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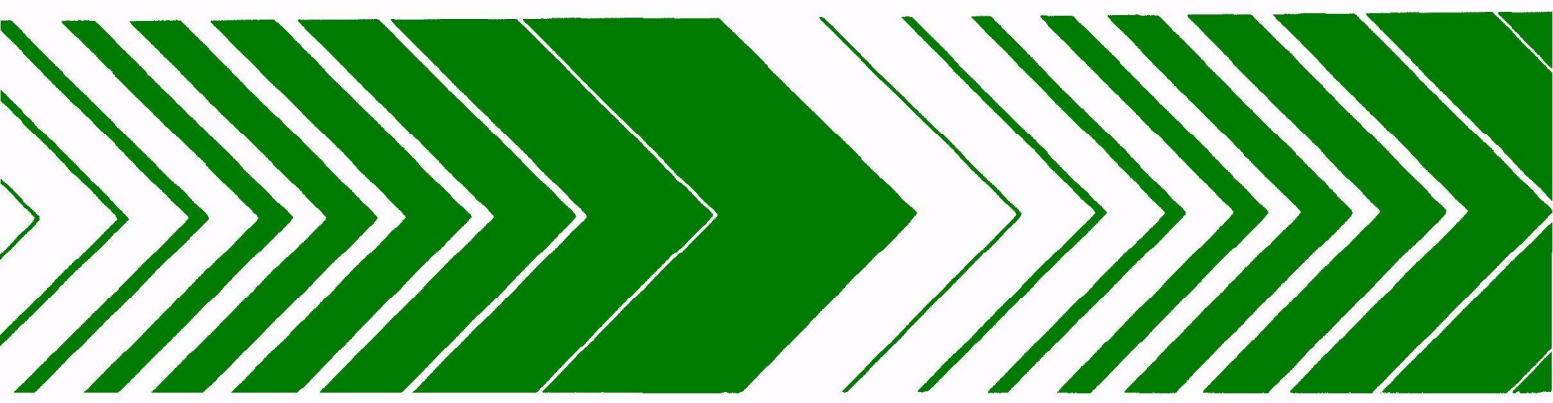
Maternal-Fetal Tissue Levels of Sixteen Trace Elements in Eight Communities



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MATERNAL-FETAL TISSUE LEVELS OF SIXTEEN TRACE ELEMENTS IN EIGHT COMMUNITIES

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, non-ionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory participates in the development and revision of air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is primarily responsible for providing the health basis for non-ionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

The developing fetus represents one of the most vulnerable subgroups of the general population to the toxic effects of trace elements. This investigation was designed to gain information on the levels of trace elements present in the blood of a term fetus, and the relationship of these levels to the levels found in the placenta and selected maternal tissues. Once transplacental transfer of trace elements is established, other researchers may attempt to ascertain the effects of the observed levels of tissue trace elements on the developing fetus.

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CONTENTS

ABSTRACT

The developing fetus probably represents one of the most vulnerable subgroups of the general population to the toxic effects of trace elements. There have been numerous reports of abortion or fetal malformation due to excessive exposure of the expectant mother to mercury and other trace elements. This investigation was aimed at gaining information on the levels of trace elements present in the blood of a term fetus, and on the relationship of these levels to the levels found in the placenta and selected maternal tissues. Once transplacental passage of the trace elements and their levels in the placenta and fetus is established, other researchers may attempt to ascertain whether these conditions actually result in overt or subtle impairments of the developing fetus.

This study took advantage of the opportunity provided by normal deliveries to obtain simultaneous tissue samples from a mother and her child. Maternal-fetal sets consisting of maternal venous blood, cord blood, placenta, maternal scalp hair, and pubic hair were collected and analyzed for the following 16 elements; boron, barium, cadmium, chromium, copper, iron, lead, lithium, manganese, mercury, nickel, selenium, silver, tin, vanadium and zinc.

SECTION 1

INTRODUCTION

Pollution of the environment by trace elements, many of which are toxic, is a subject of increasing concern in our industrial society. Environmental levels of many trace elements have increased along with industrial growth (1-5). Exposure to trace elements in the environment is via multiple routes - diet and water as well as air - and humans integrate their total environmental exposure (1). Specific substances are known to concentrate selectively in various tissues (6-7). Yet, little is known about how a great number of trace elements accumulate in man, or what the long-term effects of such accumulations might be. Ordinary tissue levels at low levels of exposure have yet to be characterized for many.

The developing fetus probably represents one of the most vulnerable subgroups of the general population to the toxic effects of trace elements. Cases in point are the Minamata Bay incident with mercury (8) and numerous reports of abortion or fetal malformation due to other trace element exposures to the expectant mother (9-14). The present investigation was aimed at gaining information on the levels of trace elements present in the blood of a term fetus, and on the relationship of these levels to the levels found in the placenta and selected maternal tissues. Once transplacental passage of the trace elements and their levels in the placenta and fetus is established, as it has been already for a few elements (9-16), other researchers may attempt to ascertain whether these conditions actually result in overt or subtle impairments of the developing fetus.

This study took advantage of the opportunity provided by normal deliveries to obtain simultaneous tissue samples from a mother and her

child. The tissues studied were either routinely collected or easily available. Maternal-fetal sets consisting of maternal venous blood, cord blood, placenta, maternal scalp hair and pubic hair were collected and analyzed for the following 19 elements; arsenic (As), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), lithium (Li), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), tin (Sn), vanadium (V), and zinc (Zn).

The CHESS* network provided a framework for the nationwide collection of tissue sets (17) for the specific purpose of characterizing the tissue trace elements as to:

1. baseline concentrations
2. geographic trends
3. covariate effects (such as age, race and parity)
4. tissue interrelationships.

A knowledge of these parameters will permit the establishment of ranges of elemental concentrations to be found across the United States. In addition, geographic variation in tissue trace element concentrations may warn of potential or existing environmental hazards to the extremely sensitive fetal population.

* CHESS is an acronym for the Community Health and Environmental Surveillance System.

SECTION 2

MATERIALS AND METHODS

Collection of Samples

Maternal fetal sets were collected from each CHESS exposure sector in eight CHESS areas. These areas were Charlotte, N. C.; Birmingham, Alabama; Riverhead, N. Y.; Elizabeth, N. J.; Ogden, Utah; Salt Lake City, Utah; West Los Angeles, California; and East Los Angeles, California. Boundaries for these CHESS areas and descriptions of the areas have been established in earlier studies (17-18). These areas have been grouped geographically into regions designated as the southeast (Charlotte and Birmingham), New York-New Jersey (Riverhead, N. Y. and Elizabeth, N. J.), Utah (Ogden and Salt Lake City), and California (East and West Los Angeles). Arrangements with local hospital departments of obstetrics provided the collection mechanism. When possible, subjects were contacted during prenatal care visits or classes. A local CHESS worker assisted the obstetrics department in the selection of possible participants according to the arrangements with the specific hospital. Subject participation was on a voluntary basis. Consent forms were signed, and the mother's questionnaire information completed during the prenatal care visits or classes. Mother's and hospital information questionnaires, prenumbered labels, and containers for tissue collection were supplied to each hospital by the CHESS program. A local CHESS worker or a staff person from the obstetrics department was responsible for completing the hospital information form. Selection factors used in this study were as follows:

1. All samples should be from normal pregnancies and deliveries and restricted to 16-39 year old mothers. "Normal" was defined by the

knowledge and judgment of the clinicians and generally excluded patients with major medical complications and/or coexisting illness, and toxemia of pregnancy.

2. All study participants must have lived in the CHESS area for at least the entire duration of their pregnancy.

3. Multiple births were excluded from the study.

Tissue sample collection procedures were as follows:

1. Maternal scalp hair was obtained from a recent haircut or trim and mailed directly to the CHESS workers; instruction sheets and postpaid envelopes, with individual prenumbered labels affixed, were given to each participating mother at clinic visits or upon delivery; hair samples were preferably obtained within two months of delivery.

2. All pubic hair shaved off in prepping was rinsed free of detergent and antiseptic and stored in a Lab-Tek* container.

3. Two 15 ml specimens of venous blood were obtained from the mother, when possible. These specimens were collected after delivery and were stored in minimal Pb B-D* vacutainer tubes.

4. Two 15 ml specimens of umbilical cord blood were drawn in minimal Pb B-D vacutainer tubes after cutting the cord, but before placenta delivery.

5. Three peripheral wedges of the placenta were cut in full thickness after placental delivery and placed in a separate clean, nonsterile Lab-Tek cup; the samples were noted to be free of gross pathology.

* Mention of commercial products or company names does not constitute endorsement by the Environmental Protection Agency.

All blood and placenta specimens were immediately stored in a freezer and kept frozen until shipped in dry ice to an EPA contract laboratory for analysis.

