STUDY OF AIR AND POPULATION LEAD LEVELS IN THE UNITED STATES

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The concentration of lead in the ambient atmosphere was determined at 59 sampling sites in eight American cities during 12-month periods during 1968—71. Nineteen sampling sites had existed in 1961—62. The concentration of lead in the blood of specific well-defined populations living in proximity to air sampling stations was also determined. Higher blood lead levels were associated with urban, as opposed to suburban, residence, and with smoking, as opposed to non-smoking. There was no significant concordance between the ranking, by site, of mean air lead levels and that of mean blood lead levels prevalent in the sampled populations. This observation suggests that factors other than the atmospheric lead level are of relatively greater importance in determining the blood lead levels in population groups.

The »Seven-City Study«, conducted in the United States during the years 1968—72, was designed to accomplish a series of objectives related to levels of lead in the ambient atmosphere and the association between such air lead levels and the blood concentrations of lead in persons residing within specific sampling areas. To a major extent the »Seven-City Study« was patterned upon the »Three-City Study« conducted in 1961—62, which had measured air levels of lead in selected areas and blood concentrations of lead among certain occupational groups in the cities of

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Philadelphia, Cincinnati, and Los Angeles. That study had shown, among other things, that higher atmospheric lead levels were associated with areas of high vehicular density, the fall and winter months, and early morning peak traffic. The study of blood lead concentrations showed a tendency toward higher levels in groups of persons as they varied from rural to center-city locations in their places of residence and work. A number of factors appeared to be related to these observations: geographical region, tobacco smoking, and occupational exposure. There was also an evaluation of interlaboratory variation in the conduct of lead assays, since the required analyses were performed by several collaborating organizations.

It was a primary purpose of the earlier »Three-City Study« to establish a baseline for lead levels in the air and in selected population groups, against which comparisons could be made in a subsequent study, such as the one here reported. Changes which might have occurred over the 8- or 9-year interval between the studies could be attributed to vehicle density, lead content of fuels, fuel consumption, mechanical design and condition of vehicles, local climatology, and population practices or distributions.

The »Seven-City Study«, therefore, was organized primarily for the following purposes:

1) To determine whether or not a change in the concentration of airborne lead had occurred after an interval of 8 years at a series of reference locations designated in 1961—62.

2) To determine the ambient atmospheric levels of lead at selected additional sites in the cities studied in 1961—62 and in other communities.

3) To examine the extent to which levels of lead in the blood of selected population groups reflect exposure to lead at various levels in community atmospheres.

METHODS AND PROCEDURES

The program of aerometric and biological studies was conducted in eight regions reflecting a range of geographic and climatological characteristics. The selection of Cincinnati, Philadelphia, and Los Angeles was based on the fact that extensive sampling had been conducted in these areas during a 12-month period in 1961—62, and that comparisons could now be made between current observations and those obtained some 8—9 years earlier. Investigations of a similar nature were included in the more recent study in the additional areas of New York City, Metropolitan Washington (D. C.), Greater Chicago, Houston, and Los Alamos, New Mexico. New York was selected because of its high vehicle and population density and Washington because of its lack of industrialization. Chicago and Houston were added as examples of large »northern«

and »southern« cities, respectively. Los Alamos represented an area with a well defined population of over 15,000 persons with minimal exposure to atmospheric metals.

Aerometric sampling

To permit an accurate appraisal of changes which may have occurred since 1961—62 in atmospheric levels of lead, stations which existed in the study conducted at that time, with few exceptions, were duplicated in the current investigation. This procedure was followed primarily for comparison purposes; the suitability or epidemiological significance of these individual sites was not reconsidered. A comprehensive photographic record of the instrument installations in 1961—62 permitted accurate duplication of station position and orientation.

In the 5 regions where long-term sampling of this type had not been conducted previously, sites were selected on the basis of relevance to population exposure, accessibility, and the area to be covered. An attempt was made to show high degrees of contrast between high and low atmospheric lead levels. In communities in which population sampling was also to be conducted, emphasis was placed on selecting an instrument location which would reflect, insofar as possible, the usual human exposure in that general neighborhood.

It is essential to emphasize that all stations, although representing certain types of neighborhoods, elevations, and proximities to major roadways, were selected arbitrarily. Data from a specific city have meaning for that site only, and pooling or »averaging« for an entire city has limited validity. Alternative sites could have been selected to yield other »averages« for each city. Pooled data for a city may have validity in certain kinds of comparisons over a period of time for the specific sites included in the pool. These data, however, cannot be precisely compared with pools based upon other combinations of sites arbitrarily selected.

