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Levels of Platinum, Palladium, and Lead in Populations of Southern California

by Donald E. Johnson,* John B. Tillery,* and R. John Prevost*

Results of an epidemiology study of populations living near a freeway and in the high desert area of Southern California for levels of platinum, palladium and lead are presented. Three age groups (children, young adults, and mature adults) were sampled twice for blood, urine, hair, and feces. Air, water, and soil samples were collected in the areas of the residences of the two populations. The primary objective of this study was to obtain baseline levels of these metals prior to the introduction of the catalytic muffler. The samples were collected in September 1974.

Introduction

Catalytic converters were introduced on many of the 1975 model automobiles in the United States to reduce emissions of carbon monoxide and unburned hydrocarbons. The catalysts used small quantities of platinum and palladium, and there have been some indications of emissions of particles of these metals. Health effects of exposure to platinum and palladium reviewed in a previous study (*1*) indicated that soluble forms of platinum can create allergic responses in sensitive individuals. However, little information is available concerning long-term chronic exposure of humans to low levels of platinum or palladium, in particular for groups that may be at greater risk such as the young or aged and for individuals with some type of medical impairment. There are also some indications that platinum can be methylated, thus possibly producing a more toxic component.

*Southwest Research Institute, P.O. Drawer 28510, San Antonio, Texas 78284.

This paper reports on an investigation aimed at establishing baseline levels of platinum, palladium, and lead in the environment and in human populations prior to distribution of 1975 automobiles so that determination can be made in future years of changes in levels of the metals. To this purpose, samples of air, soil, blood, urine, fecal matter, and hair clippings were collected and analyzed for the presence of platinum, palladium, and lead. Lead analysis was included because of the interdependence of lead with the usage of catalytic converters, i.e., requirement for unleaded gasoline. The samples were collected in an area of high exposure to auto emissions and in a control area with much lower exposure.

Methods

Study Design

The study was conducted in Southern California in persons living near a heavily travelled urban freeway and in persons living in the high desert area. Residents living near the San Diego freeway

in the Westwood area of Los Angeles exposed to heavy daily freeway traffic were recruited from a UCLA housing area and from the staff and staff families of the Wadsworth Veterans' Administration Hospital. Residents living in the high desert area near Lancaster were recruited from the staff and staff families of the Mira Loma Hospital and served as a population less exposed to heavy auto traffic. Administrative officials at the three organizations were enlisted to provide aid in recruiting volunteer participants. A questionnaire form was designed and used in the recruitment activities. Covariate information obtained with the questionnaires included age, sex, occupation, education of head of household, smoking history, years of residence in area, and frequency of change of living quarters for each study participant.

Study design provided for equal numbers of volunteer participants in each of three age groupings: age group I, 1–16 years; age group II, 17–34 years; and age group III, 35 and over. Approximately 150 individuals were initially selected for study in each of the two areas, 50 in each age group. The age distribution accomplished for the volunteers for which samples were obtained is described in Table 1. Covariate data describing other pertinent socioeconomic and demographic characteristics of the volunteers from which samples were obtained are presented in Table 2.

Collection and Analysis

The containers used for collection were made of polyethylene and were washed with acid and deionized water to remove trace quantities of metals.

A 20-ml sample of whole blood was collected twice from each subject by venipuncture, except for small children where only one 10-ml sample was collected. Vacutainers were used to collect the blood, but the blood was transferred within 2 hr to polyethylene containers. Two overnight urine specimens were collected from each subject. The volume of these specimens was measured, and an aliquot was made to 1% by volume with acetic acid as a preservative. The urine samples were then frozen until analyzed.

Two different types of hair samples were collected by a barber or beautician: short hair (from the nape of the neck, no longer than 2 in. from the scalp) and long hair (from the ends of long hair on the top of the head).

For each subject 2–3 g of hair were collected and placed into plastic bags.

Two overnight feces samples were collected, weighed and then kept frozen until analyzed.

All samples were analyzed for platinum, palladium, and lead according to the methods described by Tillery and Johnson (*2*).

Table 1. Volunteer participant age distribution.

	Los Angeles				Lancaster			
	Low	High	Median	Total	Low	High	Median	Total
Group I	1	16	6	50	2	16	9	56
Group II	17	34	27	73	17	34	23	45
Group III	35	65	38	18	35	74	51	41
				141				142

Results and Discussion

Platinum and Palladium

The data for platinum and palladium are shown in Table 3. "Less than" values (detection limits) are shown because no detectable levels were found in individual samples. A composite of blood from all age groups and both sexes from Los Angeles and from Lancaster was analyzed for platinum and palladium, and the results are also shown in Table 3. Detectable levels of platinum were found, but no palladium was found. Approximately 750 ml of blood was used for each of these composites.