Data on community dustfall were obtained monthly for the 12 months prior to the end of the study at a central site within each community in conjunction with other CHESS studies. The locations of these sites were such that the sample from each of the communities of interest in these studies was within 2.5 kilometers of the monitoring site. The dustfall was analyzed for Cd, Cr, Cu, Pb, Mn, Ni, and Zr content, expressed as milligrams per square meter per month of trace element fallout.

Analytical Methods

Hair specimens were washed with a detergent solution, rinsed and dried according to the procedure of Harrison et al. (19). Bloods and placenta samples were weighed and lyophilyzed prior to digestion which was achieved by oxygen combustion for some elements and by dry ashing for others, as indicated in Table 1. The ashing procedure consisted of wetting the tissue with quartz-distilled sulfuric acid and heating at 550°C in a muffle oven. To prevent any losses when volatile elements were to be analyzed, weighed portions of the samples were prepared by the Schöniger Flask Technique (20).

Dustfall samples were acid extracted and metal concentrations were determined by atomic absorption spectrophotometry (18).

Analytical methods for all tissues for each element are shown in Table 1 Standard laboratory quality control procedures were employed. In addition, recovery of all 19 elements added to a dustfall sample, to a hair sample,

and to a blood sample were evaluated using additions that were either twice the detection limit or twice the endogenous level, whichever was larger. Recovery rates were greater than 80 percent in all cases, and greater than 90 percent in most of the cases.

Statistical Methods

Before statistical analysis of the data, the values were edited for "outliers", values so far removed from the main body of readings as to warrant their removal from the population for statistical analysis purposes.

A statistical procedure was developed for this process, so that the editing was completely objective. In this procedure the inherent population variability, as measured by the standard deviation of the logarithms of the values, was estimated from the central section of the sample. Limits were then set at three standard deviations from the mean of the logs. Histograms of the data were carefully examined to ensure the effectiveness of this procedure, and to verify that a large number of seemingly valid observations were not being eliminated. Logarithms of the concentration values were used to normalize the data and to make significance tests valid.

If the total sample mass or concentration of trace element in the sample resulted in the amount of trace element being below the minimum detectable limit of the instrument, then the minimum detectable limit divided by the sample mass was taken as the censored value. These censored values were flagged, but were used as measured values in the analysis. Computations involving data where the censored values exceeded 10 percent were not considered reliable by the authors. Arsenic, Be, and Co were excluded from statistical analyses because of the high frequency of censored values in all five tissues.

Standard statistical methodologies of correlation and linear models were applied to the trace element concentrations to detect effects and interrelationships of the measured variables (21). Covariate groupings used in the statistical analyses are shown in Table 2.

Monthly dustfall trace metal concentrations (Pb, Cd, Cu, Zn, Mn, Ni, and Cr) observed in each sector were averaged over the 12-month period ending in June 1972, the month the study was completed. These mean metal levels were used as crude indices of environmental exposure in a portion of the study.

SECTION 3

RESULTS

Demographic Characteristics

The study population consisted of 198 subjects who provided sufficient tissue samples for analysis. Demographic characteristics considered were smoking patterns, parity, socioeconomic status, and age. The distributions of these characteristics by CHESS sector are given in Table 3. Considering each of these factors singularly does not show the high degree of interdependency between them. There are significant correlations between socioeconomic status and maternal age, parity and maternal age, and socioeconomic status and smoking status (Table 4). This limits the reliability of the assignment of significant effects to specific covariates. However, this study was not specifically designed to investigate such delineations, but rather to take the covariates into account in looking for geographic differences in trace element levels.

Study Population Trace Element Concentrations

Tables 5 through 9 display the basic parameters estimated for each trace element distribution by tissue. The last two columns are the endpoints of the interval expected to contain 68 percent of the population observations if the observations were from a log normal distribution whose parameters coincide with the estimated parameters. The percent censored refers to the percent of observations where the metal level in the sample was less than the minimum detectable level. Statistics computed from samples where this level exceeds 10 percent are not considered reliable by the authors.

The ranking of tissues by the number of metals for which the percent

censored exceeded 10 percent was maternal blood with eight, placenta with seven, cord blood with six, pubic hair with four and scalp hair with three. Arsenic, Be, and Co were highly censored in all tissues, and were therefore not included in further analyses.

There were fewer scalp hair samples than pubic hair samples, primarily because subjects were asked to mail in scalp hair samples whereas pubic hair samples were taken as a matter of hospital procedure. When the weight of scalp hair samples was too small for analysis of all elements, only Pb, Cd, Cu, Zn, Hg, Li, and Fe were analyzed.

Few trace element studies have been done on maternal-fetal sets (22-27). A comparison of the trace element levels found in maternal and cord blood and placenta in these studies with our results (Table 10) shows excellent agreement for the five elements available, with the exception of a study of placenta by Dawson et al. (27). There is a marked disparity of Dawson's results from the results of Baglin and Brill et al. and Finklea et al., as well as from ours.

A comparison of the five trace elements in scalp and pubic hair reported in previous publications with the findings of our study reveals two facts: First, there is little information available on the trace element content of hair for this type of population (2,22,23,28,29); Second, there is generally good agreement with the trace element levels published in these similar studies of adult females (Table 11).

To our knowledge, for most of the 11 remaining trace elements in our study, there were no published values for this type of population with which to make a comparison. Hence, these reported levels should serve as a frame

of reference for future studies.

An examination of the geometric means in Tables 5 through 9 reveals that both scalp and pubic hair trace element concentrations are higher than blood or placenta values for all the trace elements except Fe. The exception of Fe is understandable since about 70 percent of the body iron is contained in blood (30).

Placenta trace element levels were higher than cord and maternal blood levels for Pb, Cd, Zn, Se, and Mn. For Pb and Se, these differences were relatively small even though they were statistically significant, whereas in Cd, Zn, and Mn, the levels in placenta were about twice those found in maternal and cord blood. Zinc levels would be expected to be elevated in placenta, since the placenta contains large amounts of zinc-rich vascular tissue (31). It appears then that, with the possible exceptions of Cd and Mn, the placenta is not acting as a sink for trace element storage.

In order to closely examine the relative levels of maternal and cord blood trace elements, and the relative levels of scalp and pubic hair trace elements, ratios of these values were computed for all cases where both values were present. A standard t-test was then carried out on the logs of these ratios.

Concentrations of four of the 16 trace elements — Pb, Cd, Cu and Zn — were lower in the cord blood than maternal blood. Only Cu and Zn had ratios significantly different from one at the 0.05 level. The other 12 elements were higher in the cord blood. Eight of the 12 elements higher in cord blood had ratios significantly different from one. (Table 12).

The average scalp hair levels were higher than pubic hair levels for all 16 trace elements, since every geometric mean ratio is greater than or

equal to one (Table 12). Ten of the 16 ratios were significantly different from one at the 0.05 level.

Many of these ratios agree quite well with those computed from other studies. Using the data on the five trace elements in Tables 10 and 11 to compute ratios, 12 of the 15 possible available ratio comparisons from other studies varied in the same direction from unity as did the ratios found in these data. Two of the three cases in disagreement involved comparisons with data from Finklea et al. (23).

Tissue Trace Element Interrelationships

Several authors have attempted to use some or all of these tissues as indices of trace element exposure (2,3,22,23,32-34). Since many of the trace elements are present at elevated levels in polluted environments, one might expect tissues acting as depositories for trace elements to show correlations between elements within that tissue. An example of such a phenomenon is Cd and Pb in scalp hair as found by Hammer et al. (33). Although scalp hair has been shown to be an effective index for some elements, there are several potential sources of variation (such as hair grooming differences, use of dyes and tints, and hair sampling techniques) which may be avoided by the use of pubic hair as an index. Hence, one would expect to find (1) a number of significant correlations between trace elements in scalp hair, and (2) if pubic hair is another reliable index for these elements, even more significant correlations between trace elements should be found in this tissue. Since the sample numbers for pubic hair are substantially larger than those for scalp hair, one would expect the second condition to hold even if scalp and pubic hair were equally effective exposure indices. Of the 45 possible correlation

coefficients, there were 22 significant positive correlations and one significant negative correlation in pubic hair, and 16 significant positive correlations in scalp hair. (Table 13). In 11 instances significant correlations were found for the same combination of elements in both pubic and scalp hair. The differences between the correlation matrices for scalp and pubic hair were generally found in Pb, Se, and Fe. These three elements have far more significant correlations in pubic hair than in scalp hair.

There were nine significant maternal blood correlations and 18 significant cord blood correlations, with seven metals being significant in both tissues. Five of these seven trace element pairs had nearly identical correlation coefficients in both types of blood. (Table 14).

The lower number of significant correlations in maternal blood as compared to other tissues is understandable, since maternal blood is more a transport tissue than a storage tissue. Cord blood, on the other hand, is quite possibly acting as a repository for these elements. Also, the placenta could be acting as a selective filter, allowing certain trace elements to pass more freely than others. The placenta is an extremely complex organ whose interactions with trace elements is poorly understood. We cannot investigate such subtle interactions in this study. However, it is of interest to note that the pattern of trace element correlations in the placenta is very similar to that found in cord blood (Table 15). There were 21 significant correlations between trace elements in placenta, 12 of which were also significant in cord blood, and only five of which were significant in maternal blood.

