From the Director of Health and Safety
Lead Industries Association, Inc.
292 Madison Ave.
New York 17, N. Y.

Look Ahead with Lead

September 2, 1965

LEAD HYGIENE AND SAFETY BULLETIN
No. 164

To All Members of the Lead Industries Association, Inc.:

We are attaching for you a copy of the first published report on the survey made by the United States Public Health Service and entitled "Survey of Lead in the Atmosphere of Three Urban Communities; A Summary." This survey is the most extensive ever conducted anywhere of potential lead exposure in air. The results of this survey indicate that there is no lead hazard at the present time as far as the atmosphere is concerned. The medical studies mentioned in the report were most complete and show that the United States population is not absorbing excessive or appreciable amounts of lead.

We believe you will be interested in reading this entire report, and hope you will be able to make good use of it.

Very truly yours,

Don O. Fowler

Don O. Fowler

DOF:sw
attachment

Survey of Lead in the Atmosphere of Three Urban Communities: A Summary

J. H. LUDWIG, Sc.D., D. R. DIGGS, Ph.D., H. E. HESSELBERG, and J. A. MAGA

Reprinted from AMERICAN INDUSTRIAL HYGIENE ASSOCIATION JOURNAL
Volume 26, May-June, 1965

Survey of Lead in the Atmosphere of Three Urban Communities: A Summary

J. H. LUDWIG, Sc.D., D. R. DIGGS, Ph.D.,* H. E. HESSELBERG,† and J. A. MAGA‡

U. S. Public Health Service, Division of Air Pollution, Cincinnati, Ohio

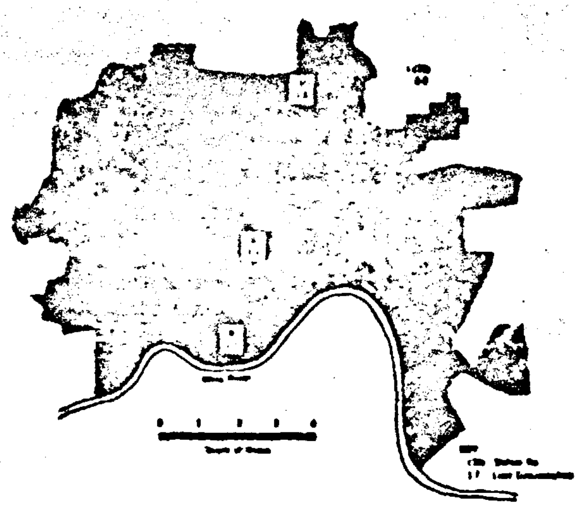
A joint study of the concentrations of lead in the atmospheres of three cities was conducted during the period June 1961 through May 1962. The annual average concentrations at various locations ranged in Cincinnati from 1 to 2 $\mu g/m^3$, in Philadelphia from 1 to 3 $\mu g/m^3$, and in Los Angeles from 2 to 3 $\mu g/m^3$, with over-all averages respectively of 1.4, 1.6, and 2.5 $\mu g/m^3$. In heavy traffic, concentrations averaged from 14 to 44 $\mu g/m^3$ in various locations. Blood and urine samples analyzed for lead were within the "normal" limits, except for a few persons with occupational exposures.

Introduction

On March 30, 1959, a report[1] was submitted to the Surgeon General of the Public Health Service on the public health aspects of increasing the tetraethyl lead content in motor fuel. The report concluded that data then available did not indicate that the recommended change in the maximum permissible tetraethyl lead content of gasoline from 3 to 4 milliliters per gallon would significantly increase the hazard to public health from air pollution. In submitting the report, the committee recommended, however, that additional studies be conducted to provide more definitive data on levels and trends of atmospheric lead contamination in selected urban areas and of the body burden of lead of selected population groups. These studies, to be conducted jointly by the Public Health Service, the manufacturers of lead antiknock additives, the petroleum industry, and other appropriate organizations, would, if they brought to light new data of significance, serve as the basis for reconsidering the recommendation of the committee by the Surgeon General. This paper is a summary of studies conducted principally in three American cities to carry out the mandate cited above. A complete report[2] of these studies is available for those who wish to examine the data in greater depth than that provided herein.

A discussion of the methods used in the investigations was presented in May 1962.[3] As this information is available for detailed review, only an orientation to the study is presented in this paper. The program was carried out under the over-all direction of a working group composed of members from the Public Health Service, California State Department of Public Health, American Petroleum Institute, Automobile Manufacturers Association, E. I. duPont de Nemours and Company, Ethyl Corporation, and Kettering Laboratory of the University of Cincinnati. The studies consisted principally of continuous air sampling over the one-year period, June 1961 through May 1962, at a number of locations in Cincinnati, Los Angeles, and Philadelphia, and the gathering of blood and urine samples from selected population groups in these cities. Approximately 3000 samples of lead-bearing particulate material from the

Presented at the [illegible] Annual Meeting of the American Industrial Hygiene Association, Houston, Texas, May 7, 1965.
*E. I. duPont de Nemours & Co., Wilmington, Delaware.
†Ethyl Corporation, Ferndale, Michigan.
‡California State Department of Public Health, Berkeley, California.



