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Final Report

FOOD CHAIN AND HEALTH IMPLICATIONS OF AIRBORNE LEAD

By

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Abstract

In January 1970, lead poisoning among horses in the Carquinez Strait Area led to questions as to whether lead in air might be affecting human food supplies in that area or elsewhere in California. This added further urgency to the Department's interest in seeing whether sensitive methods could be applied to distinguishing blood lead levels in population samples of California adults and children.

Air samples and food samples reflecting usual local purchase and consumption habits were obtained in five areas; one an isolated mountain community and two paired communities each in the San Francisco Bay Area (Martinez and Crockett) and in Los Angeles (Manhattan Beach and Burbank). In addition, blood and urine samples from adults and children were obtained and analyzed for lead or for metabolic evidence of lead exposure.

The first hypothesis tested was that there was a relationship between ingestion of lead by humans through food chain mechanisms and blood lead levels. The second hypothesis tested was that there was an important association between airborne lead levels, and lead levels in blood or evidence of impairment of biochemical processes through the effect on delta-amino-levilinic acid dehydratase.

Supplemental support permitted further studies of the factors influencing lead levels in the blood of children in Los Angeles and in San Diego.

We found no appreciable contribution of food lead levels to lead body burden as reflected by blood lead or other biological indices. We found blood lead among school children in Burbank to be significantly higher than in Manhattan Beach, and blood lead among adults to be higher in Crockett than in Benicia. Air samples from Burbank also showed higher concentrations of lead than did those from Manhattan Beach. We did not find any evidence of high blood lead levels among children in San Diego who lived in older housing. We recommend further monitoring of lead in children in relation to atmospheric exposure and to other sources. We recommend further application of vegetation sampling (Avena) as an indicator of particulate metalic pollutant.

LIST OF TABLES

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Community participants in Alpine County, Benicia, Crockett, Manhattan Beach, Burbank, and San Diego.

In general, biochemical tests and urinary lead, where available, support these contrasts.

In Alpine County, the blood lead values in adults are as low as any populations included (within measurement error), but are not much lower than urban samples, as was also the case in our study there in 1960. While our laboratory tests of high volume filters agree with samples split with the Kettering Laboratory, our blood lead values are significantly lower (Figure I).

CONCLUSIONS

The conclusions are based on Tables 1, 2, and 3, appended. Raw data for environmental, food, and biological reactions were submitted earlier.

A. Food Chain Aspects

Food intake as determined by dietary history in each of the five communities was sampled by purchase from local grocery stores and by "backyard" garden samples. The highest lead value was in carrot greens (not usually a human food), followed by other leafy vegetables; the highest value in meat was in veal kidney (probably not used in quantity). No important differences by area occurred. Canned milk has enough lead (even when diluted 1:1) so that it could contribute an excessive amount to infant ingestion. We find no evidence that in areas polluted by lead sufficient to poison horses, human ingestion of lead through food chain mechanisms is a public health problem.

B. Health Hazards

When men and women in Benicia and Crockett are compared with respect to blood lead, the Crockett populations have significantly higher values. The sources may have been via food in the past or it may reflect respiratory exposure. It was not due to occupational exposure, for occupationally exposed individuals were not included. The levels observed were not in the range likely to be clinically important. No significant differences in blood lead in children from Benicia and Crockett were noted.

Significant differences in blood lead from both male and female children were observed between Burbank and Manhattan Beach. Burbank boys have mean blood lead slightly greater than 23 μg/100 g and girls greater than 20 μg/100 g, both of which exceed the "acceptable biological limits" proposed for groups of children by Zielhuis. It should be noted that the California laboratory methods may not be strictly comparable with those used in defining the Zielhuis standards. Also, the California blood lead results are reported in μg/100 g. These should be multiplied by a conversion factor of about 1.05 to give results for comparison with the Zielhuis standards, which are expressed as μg/100 ml.

Among preschool children in San Diego living in houses which are positive for lead paint, no exceptionally high blood lead levels were observed. The highest reported value was 31 μg/100 g. No relationship was found between blood lead levels and concentration of lead in dirt from play areas. The limits for individual blood lead levels (>40 μg/100 g) were exceeded for two out of twenty male adults in Crockett.

in alpine

RECOMMENDATIONS

Studies of the association of childhood hyperactivity and probable lead exposure should be undertaken in Los Angeles. Further studies of children can give useful validation to the scanty data reported here.

Results of studies of blood lead levels and biochemical indices, especially in children, are a useful guide to the magnitude of pollution and the need for control. Measurement of lead and other contaminants in vegetation samples provided a useful supplement to high-volume air monitoring.

The results reported here in our opinion suffice to indicate the urgent adoption of policies on local, state, and federal levels to meet as soon as possible the Air Quality Standard for Lead.

I. INTRODUCTION AND NARRATIVE HISTORY OF THE PROJECT

The California State Health Department first focused on the Community exposures to lead in 1959, in connection with the first report on ambient air quality standards. At that time, the fundamental research of Professor Kehoe had provided guidelines which indicated that "absorption from all routes of 120 micrograms of lead a day might be harmful, while a total of 60 micrograms is presumably safe". Blood levels for lead appeared to give a sensitive indication of the potential toxicity. Based on data at that time available, it was indicated that the possible air pollution standard might be 6 micrograms per cubic meter. It was understood that community air pollution exposure should be allocated only a portion of the allowable body burden as estimated by absorption or excretion.

At the same time, (1959), the industries using lead in motor fuel, were requesting the Surgeon General of the Public Health Service to evaluate a proposed increase in the maximum amount of lead in motor fuels from 3 milliliters per gallon of ethyl fluid to 4 milliliter per gallon. In the course of this evaluation, additional data came to light concerning the proportional retention in the body of lead of a particle size likely to occur in community air pollution.

Accordingly, a number of health authorities undertook to actively study the extent to which elevated levels of blood lead could be associated with the atmospheric exposure variations in different parts of the country. This resulted in the so called Three City Study (1965), which documented the substantial and persistent excess of lead in urban dwellers as opposed to blood samples taken from rural populations.

The set of results from the Three City Study indicated that with increasing respiratory exposure, there tended to be increasing blood levels which presumably reflected respiratory exposure and body burden increases. A number of requests for studying populations living near California freeways led to a study being undertaken in 1966 to determine whether people living near a freeway had a higher concentration of blood lead than that of people living at some distance.

