THE PUBLIC HEALTH
SIGNIFICANCE OF
ATMOSPHERIC LEAD

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The Public Health Significance of Atmospheric Lead

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Introduction

The toxic manifestations related to excessive exposure to lead have been well defined by physicians and toxicologists. On the basis of such evidence, tolerable limits have been established for industry. Despite this background of information there has been renewed concern recently about the hazard of lead as an airborne toxin.

Particulate lead is contributed to the ambient atmosphere by the combustion of soft coal and wood and by certain industrial emissions. Another source of increasing concern is the lead discharged in motor vehicle exhausts. In addition to atmospheric exposure, people ingest and inhale lead which is widely present in food, water, and tobacco.

Since lead is such an ubiquitous substance, all segments of the United States population are exposed to it in some form. While tolerable limits for industrial exposure have been established, such exposures usually involve comparatively small numbers of relatively healthy people. Community exposures, in addition, affect the sick as well as the healthy and the old as well as the young. Therefore, the full evaluation of the public health hazard of lead necessitates studies of the most susceptible segments of the population as well as those experiencing maximum exposure.

During the past year the Division of Air Pollution of the Public Health Service conducted several surveys to obtain information concerning the range of blood and urine lead concentrations existing in representatives of urban and rural populations. Similar data were obtained from a group of workers exposed to unusual amounts of vehicular exhaust in their customary working environment. Approximately 1,000 blood samples and 250 urine specimens were collected and analyzed. It is hoped that this information will provide some enlightenment concerning the potential public health hazard of atmospheric lead, and that the data also will serve as a base line for comparison with those obtained in other studies.

Survey Procedures and Sites

Blood samples for lead analysis were obtained from approximately 120 people in each of 6 cities and from 162 persons in 1 rural area. Samples of approximately 10 ml. volumes were drawn through lead-free needles into lead-free Vacutainers. From 25% of the subjects in each urban location, a single specimen of urine was collected in lead-free bottles. The circumstances existing at the rural sampling site precluded collection of urine specimens. The 6 cities

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surveyed were New Orleans, Dallas, Denver, Chicago, New York, and Cincinnati; the single rural area was in central Ohio. The subjects were selected from volunteers at official blood collection agencies. Only persons who had lived in an area for at least 5 years were included in the surveys. A social history, which was obtained from each subject, provided information concerning residence, occupations during the past 10 years, and smoking habits. A brief medical history was elicited from each participant.

Blood and urine samples were collected also from a group of 88 men exposed to unusual amounts of motor vehicle exhaust in their working environment. These men were employed at an auto inspection facility and a vehicular maintenance garage operated by a large midwestern city. Blood samples were drawn from the 88 workmen on Monday and from 66 of these men on Friday of the same week. At the time the blood sample was drawn, a urine specimen was obtained from each workman. The social and medical history form employed in the community surveys also was used in this one.

The auto inspection and maintenance facilities are housed in adjoining buildings. The inspection center serves as the principal site for assessing the safe performance and road worthiness of all types of motor vehicles. During the inspection, the engines are in various phases of acceleration, deceleration, and idling. Approximately 27,000 vehicles are inspected each month.

In conjunction with the medical aspects of this latter survey aerometric measurements of the working environment were made concurrently. Particulate lead concentrations at breathing levels were determined with Staplex hi-volume samplers. Samplers were located in areas suspected of having the highest concentrations of atmospheric lead. Additional sampling was conducted for particulate lead using sequential tape samplers. Organic lead content was measured with the Unico Lead in Air Apparatus.