Site No.	Classification	Average Annual Concentration, μg/m³	Location
10*	Commercial	1.7	Cincinnati Main Library
11*	Residential	1.1	Kettering Laboratory
12*	Industrial	1.8	Vine and Seymour Fire Station
13*	Rural	0.9	French Park

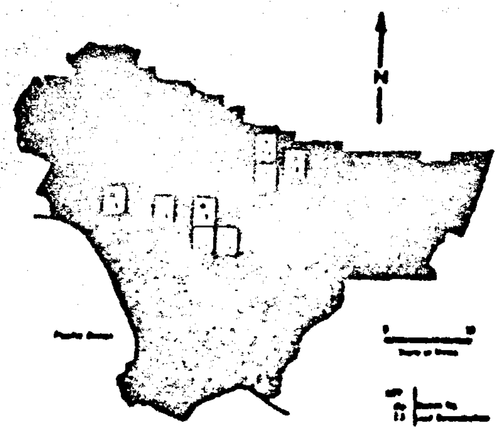
*Equipped with sequential tape sampler.

FIGURE 1. Annual average concentrations of lead in the atmosphere at sampling sites in the Cincinnati area.

atmosphere were obtained at a total of 20 sites in the three cities. The concentration of lead in the blood of approximately 2300 individuals was determined, as was that in the urine of approximately 1700 males within the same groups. In addition to these major activities, special studies were undertaken to determine the concentrations of particulate lead in the atmosphere along streets with heavy traffic and in a vehicular tunnel, and preliminary investigations were made of the concentrations of organic lead in the atmosphere.

Purpose

Although the impetus for the cooperative study stemmed from the use of lead antiknock additives in motor fuels, the goal of the project was to determine the amounts of lead in the atmosphere and in the blood and urine of humans as derived from all community sources. No attempt was made to pinpoint the sources of lead that contributed to the over-all ambient levels of the communities studied. The specific purposes of the program were to (1) establish baselines for the lead content of the atmosphere in urban areas, and of the blood and urine of selected population groups; (2) ascertain whether differences exist in levels of lead in the blood and urine of groups of individuals exposed to different amounts of lead in a community atmosphere;



Site No.	Classification	Average Annual Concentration, µg/m³	Location
1*	Commercial	2.9	Downtown Los Angeles - County Air Pollution Control District
2*	Commercial	3.0	West Los Angeles - County Air Pollution Control District
3*	Rural	2.0	Arcadia - County Arboretum
4	Residential	2.4	Pasadena - County Air Pollution Control District
5	Residential	2.1	Pasadena - California Institute of Technology
6	Residential	1.5	Inglewood - University of California at Los Angeles
7*	Industrial	3.3	Vernon - Vernon City Health Dept.
8	Commercial	4.9	Downtown Los Angeles - Los Angeles City Health Dept.

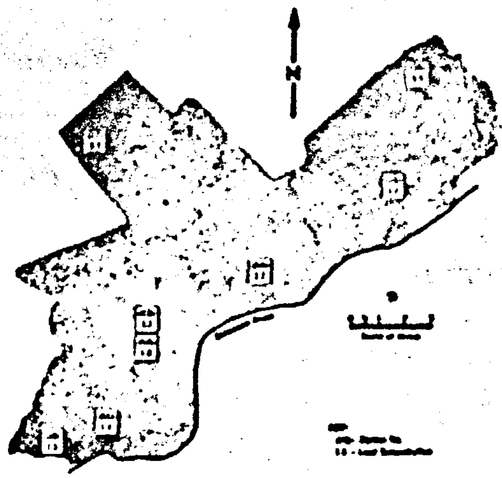
*Equipped with sequential tape sampler.

FIGURE 2. Annual average concentrations of lead in the atmosphere at sampling sites in the Los Angeles area.

and (3) obtain data that would permit review of the potentially harmful effects of existing lead concentration in the atmosphere on the general population or segments of the population.

Lead in Environment

Lead is contributed to the environment through both natural and man-made processes. The use of lead-containing additives in motor fuels results in the discharge to the atmosphere of both inorganic particulate and organic lead compounds. Lead enters the atmosphere in the flyash resulting from the combustion of coal. It is used in practically every type of industry to the extent of about one million tons per year, of which a portion may escape to the atmosphere as fume, dust, or organic vapors from industrial plants engaged in processing lead-containing raw materials, e.g., storage battery manufacture, nonferrous foundries, etc., lead finds its way to the environment through the use of pig-



Site No.	Classification	Average Annual Concentration, $\mu g/m^3$	Location
10*	Commercial	[illegible]	International Airport, WFPB
11*	Mixed	1.6	U.S. Naval Hospital
12*	Commercial	1.8	Philadelphia City Health Dept.
13*	Commercial	[illegible]	19th and Market
14*	Industrial	1.2	Air Pollution Control Laboratory
15*	Residential	1.1	Pennypack Home Owners Assn.
16*	Rural	0.9	Private Residence
17	Rural	[illegible]	Roo and Decatur Water Treatment Plant

*Equipped with sequential tape sampler.

FIGURE 1. Annual average concentrations of lead in the atmosphere at sampling sites in the Philadelphia area.

ments, insecticides, and other manufactured materials; lead is a natural constituent of soils. The chain of events by which lead from these various environmental sources reaches the human body is in many cases quite devious.

Sources of Lead in Man

In considering the effect of lead in the atmosphere on the lead content of the blood and urine of humans, it is imperative that the subject be reviewed from the context of the total intake of lead into the body. Lead is taken into the human body from a number of sources in the environment. It is ingested in various amounts in food depending on the amount and variety consumed and in water depending on the source of supply; it is inhaled during normal respiration or in the smoke of cigarettes. In addition, those engaged in occupations involving the manufacture, processing, or use of lead-containing materials are subject to intake of lead through exposure during working hours. No attempt was made in the studies reported herein to trace specific sources of pollution and the multiple routes by which these sources contribute to the body burden of lead. For the purpose of examining the data reported in the present study, it is noted that investigations of large numbers of persons who have not been subject to discoverable exposures to lead in industry or under other unusual conditions, indicate a normal upper limit of 0.06 milligrams of lead per 100 grams of blood. The corresponding value for the lead content in the urine is not so precisely defined. For a much more complete discussion of this subject, reference is made to the complete report,[4] or to the general literature in this field.