The location of sampling sites in 2 examples is shown in the following diagrams:

The equipment utilized in this study consisted, in essence, of a filter holder for 106-mm Millipore filters (Type WS), a vane pump and motor unit drawing a nominal free air volume of 5.9 cfm, and a cooling fan. The housing was constructed of plywood and is designed to permit necessary ventilation of the equipment while attenuating objectionable pump noise. Initial and final air flows through each filter were determined from orifice meter measurements, which permitted the computation of the volume of air which had passed through the filters.

Sampling units were operated over a 12-month period at each site. Filters were changed 3 times weekly at most locations, and were conditioned in a controlled atmosphere and weighed prior to use. Each exposed filter, upon return to the laboratory, was similarly conditioned and weighed prior to being divided into ten equal wedges suitable for analysis.

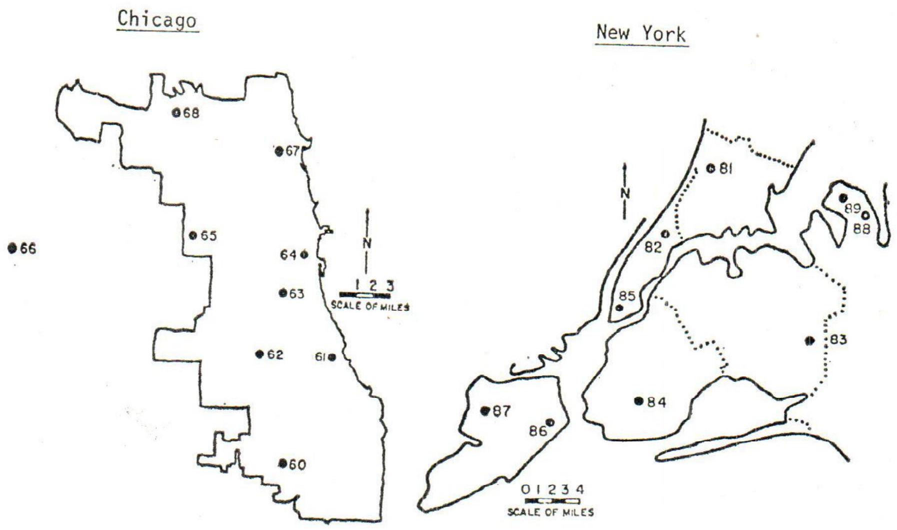

Fig. 1. *Location of sampling stations*

Lead contained in particulate matter on the filter wedges had been determined in 1961—62 by the dithizone colorimetric technique. Developments in atomic absorption spectrometry (AAS) since then indicated that greater efficiency in filter analysis might be achieved in the subsequent study with this method. Consequently this procedure was adopted for filter samples with special attention to an examination of the relationship between analytical results obtained by these two methods: dithizone and AAS. Since a primary purpose of the entire study was the determination of changes in air lead concentrations over a time interval, it was essential to assure that demonstrated differences were not due to variations in technique. The results of the comparison study did show a small but significant difference between the sampling techniques in Cincinnati (lower readings in AAS 1969); however no inter-method variation was found at the other two original cities, Philadelphia and Los Angeles. The small variation in Cincinnati does not alter the significance or interpretation of this study.

Biological studies

A principal objective of this investigation was an evaluation of the relationship between atmospheric lead levels and the concentrations of lead in the blood of persons exposed to the atmospheres in question. While a number of different population groups had been studied in attempts to establish this relationship, multiple uncontrolled variables associated with these groups have confused the appraisal of the actual exposure and the construction of the correct inference. In the absence of personal monitoring devices one cannot establish the total integrated exposure over months or years of police officers, garage mechanics, »drivers«, »commuters«, aircraft workers, or other similar groups. Occupational and wide-ranging geographical factors are not reflected in air sampling at fixed locations not clearly related to the population in question.

For these reasons particular attention was focused in this study on the definition of populations with a specific consistent relationship to known air levels of lead. The eleven population groups sampled in this study were derived from women volunteers living within prescribed regions surrounding an air sampling site. Women, in general, currently tend to spend a greater proportion of their time at home or in the neighborhood of their home than do men. Furthermore, women who are employed at a distance from their homes rarely work in lead-using trades. For inclusion in the study a continuous residence time of not less than 5 years within this area was required. The area was defined either by political community boundaries or by the circumference of a circle one mile or less in radius drawn about the reference station. Homogeneity of land use within each area was reasonably consistent. This study was concerned exclusively with absorption of ambient community atmospheric lead via the respiratory system and did not involve pediatric exposures nor exposures of men with a variety of possible occupational opportunities for additional lead adsorption. The extent to which blood lead levels in women reflect such levels in the general population was not examined.

An attempt was made to sample both »suburban« and »urban« populations in 3 of the metropolitan areas under study. In some areas this objective was confounded by the fact that highly mobile populations and rapidly changing neighborhoods made it unlikely that a group of acceptable volunteers could be recruited without extensive personal solicitation. In the same metropolitan area a comparison of »suburban« and »urban« populations would tend to minimize the influence of regional factors which might influence general biological lead levels. Climate and sources of food and water would tend to affect equally populations living in the same general metropolitan area, regardless of their being »urban« or »suburban«. Approximately 150—200 women who met the residence criteria participated at each location, of which there were 11 (Table 1).