Samples of blood were taken from two groups of 50 persons each. The homes of the first group were adjacent to a heavily traveled freeway, and in the second, near the coast, in an area with substantially less atmospheric lead. There was found to be a consistently significant excess of blood lead among the populations living near the freeway, independent of age, sex or ethnic status. However, the values observed did not deviate markedly from the values found for other populations in the Los Angeles Basin. The significant finding was that the population living along the sea coast had lower values than other population groups.

In 1967, there became available experimental human exposure data that reflected the range of exposures similar to those occurring in community air pollution. Goldsmith and Hexter thereupon published a paper proposing that there existed a statistically significant increase in body burden of lead in male populations that was associated with increased respiratory exposure to lead.

Following this, the Department set about the process of using such findings as a basis for air quality standards. In 1969, the Department proposed such standards in a seminar at the Air Pollution Control Association. In 1970, standards were proposed by the Department to the Air Resources Board. A standard of 1.5 micrograms per cubic meter, based on a 30 day average was recommended and after public hearings, was adopted.

In the meanwhile, the federal air pollution research groups in collaboration with the American Petroleum Institute, and the International Lead-Zinc Research Organization was undertaking the so-called "Seven City" Study, the results of which have not been published though they have been widely quoted by industry representatives.

Between 1967 and 1970, the Department repeatedly sought to obtain funds from the Federal Government to study the blood lead levels and biochemical indices of California populations who, on the basis of previous work, were expected to have lead exposures of differing magnitude. The efforts to obtain research support were without avail.

Between 1967 and 1969, the Department received contract support to evaluate air quality criteria and make recommendations to the Federal Government, and a portion of the work involved, the collection and organization of information about lead. The National Academy of Sciences-National Research Council, however, appointed a panel to consider lead in perspective and the further support of work toward air quality criteria by the Federal Government was held in abeyance.

In January 1970, the Department of Public Health and the University of California School of Veterinary Medicine were asked to determine the cause of death of horses in pastures in southern Solano County. Preliminary work indicated the horses had died of lead poisoning and that other animals in the vicinity had elevated levels of lead in blood and hair samples and in tissues. Atmospheric sampling at the same time did not give evidence of unusually high exposures, though there were several large sources in the area which might have been contributing, including traffic over the Carquinez bridges, and the Selby smelter. Between March of 1970 and November of 1971, the State Health Department and the Air Resources Board, with the assistance of other agencies, carried out a study on lead contamination relative to horse deaths in southern Solano County. This study utilized a systematic sampling of lead levels in *Avena fatua* which was developed in the Department. This permitted the determination of gradients that fit the estimates of exposure and dissemination. It was based on analysis for two substances, lead and cadmium.

In recognizing that the pastures in the Carquinez Strait area were widely contaminated with lead and cadmium and other metals, the stage was set for concern that other food sources were contaminated as well, and this became one basis for the proposal which led to the present research.

In early 1971, the Department put forth a proposal to study both the food chain and health effects of air-borne lead. This proposal was accepted and initiated on July 1, 1971.

The continuation and completion of the work on vegetation sampling in relation to Benicia, Crockett and the Selby smelter, was carried on with support from the Air Resources Board during the period of study. The plant pathologist, Mrs. Thornton was able to assist us in obtaining vegetation samples, and backyard garden produce was obtained in as many places as possible.

Initial community studies were carried out in Alpine County cooperatively with the Kettering Laboratory, which was supported by industry and by the Federal Government. Benicia and Crockett were studied in northern California, and Manhattan Beach and Burbank were studied in Southern California.

While the work was underway, and without notifying us, Dr. Tepper made available the data from the blood samples in Alpine County, and they were used as evidence against proposed regulations of the Environmental Protection Agency. The lack of agreement between the Kettering Laboratory results and our results for blood lead is to be contrasted with the agreement between air samples obtained by the Kettering Laboratory and analyzed both by their laboratory and ours.

The organization and conduct of an international symposium on public health aspects of lead occurred at a time which has permitted the development of acceptable levels for tentative population exposure, and this is covered in Section II.

At the end of the study period, it is still not possible for us to look forward with certainty to control of the emission of high amounts of lead from motor vehicle exhausts, which is necessary to meet the State's air quality standards.

II. CONCURRENT RESEARCH ACTIVITY AND ITS RELEVANCE

A. International Symposium on Environmental Health Aspects of Lead, Amsterdam

At this meeting jointly sponsored by the U.S. Environmental Protection Agency and the Council of European Communities, current research was presented and appraised.

There were several highlights of the meeting. Biochemical indices were found to be useful; ALAD was recommended as the most sensitive test and appropriate for estimating community exposures in a range capable of derangement of hemoglobin synthesis. However, the importance of such derangement to health has not yet been fully evaluated.

Dr. Zielhuis, from the Netherlands, proposed acceptable biological limits both for individuals and for groups, and for adults and for children. These included lead in blood (PbB), amino-levulinic acids in urine (ALAU), and amino-levulinic acid dehydratase (ALAD). These values are shown on the next page. Provided that groups are representative and include at least 15 persons, and that the methods used are standardized, the participants accepted these as guidelines. In comparing the results of the California data with them, however, it should be noted that there is a conversion factor of about 5% between µg/100ml (used in the Amsterdam recommendations) and µg/100g used in the California study. Also, the methods used may not be strictly comparable.

Excerpt from:

LEAD ABSORPTION AND PUBLIC HEALTH: AN APPRAISAL OF HAZARDS
by R. Zielhuis

International Symposium: Environmental Health Aspects of Lead, Amsterdam, October 2-6, 1972

Acceptable biological limits

Environmental standards have to take into account total daily uptake; this can be measured indirectly by biological monitoring of PbB, ALAD and ALAU. Particularly for more or less homogeneous groups one may conclude to acceptable biological limits, characterized by group averages and upper limits; for individuals one may present upper limits. These limits should not be regarded as fine lines discriminating innocent from nocuous environments; however, if these limits are exceeded, the possibility of undue acute effects and/or chronic sequelae increases. The data as established in population groups should always be interpreted by experts, and not by the lay public as such. Single values moderately exceeding upper limits in individuals should cause awareness and caution; the measurement should be repeated. Group data have a stronger significance than individual data.

reduced amounts of hemoglobin. The hypophospatemia was "consistent with disturbed function of the proximal renal tubules and failure to reabsorb phosphate". It may reflect damage by cadmium or lead or a combination. Since it occurs in an area also covered in our study, this work provides a useful basis for reference. However, persons with occupational exposures were excluded from our studies.