Atmospheric Sampling at Fixed Stations

The selection of cities in which to conduct studies involved a number of factors. It was believed desirable to include cities in which the lead levels appeared to be among the highest in the country and, therefore, the exposure of the population from these sources would be greatest. A range of geographical and climatological factors was also desired. Because of the extensive nature of both the atmospheric and medical studies envisioned at each location in comparison with the available budget, the choice of locations was limited to three cities — Cincinnati, Los Angeles, and Philadelphia. Fixed sampling stations were established in each of the cities: four in Cincinnati and eight each in Los Angeles and Philadelphia. The sites selected were representative of four major types of areas — industrial, commercial, residential, and rural. One station in each city was located at the site of the National Air Sampling Network. In addition, the stations were located, insofar as possible, within the same general areas from which subjects were selected for the medical phase of the study. Site locations are indicated on Figures 1, 2, and 3.

All sites were equipped with similar sampling equipment consisting of a filter holder containing a 4½-inch-diameter membrane filter (Type WS), a vane-type pump and motor capable of supplying a free flow of 5.9 cfm, and an auxiliary orifice-type metering device for determining initial and final flows (Figure 4). In addition, at certain of the sites, an AISI sampler utilizing Whatman No. 4 tapes was installed to determine diurnal variations. Sampling equipment housed in the special shelter constructed for the purpose is shown in Figure 5. Samples were collected continuously for the duration of the study on the membrane filters on

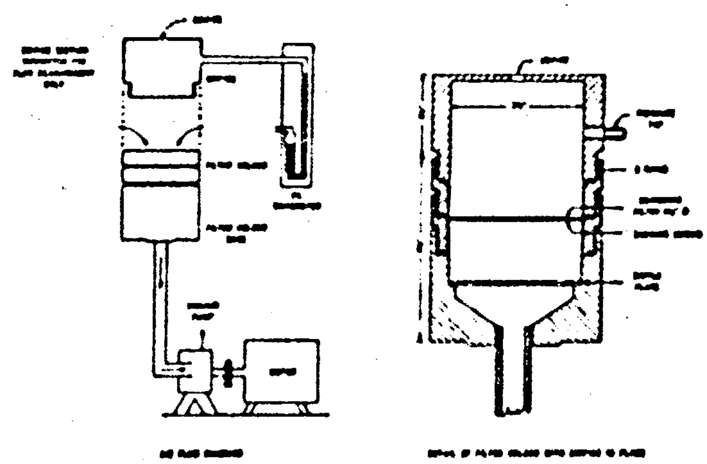


FIGURE 4. Diagram of atmospheric lead sampling equipment.

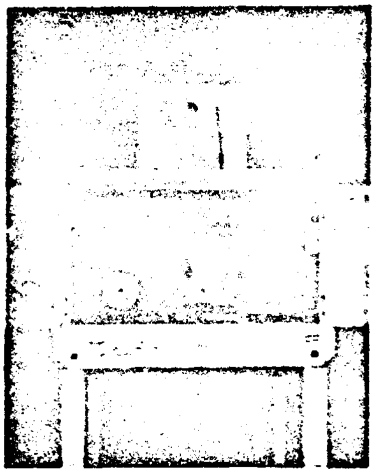


FIGURE 5. Aerometric sampling equipment in specially designed shelter

cycles of 72, 48, or 24 hours at a nominal flow rate of 4 cfm. The time cycle was chosen to accommodate both weekday and weekend sampling. In those instances where the plugging of the filter resulted in a substantial decrease in flow, filters were changed as often as once per day so as to maintain a final flow of at least 3 cfm. Filter plugging, to the degree that required a 24-hour sampling period, occurred only in Los Angeles, and was accentuated during periods of photochemical air pollution.

After the samples were collected in the field they were sent to a "clearing house" operated by the Public Health Service in Cincinnati for determination of the weight of total particulates. The filters were then cut into 10 equal sectors, five of which were returned to the originating laboratory for determination of lead content by analysis of one or more of the sectors or "wedges." The remaining wedges were retained by the clearing house for possible future studies and for interlaboratory quality control comparisons. The Whatman No. 4 sequential tapes were processed by the participating laboratories to provide six 4-hour or twelve 2-hour samples per day on a seasonal basis (December through February, March through May, June through August, and September through November).

Each of the participating laboratories performed the chemical analyses of the samples from a particular city, *i.e.*, Los Angeles samples were analyzed by the California State Department of Public Health Laboratory, Cincinnati samples by the Kettering Laboratory, and Philadelphia samples by the Public Health Service Laboratory. All laboratories used the dithizone method of analysis, modified slightly by each laboratory to suit its experience.

To establish the extent of the variability of analyses within and between laboratories, the clearing house established a program of interlaboratory comparisons involving synthetic samples, sections of special membrane filters containing atmospheric particulate, and about 5% of all atmospheric samples collected during the study in the three cities. The differences in results from the three laboratories with the synthetic samples were not statistically significant. In analysis of membrane filters containing atmospheric particulate, however, the agreement among results was not as satisfactory. Although concerted attempts were made to determine the reasons for these differences and thus completely to correct the situation, efforts were not entirely successful. The reasons for the final differences were not determined, but may arise from a lack of discrimination of the method in analyzing the complex particulate sample as compared to a soluble, essentially pure lead compound in the synthetic sample.