Laboratory Analysis of Samples

All blood and urine samples were analyzed at the Occupational Health Research and Training Facility, Public Health Service, Cincinnati, by the procedure identified as the U.S.P.H.S. Method for Lead in Air and Biological Material—a dithizone method. The 95% confidence interval for single blood samples determined in this laboratory by this method was found to be ±0.010 mg. per 100 gm. of blood, based upon analysis of data from 45 duplicate samples. Analyses for particulate lead in air samples were made in the same laboratory using the U.S.P.H.S. Method. Organic lead was analyzed colorimetrically by the method of Snyder, Barnes, and Tolan.[10]

Survey Data

The blood and urine lead concentrations in the subjects from 6 urban areas and 1 rural location are shown in Table 1. The mean for all the urban blood samples was

Table 1—Blood and Urine Lead Concentrations Among Urban and Rural Inhabitants

Survey Site	Blood Lead				Urine Lead			
	No. of Samples	Mean Mg/100 Gm.	Range	Std. Dev.	No. of Samples	Mean Mg/L.	Range	Std. Dev.
New Orleans	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dallas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Denver	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chicago	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cincinnati	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rural	[illegible]	[illegible]	[illegible]	[illegible]	--	--	--	--

Table 2.—*Frequency Distribution of Blood Lead Values*

	Urban		Rural	
Blood Lead in Mg/100 Gm Whole Blood	No. of Samples	Per Cent of Total Samples	No. of Samples	Per Cent of Total Samples
[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]	—	—

0.020 mg/100 gm whole blood; the mean value for rural blood samples was 0.014 mg/100 gm. There is a highly significant difference ($p<0.01$) between these mean values. The composite mean for urban urine samples was 0.022 mg. per liter. The mean urban blood level of these subjects from whom urine samples also were obtained was the same as the value for the entire group.

An examination of the frequency distribution of the blood analyses, as shown in Table 2, demonstrates that over 90% of the values in both the urban and rural areas are below 0.031 mg/100 gm whole blood. Mean values slightly under 0.030 mg/100 gm have been observed repeatedly when groups of people with no known occupational exposure to lead have been surveyed.[4]

Among the 58 individuals from urban areas having blood lead levels greater than 0.030 mg/100 gm, 14 had a known occupational exposure to lead. Three of the 5 persons from the rural area having blood lead values greater than 0.030 mg/100 gm also had a known occupational exposure to lead. If the values for these occupationally exposed individuals are excluded in the computation of the means for the urban and rural areas, the composite mean value for the urban blood samples becomes 0.019 mg/100 gm, but for the rural samples it remains at 0.014 mg/100 gm.

When the results of the blood lead determinations from the community surveys are grouped by sex, age, and smoking history, the values are as illustrated in Table 3.

There is a highly significant difference between the average blood lead values for males and females from both urban and rural areas. When the samples from individuals with an occupational exposure to lead were excluded in the computations, the mean values remained essentially unchanged and were still highly significantly different.

Grouping of the urban and rural populations into 3 arbitrary age classifications revealed no notable tendency toward increase or decrease of blood lead level with age.

There is a highly significant difference between the mean values for blood lead concentrations in smokers and nonsmokers

Table 3.—*Influence of Sex, Age, and Smoking History on Blood Lead Concentrations*

	Urban Area			Rural Area		
Group	No. of Obs.	Mean Blood Lead (Mg/100 Gm)	Range	No. of Obs.	Mean Blood Lead (Mg/100 Gm)	Range
Male	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Female	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Yr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Yr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Yr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Smokers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nonsmokers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 4—*Blood and Urine Lead Concentrations Among Occupationally Exposed Men*

	Blood				Urine			
Occupation	No. of Samples	Mean Lead (Mg/100 Gm.)	Range	Std. Dev.	No. of Samples	Mean Lead (Mg/L)	Range	Std. Dev.
Auto inspector	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mechanic	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]*	[illegible]	[illegible]	[illegible]
Clerk	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* Three specimens of insufficient volume for analysis.

illustrated in Table 3. Again, this highly significant difference holds for both urban and rural groups.

The slightly higher blood and urine lead levels present in the 88 men exposed to unusual amounts of vehicular exhaust in their customary working environment are shown in Table 4. A significant correlation was observed between the lead values obtained from replicate samples for 66 of these men. The correlation coefficient for the replicate blood and urine samples were +0.6 and +0.4 respectively.

Some of the participants in the community surveys also were exposed to unusual levels of atmospheric lead in their customary working environment. Policemen, taxi drivers, postmen, gas station attendants, and bus drivers were among the occupations represented. The mean values for blood lead concentration for each of these groups were quite similar to the composite urban mean. However, the small numbers of individuals in these particular job classifications preclude their use for prediction of values expected for the general populations of such occupational groups.