Significant correlations of trace element concentrations between tissues are shown in Table 16 for each element. The maternal-to-cord-blood correlations had the largest number of significant coefficients (12 of 16), followed by maternal blood to placenta (7 of 16) and cord blood to placenta (6 of 16). Scalp and pubic hair showed little relationship to maternal and cord blood and to placenta, with only nine significant positive correlations and eight significant negative correlations out of the 96 correlations possible. Scalp hair to pubic hair correlations showed only Ba with a significant positive coefficient and B and Fe with significant negative coefficients.

A comparison of these between-tissue correlations with those of other authors for the few metals available is given in Table 17. The comparison of our ratio of scalp to pubic hair results with those of Baumslag et al. (28) is poor; however, most of his subjects were black while most of our subjects were white. In the maternal-to-cord-blood results, our study found many more significant correlations than Baglin et al. (22). Our sample sizes for both maternal-to-cord-blood and maternal-blood-to-placenta correlations were much larger for Pb and Cd than were Baglin's, which could explain the differing results for these elements in the tissue comparisons. Mercury was highly censored in blood in this study (41%) and no significant correlations were found in this study, while they were significant in both Baglin's study for maternal-to-cord-blood and maternal-blood-to-placenta, and the work of Dennis's study (24) for maternal blood to cord blood. The agreements between these studies is encouraging, but the disagreements point out the need for further studies to provide clarification of the true interrelationships of many of these

elements between tissues.

Effects of Covariates on Tissue Trace Element Levels

Some previous studies have shown significant effects of selected covariates on tissue trace element levels for some elements (2,22,28,33). Creason et al. (2) found that some scalp hair trace element levels were affected by area of residence, age, smoking, and socioeconomic status. Baumslag (28) found race, age, and parity effects in hair for some trace elements in a population of mothers and their newborn. Geographic differences in tissue trace element levels have been reported by Hammer et al. (33) among others. In view of all the above findings, it is important to ascertain whether or not these or other covariates affected tissue trace element levels in this study.

Almost all of the black subjects were in the southeastern region (Charlotte, N. C. and Birmingham, Alabama) in this study. To avoid confounding the race effect with geographic effects, only subjects in the Southeast were included in making the race comparisons.

In both cities in the Southeast, there was one sector in which all the women were black and one sector in which all the women were white. The women in each of these sectors were well matched with respect to education but smoking was less prevalent among blacks (Table 3). In addition, the blacks generally reported less frequent shampooing of their hair than whites.

A joint analysis of race and city effects was carried out on the southeastern region subjects in order to compensate for city-to-city differences (21). A significant race effect was noted for Pb, Hg, Se, Fe, and Mn in pubic hair and Li, Fe, Cr, and Mn in scalp hair (Table 18). No significant race effects were noted for any elements in maternal blood,

cord blood or for any elements in maternal blood, cord blood, or placenta. The blacks averaged higher scalp and pubic hair trace element levels in both cities in the cases where a significant racial effect was noted. Although a significant racial effect was not found for both hair types in each of these instances, generally, the nonsignificant hair type reflected the same relation between races as the significant hair type. Exceptions to this occurred in scalp hair (selenium was higher among whites in Charlotte) and in pubic hair (lithium concentrations were higher among whites in Charlotte and Birmingham).

Scalp hair Se was the only tissue trace element with a significant city by race interaction, indicating larger differences between the blacks and whites in Birmingham than in Charlotte.

In view of the race effect on tissue trace element levels, blacks in the Southeast were not included in subsequent analyses.

In each of the five tissues the two sector mean trace element levels within each region were compared (Tables 19 through 23). Also, for each of these tissues the four pooled regional mean trace element levels were compared. Tables 24 through 28 list the geometric means of those trace elements for which a significant difference was found. Significant geographic differences were found for at least three of the five tissues in 13 of the 16 trace elements tested. A majority of the sector differences within regions were concentrated in the Southeast and Utah. Regional differences were more frequent and often stronger than sector differences within regions. Most of the regional effects were the result of the southeast being significantly different from the other regions. Maternal blood, cord blood, and placenta consistently exhibited the same

regional trends.

The geographic effects noted above were not adjusted for the possible effects of other covariates such as age, parity, socioeconomic class, and smoking status, and, in the case of scalp hair, the usage of dyes and the frequency of shampooing. In order to detect important factors and to assess the contribution of these factors to the distortion of geographic effects, a regression analysis on each tissue type was carried out. First, the linear effects of all appropriate covariates were included in the analysis. Next, geographic effects were included along with the covariates. Riverside, N.Y. was omitted from this analysis since only one person had covariate information in that community. The two sectors in Los Angeles were pooled because of their small sample sizes. There were 27 tissue/element combinations for which a significant city effect was found even after accounting for the linear effects of the covariates (Tables 29 and 30). Scalp hair had two elements with significant geographic effects. However, the sample sizes for scalp hair were much smaller than for the other tissues, sometimes being as small as 30 subjects. Thus it would be less likely to find differences between regions in this tissue than in the others. Cadmium and Lithium were the only elements with significant geographic effects for all three tissues, maternal and cord blood and placenta, after adjusting for the covariates, while Li was the only element with significant geographic effects for all five tissues. In every case where significant geographic effects were found, the covariates that were significant excluding geographic effects were no longer significant when geographic effects were included. In the six instances when a covariate was still significant after including geographic effects, the

geographic effects were found not to be significant. These cases were Se and B in cord blood, Fe in maternal blood, Cr in placenta, and Cr in scalp hair. Of these six tissue/element combinations, only B in cord blood had been found to vary geographically.

Because of the unequal distribution of factors across sectors, it can not be assured that covariates found to be unimportant after including geographic effects do not have some effect. The proper conclusion is that variation was better explained statistically by geographic effects. Because of this fact it was felt important to report the covariate findings when geographic effects were not considered (Tables 29 and 30). Before examining these findings, it should be noted that a principal components analysis (36) on smoking, parity, age, and socioeconomic status indicated that over 73 percent of the variation in these factors could be explained by the first two principal components. This finding reflects the high degree of interrelationship among these factors and means that the ability of standard statistical techniques to separate important from unimportant cofactors is rather limited.

The most noticeable covariate in the analysis is the socioeconomic factor, especially in scalp and pubic hair. Fourteen tissue/trace element combinations were significantly related to this factor when geographic effects were excluded, versus at most four for any of the other covariates. The fact that only three tissue/trace element combinations are significant when city effects are included indicates that there are differences in socioeconomic conditions across communities that are confounded with the geographic differences. These differences are apparently explained better by the geographical covariate (city effects) than by the socioeconomic

covariate in this study, but it may be that socioeconomic differences play an important role in environmental exposure to trace elements and/or their uptake by the expectant mother.

Relationships of Dustfall Trace Elements to Tissue Trace Elements

The minimum, maximum, and arithmetic mean of dustfall trace metals for the 12 months immediately preceding the conclusion of the study are given in Table 31. Only seven elements were analyzed in dustfall: Cd, Pb, Zn, Cr, Cu, Mn, and Ni. Some element measurements were not available for several of the months during this time period, as noted in the table. When a correlation analysis of dustfall versus each of the tissues was carried out for each of the seven elements, only two of the 35 possible correlations were significant: Cd in scalp hair ($r=0.18$, $p=0.03$) and Cr in maternal blood ($r=0.15$, $p=0.02$). Because dietary intake is quite probably more important than the inhalation route in determining tissue trace element levels, multimedia indices of exposure should be used in looking for relationships between environmental exposure and trace element body burdens. Unfortunately, only dustfall data were available, and in many cases these data were scanty. In addition, the dustfall data were not collected specifically for this study. Possibly better correlations could have been found if more emphasis had been placed on this phase of the study.

SECTION 4

SUMMARY

Trace element levels for 16 elements in five different tissues — maternal blood, cord blood, placenta, scalp hair, and pubic hair — collected from 198 subjects in eight communities in four distinct geographic sections of the continental United States (the southeast, New York-New Jersey, Utah, and California) have been reported. There was generally good agreement with tissue levels published in similar studies for five elements. This is the first report, to our knowledge, of levels for the remaining 11 elements. The tissue trace element levels generally ranked from highest to lowest in scalp hair, pubic hair, placenta, and cord and maternal blood. The cord blood and maternal blood rankings varied depending on the element involved, with Pb, Cd, Cu, and Zn concentrations higher in maternal blood and the other 12 elements higher in cord blood.

Correlations of trace elements within tissues were reported. The pattern of correlations in the placenta was very similar to that found in cord blood. Maternal blood had the fewest significant interelement correlations.

Correlations of trace element concentrations between tissues for each element showed that the maternal to cord blood correlations had the largest number of significant coefficients. Scalp and pubic hair showed little relationship to maternal and cord blood and to placenta.

