg.*, 15, 150 (1933).

61. Hemeon, W. C. L., "Current Conceptions on Air Pollution," presented at A. I. S. I. Regional Meeting, Philadelphia, Pennsylvania, Oct. 6, 1954.

62. 1951 Report, Bureau of Smoke Prevention, Department of Public Health, City of Pittsburgh, Pennsylvania.

63. 1953 Report, Bureau of Smoke Prevention, Department of Public Health, City of Pittsburgh, Pennsylvania.

64. "Dustfall Surveys, Lehigh Valley Portland Cement Communities," Lehigh Valley Air Pollution Control, Northampton, Pennsylvania, May, 1959.

65. Brandt, A. D., "Recent Developments and Progress in Air Pollution Abatement," paper no. 52-A-70 presented at A.S.M.E. ann. mtg., New York, New York, November 30, 1952.

66. "Some Engineering Phases of Pittsburgh's Smoke Problem," Smoke Investigation Bulletin No. 8, University of Pittsburgh, Pittsburgh, Pennsylvania, 1914.

67. Meller, H. B., "Economy through Smoke Abatement," ***Ind. Eng. Chem.***, 16, 1049 (1924).

68. Meller, H. B., "The Facts about Pittsburgh's Soot and Dust," ***Pittsburgh Record***, University of Pittsburgh, Pittsburgh, Pennsylvania, June-July, 1931.

69. 1954 Report, Bureau of Smoke Prevention, Department of Public Health, City of Pittsburgh, Pennsylvania.
70. 1956 Report, Bureau of Smoke Prevention, Department of Public Health, City of Pittsburgh, Pennsylvania.
71. Personal Correspondence with Pennsylvania Power and Light Company, Sunbury, Pennsylvania. June 5, 1960.
72. Unpublished material, Files of Bureau of Air Pollution Control, Department of Health, Allegheny County, Pittsburgh, Pennsylvania.
73. Correspondence with Thistle Laboratory, Washington & Jefferson College, Washington, Pennsylvania. Data obtained using an AISI automatic smoke sampler, COH Units, from May, 1952 to March, 1959 Report of 15 May, 1959.
74. U. S. Bureau of the Census, "16th Census of the U. S., 1940—Housing, General Characteristics, Pennsylvania," U. S. Government Printing Office, Washington, D.C., 1943, p. 884.
75. "Threshold Limit Values for 1959," *A. M. A. Arch. Ind. Health 20*, 266 (1959).
76. Silverman, L., "Control of Neighborhood Contamination Near Beryllium-Using Plants," *A.M.A. Arch. Ind. Health*, 19 , 254 (1959).
77. Anderson, D. M., "Effects of Aerosols in the Community Atmosphere," presented at the Conference on Solids Separation from Gaseous and Liquid Industrial Wastes, sponsored by Mid-Atlantic States Section APCA and N. J. Sewage and Industrial Wastes Association Industrial Wastes Committee, Atlantic City, New Jersey, March 10, 1959.
78. Manos, N. E., "Comparative Mortality Among Metropolitan Areas of the United States, 1949-51, 102 Causes of Death," Public Health Service Publication No. 562, U. S. Government Printing Office, Washington, D.C., 1957.
79. Pennsylvania Statistical Abstract, 1958, Tables prepared by the Department of Internal Affairs.
80. Clark, W. K., Smith, A. L., and [illegible] A. E., "Five-year Mortality Study, 1946 through 1950, in the Commonwealth of Pennsylvania," Department of Health, Commonwealth of Pennsylvania, Harrisburg.
81. Pennsylvania Department of Health, Division of Cancer Control, "Tumor Clinic Secretary's Handbook."
82. Haenszel, W. and Shimkin, M. B., "Smoking Patterns and Epidemiology of Lung Cancer in the United States; Are They Compatible?", *J. National Cancer Institute*, 16, 1417 (1956).
83. Thompson, D. J., "Mortality, 1948-1957, and Morbidity, 1957 among persons residing in Donora, Pennsylvania, during the Smog episode of October, 1948," Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania.
84. Personal Correspondence with U. S. Weather Bureau, Pittsburgh Office re: "Records of Smoke Observations in Pittsburgh, 1945-1957."
85. "Industrial Ventilation, A Manual of Recommended Practice," American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation, Lansing, Michigan, 1954, p. 11–18.
86. Kennedy, H. W., "Levels of Responsibility for the Administration of Air-Pollution-Control Programs," Proc. National Conference on Air Pollution, pp. 389-400, Public Health Service Publication No. 654, U. S. Government Printing Office, Washington, D.C., 1959.
87. "Report of Budget and Personnel for the Air Pollution Control Section," Philadelphia Department of Public Health, Philadelphia, Pennsylvania, February, 1957.
88. Unpublished material, Files of Air Pollution Control Section, Philadelphia Department of Public Health, Philadelphia, Pennsylvania.
89. Personnel Communication, Lee Schreibeis, Jr., Acting Chief, Bureau of Air Pollution Control, Allegheny County Health Department, Pittsburgh, Pennsylvania, August 17, 1959.
90. Personal Communication, Thomas Ford, Chief, Environmental Develop-