Particulate high volume air samplers were used to determine ambient levels of platinum and palladium. The samplers were located in areas of each city near the residences of populations under study. The samplers were operated for a period of 14 days, and the filters were changed every 24 hr. The filters were combined for each of the two study areas and analyzed for platinum and palladium. No platinum or palladium was detected in these samples. The lower limit of detection in both areas was 5×10^{-8} $\mu g/m^3$ for platinum and less than 6×10^{-8} $\mu g/m^3$ for palladium.

These results indicate that baseline levels of platinum and palladium in environmental and in

Table 2. Pertinent socioeconomic and demographic characteristics of volunteer participants.

	Total	Sex		Education level of head of household			Smoking history			Years residence in area			Frequency of change in living qtrs. (last 5 yr)		
		M	F	0-12	13-16	Degree	Never	< 1 pk/da	> 1 pk/da	0-1	2-3	4+	0-1	2-4	5+
Los Angeles															
Group I	50	23	27	7	7	33	49	1	0	8	20	19	24	22	4
Group II	73	29	44	0	15	56	46	15	12	21	26	17	19	42	12
Group III	18	8	10	8	3	7	10	0	8	1	6	11	11	6	1
Total	141	60	81	15	25	96	105	16	20	30	52	47	54	70	17
Lancaster															
Group I	56	27	29	23	15	17	55	1	0	1	11	43	43	10	1
Group II	45	25	20	17	22	8	27	6	12	3	9	33	24	15	6
Group III	41	12	29	17	14	10	17	6	18	2	2	37	33	8	0
Total	142	64	78	55	51	35	99	13	30	6	22	113	100	33	7

Table 3. Platinum and palladium levels in southern California.

	Los Angeles and Lancaster								Composite blood sample, μg/100 ml			
	Blood, μg/100 ml		Urine, μg/l.		Hair, μg/g		Feces, μg/g		Los Angeles		Lancaster	
Age group	Pt	Pd	Pt	Pd	Pt	Pd	Pt	Pd	Pt	Pd	Pt	Pd
I	<3.1	<0.9	<0.6	<0.3	<0.05	<0.02	<0.002	<0.001				
II	<3.1	<0.9	<0.6	<0.3	<0.05	<0.02	<0.002	<0.001	0.049	<0.01	0.180	<0.1
III	<3.1	<0.9	<0.6	<0.3	<0.05	<0.02	<0.002	<0.001				

human populations in the Southern California area are extremely low. The levels in all instances other than composite samples are below the detection limits of atomic absorption procedures. The information collected provides a sufficient baseline that can be used for future comparisons.

Lead

Ambient air lead was determined by using high volume air samplers located near the residential areas being studied. In Los Angeles, the sampler was operated for 7 days, and the lead values averaged 6.3 μg lead/m^3 (standard deviation 0.66 μg/m^3). Air lead values for Lancaster covering a 14-day period averaged 0.64 μg/m^3 (standard deviation 0.21 μg/m^3). Two samplers were utilized in this urban area.

Soil samples were collected and analyzed for lead in both areas. Most of the children and young adults from Los Angeles were from the UCLA Married Student Housing Unit in which soil lead levels ranged between 3633 and 673 μg/g. Soil samples from Lancaster averaged 66.8 μg/g with a range from 42.5 to 98.4 μg/g. These data indicate that levels of lead in soil in Los Angeles near residences of the study population are quite high, while the data for Lancaster, although higher than those normally seen in the United States, are substantially lower than those in Los Angeles.

The statistical analysis was limited to the lead data, as individual samples had no detectable platinum or palladium. The primary comparisons were between lead concentrations in all samples from populations in Los Angeles versus those in Lancaster. The two blood, urine, and feces samples from each participant were considered replicates, and their mean was utilized as the participant value.

The standard *t* test of two independent samples was utilized to compare corresponding participant groups from the two sites with respect to significant differences in population means. Site comparisons were conducted for each tissue on the total participant groups and on subgroups stratified by sex and age. The *t* test assumes both sampled populations are normally distributed with equal variances. The normality assumption was examined by testing the skewness of the group observations (*3*). The equality of variance assumption for the two independent comparable groups was tested by the standard *F* test. The validity of these assumptions was examined for each set of tissue data without transformation, under logarithmic transformation, and under square-root transformation for the total group and the male and female subgroup comparisons across site. In every case, the logarithmic transformation yielded the more valid *t* tests. Thus, logarithmically transformed lead concentration data were utilized. Each *t* statistic tested the null hypothesis of equal population or stratum means across site against the two-sided alternative of unequal means.