Race was significantly associated with several scalp hair and pubic hair trace element levels with the blacks averaging higher levels than the whites. No significant race effects were noted for maternal blood, cord blood, or placenta.

Significant geographic variation in trace element levels were found for many elements in all five tissues. Regional differences were stronger than differences within regions. Maternal blood, cord blood, and placenta consistently exhibited the same regional trends. In examining covariates and their possible influence upon tissue trace element concentrations, it was found that the socioeconomic factor was a possible influence, especially on scalp and pubic hair. Since there were distinct differences between regions in socioeconomic levels, the exact relationship could not be established in this study. Age, parity of the mother, and smoking habits were not found to be strong influences, although a few trace elements showed some possible relationships to these factors. In scalp hair, shampoo frequency was related only to Se, while use of hair treatments was related only to Cr.

SECTION 5

DISCUSSION

This study was not designed to afford a thorough investigation of the covariates that could be affecting trace element levels in the five tissues. The purpose of considering covariate information here was to detect important sources of variation in the data. Such detection affords other researchers in the field background information for improved design of studies and a reference point for comparison of results.

In epidemiology, causation is rarely shown. However, even valid associations require that strict designs be carried out. When a multitude of possible factors are being considered, such designs are impractical. In view of these considerations, and of the strong interrelationships between some covariates, the reader is warned that indicated significant associations with covariates may be spurious. The reader is also warned that this population of women was selected by convenience and controlled for several factors; therefore, all statistical inferences should be specific to this population. Careful judgment as to the applicability of these inferences to the general population must be used. We have included results from the few other available studies throughout our report in order to afford readers an opportunity to make this judgment for themselves.

Even in view of the above restrictions, this report has provided insight into many gaps in our knowledge of the transplacental transfer of trace elements. It has also served to establish baseline levels for a large number of trace elements in maternal and fetal tissues in a realistic setting, and has shown that these levels vary widely across the country for

many elements.

More definitive studies are obviously needed in this critical area. The transplacental transfer of some elements found in contaminated environments has been demonstrated. The excessive exposure of the fetus to Pb in urban environments may already be occurring, based upon the cord blood levels reported in this and other studies (26, 32). There could be as yet unknown metabolic effects of pregnancy on trace element distribution and toxicity in the placenta and developing fetus, as well as in the expectant mother. The levels of exposure of the placenta and the fetus to 16 trace elements have been reported here. However, the mere presence of a pollutant in tissue is not always sufficient evidence for disease potential. Now, the toxicity of the various trace elements to the expectant mothers, to the placenta, and to the developing fetus must be established in order to protect them from existing or future hazards of environmental trace element exposure.

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TABLE 1. SAMPLE PREPARATION AND ANALYSIS METHODS

Metals	Preparation	Analysis
Cd, Pb	Oxygen combustion	AA aspiration
Cu, Mn, Zn, Fe	Oxygen combustion	AA aspiration
As, Hg, Se	Oxygen combustion	AA on vapor
Li	Oxygen combustion	Flame photometry
Ag	Oxygen combustion	ES
Ba, Be, B, Cr	Dry ashing	ES
Co, Ni, V, Sn	Dry ashing	ES

Remarks:

1. Managanese in hair was evaluated from ES data when detection from AA was found to be inadequate.

2. AA = atomic absorption
   ES = emission spectroscopy

TABLE 2. GROUPINGS USED TO ANALYZE COVARIATE INFORMATION

Maternal Age	16-19 20-24 25-29 30-34 35-39
Parity	1 2-3 4+
Smoking Status	Nonsmoker Exsmoker Current Smoker
Socioeconomic Status (Education)	<High School High School >High School
Shampoo Frequency	At least once a week Less than once a week
Scalp Hair Color	Black Brown Blonde Red
Pubic Hair Color	Black Nonblack
Scalp Hair Treatment	No Yes (a) Dyes (b) Tints (c) Shampoo Rinses

TABLE 3. DEMOGRAPHIC CHARACTERISTICS OF MOTHERS BY CHESS SECTOR

	Charlotte Whites	Charlotte Blacks	Birmingham Whites	Birmingham Blacks	Riverhead New York	Elizabeth New Jersey	Ogden Utah	Salt Lake City Utah	West Los Angeles	East Los Angeles	Overall
SMOKING PATTERNS											
Never	7	17	8	13	1	8	12	7	5	7	85
Ex	1	2	2	0	0	3	1	4	2	5	20
Current	18	8	16	10	0	6	0	9	0	1	68
Unknown	1	0	0	0	19	3	0	0	0	2	25
PARITY											
One	9	8	13	11	1	10	9	11	3	6	81
Two or three	11	14	9	7	0	6	3	5	4	7	66
Four or more	6	5	4	5	0	4	1	4	0	0	29
Unknown	1	0	0	0	19	0	0	0	0	2	22
EDUCATION											
< High school	19	18	17	12	0	8	0	4	0	2	80
High school	5	6	7	8	1	5	1	8	1	1	43
> High school	2	3	2	3	0	4	12	8	5	10	49
Unknown	1	0	0	0	19	3	0	0	1	2	26
AGE											
16 to 19	11	11	12	6	0	4	2	3	1	1	51
20 to 24	5	10	12	9	1	8	5	13	4	4	71
25 to 29	8	4	2	6	0	5	6	3	2	4	40
30 to 39	2	2	0	2	0	1	0	1	0	4	12
Unknown	1	0	0	0	19	2	0	0	0	2	24
TOTAL	27	27	26	23	20	20	13	20	7	15	198

TABLE 4. CORRELATION BETWEEN COVARIATES
(N=122)

	Education	Smoking Status	Parity
Maternal Age	0.23*	-0.07	0.46*
		-0.39*	-0.12
Smoking Status			0.12

*Significance level less than 0.05

TABLE 5. TRACE METAL LEVELS IN MATERNAL BLOOD*

ELEMENT	#OBS	PERCENT CENSORED	MEAN	MINIMUM	MAXIMUM	GEOM MEAN	GM/GSD‡	GM x GSD‡
PB	186	0.00	33.27	4.70	178.00	27.81	15.80	48.95
CD	186	3.23	3.17	0.10	31.30	1.72	0.52	5.67
CU	183	0.00	79.34	25.20	149.00	75.72	54.91	104.43
ZN	181	0.00	662.00	270.00	1075.00	646.00	514.00	810.00
HG	177	25.42	0.96	0.10	6.60	0.41	0.11	1.49
LI	185	1.62	0.56	0.03	2.38	0.39	0.16	0.96
SE	182	0.00	11.68	3.30	34.60	10.84	7.36	15.96
FE	187	0.00	48565.	15200.	67100.	48000.	40644.	56687.
BA	185	0.00	8.65	2.00	40.00	7.43	4.37	12.61
B	187	4.81	10.04	1.00	49.00	7.70	3.69	16.09
CR	178	0.56	11.1	1.0	90.0	6.9	2.8	17.4
NI	182	14.29	8.5	0.7	85.0	3.8	1.2	12.3
AG	187	41.71	0.40	0.06	3.80	0.26	0.10	0.65
V	181	48.07	1.3	0.3	3.3	1.2	0.8	1.7
SN	186	11.83	4.6	0.9	24.0	3.7	2.0	6.9
MN	186	5.38	3.49	.60	23.00	2.71	1.35	5.44

‡These values give a range that should include approximately 68% of the population concentrations, assuming the underlying distribution of concentrations is log normal.

*Levels in µg/100 ml.

TABLE 6. TRACE METAL LEVELS IN CORD BLOOD*

ELEMENT	#OBS	PERCENT CENSORED	MEAN	MINIMUM	MAXIMUM	GEOM MEAN	GM/GSD‡	GM x GSD‡
PB	180	.56	31.77	2.70	136.00	26.86	14.56	49.55
CD	185	4.32	2.76	.10	18.20	1.65	.52	5.26
CU	186	0.00	45.46	10.30	127.00	41.77	27.33	64.08
ZN	185	0.00	499.00	170.00	1100.00	478.00	354.00	645.00
HG	185	22.70	1.33	0.10	11.50	0.58	0.15	2.22
LI	185	1.62	0.78	0.05	5.21	0.51	0.19	1.36
SE	180	0.00	12.71	3.70	35.60	11.83	8.16	17.15
FE	185	0.00	50825	27200.	78900.	50369.	43857	57848.
BA	183	0.00	10.01	2.00	45.00	8.32	4.71	14.72
B	187	0.00	13.62	0.70	94.00	10.74	5.44	21.20
CR	184	0.00	12.4	1.0	74.0	7.9	3.2	19.6
NI	182	5.49	8.1	0.7	56.0	4.5	1.6	12.9
AG	186	29.03	0.53	0.08	9.00	0.33	0.13	0.84
V	187	41.71	1.6	0.5	6.0	1.4	2.2	2.3
SN	187	7.49	5.6	0.9	42.0	4.31	2.2	8.5
MN	186	0.54	4.18	0.85	21.00	3.56	2.00	6.34

‡These values give a range that should include approximately 68% of the population concentrations, assuming the underlying distribution of concentrations is log normal.