ment Section, Pennsylvania Department of Health, Harrisburg, Pennsylvania, November, 1959.

91. "Zoning Ordinance Rank," Bureau of Community Development, Commonwealth of Pennsylvania, Department of Commerce, Harrisburg, Pennsylvania, March 20, 1959.

92. Meetham, A. R., "Atmospheric Pollution—Its Origin and Prevention," Permagon Press, London, 1956.

93. Crumley, P. H. and Fletcher, A. W., "The Emission of Sulfur Gases from a Domestic Solid Fuel Appliance," J. Inst. Fuel (London), 30, 608 (1957).

94. "Committee on Air Pollution, Interim Report," Cmd. 9011, Her Majesty's Stationery Office, London, 1953.

95. Yeau, J. S. and Schnidman, L., "Flue Products of Industrial Fueld," Ind. Eng. Chem., 28, 999 (1936).

96. Orning, A. A., "Air Pollutants from Coal-Fired Electric Power Plants," presented at National Conference on Air Pollution, Washington, D.C., November 19, 1958.

97. Myers, J. W., et al., "Calculation of Theoretical Flame Temperatures in Furnaces" Trans. Amer. Soc. Mech. Engrs., 80, 202 (1958).

98. Evans, R. and Davenport, J., "Analysis of Combustion in Flue Gas," Ind. Eng. Chem. (Anal. Ed.), 7, 174 (1935).

99. Committee on Chemical Utilization of Coal, National Research Council, "Chemistry of Coal Utilization," John Wiley & Sons, Inc., New York, 1945, p. 1075.

100. Swengel, F. M., "Correlation of Data Concerning Spreader Stokers and Fly Ash," *Plant*, 6 (4), 46, October, 1952.

101. Kaiser, E. R., "Factors Affecting Dust Emission from Boiler Furnaces," Proc. Air Pollution Smoke Prev. Assoc. Amer., 44th Ann. Conv., 1951, pp. 65-74.

102. Marks, C. H. and Kaiser, E. R., "Reducing Flue-Dust Emission from Small Industrial Boiler Plants," Bituminous Coal Research, Inc., Pittsburgh, Aug. 1953.

103. Miller, C. E., "What Can the Small Plant Do About Fly Ash," Bituminous Coal Research, Inc., Pittsburgh, April, 1949.

104. Boer, E. J. and Porterfield, C. W., "Dust Emissions from Small Spreader-Stoker-Fired Boilers," presented to Amer. Soc. Mech. Engrs. Columbus, Ohio, April, 1953.

105. Holton, W. C., and Engdahl, R. B., "Methods of Reducing Dust Emissions from a Spreader-Stoker-Fired Boiler Furnace," *Trans. Amer. Soc. Mech. Engrs.*, 74, 207 (1952).

106. Cave, G. A., "Dusts and Smokes in Flue Gases," *Brit. Coal Utiliz. Res. Assoc. Mo. Bul.*, *10*, 61 (1946).

107. Committee of Investigation, Chicago Association of Commerce, "Smoke Abatement and Electrification of Railway Terminals in Chicago," Rand McNally and Co., Chicago, 1915, p. 1143.

108. ibid., p. 153-163.

109. Anon., "Where Much of the Responsibility Rests for Poor Heating and Air Pollution," *Coal-Heat*, 51 (4), 8, April 1947.

110. Lammers, H. B., "What a Survey of Heating and Power Plants will Disclose in Most Cities," *Coal-Heat*, 51 (6), 8, June 1947.

111. Anon., "Recommendations for the Abatement of Smoke and Atmospheric Pollution," *Coal-Heat*, 52, (5), 28, November 1947.