Blood lead values are shown in Table 4. The results show that there was a highly significant difference in blood leads in the total population of Los Angeles versus Lancaster and for both males and females. The differences were more pronounced in younger ages of both sexes. Lead values were higher in males than in females, and values tended to be lower for younger age groups in both Los Angeles and Lancaster. Of the blood samples from males and females of Group I in Los Angeles, 10% had 40 μg lead/100 ml blood or higher. No blood leads of 40 μg/100 ml or above were seen in Lancaster for any age group, nor were such levels found in any Los Angeles samples from age groups II and III.

Table 5 shows the values for lead in long hair. There are highly significant differences between the total populations of Los Angeles versus similar populations in Lancaster. Values for the males of Group I were highly significantly elevated for Los Angeles, whereas those for the other age groups in this sex were not. Females for Group I also had a highly significant difference in hair lead values between Lancaster and Los Angeles. Table 6 shows similar data for short hair samples in which the significance was even more pronounced between Los Angeles and Lancaster for both males and females,

Table 4. Lead in blood from two populations.

Group	Lead in blood, μg/100 ml: Los Angeles N[a]	Los Angeles Arithmetic mean (± std. dev. of mean)[b]	Los Angeles Geometric mean[c]	Lancaster N	Lancaster Arithmetic mean (± std. dev. of mean)	Lancaster Geometric mean	Significance of difference p
Total	126	16.4 (± 0.7)	14.6	119	10.5 (± 0.4)	9.6	≪0.001
Males	56	19.3 (± 1.1)	17.2	50	11.8 (± 0.6)	10.8	≪0.001
I	20	23.5 (± 2.5)	20.8	21	11.1 (± 0.8)	10.4	≪0.001
II	29	16.6 (± 1.1)	15.1	18	11.8 (± 0.9)	10.9	0.003
III	7	18.5 (± 2.0)	17.1	11	13.0 (± 2.0)	11.1	0.09
Females	70	14.2 (± 0.7)	12.8	69	9.6 (± 0.4)	8.8	≪0.001
I	18	16.7 (± 1.8)	14.9	25	10.2 (± 0.7)	9.6	<0.001
II	41	12.9 (± 0.6)	11.8	16	9.1 (± 1.2)	8.0	<0.001
III	11	14.7 (± 1.5)	13.4	28	9.3 (± 0.5)	8.7	<0.001

[a]N = number of participants providing at least one analyzed sample.
[b]Arithmetic mean = average of untransformed observations; standard deviation of mean measures amount of variation in the group arithmetic mean = $SD/\sqrt{N}$, where SD = standard deviation of the N participant observations.
[c]**Geometric mean = average of the logarithmically transformed observations reported in the original untransformed scale.**
[d]Significance of difference p is the probability of obtaining a difference as large or larger in absolute value than the observed difference in geometric means, assuming the two populations were actually identical. If p is less than 0.05, the difference is generally considered to be significant; $p < 0.01$ implies a very significant difference.

Table 5. Lead in long hair from two populations.

Group	Lead in long hair, μg/g: Los Angeles N	Los Angeles Arithmetic mean (± std. dev. of mean)	Los Angeles Geometric mean	Lancaster N	Lancaster Arithmetic mean (± std. dev. of mean)	Lancaster Geometric mean	Significance of difference p
Total	115	44.9 (± 4.3)	27.2	109	19.3 (± 3.1)	12.0	≪0.001
Males	45	43.9 (± 7.8)	24.6	44	21.2 (± 2.8)	16.1	0.04
I	18	59.4 (± 9.0)	49.7	20	20.7 (± 3.0)	16.9	≪0.001
II	24	35.3 (± 12.7)	15.3	16	20.2 (± 3.5)	16.3	—
III	3	20.5 (± 10.0)	16.4	8	24.6 (± 12.3)	13.9	—
Females	70	45.5 (± 5.0)	29.0	65	18.1 (± 4.9)	9.8	≪0.001
I	25	76.7 (± 9.9)	59.6	22	17.3 (± 2.5)	13.7	≪0.001
II	35	26.7 (± 3.6)	19.5	17	10.9 (± 1.9)	8.5	0.001
III	10	33.2 (± 10.3)	19.3	26	23.4 (± 12.1)	8.0	0.06

Table 6. Lead in short hair from two populations.

Group	Lead in short hair, μg/g: Los Angeles N	Los Angeles Arithmetic mean (± std. dev. of mean)	Los Angeles Geometric mean	Lancaster N	Lancaster Arithmetic mean (± std. dev. of mean)	Lancaster Geometric mean	Significance of difference p
Total	94	56.2 (± 7.0)	33.3	88	15.7 (± 1.3)	11.7	≪0.001
Males	50	67.1 (± 12.2)	36.3	45	17.4 (± 1.9)	13.2	≪0.001
I	19	107.2 (± 24.9)	74.1	23	16.6 (± 2.5)	12.8	≪0.001
II	27	39.5 (± 11.3)	21.5	13	16.9 (± 2.8)	14.2	—
III	4	63.2 (± 28.5)	42.3	9	19.9 (± 6.4)	12.8	0.09
Females	44	43.8 (± 6.6)	30.2	43	13.9 (± 1.7)	10.3	≪0.001
I	9	70.2 (± 11.8)	63.0	11	12.4 (± 2.6)	10.1	≪0.001
II	26	33.4 (± 5.4)	23.7	9	17.8 (± 5.6)	12.3	0.07
III	9	47.4 (± 13.6)	29.3	23	13.0 (± 2.1)	9.8	0.005

again primarily for Group I. Table 7 shows the values for lead in urine; some values show significant differences between data for Los Angeles and Lancaster.