*Levels in ug/100 ml.

TABLE 7. TRACE METAL LEVELS IN SCALP HAIR*

ELEMENT	#OBS	PERCENT CENSORED	MEAN	MINIMUM	MAXIMUM	GEOM MEAN	GM/GSD‡	GM x GSD‡
PB	114	0.88	20.158	2.500	78.900	14.908	6.800	32.685
CD	112	3.57	1.0074	0.0960	4.5000	0.7736	0.3658	1.6362
CU	110	0.00	17.958	4.140	80.300	14.977	8.380	26.769
ZN	109	0.00	143.3	50.0	280.0	134.9	94.1	193.4
HG	112	0.00	2.2246	0.1040	16.5000	1.4125	0.5227	3.8168
LI	112	0.00	.1723	0.0180	1.1300	0.1318	0.0642	0.2705
SE	112	0.89	0.9445	0.0300	6.3000	0.6596	0.2859	1.5215
FE	113	0.00	36.09	1.88	236.00	20.68	7.57	56.54
BA	61	0.00	2.491	0.170	14.000	1.789	0.753	4.251
B	63	0.00	1.053	0.020	8.000	0.523	0.153	1.786
CR	62	0.00	1.176	0.020	7.900	0.591	0.169	2.066
NI	63	0.00	1.674	0.130	10.000	1.011	0.376	2.723
AG	62	0.00	0.1400	0.0080	1.1000	0.0744	0.0241	0.2293
V	61	8.20	0.140	0.004	1.400	0.061	0.016	0.228
SN	62	0.00	1.405	0.070	5.200	0.874	0.288	2.653
MN	62	0.00	1.203	0.060	5.500	0.735	0.264	2.045

‡These values give a range that should include approximately 68% of the population concentrations, assuming the underlying distribution of concentrations is log normal.

*Levels in µg/g.

TABLE 8. TRACE METAL LEVELS IN PUBIC HAIR*

ELEMENT	#OBS	PERCENT CENSORED	MEAN	MINIMUM	MAXIMUM	GEOM MEAN	GM/GSD‡	GM x GSD‡
PB	153	0.00	8.905	0.828	35.100	6.868	3.306	14.271
CD	158	5.06	0.4309	0.0100	3.2300	0.2539	0.0813	0.7924
CU	148	0.00	11.764	2.710	51.900	9.813	5.476	17.588
ZN	158	0.00	110.69	6.14	885.00	73.09	29.17	183.14
HG	158	1.90	3.7600	0.0060	43.1000	0.7121	0.1142	4.4407
LI	155	5.81	0.1977	0.0030	0.8420	0.1070	0.0280	0.3957
SE	151	0.00	0.7031	0.0410	4.6200	0.4867	0.2046	1.1578
FE	155	4.52	29.86	0.60	233.00	15.48	4.44	53.98
BA	110	0.00	2.168	0.070	11.000	1.372	0.482	3.902
B	107	0.00	0.729	0.010	6.800	0.416	0.138	1.254
CR	108	0.00	1.614	0.030	17.000	0.794	0.250	2.522
NI	110	0.00	0.693	0.030	5.400	0.414	0.151	1.133
AG	113	0.00	0.1334	0.0040	0.8800	0.0736	0.0223	0.2428
V	103	41.75	0.051	0.006	0.540	0.029	0.010	0.080
SN	113	0.88	0.785	0.020	7.000	0.430	0.131	1.409
MN	154	0.00	1.981	0.040	17.210	0.950	0.275	3.277

‡These values give a range that should include approximately 68% of the population concentrations, assuming the underlying distribution of concentrations is log normal.

*Levels in µg/g.

TABLE 9. TRACE METAL LEVELS IN PLACENTAL TISSUE*

ELEMENT	#OBS	PERCENT CENSORED	MEAN	MINIMUM	MAXIMUM	GEOM MEAN	GM/GSD$^{\pm}$	GM x GSD$^{\pm}$
PB	165	0.00	37.26	8.10	150.00	31.56	17.91	55.61
CD	169	0.00	4.41	0.90	15.80	3.74	2.08	6.73
CU	166	0.00	42.21	4.40	118.00	33.75	15.82	72.01
ZN	166	0.00	1344.	600.	3200.	1267.	906.	1771.
HG	164	9.15	2.39	0.10	81.90	0.65	0.14	2.90
LI	167	0.00	0.65	0.05	3.35	0.49	0.21	1.12
SE	160	0.00	14.39	6.10	24.80	13.85	10.42	18.41
FE	169	0.00	30420.	3800.	91400.	28930.	14280.	47100.
BA	167	0.00	10.1	3.0	31.0	8.9	5.4	14.5
B	169	20.12	8.3	2.0	47.0	6.1	2.9	12.7
CR	167	4.19	6.3	1.0	27.3	4.8	2.3	10.1
NI	169	43.20	3.4	0.8	32.0	2.2	1.0	5.2
AG	168	60.12	0.47	0.09	4.40	0.26	0.09	0.71
V	169	88.76	1.5	0.8	8.0	1.3	0.9	2.1
SN	168	30.36	5.0	2.0	29.0	3.9	2.1	7.4
MN	167	0.60	9.4	1.0	50.0	6.9	3.3	14.3

$^{\pm}$These values give a range that should include approximately 68% of the population concentrations, assuming the underlying distribution of concentrations is log normal.

*Levels in µg/100g.

TABLE 10. A COMPARISON OF MEAN TRACE ELEMENT LEVELS FOUND IN SEVERAL STUDIES IN MATERNAL AND CORD BLOOD AND PLACENTA*

		This Study	Baglin & Brill et al. (22)	Finklea et al.(23)	Dennis et al.(24)	Harris & Holley (25)	Scanlon (26)	Dawson et al.(27)
Cd	MB	3.0	1.7	3.7				
	CB	2.7	1.6	4.6			-	
	PL	4.4	1.7	6.8				
Fe	MB	48565	42072					
	CB	50825	58575	-				
	PL	30424	12183					896
Hg	MB	0.96	0.87	0.50	0.68			-
	CB	1.33	1.15	0.60	0.75			
	PL	2.39	2.08	1.40				
Pb	MB	33.0	16.5	33.0		14.0		
	CB	31.0	12.3	46.0		12.7	22.1	-
	PL	37.0	30.5	96.0				390
Zn	MB	661	663			-		-
	CB	498	317					
	PL	1344	1175	-		-	-	1713

*Maternal blood (MB) and cord blood (CB) in µg/100g.

TABLE 11. A COMPARISON OF GEOMETRIC MEAN TRACE ELEMENT LEVELS* FOUND IN SEVERAL STUDIES IN MATERNAL SCALP AND PUBIC HAIR

		This Study	Baumslag et al. (28)	Finklea et al. (23)	Creason[a] et al. (2)	Baglin & Brill et al. (22)	Sorenson et al. (29)
Cd	SH	0.8		3.7[b]	0.6		0.8
	PH	0.3		3.1	-		-
Fe	SH	20.7	22.1		24.0	-	-
	PH	15.5	15.0				-
Hg	SH	2.2	-		1.0	1.4[c]	17.1
	PH	0.7	-	-	-		-
Pb	SH	14.9	31.5	29.3[b]	11.0	-	14.1
	PH	6.9	16.6	12.4[b]			-
Zn	SH	135	136		112	-	174
	PH	73	151				-

(a) Females ages 15-50
(b) Arithmetic Means
(c) Median

*All values are in μg/g of scalp hair (SH) and pubic hair (PH).

TABLE 12. RATIOS BETWEEN TRACE ELEMENT LEVELS OF THE TWO TYPES OF HAIR AND THE TWO TYPES OF BLOOD

Element	# of Obs.	Geometric Mean of Ratio Between Scalp Hair and Pubic Hair Trace Element Levels	# of Obs.	Geometric Mean of Ratio Between Cord Blood and Maternal Blood Trace Element Levels
Pb	97	2.09*	173	0.94
Cd	99	2.96*	175	0.93
Cu	90	1.54*	177	0.55*
Zn	96	1.79*	173	0.73*
Hg	100	1.80*	146	1.49*
Li	99	1.15	175	1.35*
Se	94	1.32*	170	1.08
Fe	98	1.00	180	1.04*
Ba	38	1.52*	170	1.12
B	37	1.59	175	1.41*
Cr	39	1.04	163	1.15
Ni	39	2.69*	166	1.15
Ag	38	1.60	164	1.28*
V	37	2.61*	142	1.25*
Sn	38	2.22*	174	1.18*
Mn	49	1.05	172	1.33*

* Ratio significantly different from 1 at .05 level.