Additionally husbands of 80 women participants in Los Alamos were sampled to see whether or not there is a male-female differential in the blood level of lead. It was possible to define the occupational exposures of these men, most of whom were employed by the Los Alamos Scientific Laboratory. The atmosphere at the Laboratory does not vary from that in the residential areas. Husband-wife pairs were considered to consume approximately the same food, although the quantity consumed by the husband will, of course, generally exceed that consumed by the wife.

Table 1
Population groups sampled

Community	Urban	N	Suburban	N
Philadelphia	Rittenhouse Square	137	Ardmore-Wynnewood	156
Cincinnati	—	—	Okeana	166
Los Angeles	Pasadena	209	—	—
Los Alamos	—	—	Los Alamos	204
Washington	Woodly-Cleveland Park	224	—	—
New York	Greenwich Village	140	Port Washington	203
Chicago	Bridgeport	148	Lombard	208
Houston	Nw. Houston	204	—	—

In the absence of occupational lead exposure and under these circumstances it was believed that the degree of difference in male and female blood lead levels could be determined.

The study also included examinations of several smaller populations including a small group in the Sierra Nevada with an atmospheric lead background close to zero, viz., 0.03 $\mu g/m^3$.

Persons participating in the study were interviewed with respect to occupation, hobbies, smoking habits, medical history, and sources of food and water. Data were entered on a worksheet for subsequent statistical analysis. Twenty ml of venous blood was obtained from each participant for lead assay by the dithizone technique.

Since lead levels in man reflect intakes from both the respiratory and gastrointestinal systems, it is not prudent to make quantitative inferences about absorption from the lungs with knowledge reflecting only total lead adsorption. Without standardized alimentary intakes of lead or knowledge of its level in each population, a situation may exist in which differences in blood lead levels may be incorrectly attributed to variability in atmospheric lead levels. It is also true that a *lack* of difference in mean blood lead levels between populations may be due to compensatory variations between sources of adsorption for those populations. In other words, high alimentary lead and low respiratory lead levels in one population may produce the same blood lead level which is observed in a population exposed to high atmospheric and low food lead levels.

In carefully controlled studies of lead metabolism, it has been possible to collect accurate duplicate diets of the experimental subjects, for whom alimentary lead intakes could then be determined. This approach did not lend itself to the study reported here, however, because of the cost of duplicate diets for large numbers of people and the difficulty in obtaining accurate duplicate diets for large numbers of people and the difficulty in obtaining accurate duplicates from inexperienced people. It was determined that information of approximately the same utility might be derived from measurement of lead excreted in the feces, which contain some 90—92% of lead ingested in the diet. Accordingly 20 volunteers in each region were recruited to participate in a ten-day excretory collection. Urine and feces were collected separately in low-lead plastic containers.

There are obviously differences between individuals in their choice of foods, but we believe that the sampling method gave a reliable index for the region. We further believe that the dietary habits of 20 people over the course of ten days are representative of the general habits of the parent population of 200 people. Obviously there are other limitations, however, such as extrapolating from ten days' intake to intakes over months or years.

Analyses of excreta for lead were conducted by the atomic adsorption technique; 10% of the samples were also analyzed by duplicate dithizone procedures. In the case of the fecal samples, which were received and weighed in plastic bags, the entire sample with the bag was ashed for assay. Lead content of control bags had been determined and found to be only several micrograms per bag.

OBSERVATIONS AND DISCUSSION

The concentration of lead in the ambient atmosphere was determined at 59 sites in eight communities (Table 2). The observed annual mean atmospheric concentrations of lead varied from 0.14 $\mu g/m^3$ (Los Alamos)

Table 2

Yearly means and confidence intervals of air Pb concentration for each station

Area	Population group	Station	Geometric mean $\mu g/m^3$	95% confidence limit $\mu g/m^3$
Cincinnati		30	1.92	(1.63, 2.27)
		31	1.45	(1.16, 1.83)
		32	2.13	(1.75, 2.60)
		33	0.85	(0.71, 1.01)
	Okeana	34	0.31	(0.24, 0.41)
	Okeana	35	0.33	(0.20, 0.40)
Philadelphia	Ardmore	19	1.28	(1.06, 1.55)
	Wynnewood	20	1.01	(0.86, 1.19)
		11	1.89	(1.63, 2.20)
		12	1.74	(1.52, 2.00)
		13	3.75	(3.30, 4.26)
		14	2.18	(1.90, 2.52)
		15	1.39	(1.19, 1.65)
		16	1.09	(0.90, 1.33)
		17	1.08	(0.92, 1.27)
	Rittenhouse Square	18	1.67	(1.42, 1.93)