C. "Seven City Study"

This study generally confirms that urban women have higher blood lead levels than rural ones, and that smokers have higher values that non-smokers. It suggests that with increasing urban lead levels, there is increasing lead storage, although the gradients do not appear to be as steep for women as for men. Inclusion of Los Alamos (elevation 7,300 feet) implies an expected high hematocrit, and the role of this factor is not appraised either in the draft report on the "Seven City Study" or in interpreting results from Alpine County.

Fecal lead measurements were made, partially to test the allegation that previously observed differences in blood lead were due to dietary differences. No data supporting this allegation were found. This is similar to our study's finding of no appreciable differences in lead intake in market-purchased foods in the several areas. (Environmental Protection Agency, "A Survey of Air and Population Lead Levels in Selected American Communities", EPA-R1-73-005, December 1972.)

D. Manuscript on Vegetation Monitoring

During the period of support, we completed a manuscript for publication entitled "Vegetation Monitoring for Airborne Heavy Metal Pollution" (appended). This proposes a supplemental monitoring system, one which has also been applied by Kalman and Graham at Stanford, who also are publishing supporting data from Palo Alto.

E. Studies of Environmental and Population Exposures in the Vicinity of El Paso, Texas Smelter.

The U.S. Public Health Service has been studying lead levels in individuals living near a smelter. According to a preliminary report, highest levels were found among children 1-4 years old living within 1 mile of the smelter (42.4% $\geq$ 40 μg/100 ml). Air samples within 1 mile showed significantly high values (annual mean 8-10 μ lead/m^3). A relationship between blood lead levels and concentration of lead in house dust is demonstrated by the finding that children within 1 mile who had levels $\leq$ 40 μg/100 ml were exposed to 3.5 times amuch lead in dust as those with lower levels (6,447 ppm versus 2,067, $p<0.0001$).

The revelance of this to our work is that it confirms the inadequacy of air sampling as a basis for health risk estimation in the vicinity of point sources.

The population sampling data obtained in Benicia and Crockett do not indicate an exposure of the level of severity apparent in the preliminary data from El Paso. A preliminary report of the El Paso study is available from the Center for Disease Control, Atlanta, Georgia. An article is being submitted for publication in the New England Journal of Medicine.

The following acceptable limits are suggested as guidelines:

For adults

	individual upper limit	group average	unit
PbB	≤40	≤25	μg Pb/100 ml
ALAU	≤ 6	≤ 3	mg/1 urin
ALAD	≥20	≥30	procentual decrease from 100% (at PbB = 10 μg Pb/100 ml)

For children

	individual upper limit	group	
PbB	≤35	≤20	as above
ALAU	≤ 5	≤ 3	"
ALAD	≥30	≥40	"

The Environmental Protection Agency input to the meeting emphasized its concern about the contribution motor vehicle emissions were making to the exposure, uptake, and lead burden in children. There was no clear agreement as to the risk or contribution of air pollution to lead toxicity in children.

Professor Truhaut reported on a joint expert committee of the Food and Agricultural Organization/ World Health Organization concerning food additives, which evaluated toxicology of lead. They established in adults, based on the assumption of only 10% of ingested lead from food and water being absorbed, a provisional tolerable weekly intake of 3 mg. lead per person, equivalent to 0.05 mg/kg body weight. This is equivalent to 3000 x 10% = 300 micrograms per week or 42.8 micrograms of lead absorbed per day. The experts went on to say that "Any increase in the amount of lead derived from the drinking water or inhaled from the atmosphere must decrease the amount which can be tolerated in food. The contribution of lead in air is probably the one most accessible to action for reducing the total body burden of lead, especially where this fraction is large compared with that absorbed from food."

This position supports the complementarity of food and air pollution as important routes in ingestion.

B. Occupational Health Study in Smelter Employees

At the Amsterdam meeting, Cooper, Tabershaw and Nelson reported follow-up studies of former employees of the Selby smelter. An unexpected finding was a depression of serum inorganic phosphorous in individuals with blood lead levels above 40 μg/100g of blood (i.e., those with little or no lead exposure were normal). Higher blood lead levels were associated with

III LABORATORY METHODOLOGY

A. Analytical Methods

During this study several methods were adapted by the Air and Industrial Hygiene Laboratory for the analysis of lead in biological specimens, food-stuffs, and air. Blood specimens were also analyzed for amino-levulinic acid dehydratase (ALAD) and urine specimens for aminolevulinic acid (ALA). A concurrent study was conducted to optimize blood sample storage conditions to assure the stability of the ALAD.

1. Lead in Blood, Foodstuffs and Air

Blood samples were analyzed by two atomic absorption methods: the methyl isobutyl ketone extraction (IBK) method of Yeager, Cholak, and Henderson(1) and the Delves method(2,3). Samples collected early in the study were clotted and had to be analyzed by the MIBK method. Subsequent samples, thoroughly mixed with heparin in the field, were analyzed by the more rapid Delves method. Therefore, a study was conducted by AIHL to determine the equivalency of the two methods, cf. AIHL Report 161, Appendix. The results demonstrated the Delves ratio method, when adjusted by the appropriate proportionality factor, to be equivalent to MIBK, the reference method. The MIBK method was used for the analysis of foodstuffs including market samples, garden vegetables, and hospital diets (AIHL Method No. 42, Appendix).

Air samples collected on cellulose paper were analyzed by an atomic absorption method following acid digestion of the filters (AIHL Method No. 41, Appendix).

2. Aminolevulinic Acid Dehydratase (ALAD) in Blood

a) Method

Blood was analyzed for ALAD by the method of Bonsignore et al(4). The method is based on the formation of porphobilinogen (PBG) from δ-aminolevulinic acid under the influence of ALAD in blood. The resulting PBG reacts with p-dimethylamino-benzal-dehyde to form a red color which is read spectrophotometrically at 553 nm.

b) ALAD Stability Study

Because of questions concerning stability of ALAD, only those blood samples collected in northern California were analyzed for ALAD. In a concurrent study it was established that blood specimens for ALAD determination should be analyzed within 10 hours after drawing the blood. The enzyme activity is best determined within 4 hours of drawing the blood. When the analysis cannot be done in this period, it is possible to correct the results for the decrease in activity. The results from the stability study are described in a paper by Prpic-Majic, et al, Appendix. We adjusted ALAD results as described in the article.