TABLE 13. SIGNIFICANT CORRELATIONS BETWEEN ELEMENTS WITHIN THE TWO HAIR TYPES

	Pb	Cd	Cu	Zn	Li	Se	Fe	Ba	Cr	Mn
Pb		.28	.40	.25	.24	.23	.35	-	-	.20
Cd	.62		.18	-	.24	-	.23	-	-	-
Cu	-	.26		.40	.46	.38	.51	-	-	-
Zn	-	-	.24		.43	.24	.62	-	-	-
Li	.21	-	-	.38		-	.39	-.24	-	-
Se	-	-	-	-	.42		.28	-	-	-
Fe	.35	.28	-	-	.49	-		-	-	-
Ba	-	-	-	-	-	-	.47		.42	.63
Cr	-	-	-	-	.30	-	.53	.69		.46
Mn	-	-	-	-	-	-	.30	.64	.69	

Pubic Hair

Scalp Hair

Remarks:

1. Only includes elements whose censoring level was small in all tissues in order to simplify the task of making valid comparisons of the correlation structure between tissues. Significance level less than 0.05 two sided.

2. Sample sizes between Pb, Cd, Zn, Li, Se and Fe varied from 157 to 141 in pubic and from 113 to 106 in scalp hair. For the remaining metals sample sizes varied from 105 to 101 in pubic hair and from 61 to 58 in scalp hair.

TABLE 14. SIGNIFICANT CORRELATIONS BETWEEN ELEMENTS WITHIN THE TWO BLOOD TYPES

	Pb	Cd	Cu	Zn	Li	Se	Fe	Ba	Cr	Mn
Pb		.45	.18	-	.27	.17	.16	-	-	-
Cd	.20		-	.22	-	.16	.21	-	-.24	-
Cu	.15	-		-	.38	-	-	-	-	.17
Zn	-	-	-		-	-	.35	.17	-	-
Li	-	-	-	-		-	-	-.16	.20	-
Se	-	-	-	-	-		-	-	-	-
Fe	-	-	-	.46	-.17	-		.19	-	.21
Ba	-	-	-	.15	-	-	-		-	-
Cr	-	-.24	-	-	.19	-		.20		.30
Mn	-	-	-	-	-	-		-	.17	

Cord Blood ↑

Maternal Blood ↓

Remarks:

1. Remark #1 on Table 13 applies.
2. Sample sizes varied from 184 to 172.

TABLE 15. SIGNIFICANT CORRELATIONS BETWEEN ELEMENTS WITHIN PLACENTA

	Pb	Cd	Cu	Zn	Li	Se	Fe	Ba	Cr	Mn
Pb		.17	.32	.21	.24	-	-	.17	-	-
Cd			-	.22	-.16	.30	.32	.20	-	.42
Cu				-	.56	-	-	-	-	-
Zn					-	-	.25	.26	-	.35
Li						-	-	-	-	-.21
Se							.18	-	-	.20
Fe								.28	-	.42
Ba									-	-
Cr										.24
Mn										

Remarks:

1. Remark 1 on Table 13 applies.

2. Sample sizes varied from 155 to 167.

TABLE 16. A SUMMARY OF SIGNIFICANT[1] CORRELATIONS BETWEEN TISSUES BY ELEMENT

	Tissue Pairs									
	MB to CB	MB to PL	CB to PL	MB to SH	CB to SH	MB to PH	CB to PH	PL to SH	PL to PH	SH to PH
Ba	.17** (177)								-.18* (106)	.29* (39)
B		-.13* (164)			.25* (59)		-.21** (103)	-.28** (51)	.17* (104)	-.36** (37)
Cd	.29*** (179)	.23*** (162)	.24*** (161)	-.18* (104)	-.26 (103)					
Cr	.26*** (170)		-.22*** (159)	.22* (54)	.36*** (57)					
Cu	.17** (177)	.13* (157)	.14* (158)						-.19** (138)	
Fe	.33*** (181)	.15** (164)					.15* (148)	-.24** (99)		-.20** (98)
Pb	.20*** (174)	-.14* (159)								
Li	.41*** (178)	.26** (159)	.31*** (159)							
Mn			-.13* (159)					-.23* (51)		
Hg						.17* (148)				
Ni	.20*** (172)									
Se	.14* (171)			.17* (102)						
Ag	.16** (181)				-.29** (57)					
Sn							.17* (109)			
V	.19** (176)									
Zn	.15** (174)	.24*** (159)	.14* (158)							

[1] Two-sided test, i.e. $H_0: \rho = 0$ vs $H_1: \rho \neq 0$

* Significant at 10% level

** Significant at 5% level

*** Significant at 1% level

▨ More than 10% of pairs contain at least 1 censored value.

MB - Maternal Blood

CB - Cord Blood

PL - Placenta

SH - Scalp Hair

PH - Pubic Hair

TABLE 17. A COMPARISON OF SIGNIFICANCE TESTS FOR CORRELATIONS BETWEEN TISSUES*

Scalp to Pubic Hair

	This Study (N=95)	Baumslag et al.(28) (N=50)
Cd	NS	0.01
Cu	NS	0.01
Fe	0.05 (neg. r)	0.01 (pos. r)
Pb	NS	0.01

Maternal to Cord Blood

	This Study (N>171)	Baglan & Brill et al.(22) (N=600)	Dennis et al.(24) (N=43)	Harris & Holley (25) (N=22)
Cd	0.01	NS		
Fe	0.01	0.05		-
Pb	0.01	NS(N=10)		NS
Hg	NS	0.01	0.01	-
Se	0.10	0.01	-	
Zn	0.05	NS(N=12)	-	-

Maternal Blood to Placenta

	This Study (N>155)	Baglan & Brill et al. (22) (N=600)
Cd	0.05	NS(N=34)
Fe	0.05	0.05
Pb	0.10(neg.)	NS(N=73)
Hg	NS	0.05
Se	NS	0.01
Zn	0.01	0.05

* The probability of getting a value as large as observed if the true correlation was zero is given. NS means not significant at the .10 level (p>0.10).

TABLE 18. SIGNIFICANCE LEVELS OF TESTS FOR RACE EFFECTS AND RACE BY CITY INTERACTION IN BIRMINGHAM AND CHARLOTTE*

Effect	Race Effect		Race by City Interaction Effect	
	Scalp Hair	Pubic Hair	Scalp Hair	Pubic Hair
Cr	<0.05			
Fe	<0.001	<0.05		
Hg		<0.02		
Li	<0.05			
Mn	<0.01	<0.01		
Pb		<0.01		
Se		<0.01	<0.05	

*No significant effects were found for maternal blood, cord blood, or placenta.

TABLE 19. TESTS OF SIGNIFICANCE OF REGIONAL DIFFERENCES IN SCALP HAIR TRACE ELEMENT LEVELS*

Trace Elements	Between Sectors Within the Same Region				Between Regions
	Southeast	NY-NJ	Utah	California	
Pb			0.05		0.01
Cd	-				0.01
Zn			0.05		-
Li	0.05		0.05		0.001
Se		0.01	0.01		
Fe	0.01			-	0.001
Ba	0.05	-	NO TEST		
V	0.01		NO TEST		
Sn	0.01		NO TEST		0.05
Mn	0.05		NO TEST		

* Values given are the probability of the observed difference in sample geometric mean levels between categories assuming no difference in the original population. Only values of 0.05 or less are listed. Elements omitted from the table had no significant differences in any of the above comparisons.

TABLE 20. TESTS OF SIGNIFICANCE OF REGIONAL DIFFERENCES IN PUBIC HAIR TRACE ELEMENT LEVELS*

Trace Elements	Between Sectors Within the Same Region				Between Regions
	Southeast	NY-NJ	Utah	California	
Pb	-				0.001
Cu		0.01		0.01	0.001
Zn		0.05		-	-
Hg			0.01		0.001
Li		-			0.001
Se		0.05	0.05		0.001
Fe				-	0.001
Ba					0.01
B			0.01	0.01	-
Cr	0.05				
Sn		-	-		0.001
Mn	0.05	-	-		

* Values given are the probability of the observed difference in sample geometric mean levels between categories assuming no difference in the original population. Only values of 0.05 or less are listed. Elements omitted from the table had no significant differences in any of the above comparisons.

TABLE 21. TESTS OF SIGNIFICANCE OF REGIONAL DIFFERENCES IN MATERNAL BLOOD TRACE ELEMENT LEVELS*

Trace Elements	Between Sectors Within the Same Region				Between Regions
	Southeast	NY-NJ	Utah	California	
Pb	0.05		0.05	-	-
Cd		0.05		-	0.001
Cu		-		-	0.01
Zn	0.05			-	0.01
Li				0.05	0.001
Se	-				0.05
Ba	0.05				0.05
B	0.001				0.001
Cr				-	0.001
Ni				-	0.001
Sn	0.05		-	-	

* Values given are the probability of the observed difference in sample geometric mean levels between categories assuming no difference in the original population. Only values of 0.05 or less are listed. Elements omitted from the table had no significant differences in any of the above comparisons.