Area	Population group	Station	Geometric mean $\mu g/m^3$	95% Confidence limit $\mu g/m^3$
Los Angeles		1	4.03	(3.40, 4.76)
		2	4.34	(3.58, 5.26)
		3	3.46	(2.96, 4.05)
	Pasadena	4	3.72	(3.20, 4.32)
	Pasadena	5	3.06	(2.62, 3.57)
		6	2.36	(1.92, 2.90)
		7	3.39	(2.62, 4.39)
		8	4.55	(3.71, 5.60)
Los Alamos		41	0.14	(0.11, 0.18)
		42	0.20	(0.16, 0.25)
Washington, D. C.		70	1.10	(0.95, 1.27)
		71	1.64 (7 mo.)	(1.36, 2.00)
		72	2.21	(1.91, 2.55)
		73	1.78	(1.53, 2.06)
	Woodley Park	74	1.19	(1.07, 1.32)
	Cleveland Park	75	1.13	(0.99, 1.28)
		76	2.34	(2.05, 2.67)
		77	1.08	(0.94, 1.24)
New York	Port Washington	88	1.14	(1.03, 1.27)
	Port Washington	89	1.10	(0.98, 1.24)
		81	1.76	(1.44, 2.15)
		82	2.04	(1.74, 2.38)
		83	1.73	(1.57, 1.90)
		84	1.71	(1.54, 1.89)
	Greenwich Village	85	2.08	(1.79, 2.43)
		86	1.34	(1.13, 1.58)
		87	1.22	(1.06, 1.39)
Chicago		60	1.30	(1.17, 1.45)
		61	1.35	(1.23, 1.49)
		62	1.53	(1.33, 1.76)
	Bridgeport	63	1.76	(1.60, 1.93)
		64	1.83	(1.67, 2.02)
		65	1.57	(1.39, 1.78)
		67	1.55	(1.37, 1.76)
		68	1.87	(1.51, 2.31)
	Lombard	66	1.18 (7 mo.)	(0.83, 1.68)
Houston		50	1.15	(0.92, 1.43)
		51	1.02	(0.86, 1.21)
		52	2.13	(1.83, 2.47)
		53	2.26	(1.87, 2.73)
		54	1.32	(1.16, 1.49)
		55	0.87	(0.73, 1.03)
	NW Houston	56	0.85	(0.75, 0.96)

Table 3

Annual means of monthly average concentrations of lead and particulate matter based on December 61 — November 62 and December 68 — November 69

Location	Station	Geometric Pb ($\mu g/m^3$) 61—62	Geometric Pb ($\mu g/m^3$) 68—69	% Change (4)/(3)	Confidence limits for % change		Geometric Pb ($\mu g/m^3$) 61—62	Geometric Pb ($\mu g/m^3$) 68—69
(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)
Los Angeles	1	2.51	4.03	+61**	37	90	121.68	79.35
	2	2.75	4.34	+58**	27	99	105.57	57.72
	3	2.63	3.46	+32**	12	57	112.67	86.77
	4*	2.40	3.72	+55**	36	97	107.71	80.20
	5*	2.04	3.06	+50**	24	80	104.16	79.91
	6	1.48	2.36	+59**	21	107	96.64	57.05
	7	2.17	3.39	+56**	39	76	138.11	83.42
	8	2.80	4.55	+63**	40	88	132.32	80.75
Philadelphia	11	1.39	1.89	+36**	17	56	121.54	97.14
	12	1.75	1.74	— 1	—16	19	117.07	82.00
	13	3.26	3.75	+15	— 2	34	145.07	123.81
	14	2.13	2.18	+ 2	—15	22	124.63	97.78
	15	1.10	1.39	+26**	2	54	83.62	60.29
	16	0.87	1.09	+25**	9	47	68.27	56.11
	17	0.86	1.08	+26**	6	48	78.92	55.97
	18*	—	1.67	—	—	—	—	79.79
	19*	—	1.28	—	—	—	—	64.03
	20*	—	1.01	—	—	—	—	53.84
Cincinnati	30	1.70	1.92	+13	— 5	35	98.14	68.80
	31	1.09	1.45	+33**	6	66	76.31	74.64
	32	1.70	2.13	+25**	7	47	94.12	75.87
	33	0.87	0.85	— 2	—26	28	53.76	56.80
	34*	—	0.31	—	—	—	—	46.07
	35*	—	0.33	—	—	—	—	45.10