3. δ-Aminolevulinic Acid (ALA) in Urine

The method used is based on condensing ALA with acetylacetone to form a pyrrole which in turn reacts with p-dimethylamino-benzaldehyde to form a red color. The method was modified to permit the use of disposable ion-exchange columns. The method is described in AIHL Method No. 20, Appendix.

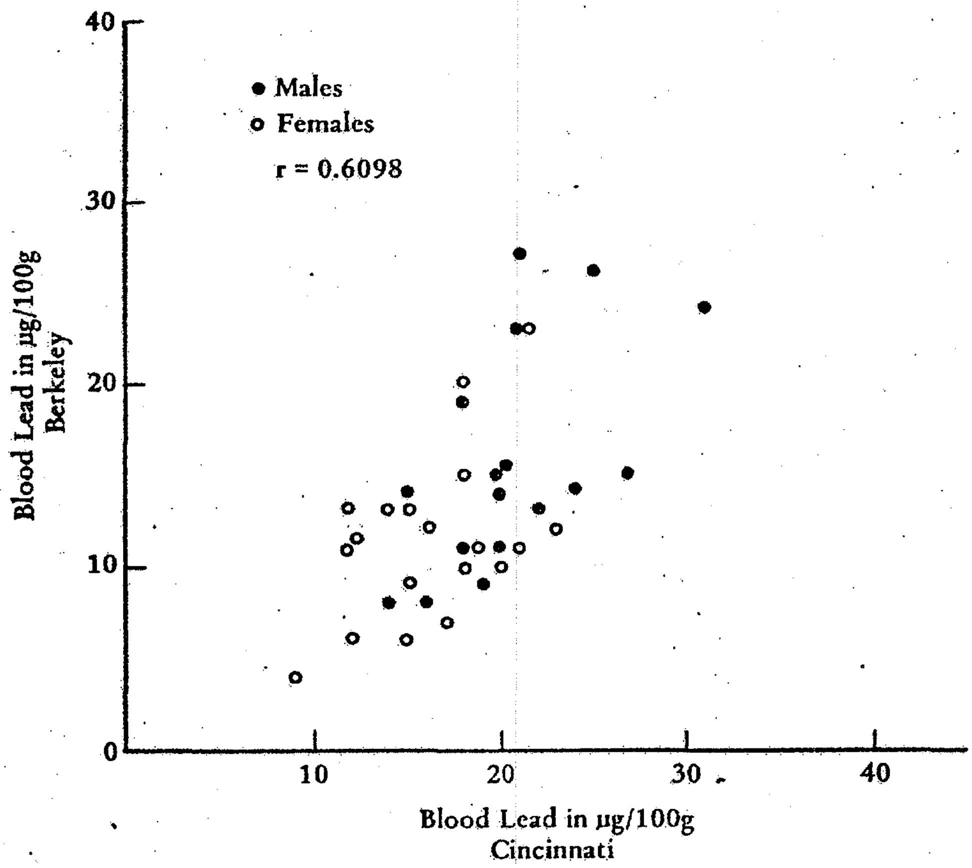
B. Interlaboratory Comparisons

For blood and air samples obtained in Alpine County, samples were split between the AIHL and The Kettering Laboratory of the University of Cincinatti School of Medicine. For air samples, excellent agreement was observed. For blood samples, the Cincinatti readings were nearly always higher than Berkeley. (See Figure 1.) There is a correlation of 0.57 for males (N = 17) and 0.47 (N = 19) for females.

There is a peculiar distribution of values as well, suggesting a constant excess of about 5 μg/100g in Cincinatti, for values less than 15 μg (Berkeley.)

Assuming that these differences are constant and that the true values lie between the Berkeley and Cincinatti results, Berkeley reports may underestimate lead in blood and Cincinatti may overestimate it.

Figure I
BLOOD LEAD CONCENTRATION
ALPINE COUNTY SPECIMENS
INTERLABORATORY COMPARISON



	Berkeley (CSDPH)		Cincinnati (Kettering)
Males			
Mean	15.65		20.65
S.E.	1.475		1.043
N		17	
r		0.573	
Females			
Mean	11.42		16.16
S.E.	1.044		0.866
N		19	
r		0.465	
Both Sexes			
Mean Cincinnati ÷ Mean Berkeley		1.362	

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IV. CHOICE OF COMMUNITIES

The choice of communities to be studied was motivated by the basic plan of the study, which was to obtain both environmental and health data from areas which would represent exposure of human populations to several different levels of lead in the ambient air.

Benicia and Crockett were chosen to represent relatively high exposure in northern California, partly because of the relatively high exposure to lead suggested by the high levels of lead found in vegetation (Avena) sampled in the area, and partly as a result of the concern for the effects on human health of the exposure through the food chain which was believed to be a cause of the horse deaths in the Benicia area.

In early discussions of possible choices for an area of low exposure in California, Alpine County was suggested because it had previously been shown to yield relatively low levels of lead in blood and urine obtained from residents. However, it was proposed that a more urban coastal area might be more suitable in terms of selecting a population whose other characteristics (relevant to exposure to lead from other sources) would be more nearly comparable to those of the Benicia-Crockett area. The Bodega Bay and Fort Bragg areas were proposed as candidates. However, it was subsequently learned that the Kettering laboratory was planning a study which would involve obtaining blood specimens from residents of Alpine County during a health fair and that ambient air sampling would also be carried out. It was therefore decided to enter into a cooperative arrangement to obtain blood, urine, and questionnaire data from participants in the health fair.

The obvious choices of areas in southern California were an area near the coast to represent low exposure and an inland area to represent high exposure. Again, areas were sought which would yield populations whose exposure to lead from sources other than the ambient air would not be drastically different. Pasadena was tentatively selected as the high exposure area, but upon inspection, was rejected for the following reasons: 1) Much of the downtown area was being converted from older single-dwelling units to newer multiple dwelling units, which suggested that relatively few residents would meet the minimum residence requirement of three years (discussed below) as well as that they might represent significant demographic differences from occupants of single dwelling units, 2) some residential areas near the downtown area were being demolished for freeway construction, 3) the southern area of the town (toward San Marino) represented an obviously high income level, 4) the northern end of town (Altadena) was at a higher elevation and would probably not have represented as high an exposure to air pollution. Burbank appeared to offer a more stable, typical area with high exposure to air pollution.