A summary of results of analysis of the "5% sample" is shown in Table I. This

TABLE I
Interlaboratory Comparison of Samples

Month	Average percent difference from the mean		
	Laboratory		
	California	PHS	Kettering
June [illegible]	− [illegible]	+ 10	− [illegible]
July	− [illegible]	+ 9	− 8
September	− 10	+ 17	− [illegible]
October	− [illegible]	+ 17	+ [illegible]
December	− 10	+ 7	+ 8
February [illegible]	− [illegible]	+ 1	0 [illegible]
April	− [illegible]	[illegible]	+ [illegible]
All months	− [illegible]	+ [illegible]	[illegible]

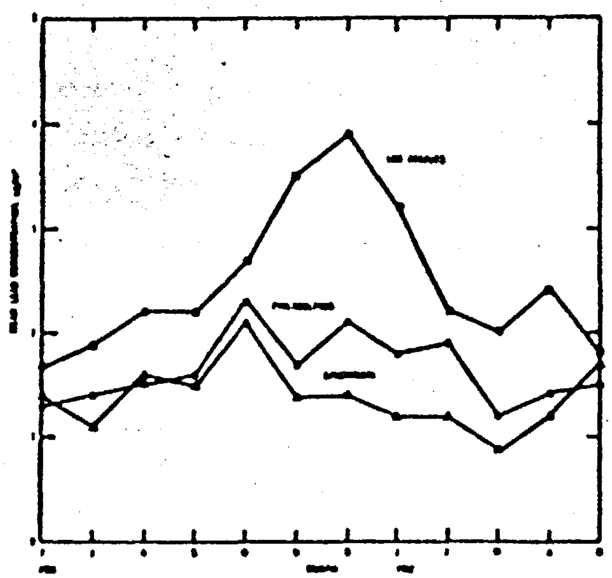


FIGURE 6. Monthly mean concentrations of lead in the atmospheres of Cincinnati, Los Angeles and Philadelphia - all sites - June 1961 through May 1962.

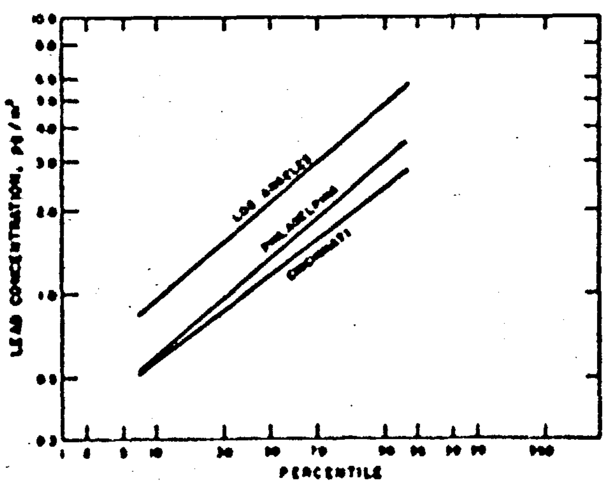


FIGURE 7. Frequency distribution of concentrations of lead in the atmospheres of Cincinnati, Los Angeles and Philadelphia June 1961 through May 1962.

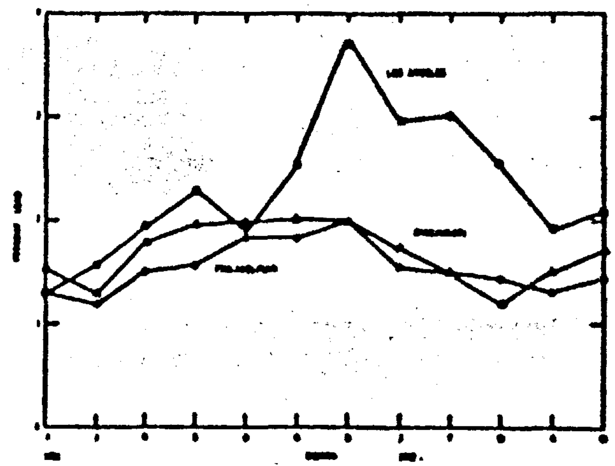


FIGURE 8. Percentage of lead in samples of particulates from the atmosphere of Cincinnati, Los Angeles and Philadelphia—all sites—June 1961 through May 1962

sample involved 186 filters. One sector of each filter was analyzed by each of two laboratories, and two sectors were analyzed by the originating laboratory, the first at the time of the original analysis and the second for the inter-laboratory comparison check. Average values from the California laboratory were 9% below the over-all mean, those from the Public Health Service Laboratory were 9% above the over-all mean, and those from the Kettering Laboratory were the same as the over-all mean. Differences are statistically significant. Although these differences are not so large as to affect the comparability of the study results, they should nevertheless be kept in mind when the data from the various cities are assessed.

Data on Lead in the Atmosphere

No attempt is made to list in detail the data obtained during the study or to discuss all the evaluations that were made. Rather, an over-all summary of the ranges of values, illustrating the principal results of the study, are presented in Table II and in Figures 1 through 3 and 6 through 9.