112. Kressinger, H., Augustine, C. E. and Katz, S. H., "Low-Rate Combustion in Fuel Beds of Hand-Fired Furnaces," U. S. Bureau of Mines Tech. Paper 139, Pittsburgh, 1918.

113. Landers, W. S. and Parry, V. F., "Domestic Storage of Subbituminous Lump Coal and Its Performance in a Hand-Fired Furnace," U. S. Bureau of Mines Report of Investigation 3759, Pittsburgh, June 1949.

114. Yancey, H. F. et at., "Burning Washington Coals on Different Types of Domestic Stokers in the Same Hot-Water Boiler, Comparison with Hand and Oil Firing," U. S. Bureau of Mines Bull. 475, Washington, 1949.

115. Monkhouse, A. C., "Coal Smoke—Its Nature and Prevention," *Chem. Ind.*, 68, 1129 (1951).

116. Cleghorn, M. P. and Helfinstine, R. J., "Use of Iowa Coals in Domestic Stokers," Iowa Eng. Exp. Stat. Bull, 144, Iowa State College, Ames, Iowa, 1939.

117. Meetham, A. R., "Natural Removal of Air Pollution from the Atmosphere," *Quart. J. Roy. Met. Soc.*, 76, 359 (1950).

118. "The Smog Problem in Los Angeles County," Stanford Research Institute, Menlo Park, California, 1954.

119. Magill, P. L. and Benoliel, R. W., "Air Pollution in Los Angeles County, Contribution of Combustion Products," *Ind. Eng. Chem.*, 44, 1347 (1952).

120. Faith, W. L., "Combustion and Smog," Report No. 2, So. Cal. Air Poll. Found., Los Angeles, September 1954.

121. Hall, E. L., "Products of Combustion of Gaseous Fuels," Proc. 2nd, Nat'l. Air Poll. Symp., Pasadena, Cal., May 1952, p. 84.

122. Tebbens, B. D., Thomas, J. F. and Meisuge, M., "Hydrocarbon Synthesis in Combustion," *Arch. Ind. Health*, 13, 567 (1956).

123. Connolly, T. J. and Nobe, K., "The Formation of Oxides of Nitrogen in Gas-Fired Heaters," 1st Report of Air Poll. Studies, Report 55-27, Univ. Cal. in Los Angeles, July 1955.

124. Lunde, K. E., "Investigation of Air Pollution in the Vicinity of Portland, Oregon," Stanford Res. Inst. Proj. No. 5-1674, Menlo Park, Cal., October, 1956.

125. Churchill, H. V., Rowley, R. J. and Martin, L. N., "Fluorine Content of Certain Vegetation in a Western Pennsylvania Area," *Anal. Chem.*, 20, 69 (1948).

126. "Technical and Administrative Report on Air Pollution Control in Los Angeles County," Los Angeles County Air Pollution Control District Annual Report, 1949-1950.

127. Magill, P. L. and Hutchison, D. H., and Stormes, J. M., "Hydrocarbon Constituents of Automobile Exhaust Gases," Proc. 2nd Nat'l Air Poll. Symp., Los Angeles, 1952, pp. 71-83.

128. "Second Technical and Administrative Report on Air Pollution Control in Los Angeles County," Los Angeles County Air Poll. Control Dist., 1950-1951, p. 37.

129. Hirschler, D. A., et al., "Particulate Lead Compounds in Automobile Exhaust Gas," *Ind. Eng. Chem.*, 49, 1131 (1957).

130. Doyle, G. J., "The Formation of Aerosols by Irradiation of Dilute Auto Exhaust," *JAPCA*, 8 (1), 23, May 1958.

131. Silverman, L., "Experimental Test Methods," Section 12, "Air Pollution Handbook," Magill, P. L., et al., eds., McGraw-Hill Book Co., Inc., New York, 1956, pp. 13-16.

132. Faith, W. L., op. cit., Tables 18 and 19, pp. 46, 47.

133. Rounds, F. G. et al., "Some Effects of Engine-Fuel Variables on Exhaust Gas Hydrocarbon Content," *JAPCA*, 5 (2), 109, August 1955.

134. Elliot, M. A., "The Composition of Exhaust Gases from Diesel, Gasoline and Propane Powered Motor Coaches," *JAPCA*, 5 (2), 103, August 1955.

135. Faith, W. L. et al. "First Technical Progress Report." Air Pollution Foundation, Los Angeles, Calif., March 1955.

136. Chass, R. L. and Rose, A. H. Jr. "Discharge From Municipal Incinerators." *Air Repair*, 3, 119-123 (1953).