The aerometric measurements obtained at the site of the municipal auto inspection center and garage are presented in Table 5. All measurements for inorganic lead were well below the industrial threshold limit value. All values for organic lead concentration were below the minimum detectable limit of the field sampling instrument (16 µg. per cubic meter).

TABLE 5—*Aerometric Measurements**

Location Sampled	Avg. Particulate Lead Concentration (µg. per m.³)	Range (µg. per m.³)
Outside of buildings	[illegible]	[illegible]
Inspection lane	[illegible]	[illegible]
Garage area	[illegible]	[illegible]

* Industrial Threshold Limit Value is [illegible] µg. per cu. m. of air.

Comment

Because of the circumstances under which the surveys were conducted, there was limited opportunity to utilize scientific sampling procedures in the selection of the subjects. Examination of the resultant data has not revealed any evidence of biased sampling in any of the measured characteristics of the subjects. These data represent a substantial addition to the published reports of blood and urine lead concentrations in people living in the United States.

It has been reported[8] that the blood lead concentration of normal North Americans with no occupational lead exposure ranges from 0.01 to 0.06 mg. per 100 gm. of whole blood. Values in excess of 0.05 mg. per 100 gm. are detected rarely in normal individuals who do not experience unusual exposure, and most are between 0.01 and 0.04 mg. per 100 gm. Normal individual values for urine lead concentration ranges from 0.01 to 0.08 mg. per liter when the 24 hour sample volume is a liter or more. The values for single urine samples vary from 0.005 to 0.12 mg. per liter.

According to Goodman and Gilman,[9] "Lead intoxication rarely occurs, and then only in its mildest manifestation, if the mean urinary concentration is kept below 0.10 mg. per liter, and if the exposure is controlled so continuously that any single determination rarely exceeds 0.15 mg. per liter. Safe blood levels have been less precisely defined, but the upper limit has been tentatively placed at 0.07 mg. per 100 gm. of whole blood. In lead intoxication, values usually range from 0.09 to 0.3 mg. per 100 grams."

The mean values for blood and urine lead concentrations found in the community surveys are all within the recognized normal range. Not only were the means within this range, but not one of the individual values exceeded normal limits.

There is a significant difference between the average blood lead concentrations of the urban and rural groups, the latter having the lower value. Vouk's[14] study is in agreement with this finding. That a contrast in exposure to atmospheric lead may account for some of this difference is suggested by data obtained by the National Air Sampling Network.[10] In 15 cities (population over 500,000) of the United States, the recorded range in average atmospheric lead values extends from a high of 9.5 μg. per cubic meter to a low of 0.5 μg. per cubic meter. Values obtained in nonurban areas ranged from 0.1 to 0.9 μg. per cubic meter. Although atmospheric lead values appear to be lower in rural and suburban areas than in urban areas, differences in exposure to lead in food or water might also account for the disparity in blood and urine lead levels.

The higher blood lead levels observed among men, both in the urban and rural groups, may be attributed to a greater exposure to all sources of lead. Differences in dietary and smoking habits, as well as differences in exposure to atmospheric lead, may well account for the disparate values. To the best of our knowledge there have been no reports in the literature that bear directly on this point, but there has been much discussion concerning the difference in the incidence in lead poisoning in the 2 sexes. According to many observers,[1] the incidence of lead poisoning is higher in women than in men workers in lead industries. However, Hamilton[6] has stated that many of these studies are not conclusive because of failure to consider certain essential differences in the nature of the work and conditions of exposure within the same industry. Hamilton[6] also noted that the variation in the incidence of lead poisoning may depend upon such extrinsic factors as diet, alcoholism, and various diseases rather than on any innate sex difference.

Although lead is a cumulative substance in the body, its accumulation in body tissues is dependent on the rate of daily absorption. Kehoe, Cholak, and Story[7] have shown that there does not appear to be any relationship between lead concentration in the skeleton and age. Our data do not reveal significant differences between blood lead values at different ages. These observations suggest that blood lead concentrations reflect a dynamic equilibrium which usually exists between the lead absorbed and excreted and that retained in the body. This equilibrium may be disturbed when absorption becomes markedly altered, when excretory processes are impaired, or when there is unusual mobilization of body stores.