The annual average concentrations of lead in the atmosphere are shown on the site location diagrams, Figures 1, 2, and 3. In Cincinnati the concentrations ranged from

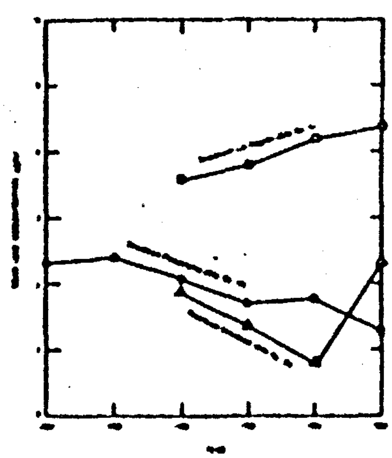


FIGURE 9. Annual mean concentration of lead in the atmosphere of Cincinnati, Los Angeles and Philadelphia 1957-1962

Table II
Concentrations of Lead in the Atmosphere
(in micrograms per cubic meter)

Item	Cincinnati	Los Angeles	Philadelphia
Annual Average (All Sites)	1.4	2.5	1.6
Annual Range (All Sites)	0.9 - 1.8	1.5 - 3.0	0.9 - 2.2
Seasonal Averages (All Sites)			
Summer	1.3	1.9	1.4
Fall	1.7	2.8	1.9
Winter	1.3	3.1	1.9
Spring	1.3	2.1	1.4
Minimum Seasonal (Single Site)	0.8 (Spring and Fall)	1.2 (Summer)	0.6 (Spring)
Maximum Seasonal (Single Site)	2.4 (Fall)	4.1 (Fall)	3.8 (Fall and Winter)
Minimum Monthly Average (All Sites)	0.9 (Mar.)	1.7 (Jun.)	1.2 (Mar.)
Maximum Monthly Average (All Sites)	2.1 (Oct.)	3.9 (Dec.)	2.3 (Oct.)
Minimum Monthly Average (Single Site)	0.5 (Mar.)	0.8 (Mar.)	0.5 (Mar.)
Maximum Monthly Average (Single Site)	3.1 (Oct.)	6.4 (Dec.)	4.4 (Oct.)
Minimum Individual Sample	0.2 (Mar.)	0.1 (June.)	0.1 (Mar.)
Maximum Individual Sample	6.4 (Oct.)	11.4 (Dec.)	7.6 (Oct.)

about 2 µg of lead/m³ of air in the downtown and industrial areas to about 1 µg/m³ in the outlying areas. The concentrations in corresponding areas in Philadelphia ranged from about 3 to 1 µg/m³, and in Los Angeles from 3 to 2 µg/m³. The more limited range in Los Angeles as compared to the other two cities is attributed to the absence of as well-defined suburban, downtown, and industrial areas in that city. The average concentration for all samples collected over the year was 1.4 µg/m³ in Cincinnati, 1.6 in Philadelphia, and 2.5 in Los Angeles (Table II).

Fall and winter were the seasons during which the highest concentrations of lead were found in all three cities. The average concentration of all samples during the fall season in Cincinnati was 30% greater than that obtained in the summer. In Los Angeles the average for all winter samples was 63% higher than for summer, and in Philadelphia the average for both the fall and winter seasons was 35% greater than for summer. The highest seasonal concentration at a single station was 2.4 µg/m³ in Cincinnati, 3.8 in Philadelphia, and 4.1 in Los Angeles (Table II).

The variation in the monthly mean concentration of lead for all sites is shown in Figure 6. The highest monthly concentration for all samples in each city was 2.1 µg/m³ in Cincinnati (October); 2.3 in Philadelphia (October); and 3.9 in Los Angeles (December). The highest monthly concentration for any one site was 3.1 µg/m³ in Cincinnati (October); 4.4 in Philadelphia (October); and 6.4 in Los Angeles (December) (Table II).

The highest concentration of lead found in any sample in each of the three cities was 6.4 µg/m³ in Cincinnati (October); 7.6 in Philadelphia (October); and 11.4 in Los Angeles (December) (Table II). The average of all weekday samples was 23% greater than the average for all weekend samples in Los Angeles. In Cincinnati and Philadelphia the values were similar for weekdays and weekends. At individual sites in all three cities, however, the monthly lead concentrations were often lower on weekdays than on weekends. The logarithmic probability frequency distribution of individual airborne lead samples is shown in Figure 7. Variation in values about the geometric mean for Los

Angeles and Philadelphia is quite similar, as indicated by the parallelism of the distribution. Not only is the average level in Cincinnati lower, but the variability of values is less.

The correlation between the amount of lead and the total particulate matter on filters for Cincinnati and Philadelphia sites was about 0.7 and that in Los Angeles 0.6. The average content of lead in all samples of particulate matter was 2.3% in Los Angeles, 1.7% in Cincinnati, and 1.5% in Philadelphia. Variation over the year is shown in Figure 8. The greatest seasonal difference occurred in Los Angeles, where the winter percentage was about 50% higher than the summer value. The factors responsible for this difference are not clear. An explanation is confounded by the fact that there was little change in the average quantities of suspended particulate matter between the summer and the fall-winter seasons. Figure 8 also shows that the percentage of lead in particulate matter was higher in the fall and winter than in the spring and summer in both Cincinnati and Philadelphia.

The annual average concentration of lead in the atmosphere was about 75% greater during the early morning daylight hours, when nocturnal inversions were most frequent and traffic heaviest, than in the early afternoon daylight hours, when solar heating was the greatest and traffic was at an intermediate level. This general pattern held throughout all seasons, with an early morning excess in the range of 25% to 120% as compared to the annual average of 75% cited above.

Since one of the sites in each of the three cities was the location of the National Air Sampling Network station of the Public Health Service, a comparison was made between the NASN values obtained from glass fiber filters and analyzed by emission spectrometry (the usual NASN technique) and the values obtained in the present study from analysis of millipore samples by the dithizone method. In Cincinnati and Philadelphia, the mean concentrations measured by the methods of this investigation were about 10% greater than those obtained by the NASN techniques; in Los Angeles they were 10% lower.