* Blood sampled
** Significant at 5 % level

to 4.55 $\mu g/m^3$ (Downtown Los Angeles). At 19 of these sites a similar sampling program had been conducted during the »Thee-City Study« 8—9 years earlier. At 14 of these sites for which data were available for both periods, a higher value was found during the later study (Table 3). A careful examination of experimental methodology tended to exclude the possibility that this change was an artifact reflecting changes in technique. Recent assays of 1961—62 filter wedges from Los Angeles and Philadelphia validated the lead assay techniques used during the period 1968—71. Because of the observation that filter wedges from the 1961—62 Cincinnati study, when re-assayed in 1969, yielded results approximating 91% of those obtained in the earlier period, it is possible that increases in atmospheric lead levels at the re-established Cincinnati sites were greater than may be apparent. Consequently, increases in the current study can hardly be attributed to the lead assay technique. Air flow measurements have been based upon identical procedures during the two test periods. Insofar as can be determined, therefore, the sampling and assay procedures during the two periods are directly comparable. An example of month-to-month comparison between the two studies at typical Los Angeles sites is shown in Figure 2.

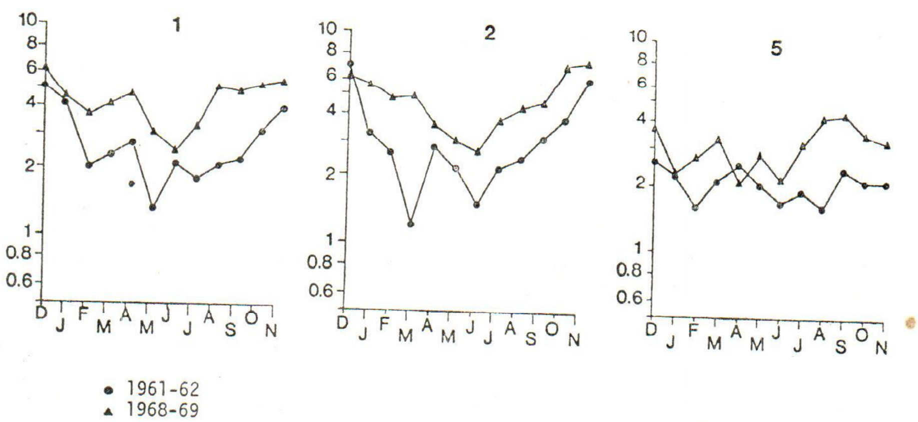

Fig. 2. *Atmospheric lead levels ($\mu g/m^3$) by month*

Mean blood lead values and their 95% confidence limits are presented in Table 4. The age distribution was not consistent for subjects at each area under consideration; however, the regression of lead on age was shown to be not significant in each location. Therefore no adjustment for age has been made in the analysis of data.

Table 4

Geometric means and confidence intervals of blood lead levels based on a single determination from each subject

Area	N	95% confidence limits (μg/100 g)	Geometric mean (μg/100 g)
Okeana	162	0.0157	(0.0150, 0.0165)
Ardmore	150	0.0180	(0.0171, 0.0190)
Rittenhouse	136	0.0205	(0.0196, 0.0215)
Pasadena	193	0.0175	(0.0169, 0.0182)
Los Alamos	191	0.0149	(0.0144, 0.0155)
Washington, D. C.	219	0.0192	(0.0186, 0.0198)
Pont Washington	198	0.0153	(0.0148, 0.0159)
Greenwich Village	140	0.0166	(0.0159, 0.0173)
Lombard	208	0.0139	(0.0135, 0.0144)
Bridgeport	147	0.0176	(0.0169, 0.0183)
Houston	191	0.0125	(0.0120, 0.0130)
All females	1935	0.0162	(0.0160, 0.0164)
Los Alamos (M)	80	0.0172	(0.0163, 0.0182)

The effect of smoking was shown to be clearly significant as shown in Table 5, the blood lead level of smokers exceeding that of non-smokers and previous smokers.

Table 5

Geometric means of blood lead levels by location and smoking status (μg/100 ml)

	Non-smokers	Previous smokers	Smokers
Okeana	0.0156	0.0139	0.0171
Ardmore	0.0180	0.0177	0.0181
Rittenhouse	0.0202	0.0200	0.0214
Pasadena	0.0172	0.0179	0.0183
Los Alamos (F)	0.0144	0.0154	0.0160
Washington D. C.	0.0181	0.0205	0.0201
Port Washington	0.0149	0.0150	0.0162
Greenwich Village	0.0158	0.0167	0.0173
Lombard	0.0136	0.0146	0.0146
Bridgeport	0.0167	0.0166	0.0191
Houston	0.0126	0.0120	0.0124
All females	0.0158 (1127)	0.0162 (304)	0.0173 (495)
Los Alamos (M)	0.0165	0.0168	0.0193

Comparison	E	
Smokers vs. Non-Smokers.	40.01**	Smokers > Non-Smokers
Smokers vs. Prev. Smokers	10.37**	Smokers > Prev. Smokers
Prev. Smokers vs. Non-Smokers	2.57	Prev. Smokers > Non-Smokers

** Significant at the 1% level.

The investigations of whether mean blood lead levels reflect degree of urbanization was carried out by applying a binomial test to the data from three metropolitan areas where an urban and suburban population had been sampled.