Table 8 shows values for lead in feces for the same populations. Fecal lead values provide an indication of the total quantities of lead consumed by ingestion rather than inhalation. Examination of the data and the statistical comparisons indicates that, if anything, the quantities of lead consumed by ingestion in the populations in Lancaster are higher than those in Los Angeles. In most instances, there is little or no difference between the two populations for lead in feces.

These results indicate that the probable sources of the elevated levels of lead seen in blood and hair of the populations in Los Angeles are airborne lead rather than from ingested lead. The building surfaces in the UCLA Married Student Housing Facility were examined for lead, and the values were less than 0.5 μg/g of dried paint. Additional studies are in progress to examine the contents of ^{210}Pb in various samples collected in the Los Angeles area to assist in clarifying the sources of the elevated lead levels.

The probable primary source of the ambient air lead is from automotive emissions. The site studied in Los Angeles is immediately adjacent to a freeway with traffic densities of 250,000 cars per day. The area studied was east of this freeway, and the prevailing winds are from the west from the Pacific Ocean some 5 miles away. This minimizes the chances for intrusion of airborne lead from sources other than automotive emissions.

Comparison of these data with data from other populations of nonoccupationally exposed individuals shows that the blood lead values from Los Angeles are similar or possible slightly lower than from comparable studies such as the Seven City study (*4*), whereas hair lead values are higher. This is especially true in the short hair samples, in which the arithmetic means for young males was 107.2 μg/g and for young females the average was 70.2 μg/g. This is extremely high for nonoccupa-

Table 7. Lead in urine from two populations.

	Lead in urine, μg/l.						
	Los Angeles			Lancaster			Significance
Group	*N*	Arithmetic mean (± std. dev. of mean)	Geometric mean	*N*	Arithmetic mean (± std. dev. of mean)	Geometric mean	of difference *p*
Total	136	14.3 (± 0.7)	11.5	121	10.5 (± 1.0)	8.3	$\ll 0.001$
Males	59	16.1 (± 1.1)	13.2	51	10.6 (± 0.8)	9.0	< 0.001
I	23	17.7 (± 1.6)	15.4	21	11.0 (± 1.1)	9.6	0.001
II	29	14.9 (± 1.7)	11.6	19	9.0 (± 0.9)	8.0	0.01
III	7	15.8 (± 2.5)	13.5	11	12.5 (± 2.9)	9.5	—
Females	77	12.9 (± 0.9)	10.3	70	10.5 (± 1.7)	7.8	0.003
I	25	16.4 (± 2.2)	12.6	26	14.7 (± 4.3)	9.7	—
II	41	10.8 (± 0.9)	9.1	16	8.9 (± 1.2)	7.5	—
III	11	12.4 (± 1.8)	10.4	28	7.6 (± 0.8)	6.6	0.003

Table 8. Lead in feces from two populations.

	Lead in feces, μg/g						
	Los Angeles			Lancaster			Significance
Group	*N*	Arithmetic mean (± std. dev. of mean)	Geometric mean	*N*	Arithmetic mean (± std. dev. of mean)	Geometric mean	of difference *p*
Total	124	0.90 (± 0.09)	0.69	113	1.22 (± 0.08)	0.95	< 0.001
Males	52	1.08 (± 0.20)	0.76	46	1.14 (± 0.13)	0.87	—
I	16	1.62 (± 0.59)	1.03	19	1.37 (± 0.23)	1.05	—
II	29	0.84 (± 0.12)	0.66	16	0.97 (± 0.18)	0.81	—
III	7	0.88 (± 0.26)	0.71	11	0.98 (± 0.24)	0.72	—
Females	72	0.76 (± 0.06)	0.64	67	1.27 (± 0.10)	1.01	$\ll 0.001$
I	21	1.09 (± 0.14)	0.91	24	1.60 (± 0.21)	1.26	0.09
II	41	0.67 (± 0.06)	0.58	15	1.34 (± 0.14)	1.16	$\ll 0.001$
III	10	0.49 (± 0.05)	0.47	28	0.96 (± 0.12)	0.78	0.004

tionally exposed children with no apparent exposure to leaded paint.

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