To obtain some idea of the trends in lead concentration in the three cities, unanalyzed portions of samples retained in NASN files were analyzed for lead by the dithizone method. The results are shown in Figure 9. There is no consistent trend for all three cities; values in Cincinnati and Philadelphia decreased, while those in Los Angeles increased. Since air pollutants may vary significantly in concentration from year to year because of meteorological and source factors, it is not possible to establish trends on the basis of the limited period for which data are available. Over-all, the data reveal little change over the period 1960-62.

Special samples were obtained in Cincinnati and Los Angeles by use of mobile samplers to determine lead concentrations when the test vehicles were traveling in traffic streams or parked at the curb at various locations. Also, a study of a vehicular tunnel was undertaken, and preliminary investigations were made of the concentrations of organic lead in the atmosphere along streets. In Los Angeles heavy traffic, mean atmospheric lead levels were about 25 $\mu g/m^3$; in Cincinnati the mean values were about 14 $\mu g/m^3$. Successively lower values were found at greater distances from the traffic: *e.g.*, values obtained at curbside along a busy residential street in Cincinnati averaged 4.6 $\mu g/m^3$, and those on a country road were about 3 $\mu g/m^3$. In the Sumner Tunnel study in Boston,[9] wherein 33,000 vehicles per day traversed the then two-way tunnel, outlet air from the ventilating system contained 44.5 $\mu g/m^3$ of lead, compared to 1.1 $\mu g/m^3$ in the inlet air. The contribution of lead per vehicle was computed to be 31 milligrams per mile traversed. The results of the determination of the concentrations of organic lead[7] in dense traffic on city streets were highly inconsistent because of the low levels of organic lead encountered. Several sampling techniques were utilized, and it was noted that the concentration of organic lead appeared to vary inversely with the volume of air sampled. Precise evaluation of levels of organic lead

TABLE III
Distribution of Persons in Various Occupational Groups According to Concentrations of Lead in Blood—Cincinnati

Lead in blood, mg/100g	Service station attendants [illegible]	Refinery handlers of gasoline [illegible]	Parking attendants [illegible]	Garage Mechanics [illegible]	Drivers of cars [illegible]	Drivers of cars [illegible]	Police: Traffic officers [illegible]	Police: Traffic officers [illegible]	Police: All police* [illegible]	Firemen [illegible]	Post Office Emp. [illegible]	City Health Dept. Emp. [illegible]
[illegible]												
[illegible]	1	2				1		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1	[illegible]	17	4	7	[illegible]	[illegible]	120	[illegible]	[illegible]
[illegible]	71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
[illegible]	14	[illegible]	[illegible]	73	[illegible]		1	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	2			[illegible]							[illegible]	
[illegible]			1	4				1	1		[illegible]	
Totals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14	17	[illegible]	[illegible]	[illegible]	140	[illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Std. Dev.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Includes traffic officers for [illegible].

in the atmosphere can be done only after development of improved methods of sampling and analysis. Although it was not possible to assign any degree of reliability to the specific values of organic lead determined, the results indicated that the organic lead constitutes less than 10% of the inorganic lead, and that in all probability it is considerably under this value.

Biological Studies

In conjunction with the atmospheric studies, investigations were conducted to determine the lead content of the blood and urine of selected population groups in the three cities. In general, the subjects were selected on the following bases:

(1) Most of the individuals had no known industrial exposure to lead. A few groups had some opportunity for occupational exposure.

(2) As wide an adult age range as possible was obtained.

(3) Within specific groups, an equal number of males and females were selected wherever possible.

(4) All subjects had lived in the survey area for at least five years.

The general procedure employed in Philadelphia and Los Angeles was to draw from each subject one sample of blood of 10 to 20 ml through a lead-free stainless steel needle into a lead-free Vacutainer. A single specimen of urine was taken from each male subject at the time the blood sample was drawn. After digestion of the blood and urine samples, a dithizone analysis was performed to determine the total lead content. (The procedure in Cincinnati differed somewhat in that duplicate samples of blood were obtained for analysis by spectrography in addition to the dithizone method.) A social and medical history, including smoking habits, was obtained from each individual.

Because there were some differences in the detailed procedures of the biological phase of the program in the three cities, each study is discussed individually.

Cincinnati

Investigations of the biological effects of general environmental exposure to lead in Cincinnati proceeded along somewhat different lines than those in the other cities, largely because of the availability of data obtained previously on groups of subjects in that city. It was desired to incorporate into this study the data from these investigations made in 1955-56, involving about 500 persons and to supplement the earlier data by choosing groups of persons who spent most of their

TABLE IV
Distribution of Persons in Various Occupational Groups According to Concentrations of Lead in Urine—Cincinnati

Lead in urine, mg/l	Service station attendants [illegible]	Refinery handlers of gasoline [illegible]	Parking attendants [illegible]	Garage Mechanics [illegible]	Drivers of cars [illegible]		Police: Traffic officers [illegible]		Police: All police [illegible]	Firemen [illegible]	Post-Office Emp. [illegible]	City Health Dept. Emp. [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	47	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]		
[illegible]				[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]			[illegible]				[illegible]	[illegible]			
Totals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	116	[illegible]	[illegible]	[illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Std. Dev.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

working hours regularly in the streets and on the sidewalks of the city close to motor traffic, *e.g.*, city police, postmen, firemen, and health department employees.

The principal analytical data on levels of lead in the blood are assembled in Table III according to the frequencies of occurrence of various ranges of the concentration of lead in the blood and urine. The outstanding example, on the high side, is that of the garage mechanics, who as a group are known to be subject to occupational exposure to lead other than emissions from vehicles. Following in order come parking attendants, drivers of cars, traffic officers, service station attendants, refinery handlers of gasoline, all policemen and firemen, post-office employees, and city health department employees. The differences between these groups reach statistical significance at several intervals from the lowest to the highest. In only seven persons did the level of lead in the blood exceed 0.060 mg per 100 gm.