In both smoking categories the Philadelphia urban groups (»Rittenhouse«) were higher than the suburban (»Ardmore«); the Chicago urban groups (»Bridgeport«) were higher than the suburban (»Lombard«): and in New York the urban groups (»Greenwich Village«) were higher than the suburban (»Port Washington«). The probability of obtaining 6 relationships in this direction (urban > suburban) out of 6 comparisons is approximately equal to $1/2^6 = 1/64 = 0.015$, if one assumes either direction is to be equally likely. Consequently it was those from related suburban areas (at the 1.5% level), based on data from three paired locations in Philadelphia, New York, and Chicago.

In these cities in which both an urban and a suburban population were studied, the urban mean blood lead value was significantly higher than the suburban for 2 of 3 cases. In two of the three areas the blood lead level was higher in urban smokers and non-smokers than in the corresponding suburban populations, classified by smoking habits. The magnitude of the observed urban-suburban difference (for populations comparable in smoking habits) ranged from 0.9 μg/100 ml to 4.5 μg/100

Table 6

Air and blood lead concentrations (1968—71)
(all subjects)

Air rank	Area	Air (μg/m³)	Geometric means Blood (mg/100 ml)	Blood rank
1	Los Alamos	0.17	0.0149 (F)	3
2	Okeana	0.32	0.0157	5
3	Houston	0.85	0.0125	1
4	Port Washington	1.13	0.0153	4
5	Ardmore	1.15	0.0180	9
6	Lombard	1.18 (7 mo.)	0.0139	2
7	Washington, D. C.	1.19	0.0192	10
8	Rittenhouse	1.67	0.0205	11
9	Bridgeport	1.76	0.0176	8
10	Greenwich Village	2.08	0.0166	6
11	Pasadena	3.39	0.0175	7

Relationship Between Means of Air and Blood Lead (Females) Based on Pearson Product Moment Correlation Coefficient (r) and Kendall's Rank Correlation Coefficient (τ)

$r = 0.412$ (NS)
$\tau = 0.354$ (NS)

ml. Smoking and urban residence, therefore, contribute to higher blood lead levels, as opposed to non-smoking and suburban residence.

When one examines the correlation between air lead levels and blood lead levels of persons living in proximity to the air sampling site, the association is that shown in Figure 3. Neither the association nor the rank correlation is significant, i.e., on a national basis the blood level of lead is not determined by the ambient level of lead in the air. (Table 6). This observation suggests that factors other than the atmospheric lead level are of relatively greater importance in determining the blood lead concentrations in population groups. Presumably alimentary lead intake plays a significant role; however this was not thoroughly evaluated in the short-term metabolic study.

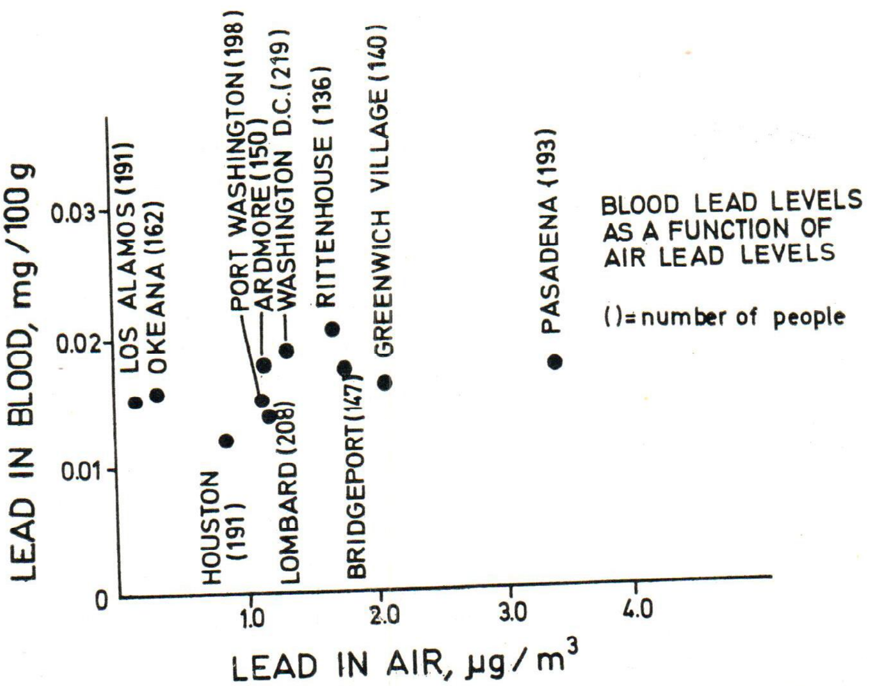

Fig. 3. *Blood lead levels and corresponding mean air lead levels*

The metabolic study did not show that observed differences in blood lead concentrations (Table 7) could be convincibly attributed to dietary factors. Climatic factors may also be relevant. In a given metropolitan area, urban-suburban comparisons tend to minimize the influence of diet and climate. That air lead contributes to the relatively higher blood lead concentrations in center-city populations would seem to be the most probable interpretation of this consistent observation.