The use of lead arsenate as an insecticide on tobacco plants has prompted the suggestion that lead may be inhaled during smoking, despite evidence that the greatest amount of lead present in tobacco probably remains in the ash and tar as metallic lead and lead oxide.[4] Cogbill and Hobbs[8] have reported that with certain cigarettes tested, 0.3 μg. of lead per puff could theoretically be inhaled. In our surveys there is a highly significant difference between the blood lead values for smokers and nonsmokers. However, to assess accurately the contribution of smoking to the total body lead burden, carefully designed, balance studies would be required. Such experiments should include the measurement of the total daily intake of lead from all sources, as well as measurement of the total output of confined human subjects observed over a period of time.

The average blood and urine lead levels of those employees exposed to unusual amounts of motor vehicle exhaust in their working environment are significantly higher than the average values found in the urban residents who are not so exposed. However, the mean values for this exposed group are well within the normal range, and not one value exceeds the normal limits. These findings are in accordance with the investigations of Kehoe.[8] He has found that garage mechanics can be differentiated from persons in the general population on the basis of a slightly larger output of lead in their urine and a slightly higher concentration of lead in their blood.

When replicate blood and urine samples were collected, the correlation between the first and second sample was greater for the blood than for the urine specimens. This greater degree of correlation for blood samples is consistent with Kehoe's observations. His studies[8] have shown that the concentration of lead in blood varies only within extremely narrow limits from day to day except under conditions involving concurrent and highly variable lead exposure. However, there is a markedly greater variation in the amount of lead in single urine specimens collected from the same individual over relatively short intervals of time. Kehoe[10] has pointed out that marked variations are largely a function of the volume of urine excreted—when the volume is low, the concentration is high, and vice versa. Another factor is the observation that an immediate past exposure to lead is reflected more promptly in urine values, whereas the blood level is a reflection of an individual's average exposure in the past.[11] An extraneous factor that also may partially explain the greater variability in urine lead values is the increased opportunity for contamination during the collection of urine specimens. Finally, it has been observed that urine lead levels are greatly elevated after exposure to organic lead compounds while blood concentrations increase but slightly.[8] It is unlikely that such exposure can account for the increased variation among urine samples collected in this survey since all atmospheric organic lead measurements were quite low ($<16 \mu g$. per cubic meter).

The medical histories were designed to obtain information in survey populations concerning the presence of overt kidney, liver, lung, and bone disease, as well as any record of treatment for lead poisoning. All of these factors may affect the lead level of body fluids. Although several individuals gave histories suggestive of kidney or liver disease, in no instance was the lead level markedly elevated.

Summary

Approximately 1,000 human blood samples and 250 urine specimens were collected and analyzed for lead content during the past year. The samples were obtained in 6 major cities and 1 rural area in the United States. The analyses for lead were done at one U.S. Public Health Service laboratory employing the U.S.P.H.S. Method for Lead.

Data from the subjects were grouped to provide comparison of the lead levels on the basis of geographic location, sex, occupational exposure to lead, age, and smoking habits. Highly significant differences were observed when blood lead concentrations were compared for urban and rural groups and for smokers and nonsmokers. Higher blood and urine lead levels also were detected consistently among workmen exposed to unusual quantities of vehicular exhaust in their customary working environment. Finally, these surveys demonstrated the existence of significantly higher blood lead levels among men than among women, none of whom were occupationally-exposed to lead.

Although significant differences were found between various classifications, the mean values for each group were within the recognized normal range of lead concentrations. Not a single value exceeded the accepted high normal limit of 0.07 mg. per 100 gm. of whole blood.

The data reported are offered as an approximation of the blood and urine lead levels associated with current urban and rural living in the United States. The results of these surveys tend to support previous reports concerning the human body's lead concentrations. It is hoped that the information collected will provide a useful basis for comparison when studies are undertaken in the future.

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