The data on lead in the urine, shown in Table IV, exhibit a remarkably small degree of variability considering that nearly 1000 persons in divergent walks of life were included in the survey. The values ranged from 0.005 to 0.12 mg of lead per liter of urine.

To determine whether the concentration of lead in the atmosphere, if distributed in a sufficiently distinctive order of magnitude throughout well-defined areas of the city, would reveal its effects through the responses of the residents of these areas, the subjects were classified according to the four general areas in which their home addresses were situated. The results failed to demonstrate a valid or consistent relationship between these areas and the lead content of the blood or urine, indicating that the effect of residence was not sufficient to override other influences that contributed to the absorption of lead by the groups selected.

A similar analysis of the data relative to smoking habits revealed that the differences, while very small and statistically not significant (with one minor exception), exhibited a slight trend toward the occurrence of larger quantities of lead in the blood and urine of smokers than of non-smokers. A series of additional relationships, such as age of subjects, duration of their employment in their specific vocational category, and certain physical ailments, failed to develop correlations that indicate an association between these factors and the absorption of lead in the body. Although duration of employment was not a factor, the occupation itself was, as noted earlier.

TABLE V
Distribution of Persons in Various Occupational Groups According to Concentration of Lead in Blood—Los Angeles

Lead in blood, mg/100g	Aircraft employees Male	Aircraft employees Female	Los Angeles policemen	Pasadena City employees Male	Pasadena City employees Female
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]				
[illegible]	[illegible]				
Totals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Std. dev.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Los Angeles

The Los Angeles study was designed to compare the levels of lead in the blood and urine of groups exposed to different degrees of air pollution during the course of their normal daily activities. Subjects were selected on the basis of both living and working areas, time spent in commuting to and from work, and the types of traffic encountered. Employees from a major aircraft plant, municipal employees in Pasadena, and Los Angeles city police were selected to reflect the above considerations as follows: (1) individuals who lived and worked in the coastal portion of the basin, (2) those who worked in the coastal area and lived in inland areas, (3) those who were exposed to heavy pollution by motor vehicle exhaust because of their occupation, and (4) those who lived and worked in an inland area. In addition several groups of chronically ill individuals were studied.

TABLE VI
Distribution of Males in Various Occupational Groups According to Concentration of Lead in Urine—Los Angeles

Lead in urine, mg/l	Aircraft employees	Los Angeles policemen	Pasadena City employees
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]
Totals	[illegible]	[illegible]	[illegible]
Mean	[illegible]	[illegible]	[illegible]
Std. dev.	[illegible]	[illegible]	[illegible]

Data on lead levels in the blood and urine are shown in Tables V and VI. The differences in the means of the various groups are small and are not statistically significant; only in four individuals did the lead level in the blood exceed 0.060 mg per 100 gm. The highest mean levels in both urine and blood occurred in the police group. The highest values of lead in the blood of females in both groups are lower than the comparable values for the males.

When the basic groups were subdivided in terms of their residence in the coastal, central, or inland areas, no significant differences in lead levels were observed. Differences between smokers and non-smokers were small, but in most instances levels in smokers of cigarettes were somewhat higher than in non-smokers. Analyses to reflect commuting time indicated no progression of values with commuting time in any employment group. Examination of the data for the chronically ill subjects gave no suggestion that illnesses of the type studied (respiratory, kidney, and bone conditions) result in any special abnormalities in the metabolism of lead.

Philadelphia

The Philadelphia study, like that in Los Angeles, was designed to compare levels of lead in the blood and urine of groups exposed to different degrees of air pollution during their normal daily activities. Subjects were selected on the basis of both living and working areas from the following groups: 113 foot-traffic and patrol-car policemen who worked in the downtown area, 106 individuals who lived and worked within a 25-block radius of the Philadelphia City Hall, 50 individuals who lived in the Philadelphia suburbs and who commuted daily to work in downtown Philadelphia, and 81 individuals who normally spent their entire time in the suburbs. In addition, data were obtained from a group of 75 individuals known to have chronic diseases of the liver, kidney, bone, or lung.

Tables VII and VIII show the frequency distribution of the concentrations of lead in

TABLE VII
Distribution of Persons According to the Type of Community Exposure versus Concentration of Lead in Blood—Philadelphia

Lead in blood, mg/100g	Suburban Male	Suburban Female	Commuter Male	Commuter Female	Downtown Male	Downtown Female	Police
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]			[illegible]		[illegible]		[illegible]
Totals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Std. dev.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

the blood and urine of the various groups. As the area of residence and occupation shifts from the core of the city toward the suburbs, levels of lead in the blood tend consistently downward. Levels for the downtown police are slightly higher than those for the downtown males. None of the values for blood lead exceeded 0.049 mg per 100 gm.

The data were also examined with respect to other factors. When smokers were compared to non-smokers, the smokers presented slightly higher mean values than did non-smokers; among the downtown females, however, the values were the same for both groups. Lead levels in the blood showed no trend with age; lead levels in the urine decreased irregularly with age. Analyses of variance indicated that the relationship between the mean concentration of lead in blood and both smoking and composition of group were statistically significant. The relationship between lead in the blood and sex was of questionable significance. The results of the studies on the chronically ill group indicate a range of values that are neither remarkably high nor low.