Table 7

Geometric averages of fecal lead ten day totals

Area	N	Fecal lead (mg/10d.)
Okeana	20	0.852
Ardmore	20	1.139
Los Angeles	20	1.147
Los Alamos (F)	20	0.973
Washington, D. C.	20	1.168
Port Washington	20	0.967
Lombard	20	0.880
Houston	20	1.505

The examination of blood lead levels in husband-wife pairs in Los Alamos revealed a significant difference between males and females.

Table 8

Blood levels of lead: male — female (g/100 ml)

	Non-smokers	Previous smokers	Smokers	All
Females (N = 191)	14.4	15.4	16.0	14.9
Males (N = 80)	16.5	16.8	19.3	17.2

This male-female differential could not be attributed to occupation, smoking habits, hematocrit or age. Men and women of husband-wife pairs consumed diets essentially identical in composition, although the men consumed a generally greater quantity of food, a possible explanation for the differential.

SUMMARY

1) The more recent atmospheric lead concentrations at selected reference sites were higher than those measured in the earlier study at 14 of 19 sites.

2) Population lead levels on a national basis were not determined primarily by atmospheric lead levels, i.e., the correlation between them was not significant, suggesting that factors other than atmospheric lead levels are of relatively greater importance in determining the blood lead levels of population groups.

3) In a given metropolitan area urban blood lead concentrations were higher than suburban, presumably reflecting the influence of atmospheric lead absorption.

4) The blood lead levels of smokers were higher than those of non--smokers.

5) The blood lead levels of males were higher than females.

6) Dietary lead levels were generally lower than that reported in the literature; 100 μg/day being a closer approximation than the widely quoted μg/day.

Sažetak

ISTRAŽIVANJE NIVOA OLOVA U ZRAKU I U LJUDIMA U SAD

Poslije istraživanja nazvanog »Proučavanje u tri grada« (Philadelphia, Cincinnati i Los Angeles) željelo se nakon višegodišnjeg razdoblja ova istraživanja proširiti i rezultate usporediti te su stoga provedena »Istraživanja u sedam gradova«. Svrha je istraživanja bila utvrditi da li se nivo atmosferskog olova povećao nakon 8-godišnjeg razdoblja, zatim da se utvrdi koja je koncentracija olova na mjestima koja ranije nisu bila obuhvaćena i da se utvrdi kakav je odnos olova u krvi odabranih populacijskih skupina i koncentracija olova u zraku u dotičnim područjima. Osim spomenutih mjesta odabrani su još New York, Washington, Chicago, Houston i New Mexico.

U toku 12-mjesečnog razdoblja uzimani su uzorci zraka sa 59 mjesta i određivana je koncentracija olova u njima. Iz blizine 11 mjesta gdje su se uzimali uzorci selekcionirano je po otprilike 150 do 200 žena od kojih je 6 skupina bilo iz urbanih sredina a 5 iz predgrađa. Da bi se utvrdila eventualna razlika muškaraca i žena, odabrano je još 80 muževa jedne skupine žena. Svim odabranim ispitanicima uzeti su uzorci krvi i mjerena je koncentracija olova u njima. U po 20 osoba iz svake skupine sakupljana je mokraća i stolica tijekom 10 uzastopnih dana i određivana je količina olova kako bi se utvrdio udio olova što je u organizam ušlo ingestijom.

Koncentracije olova u zraku kretale su se od 0,14 μg/m^3 (Los Alamos) do 4,55 μg/m^3 (Los Angeles). Nivo olova u krvi kretao se od 12,5 do 20,5 μg/100 ml. U pušača i bivših pušača nivo olova u krvi bio je veći negoli u predgrađima. Međutim, može se zaključiti da na nivo olova u krvi ne utječe samo atmosfersko olovo, već da i drugi činioci igraju vjerojatno još veću ulogu. U muškaraca je razina olova u krvi bila nešto veća nego u žena, ali tome nije bilo uzrok pušenje ili drugačiji hematokrit a prihvatljivo tumačenje nije nađeno, iako je moguće da je tome uzrok različita količina konzumirane hrane. Iz ovih istraživanja proizlazi da su količine olova što su ih ispitanici unijeli u organizam ingestijom znatno manje, otprilike 100 μg/dan, od onih što se navode u literaturi (300 μg/dan). Nije utvrđena zavisnost koncentracije olova u krvi i dobi ispitanika. Koncentracija olova u zraku bila je veća na 14 od 19 mjesta gdje su mjerenja ponovljena nakon 8 godina.