TABLE 22. TESTS OF SIGNIFICANCE OF REGIONAL DIFFERENCES IN CORD BLOOD TRACE ELEMENT LEVELS*

Trace Elements	Between Sectors Within the Same Region				Between Regions
	Southeast	NY-NJ	Utah	California	
Cd	-	-	-		0.001
Cu			-	0.05	0.01
Zn	0.05		0.05		0.005
Li				0.05	0.001
Fe			-		0.05
B	-			-	0.01
Cr					0.001
Ni	-				0.001
Mn			0.05		-

*Values given are the probability of the observed difference in sample geometric mean levels between categories assuming no difference in the original population. Only values of 0.05 or less are listed. Elements omitted from the table had no significant differences in any of the above comparisons.

TABLE 23. TESTS OF SIGNIFICANCE OF REGIONAL DIFFERENCES IN PLACENTA TRACE ELEMENT LEVELS*

Trace Elements	Between Sectors Within the Same Region				Between Regions
	Southeast	NY-NJ	Utah	California	
Pb	0.05		-	-	-
Cd	-	-		-	0.001
Cu			-		0.001
Zn			-		0.05
Li	-		0.05	-	0.001
Se				-	0.001
Fe	0.001		-	-	0.001
Mn	-			-	0.001

* Values given are the probability of the observed difference in sample geometric mean levels between categories assuming no difference in the original population. Only values of 0.05 or less are listed. Elements omitted from the table had no significant differences in any of the above comparisons.

TABLE 24. SECTOR GEOMETRIC MEANS OF TRACE ELEMENTS IN MATERNAL BLOOD*

	# of Obs. Max Min	B	Ba	Cd	Cr	Cu	Li	Ni	Pb	Se	Sn	Zn
Charlotte Whites	26-21	3.75	5.53	1.004	9.33	78.6	0.440	5.61	35.3	9.45	2.95	580.1
Charlotte Blacks	26-23	5.45	6.40	0.988	9.70	81.6	0.422	5.74	28.2	10.52	3.84	612.2
Birmingham Whites	26-25	7.08	7.67	1.102	9.92	77.2	0.591	5.80	26.1	10.93	4.25	657.4
Birmingham Blacks	23	7.17	8.10	0.892	9.41	86.8	0.656	6.57	24.3	11.91	4.34	573.2
Riverhead	20-18	9.55	7.83	4.586	5.82	60.2	0.248	3.90	27.2	11.59	3.54	709.8
Elizabeth	20-18	10.79	6.90	2.184	5.22	69.4	0.193	2.92	25.9	12.53	3.62	711.4
Ogden	8-7	9.04	8.76	3.263	4.87	61.0	0.263	1.65	18.5	10.22	4.97	630.5
Salt Lake City	19-17	11.02	9.05	3.855	4.07	71.0	0.345	1.64	31.8	11.27	3.60	678.8
West Los Angeles	6-5	12.31	8.62	3.712	3.58	88.8	0.728	2.19	31.7	8.03	3.04	667.0
East Los Angeles	14-13	15.41	9.53	2.947	5.08	81.2	0.280	1.65	27.4	9.93	3.28	709.0

*Levels in µg/100 ml.

TABLE 25. SECTOR GEOMETRIC MEANS OF TRACE ELEMENTS IN CORD BLOOD*

	# of Obs. Max Min	B	Cd	Cr	Cu	Fe	Li	Mn	Ni	Zn
Charlotte Whites	25-22	9.01	1.216	10.64	42.9	49819.	0.756	3.95	5.63	405.1
Charlotte Blacks	26-24	8.63	1.140	13.62	45.5	49994.	0.763	4.60	6.13	415.2
Birmingham Whites	25-24	10.83	1.006	11.66	48.0	48526.	0.621	3.44	7.98	492.1
Birmingham Blacks	23-21	10.74	0.573	10.63	50.3	45600.	0.781	3.71	5.31	431.3
Riverhead	20-18	14.58	3.448	6.16	36.5	52794.	0.308	2.76	3.92	517.2
Elizabeth	19-18	15.26	2.861	4.43	29.6	53006.	0.226	3.76	3.77	565.0
Ogden	11-8	9.17	3.297	6.48	44.8	53517.	0.416	4.28	3.08	610.4
Salt Lake City	19-16	9.01	3.033	4.06	37.0	51946.	0.444	2.77	2.53	489.1
West Los Angeles	6	8.82	2.071	5.24	56.7	50019.	0.838	2.73	3.20	430.1
East Los Angeles	15-13	13.03	2.976	5.42	36.5	52384.	0.313	3.20	2.32	541.6

*Levels in µg/100 ml.

TABLE 26. SECTOR GEOMETRIC MEANS OF TRACE ELEMENTS IN PLACENTA*

	# of Obs. Max Min	Cd	Cu	Fe	Li	Mn	Pb	Se	Zn
Charlotte Whites	21-18	2.822	51.8	31259.	0.685	4.48	26.9	12.36	1123.6
Charlotte Blacks	21-18	2.555	47.9	24727.	0.711	3.72	31.8	13.96	1253.2
Birmingham Whites	21-18	2.341	48.4	12624.	0.820	4.03	39.6	11.43	1206.6
Birmingham Blacks	18-17	2.625	52.4	19570.	0.874	4.42	36.9	12.03	1066.6
Riverhead	19-17	5.400	25.0	33036.	0.194	9.51	32.2	13.70	1267.9
Elizabeth	20-17	4.823	21.4	31234.	0.235	12.11	27.8	15.74	1422.2
Ogden	12-11	5.242	25.9	35841.	0.477	12.52	28.7	15.61	1528.2
Salt Lake City	19-18	4.855	19.5	27591.	0.287	10.04	27.0	14.97	1404.5
West Los Angeles	6-5	4.316	19.7	35741.	0.479	8.77	29.2	17.91	1308.0
East Los Angeles	15-14	5.983	29.6	31215.	0.608	12.15	36.6	14.68	1298.3

*Levels in μg/100 g.

TABLE 27. SECTOR GEOMETRIC MEANS OF TRACE ELEMENTS IN SCALP HAIR*

	# of Obs. Max Min	Ba	Cd	Fe	Li	Mn	Pb	Se	Sn	Zn
Charlotte Whites	10-7	2.858	1.297	29.65	0.081	0.648	23.79	0.679	0.878	108.0
Charlotte Blacks	12-10	4.020	1.129	113.69	0.160	2.127	24.64	0.425	2.006	139.2
Birmingham Whites	9-7	1.567	0.952	19.01	0.163	0.465	15.23	0.539	0.421	126.8
Birmingham Blacks	11-7	2.224	0.946	37.64	0.179	0.555	23.30	0.959	0.612	163.7
Riverhead	10-5	0.842	0.539	22.68	0.188	0.719	10.55	0.424	1.774	152.5
Elizabeth	18-5	1.823	0.671	26.35	0.236	0.568	14.06	1.033	1.708	134.3
Ogden	10-6	1.224	0.513	7.17	0.054	0.360	6.45	0.389	0.742	112.6
Salt Lake City	18-0	Missing	0.703	10.73	0.127	Missing	11.93	1.062	Missing	155.5
West Los Angeles	4-3	0.701	1.041	5.24	0.106	0.921	23.81	0.591	0.385	138.4
East Los Angeles	12-7	0.994	0.597	10.31	0.078	0.653	13.93	0.442	0.420	115.6

*Levels in μg/g.

TABLE 28. SECTOR GEOMETRIC MEANS OF TRACE ELEMENTS IN PUBIC HAIR*

	# of Obs. Max Min	B	Ba	Cr	Cu	Fe	Hg	Li	Mn	Pb	Se	Sn	Zn
Charlotte Whites	15-12	0.406	2.194	0.535	7.81	7.08	0.128	0.102	0.593	5.89	0.346	0.658	54.4
Charlotte Blacks	14-7	0.515	2.082	0.629	8.64	20.02	0.473	0.083	1.459	8.79	0.494	0.857	62.5
Birmingham Whites	21-16	0.455	2.120	0.949	6.71	9.06	0.294	0.057	0.910	5.14	0.325	1.006	65.9
Birmingham Blacks	18-7	0.409	2.153	1.332	9.80	11.47	0.852	0.036	2.130	8.66	0.749	0.626	79.3
Riverhead	19-12	0.252	1.205	1.015	13.91	21.80	0.955	0.128	0.959	5.32	0.526	0.252	100.5
Elizabeth	20-13	0.373	1.077	0.558	8.45	10.54	1.030	0.076	0.649	4.57	0.281	0.157	43.2
Ogden	11-4	0.166	0.669	1.333	9.16	39.69	5.003	.217	1.388	7.64	0.500	0.402	115.1
Salt Lake City	20-7	1.062	0.955	2.016	14.23	36.14	0.798	0.302	1.217	12.03	1.026	0.304	100.4
West Los Angeles	6-4	0.901	0.485	0.714	18.60	44.04	1.298	0.351	0.867	8.86	0.525	0.417	134.2
East Los Angeles	15-11	0.259	1.033	0.529	8.86	19.14	1.145	0.123	0.422	7.43	0.406	0.248	59.9

*Levels in μg/g.