Coastal areas in Santa Monica, Venice, and Playa del Rey were considered, but these either represented high income levels or beach areas with shoddy housing which suggested low income levels and populations with unstable residence. Manhattan Beach was selected as a better possibility, but an area of the city slightly inland was selected as being somewhat more comparable to the Burbank area than that near the coast.

V. SAMPLING AND COLLECTION OF HUMAN SPECIMENS

A. Adults

Sampling in Burbank and Manhattan Beach was carried out in relatively homogeneous (as suggested by inspection of housing), compact areas several square miles in size. Households were counted and the sampling ratio was calculated to give the number of households needed for initial screening interviews in order to obtain approximately 50 eligible adults who would satisfy the screening requirements and from whom blood and urine specimens could be obtained. Using the sampling ratio, a systematic sample of households was selected using a random start.

Similar sampling methods were used in Crockett and Benicia, except that sampling was carried out in the entire community in each case, with the exception of a new area in Benicia in which length of residence was uniformly less than the required three years. It was necessary to augment the original samples in Benicia and Crockett in order to obtain an adequate number of subjects who passed the screening test and agreed to give blood and urine specimens.

The screening questionnaire was completed by personal interview, and consisted of several parts. The first page was used to determine whether the respondent was the appropriate person in the household to be solicited for the study, that is, an adult male or female, the sex having been randomly designated ahead of time. If an adult of the required sex was not living in the household, any adult living there was accepted as a candidate for the study. If the initial respondent was not the appropriate person, an appointment for later interview was made. The candidate was then questioned whether he had lived within the study area for less than three years, had worked in any one of several occupations designated as high risk for exposure to lead, or had ever been treated for lead poisoning. A positive answer to any of these three questions immediately disqualified the candidate for inclusion in the study. If the candidate passed these screening questions, he was then asked questions concerning commuting habits, medical conditions, smoking, past or present employment in some occupations not considered high risk but with the possibility of enough exposure to lead so that it should be taken into account in evaluating the laboratory results, and a diet history to determine what foods were commonly eaten in the area and whether any individuals had diets which departed from these in such a way as to be significant in evaluating the laboratory results.

A telephone number was obtained for each respondent who passed the screening questions and agreed to donate specimens. Appointments for donation of specimens were made several days before they were collected. In Benicia, collection of the specimens was done in a private physician's office under the specifications of the study, that is, using special leadfree needles, vacuatainers, and urine containers, and with proper handling, storage, and transport of the specimens to the State laboratory. In Crockett, a laboratory technologist visited the homes fo participants to obtain specimens. In both Benicia and Crockett, specimens were delivered to the laboratory and held for a maximum of 12 hours before determination of ALAD was carried out, then both blood and urine specimens were frozen for subsequent determination of lead concentration and, in the case of urine, ALA determination.

In Manhattan Beach and Burbank, no attempt was made to deliver the specimens to the laboratory within the time limit necessary for ALAD determination, but they were frozen for transport to the laboratory for subsequent determination of lead concentration and ALA analysis. In Alpine County, refrigerated specimens were transported to the laboratory during the night following the Health Fair.

B. School Children

Selection of school children for participation in the surveys was done through the school districts serving the areas covered by the survey of adults. The judgment of each district was followed as to which third grade classes would be most suitable for inclusion in the study based on probable cooperation of children, parents, and school personnel. Class rosters were supplied, and a systematic selection of panels of children for each area was made. Parents of these children were contacted directly by the study staff in Benicia and Crockett (by mail) and through the schools in Burbank and Manhattan Beach. In Benicia, appointments were made for specimens to be obtained in a private physician's office; in Crockett, an evening clinic was held at the local community center; and in Burbank and Manhattan Beach, clinics were held at the schools with the participation of school personnel and parent volunteers. Blood and urine specimens were obtained in Benicia and Crockett, and ALAD determinations were carried out in addition to lead concentration and ALA determinations. Only blood specimens were obtained in Burbank and Manhattan Beach because of the difficulty that had been experienced in obtaining adequate urine specimens from children in northern California, and the blood specimens were not analyzed for ALAD because of the difficulty in delivering them to the Berkeley laboratories whthin the crucial time limit. Children were also screened for length of residence and previous treatment of lead poisoning.

Table 1 shows the numbers of adult respondents originally contacted, the numbers who did not pass the screening criteria for various reasons, and the numbers of specimens finally obtained.

The method of sampling adults from the general population was selected in the hope of obtaining broad representation of the area being studied and of obtaining samples unbiased with respect to relevant factors other than air pollution exposure, such as diet. However, because of the high rate of failure to meet the screening requirements, the high rate of refusal to give blood specimens, and the failure to keep clinic appointments, it is doubtful whether a "better" sample was obtained than would have resulted from the less expensive method of using individual volunteers or volunteers from organized community groups. It is unlikely that significant bias would occur from such volunteers unless special conditions of water supply or diet were encountered, and these could be screened by questionnaire.

Table 1

HOUSEHOLD SAMPLES AND SUCCESSFUL CONTACTS

HOUSEHOLD SAMPLE	BENICIA	CROCKETT	MANHATTAN BEACH	BURBANK
Number of Housing Units	194	160	205	201
Vacant housing units	8	4	1	5
Unable to locate occupant	9	0	10	31
Contacts made	177	156	194	165
Refused interview	13	17	23	25
Screening criteria not met	75	38	41	24
Less than 3 yrs. residence	55	26	24	19
Occupational exposure to lead	20	12	17	5
Past lead poisoning	0	0	0	0
Interviews completed	89	101	130	116
No specimens collected	37	50	89	73
Specimens collected	52	51	41	43

VI. POPULATION SAMPLING RESULTS

A. Raw Data

Laboratory results for individuals who participated in the study are given in the Appendix.

B. Analysis and Interpretation

1. Distributional Attributes

The departure of the distributions of results for the various tests from normality does not appear to be marked enough to invalidate the use of normal theory in performing statistical tests of significance.