DISCUSSION FOLLOWING THE PAPER

SCHWARZ: It is noteworthy that the blood lead levels you reported for groups of people in very different geological regions of the USA are all very much alike. They are also similar to those found by Dr Tsuchiya in Japan and to those reported from other areas of the world. This could be taken as an indication that the organism tends to maintain lead at a steady level.

TEPPER: Yes, it is interesting that blood levels of lead are generally found to lie within a relatively narrow range although environmental circumstances vary widely. Whether or not bone acts as a »sink« or other mechanism exists to explain this apparently general pattern is not known.

WILLOUGHBY: The results of your study did not demonstrate a correlation between exposure level of lead in air and your metabolic measurement. Would you please expand your views on the use of metabolic measurements for consumption of lead during field studies?

TEPPER: In my opinion a field metabolic study is satisfactory if it is conducted for a sufficiently long period — certainly more than 10 days. In our study I doubt that the dietary lead level was adequately evaluated for correlation with other measurements of the study. Regardless of duration the completeness of collection must be assured — an objective which was achieved in this study in spite of its relatively short duration.

BERLIN: Concerning the dietary studies, the Houston values (higher apparent lead intake and lower blood lead values) stand aside from the other seven cities; what could be the reason?

When comparing New York and Philadelphia, two cities close together with similar climates, one notices that the blood lead levels in Philadelphia are significantly higher than in New York. Could dietary differences account for this?

TEPPER: With respect to the Houston question, one might consider the climatic conditions which obtain in that city and not in the others. We know that hot weather, as occurs in Houston for a large part of the year, does influence lead-related biological phenomena in man. Consider the preponderance of cases of pediatric plumbism during the summer months. So climatic factors may be somehow involved. There may also be something about fluid balance: people in the northern cities drink little water during the day; whereas people in Houston, I would judge, drink relatively large amounts of fluids-water, beer, soft drinks.

Your other question is intriguing and I have no answer. The cities would appear to be highly comparable. It would seem that only the water supply is really different. We did not study this.

FUGAŠ: I wonder if you have tried to determine the indoor lead concentrations in some of the homes in the areas under investigation. The difference in indoor lead concentrations among various sites might be even smaller than in the outdoor.

TEPPER: We did not sample indoors or use personal monitoring devices — perhaps a shortcoming of the study. But the ratio between indoor and outdoor air lead levels is probably reasonably consistent from place to place. Therefore the respiratory exposure, although not correct on an absolute basis, is probably correct on a relative basis.

HERNBERG: I would like to give some supporting information to Dr. Tepper's very interesting paper.

During 1971 through 1973 a survey on blood lead levels was carried out in Finland by Dr. Nordman of our institute. The entire material comprised 1,378 persons, representing urban, rural and »special« (= heavy industrial pollution) conditions. There was no significant difference between the PbB's of residents in downtown Helsinki (yearly mean of PbA 1.3 $\mu g/m^3$) and those of rural people (practically no lead in air). For example, the mean of the males of the former group was 11.4 and that of the latter 12.1 μg/100 ml. A dietary survey based on the double portion techniques was carried out in the rural district. The mean (± SD) daily lead intake with food was 185 ± 60 μg for 35 males and 153 ± 61 μg for 36 females. Based on this, we calculated the average total daily lead intake for an urban man as follows (10 % absorption of ingested lead and 37 % of inhaled lead are presupposed):

Source	Daily intake (μg)		Amount absorbed (μg)	
	Mean	Range	Mean	Range
Food	169	71—310	14	6—25
Beverages	35	4—116	3	trace —9
Air	20	11—33	7	4—12
Total	224	86—459	24	10—46

Thus, the percentage obtained from air under these circumstances is less than 30 %.

A full account of this survey has been published by Dr C. H. Nordman, and it is available from the Institute of Occupational Health, Haartmanikatu 7, SF 02900, Helsinki 29, Finland.

ZAVON: 1) What you have said about indoor-outdoor levels — is this in agreement with the Thompson-Phair studies in Cincinnati in the 50's?

2) Have the differences in values in communities shown any correlation with the laboratory doing the analyses? I ask this in view, particularly, of the recent publication by Dr. Lerner of the interlaboratory variation in lead analyses.

TEPPER: I regret being unfamiliar with the Thompson-Phair study and cannot comment upon it.

All the laboratory work was conducted at one place to eliminate variation to the maximum extent possible. You are quite correct that there is still variation. We attempted to deal with this by having a large »N«, for each site (150—200 women) and by random blind mixing of blood tubes from each city. The fact that the urban-suburban and smoking-non-smoking differentials were identified with consistency, suggests that the techniques and sample sizes were adequate to show differences in blood lead levels of 1—2 μg/100 ml.