TABLE 29. TESTS OF SIGNIFICANCE OF THE EFFECT OF SELECTED FACTORS ON MATERNAL BLOOD, CORD BLOOD AND PLACENTA TRACE ELEMENT LEVELS*

		Without Controlling for City Effects				Controlling for City Effects				
		Smoking	SES	Age	Parity	Smoking	SES	Age	Parity	City Effects
Maternal Blood	Cd	-	-	-	-	-	-	-	-	<0.05
	Li	-	-	-	-	-	-	-	-	<0.001
	Fe	-	-	+0.01	-	-	-	+0.025	-	-
	Ba	-	-	-	-	-	-	-	-	<0.01
	B	-0.5	-	-	-0.05	-	-	-	-	<0.001
	Cr	-	-	-	-	-	-	-	-	<0.005
Cord Blood	Cd	-	-	+0.025	-	-	-	-	-	<0.01
	Cu	-	-	-	-	-	-	-	-	<0.01
	Zn	-	-	-	-	-	-	-	-	<0.001
	Li	-	-	-	-	-	-	-	-	<0.005
	Se	-	+0.005	-	-	-	+0.005	-	-	-
	Ba	-	+0.05	-	-	-	-	-	-	-
	B	-	-	-	+0.01	-	-	-	+0.01	-
	Cr	-	-	-	-	-	-	-	-	<0.001
	Ni	-	-	-0.05	+0.05	-	-	-	-	-
Placenta	Cd	-	+0.05	-	-	-	-	-	-	<0.001
	Cu	-	-0.005	-	-	-	-	-	-	<0.005
	Zn	-	-	-	-	-	-	-	-	<0.05
	Li	-	-0.05	-	-	-	-	-	-	<0.001
	Se	-	-	-	-	-	-	-	-	<0.01
	Fe	-	-	-	-	-	-	-	-	<0.001
	Cr	-0.025	-	-	-	-0.05	-0.05	-	-	-
	Mn	-0.05	-	-	-	-	-	-	-	<0.001

Remarks: A negative sign appearing before the p-value indicates that the element level decreased with increased smoking, higher socioeconomic status, older age groups or higher parity groups.

* Values given are the probability of the observed difference in sample geometric mean levels between categories assuming no difference in the original population. Only values of 0.05 or less are listed. Elements omitted from the table had no significant differences in any of the above comparisons.

TABLE 30. TESTS OF SIGNIFICANCE OF THE EFFECT OF SELECTED FACTORS ON SCALP HAIR AND PUBIC HAIR TRACE ELEMENT LEVELS*

		Without Controlling for City Effects						Controlling for City Effects						
		Smoking	SES	Age	Parity	Shampoo Frequency	Usage of Dyes	Smoking	SES	Age	Parity	Shampoo Frequency	Usage of Dyes	City Effects
Scalp Hair	Pb	-	-0.05	-	-	-	-	-	-	-	-	-	-	-
	Hg	-	-0.025	-	-	-	-	-	-	-	-	-	-	-
	Li	-	-0.05	-	-	-	-	-	-	-	-	-	-	0.025
	Se	-	-	-	-	+0.005	-	-	-	-	-	-	-	-
	Fe	-	-0.005	-	-	-	-	-	-	-	-	-	-	0.01
	Cr	-	-	-	-	-	+0.025	-	-	-	-	-	+0.025	-
	V	-	-	-	-0.05	-	-	-	-	-	-	-	-	-
Pubic Hair	Pb	-	-	-	-	NO TEST	NO TEST	-	-	-	-	NO TEST	NO TEST	0.001
	Cu	-	+0.025	-	-			-	-	-	-			0.025
	Zn	-	+0.05	-	-			-	-	-	-			-
	Hg	-	-	-0.025	-			-	-	-	-			0.001
	Li	-	+0.005	-	-			-	-	-	-			0.005
	Se	-	-	-	-			-	-	-	-			0.001
	Fe	-	-	-	-			-	-	-	-			0.005
	B	-	-	-	-			-	-	-	-			0.05
	Sn	-	-	-	-			-	-	-	-			0.005
	Mn	-	-	-	-			-	-0.01	-	-			-

Remarks: The positive sign before p-values under the heading of Shampoo Frequency or Usage of Dyes indicates that element levels tended to be higher among those women who shampooed more frequently or who used dyes.

* Values given are the probability of the observed difference in sample geometric mean levels between categories assuming no difference in the original population. Only values of 0.05 or less are listed. Elements omitted from the table had no significant differences in any of the above comparisons.

TABLE 31. MEAN DUSTFALL TRACE ELEMENT CONTENT BY SECTOR*

	Cadmium				Chromium				Copper			
	# of Months Observed	Minimum	Maximum	Mean	# of Months Observed	Minimum	Maximum	Mean	# of Months Observed	Minimum	Maximum	Mean
Birmingham, Ala.	12	0.01	1.58	0.13	5	0.11	0.56	0.34	7	0.55	11.93	2.88
Charlotte, N.C.												
Whites	12	0	0.19	0.07	4	0	0.23	0.13	5	1.18	4.52	1.97
Blacks	11	0.01	2.03	0.18	3	0.07	0.16	0.10	5	0.64	4.92	1.50
Salt Lake City, Utah	11	0.01	0.28	0.09	4	0.06	0.29	0.16	6	1.38	2.44	1.76
Ogden, Utah	12	0.01	0.18	0.05	5	0.05	0.18	0.11	7	0.55	2.15	1.23
LA Basin, Calif.												
West	1	0.02	0.02	0.02	1	0.06	0.06	0.06	1	0.62	0.62	0.62
East	4	0.02	0.26	0.06	2	0.10	0.34	0.22	4	0.89	2.07	1.21
Elizabeth, N.J.	3	0.09	0.12	0.14	3	0	0.46	0.21	3	2.82	7.88	5.22
Riverhead, N.Y.	12	0	0.30	0.04	4	0.02	0.11	0.05	8	0.39	13.41	3.38
	Lead				Manganese				Nickel			
Birmingham, Ala.	12	0	19.82	7.73	6	2.23	12.89	6.59	7	0.01	0.89	0.30
Charlotte, N.C.												
Whites	12	0.21	8.92	4.80	5	1.31	2.87	1.86	6	0	0.50	0.35
Blacks	12	0.10	9.86	4.62	6	0	2.55	0.73	6	0	0.30	0.09
Salt Lake City, Utah	11	0.57	17.94	6.94	6	0.63	2.34	1.45	6	0.02	0.55	0.30
Ogden, Utah	12	2.41	6.98	5.02	7	0.32	3.13	1.38	7	0.01	0.46	0.19
LA Basin, Calif.												
West	1	3.84	3.84	3.84	1	0.61	0.61	0.61	1	0	0	0
East	4	5.91	7.39	7.06	4	1.22	1.68	1.51	4	0.10	0.31	0.17
Elizabeth, N.J.	3	4.15	14.00	9.18	3	0.87	1.06	0.98	3	0.41	0.52	0.47
Riverhead, N.Y..	12	0.30	4.39	1.74	8	0.05	0.70	0.35	8	0	0.76	0.21
	Zinc											
Birmingham, Ala.	12	5.45	84.42	32.50								
Charlotte, N.C.												
Whites	12	1.07	16.90	7.92								
Blacks	11	0.75	19.29	8.14								
Salt Lake City, Utah	11	1.04	6.32	4.61								
Ogden, Utah	12	1.19	6.30	3.89								
LA Basin, Calif.												
West	1	4.38	4.38	4.38								
East	4	3.00	5.39	4.54								
Elizabeth, N.J.	3	9.43	10.88	10.12								
Riverhead, N.Y.	12	0.19	26.38	5.90								

*Dustfall expressed as mg/m^2/month.

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16. ABSTRACT

The developing fetus probably represents one of the most vulnerable subgroups of the general population to the toxic effects of trace elements. There have been numerous reports of abortion or fetal malformation due to excessive exposure of the expectant mother to mercury and other trace elements. This investigation was aimed at gaining information on the levels of trace elements present in the blood of a term fetus, and on the relationship of these levels to the levels found in the placenta and selected maternal tissues. Once transplacental passage of the trace elements and their levels in the placenta and fetus is established, other researchers may attempt to ascertain whether these conditions actually result in overt or subtle impairments of the developing fetus.

This study took advantage of the opportunity provided by normal deliveries to obtain simultaneous tissue samples from a mother and her child. Maternal-fetal sets consisting of maternal venous blood, cord blood, placenta, maternal scalp hair, and public hair were collected and analyzed for the follwing 16 elements: boron, barium, cadmium, chromium, copper, iron, lead, lithium, manganese, nickel, selenium, silver, tin, vanadium and zinc.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS			b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Embryos			trace elements	06, T
boron	barium	cadmium		
chromium	copper	iron		
lead	lithium	manganese		
mercury	nickel	selenium		
silver	tin	vanadium		
zinc				

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