2. Proportion Outside of Provisional Limits

Of the entire population sample, only two adults had blood lead concentrations greater than the acceptable individual upper limit of 40 μg/100 ml recommended at the Amsterdam symposium. Both of these were male residents of Crockett. No children had values above the recommended upper limit of 35 μg/100 ml of blood lead. The concentrations reported by our laboratory as μg/100 g have been accepted as roughly equivalent to those proposed at Amsterdam as μg/100 ml. In fact, a better approximation to the Amsterdam units would result from multiplying the California values by a conversion factor of about 1.05. Methodological differences could also result in lack of comparability of our data with the Amsterdam recommendations. Unfortunately, it is not possible to compare ALAD and d-ALA values from this study with the recommended standards proposed at the Amsterdam conference because they are reported in different units than ours, and the methods used for both these determinations are not specified. However, the blood lead values as reported above are probably roughly comparable.

3. Comparisons by Area

Comparison of mean values by area for blood lead, ALAD units, urine lead, and d-ALA are shown for adults and children respectively in Tables 2 and 3. Significance tests were done for each of these measurements for the differences between Benicia and Crockett, and the differences between Burbank and Manhattan Beach. In adults, statistically significant differences between mean values in Benicia and Crockett were found for blood lead for both males and females (Crockett higher than Benicia), and for ALAD units for males (Benicia higher than Crockett). Differences between Burbank and Manhattan Beach were not significant among adults. In children, statistically significant differences for both males and females were found between mean blood lead levels in Burbank and Manhattan Beach.

For both adults and children, ALAD unit determinations were done only for Benicia and Crockett because of the critical timing of the laboratory test. Urine lead and d-ALA determinations were not done in Burbank and Manhattan Beach because of the difficulty in obtaining adequate specimens from children and the problem of freezing and transporting specimens to the Berkeley laboratory.

4. Comparisons Among Tests

In terms of the presence or absence of statistical significance in mean area differences, the following can be said.

a. Of the four area differences for which both blood ALAD units and blood lead concentrations were available, both tests gave the same results except for adult females. That is, both tests showed significant area differences between Benicia and Crockett among adult males, neither showed significant differences between Benicia and Crockett among children of either sex. Adult females showed a significant difference in blood lead only.

b. Of the six area differences for which both urine lead concentrations and urine d-ALA measurements were available, both gave consistent results except for adult males in Benicia and Crockett, for whom only lead concentration differences were significant, and for adult females, for whom only d-ALA differences were significant.

c. Comparisons of significance tests for blood and urine results also show some inconsistencies. For the groups in which significant area differences did occur for blood lead and ALAD units (Benicia and Crockett adults), significant area urine lead concentration differences occurred only among males, and significant d-ALA differences occurred only among females. Significant area urine differences did not occur in any groups not showing blood lead or ALAD differences.

These results are shown in Tables 2 and 3. No evaluation has been done of the relationships between the results of the various tests in individuals.

Table 2

SUMMARY OF LABORATORY RESULTS
SPECIMENS FROM ADULTS

~12 — 21 µg/

- ADULTS

ANALYSIS	MALE					FEMALE				
	Alpine	Benicia	Crockett	Burbank	Manhattan Beach	Alpine	Benicia	Crockett	Burbank	Manhattan Beach
Blood Lead (µg/100 g)										
N	15	27	20	20	22	20	25	31	22	19
Mean	15.40	16.30*	20.75*	16.85	15.32	11.75	11.76**	14.29**	15.45	13.79
S.E. of Mean	1.51	0.79	2.21	1.00	0.84	1.05	0.40	0.55	0.82	0.83
ALAD Units										
N	NA	26	20	NA	NA	NA	25	31	NA	NA
Mean	NA	100.92*	71.25*	NA	NA	NA	127.16	110.06	NA	NA
S.E. of Mean	NA	7.97	7.50	NA	NA	NA	7.40	6.68	NA	NA
Urine Lead (µg/100ml)										
N	10	26	20	17	21	3	21	30	16	17
Mean	1.74	1.21*	2.04*	2.16	1.64	2.97	1.30	1.46	1.94	1.39
S.E. of Mean	0.19	0.67	0.25	0.24	0.12	1.52	0.18	0.14	0.22	0.17
D–ALA (µg/100 ml)										
N	10	26	20	20	22	5	23	31	21	19
Mean	0.27	0.16	0.16	0.21	0.25	0.30	0.23*	0.17*	0.23	0.17
S.E. of Mean	0.03	0.02	0.02	0.03	0.03	0.06	0.02	0.02	0.03	0.03

* Differences between means are significant at the 5% level.
** Differences between means are significant at the 1% level.

NA Not available.

Note: Signicance tests refer to differences between means for Benicia–Crockett and Burbank–Manhattan Beach.

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Table 3

SUMMARY OF LABORATORY RESULTS
SPECIMENS FROM CHILDREN

13 – 23 μg

ANALYSIS	MALE				FEMALE			
	Benicia	Crockett	Burbank	Manhattan Beach	Benicia	Crockett	Burbank	Manhattan Beach
Blood Lead(μg/100 g)	.34	.35	3.3c	2.41				
N	17	18	17	21	17	10	19	19
Mean	13.12	14.33	23.29**	16.81**	13.71	13.80	20.37**	17.05**
S.E. of Mean	0.64	0.89	1.14	0.88	0.76	1.53	0.67	1.00
ALAD Units								
N	14	18	NA	NA	16	10	NA	NA
Mean	116.50	94.61	NA	NA	111.60	100.50	NA	NA
S.E. of Mean	9.42	9.62	NA	NA	6.33	11.36	NA	NA
Urine Lead (μg/100 ml)								
N	19	14	NA	NA	14	6	NA	NA
Mean	2.70	2.24	NA	NA	2.35	3.13	NA	NA
S.E. of Mean	0.22	0.27	NA	NA	0.24	0.33	NA	NA
D–ALA (μg/100 ml)								
N	20	18	NA	NA	17	10	NA	NA
Mean	0.33	0.31	NA	NA	0.31	0.30	NA	NA
S.E. of Mean	0.04	0.02	NA	NA	0.02	0.03	NA	NA

** Differences between means significant at the 1% level.

NA Not available.

Note: Significance test refer to differences between means for Benicia–Crockett and Burbank–Manhattan Beach.

VII. ENVIRONMENTAL SAMPLING RESULTS

A. Raw Data

1. Food Chain Hazards

Results of determination of lead concentration in a large variety of foodstuffs are given in the Appendix. These are in the form of three lists arranged in the following ways:

a. Ascending order of food code number within each area, to facilitate comparisons of specific foods.

b. Ascending order of food code number within area within food type (vegetables, meat, fruit, fish, beverages, dairy products, bakery products, and miscellaneous).

c. Descending order of lead concentration within area, regardless of food type.