Summary

In the combined data from the three cities, the concentrations of lead in the blood were obtained for a total of 2,342 individuals, 126 of whom were selected patients with various chronic diseases. In all, 11 persons were found to have concentrations of lead in the blood equivalent to or in excess of 0.060 mg per 100 gm of blood. These 11 persons were from groups that had an opportunity for industrial exposure to lead. An additional 30 individuals were found to have levels between 0.05 and 0.06 mg/100 gm. Again, most of these individuals were from groups with potential occupational exposure to lead. Lead levels in the urine were determined for 1,663 males in the above group. These values fell mainly within a fairly narrow range that was well within the limits defined presently as "normal". The highest

TABLE VIII
Distribution of Males According to the Type of Community Exposure versus Concentration of Lead in Urine—Philadelphia

Lead in urine, mg/l	Suburban	Commuter	Downtown	Police
0 -0.009	[illegible]	[illegible]	3	2
0.010-0.019	4	4	12	[illegible]
0.020-0.029	7	11	12	[illegible]
[illegible]	1	[illegible]	13	[illegible]
[illegible]	1	1	[illegible]	[illegible]
[illegible]	1	2	4	[illegible]
[illegible]		2	[illegible]	7
[illegible]		[illegible]	1	
[illegible]		1		
Totals	19	[illegible]	[illegible]	[illegible]
Mean	[illegible]	[illegible]	[illegible]	[illegible]
Std. dev.	0.014	0.010	[illegible]	0.014

Table IX
Summary of Concentrations of Lead in Blood of Selected Groups of Males*

Mean, mg/100g	No. of Subjects	Identity of Group
[illegible]	9	Suburban commuters, Philadelphia
[illegible]	10	Residents of rural California county
[illegible]	[illegible]	Commuter [illegible], Philadelphia
[illegible]	[illegible]	Suburban students, Philadelphia
[illegible]	[illegible]	Aircraft employees, Los Angeles
[illegible]	[illegible]	City employees, Pasadena
[illegible]	[illegible]	Commuter students, Philadelphia
[illegible]	[illegible]	City Health Dept. employees, Cincinnati
[illegible]	[illegible]	Policemen, Los Angeles
[illegible]	[illegible]	Live and work downtown, commuters, Philadelphia
[illegible]	[illegible]	Post-office employees, Cincinnati
[illegible]	[illegible]	Policemen, commuters, Philadelphia
[illegible]	[illegible]	Firemen, Cincinnati
[illegible]	[illegible]	All policemen, Cincinnati
[illegible]	[illegible]	Live and work downtown, students, Philadelphia
[illegible]	[illegible]	Police, students, Philadelphia
[illegible]	[illegible]	Refinery handlers of gasoline, Cincinnati [illegible]
[illegible]	[illegible]	Service station attendants, Cincinnati [illegible]
[illegible]	[illegible]	Traffic police, Cincinnati
[illegible]	[illegible]	Tunnel employees, Boston
[illegible]	[illegible]	Traffic police, Cincinnati [illegible]
[illegible]	[illegible]	Drivers of cars, Cincinnati
[illegible]	[illegible]	Drivers of cars, Cincinnati [illegible]
[illegible]	[illegible]	Parking lot attendants, Cincinnati [illegible]
[illegible]	[illegible]	Garage mechanics, Cincinnati [illegible]
	[illegible]	Total

*[illegible]

values were as follows: 11 equal to or in excess of 0.08 mg/liter and 23 equal to or in excess of 0.07 mg/liter.

Even though the lead levels for the entire group, with a few exceptions, are within the presently accepted normal range in humans, the data show some interesting gradations. Levels of lead in the blood tend to increase gradually as the place of residence and work varies from rural to central urban areas. A second gradation is related to increasing opportunity for occupational exposure to exhausts of automobiles. Females showed lower values of lead in their blood than comparable males. In nearly all instances smokers showed slightly higher lead levels than non-smokers. All of these variables—sex, smoking habits, and exposure to automobile exhaust—appear to be independent of each other.

In Table IX the male groups are arranged in order of the mean values of lead in the blood. There is a fourfold difference (0.009 to 0.038 mg of lead per 100 gm of blood) in these values, and there appears to be an orderly progression in values according to the most likely concentration of lead in the atmosphere to which these groups were exposed. For example, values are lowest for the suburban and rural groups, intermediate for downtown employees, and highest among those working with motor vehicles, such as drivers of cars and parking attendants. Although some of the groups, *e.g.*, notably garage mechanics, are exposed to lead occupationally, they are listed to show comparative levels of lead in the blood. The likelihood that the variability of the amounts of lead ingested with food and beverages accounts for some of the differences cannot be ignored. It is important to recognize that the differences in lead levels between the lowest and the highest of the groups, while relatively large, are well within the presently accepted range for humans and are not significant in terms of a threat of the occurrence of lead intoxication within the groups.

In general, the results of both the aerometric and biological phases of the investigation confirm past findings, which were based on more limited observations.

Acknowledgments

In the conduct of the studies in the three cities, the Working Group on Lead Contamination was assisted by a great number of individuals from all of the participating organizations. Representatives of the agencies responsible for the day-to-day operation of the project and the analysis of the data rendered invaluable service. The efforts of these individuals were essential to the completion of the program, and their contributions are gratefully acknowledged.

References

1. Advisory Committee on Tetraethyl Lead. *Public Health Aspects of Increasing Tetraethyl Lead Content in Motor Fuel*. Public Health Service Publication No. 712, Washington, D.C. (1959).
2. The Working Group on Lead Contamination. *Survey of Lead in the Atmosphere of Three Urban Communities*. Public Health Service Publication No. 999-AP-12. Cincinnati (Jan. 1965).
3. [illegible]
4. [illegible]