At the end of each list the hospital diet and backyard garden data are shown.

2. Air Monitoring

Lists of the air monitoring data by day and location are appended.

3. Data for Lead Concentration in Avena Collected from Manhattan Beach

B. Analysis and Interpretation

1. Food Chain Hazards

Food intake was sampled by purchasing common food items from local grocery stores and by obtaining samples of food grown in backyard gardens in each area. Results of interviews were used to determine whether diets differed appreciably in the different locations and to determine which grocery stores were used most frequently. Comparable items of food could not be obtained consistently in all areas because of differences in seasonal or local availability and problems of transportation and storage. Lead concentrations in some common food items obtained from most areas are shown in the summary tables (Tables 4 - 6), and no consistent area differences can be detected. When more than one sample was obtained from an area, values for each sample are shown. Considerable variation occurred between different food items as well as between different samples of the same food. The highest concentration of lead occurred in carrot greens from a backyard garden in Benicia (5.60 $\mu g/g$). Other vegetables with high values were chard, parsley, lettuce, mustard greens, and spinach, with concentrations ranging from 0.85 - 2.41 $\mu g/g$. Other foods showing relatively high concentrations of lead were anchovies and anchovy paste, veal kidney, top round, tuna, and ham, with values ranging from 0.84 to 2.00 $\mu g/g$.

The Bureau of Radiological Health routinely collects samples of hospital diets for surveillance of background radiation. Each sample consists of all food and beverages from a hospital tray as it is served to patients, including all liquids. Twenty-four samples from throughout the State were analyzed for lead concentration. The values were uniformly low and range from <0.01 μg/g to 0.17, all but three of the values being less than 0.10. Individual values appear in the computer output of food lead levels.

No evidence was found that a significant amount of lead would be ingested through the food chain, nor were significant area differences detected.

Table 4

COMPARISON OF LEAD CONCENTRATIONS
IN FOOD BY AREA
(μg/g for individual samples)

	ALPINE	BENICIA	CROCKETT	BURBANK	MANHATTAN BEACH
FRUIT					
Apples	.15 .20	.09 .09 .02	<.01	.08 .03 .03 .06 .04 .07 .06	.05 .05
Tomatoes	.02 .18	<.01	<.01	.02	.02
Oranges	NA	.12 .08	.06 .08	.04 .10 .05 .04	.05
VEGETABLES					
Lettuce	.05	NA	.54	.04 .26	.10
Parsley	.20	.66 .88	.24	1.25	.49
Spinach	.32	.23	.85	.69	.42
Romaine	.26	.09 .40	.08	.35	.15
Celery	.04	NA	.00	.05	.12
Eggplant	.02	.05 .05	.02	NA	.03
Carrots	.31 .12	.12 .10	<.01	.03	.17
Potatoes	.02 .04	.09 .13	.02	.05 .05 .03	.05

NA: Not available.

Table 5

COMPARISON OF LEAD CONCENTRATIONS IN FOOD BY AREA
(μg/g for individual samples)

	ALPINE	BENICIA	CROCKETT	BURBANK	MANHATTAN BEACH
MEAT					
Ground Beef	.16	< .03	.12	.08(x2) .09(x2)	.07
Chicken	.16 .42	< .03 .16	.10	.10	.09
Bacon	.30 .06	.20 .44	.28	.03	.24
Ham	.84 .08	.13 .32	.22	.11	.16
Lamb Chops	.10 .16	.18 < .03	.17	.08	.25
Pork Chops	.16 .19	.27 .38 < .03	.15	.10	.07
DAIRY					
Butter	.12	.45 .17	.05	.09	.05
Milk	< .01 .08	.03 .06	.06	.07	.03
Eggs	.02	.12 .04	.08	.05	.07
Cottage Cheese	NA	.06	.08	.15	.04
GRAIN PRODUCTS					
Bread	.18	.83 .63	NA	.10	.13
Margarine	.52	.08 .13	NA	.06	.06

NA: Not available.

x2 : Two samples each.

Table 6

COMPARISON OF LEAD CONCENTRATIONS
IN BACKYARD GARDEN PRODUCE BY AREA
(μg/g for individual samples)

	BENICIA AND CROCKETT	BURBANK	MANHATTAN BEACH
Apples	NA	.24 .23	.07
Carrots	.47 .16 .18	.30 .06	.07
Zucchini	.19 .07 .05 < .04	.02	.02
Chard	.15 .29 2.41	.30	.57
Lettuce	NA	.70	.42
Bell Peppers	.08 .03 .18 .05 < .09	.10	.02
Tomatoes	.08 .01 .07 .06 .12	.04	.02 .04
Cherry Tomatoes	NA	.04	.03
Figs	.29 .09 .26	.18	.16
Lemons	.21 .14	.09 .08 .08 .06	.06
Strawberries	.47	NA	.45

NA: Not available.

2. Air Monitoring

Table 7 shows a summary of the air monitoring data. High volume sampling stations were set up within each of the residential areas studied. The mean lead concentrations by quarter for Burbank are consistently higher than the comparable means for Manhattan Beach, but only the differences for the second quarter of 1972 are statistically significant using a two-tailed t-test ($p < 0.05$). The differences between means for Benicia and Crockett are not consistent in direction, and the only statistically significant difference using a two-tailed t-test is for the third quarter of 1972 ($p < 0.1$).

The consistently higher mean values in Burbank when compared to Manhattan Beach suggest that these differences could be a factor in the higher blood lead concentrations found among Burbank children. This is supported by comparisons of the values for individual days, which also show a marked tendency for Burbank values to be higher than those reported from Manhattan Beach. Results of sign tests were significant at the 5% level for the first and second quarters (6 out of 6, and 9 out of 10 differences, respectively, showing higher values for Burbank than for Manhattan Beach) while a similar test for all three quarters combined was significant at the 1% level (31 out of 41 differences showing higher values for Burbank).

The significantly higher mean value in Crockett when compared to Benicia (second quarter, 1972) corresponds to the significantly higher blood lead means found among adults in Crockett.

However, the relative lack of consistency in direction of differences for individual days, as well as the uniformly low values, suggests the lack of a significant human effect, at least from inhaled air. The possibility of air exposure to lead on soil and vegetation is a different problem.

3. *Avena* Sampling

Avena sampling in Benicia and Crockett and subsequent analysis for lead has been carried out and reported under a previous interagency agreement with ARB. It was planned that *Avena* be used in this study as a supplemental method of indicating exposure to airborne lead. However, *Avena* was not generally available in the Alpine County study area nor in the Burbank area. Several *Avena* samples were collected in the Manhattan Beach area. The results of these analyses are given in the Appendix.

TABLE 7

Summary of Air Sampling Data

$\mu g/m^3$

Time Interval	Burbank			Manhattan Beach		
	N	Mean	S.E.	N	Mean	S.E.
Fourth Quarter, 1971 10/8 - 11/7	25	2.315	0.312	25	1.979	0.253
First Quarter, 1972 1/12 - 1/30	13	5.458	0.684	13	3.658	0.569
Second Quarter, 1972* 4/4 - 4&23	10	3.267	0.502	10	1.868	0.432

Time Interval	Benicia			Crockett		
	N	Mean	S.E.	N	Mean	S.E.
First Quarter, 1972 2/7 - 3/23	8	0.741	0.211	8	0.598	0.140
Second Quarter, 1972 3/30 - 6/29	9	0.211	0.052	11	0.317	0.088
Third Quarter, 1972** 7/5 - 9/27	14	0.195	0.018	15	0.303	0.033
Fourth Quarter, 1972 10/3 - 12/26	10	0.328	0.049	10	0.250	0.040

* Difference between means significant at 5% level, two-tailed t-test.
** Difference between means significant at 1% level, two-tailed t-test.

VIII. SUPPLEMENTARY STUDIES OF CHILDREN

A. Six-Community Study in Los Angeles

The six community study in Los Angeles was designed to compare the effects of air pollution on lung function and other indicators in communities representing high, moderate, and low exposure. Two communities were chosen to represent each exposure level. Results reported here are limited to blood lead concentrations in elementary school boys and girls, mostly 9-10 years old, and in male high school athletes (Table 8). In most cases, male-female differences among the elementary school children were slight, although males showed consistently higher concentrations than females. No consistent differences were observed between elementary school children and high school students. The lowest mean concentrations of lead occurred in the two low pollution communities for both elementary and high school students, but the highest mean value in elementary school students occurred in an area of moderate pollution. Means from the two high pollution areas combined (Riverside and Azusa) and the two low pollution areas combined (Lancaster and Oceanside) were tested for each sex for statistically significant differences. Both high school and elementary school differences were significant at the 5% level.

B. Housing in San Diego

Population samples of preschool children were chosen in several areas of San Diego County representing pre-World War II housing containing lead-based paint. These included east San Diego, representing whites with non-spanish surnames and "other" than low economic status; southeast San Diego, representing low economic status and a variety of ethnic backgrounds; National City, representing low economic status and with all but two individuals in the sample having Spanish surnames; Pala, an Indian reservation; Escondido, with a sample consisting entirely of individuals with Spanish surnames; and Oceanside and Carlsbad represented by one child each.

East San Diego, southeast San Diego, and National City were each represented by children who could be classified as living near traffic or away from traffic. Boundaries between "near" and "away from" traffic were set to coincide with divisions between city blocks. "Near" was within 380 feet of traffic; "away from" was between 380 and 700 feet. Differences between mean blood lead concentrations in the groups living near and away from traffic were tested separately for each of these three areas and for all three areas combined using a two-tailed t-test. The only statistically significant difference was for National City ($p < 0.05$). These results, along with mean values for other areas, are shown in Table 9. There were no mean values or individual values that exceeded the suggested limits from the Amsterdam Symposium.

Lead concentrations in soil ranged from 45 ppm to 2256 ppm. A rank correlation test (Spearman's rho) was used to determine whether there existed a significant correlation between blood lead concentration and concentration of lead in soil from corresponding play areas, either within any of the study areas or for all areas combined. The results were not statistically significant at the 5% level. For all areas combined, a median test was done to determine whether significant differences in soil lead concentration occurred between samples collected from households near traffic compared with those away from traffic. These results, also, were not statistically significant at the 5% level.

Table 8

BLOOD LEAD CONCENTRATION (μg/100 g) BY LOCATION AND SEX
SIX-COMMUNITY STUDY OF SCHOOL CHILDREN
SOUTHERN CALIFORNIA

POPULATION	HIGH POLLUTION		MODERATE POLLUTION		LOW POLLUTION	
	Riverside	Azusa	Long Beach	Culver City	Lancaster	Oceanside
Elementary School						
Male						
N	27	18	22	28	10	24
Median	11.0	11.0	11.0	14.0	8.0	10.5
Mean	12.1	12.6	11.4	14.6	9.2	10.8
S.E. of Mean	0.6	0.7	0.6	0.8	1.0	0.5
Female						
N	23	23	24	21	28	19
Median	11.0	12.0	10.0	12.0	8.0	9.0
Mean	11.4	12.0	10.7	12.4	8.5	9.8
S.E. of Mean	0.5	0.7	0.6	0.6	0.4	0.5
High School						
Male						
N	17	23	30	19	20	26
Median	11.0	14.0	12.0	13.0	9.0	9.5
Mean	12.1	14.6	12.6	14.0	9.0	10.1
S.E. of Mean	1.0	0.6	0.5	0.6	0.5	0.6

Note: Differences between pooled means for the high and low pollution areas were statistically significant at the 1% level for both high school and elementary school differences.

TABLE 9

San Diego County Study of School Children
Comparison of Mean Blood Lead Concentrations

µg/100g

	Total			Away From Traffic			Near Traffic		
	N.	Mean	S. E.	N.	Mean	S. E.	N.	Mean	S. E.
Total, Three Areas	74	15.9	0.57	26	15.2	1.03	48	16.3	0.68
East San Diego	20	15.6	0.82	8	17.4	1.46	12	14.4	0.83
Southeast San Diego	34	17.1	0.93	11	16.2	1.79	23	17.5	1.09
National City	20	14.2	1.08	7	11.0*	1.11	13	16.0*	1.33
Pala	4	11.2	2.02	4	11.2	2.02	-	-	-
Escondido	5	12.2	1.98	5	12.2	1.98	-	-	-

*Difference between means statistically significant ($p < 0.05$, two-tailed t-test).