TRAIL LEAD STUDY REP0RT

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Table of Contents

Executive Summary

The Trail Lead study was undertaken in the summer and autumn of 1989 in order to meet the following objectives:

1. To identify modifiable factors which are determinants of elevated blood lead levels in preschool children in Trail.
2. To compare the current situation with past information to determine historical trends in environmental lead contamination in Trail.
3. To review relevant experience, standards or guidelines from authorities/experts in other jurisdictions which may be applicable to the situation in Trail.
4. In consultation with the Steering Committee, to recommend appropriate precautions and protective actions as warranted by the findings in the study.

The study was conducted into two phases. In Phase 1, blood samples were drawn from all children between the ages of 2 and 6. The response rate was high, with 91.5% of children who were contacted providing a blood sample. In Phase 2, those children with the highest and lowest quarter of blood leads were followed up with a questionnaire survey and residential environmental samples of drinking water, paint, housedust, soil, and vegetables. In addition, soil samples were collected from Parks.

The study revealed that the average blood lead level among children in Trail was now 13.8 micrograms per decilitre, with a range of 4 to 30 micrograms per decilitre. This is down dramatically from the late 1970s when a previous survey was done, but is still relatively high compared to other studies. The study of environmental determinants of lead revealed that soil lead levels and, secondarily, housedust lead levels are the principal determinants of high blood lead in children in Trail. Children with high blood leads tend to concentrate in certain neighborhoods, designated as "area 3" in the text of this report. This area includes West Trail, East Trail, Tadanac, and Rivervale.

Specific Recommendations: It is assumed that an implementation strategy will be developed and approved by representatives of government and the local community which will oversee a lead

remediation program over the next several years. The recommendations made below are meant to be helpful suggestions to those implementating a strategy and not as a blueprint for action.

1. In general terms, the implementation strategy should focus on neighborhoods rather than individuals. Priority should be given to investigating and intervening in those neighborhoods defined as area 3 in Table 8 of this report, followed by area 2, then area 1. This approach recognizes the fact that opportunities for exposure to lead are not just based on the individual residence but on the opportunities for exposure throughout the neighborhood in which children live and go to school.

2. Periodic blood screening will be necessary to follow the progress of the remediation strategy in Trail. When this occurs, it should involve capillary blood samples taken in the same manner as the previous study and at the same time of year. Moreover, it should involve a similar age cross section as did the 1989 sample. Conducting followups this way will insure that seasonal variations, age related changes in exposure, and systematic differences between capillary and venous blood lead levels will not distort comparisons over time and lead to inconclusive evidence of whether or not the remediation strategy is effective in lowering children's blood lead levels. Thus, whenever a resurvey is done, it will need to be conducted on a group of children somewhat different from the original study, in that new children who have reached age two would be included and children in the previous study who were now over six would be excluded.

3. For the purposes of followup of individual children with elevated blood lead levels, venous samples should be collected, and the children should be followed until their blood lead levels are consistently below 15 micrograms per decilitre, regardless of their age. Thus, followup for individual health reasons and surveying to determine the success of environmental monitoring programs follow different principles.

4. Followup of individual children identified with high blood lead levels should be a continuous process. However, I would recommend that a resurvey of capillary blood lead levels not be carried out again until some environmental measures have been taken.

5. Carrying out a detailed environmental assessment of the community is an immediate priority. It should concentrate on tracking lead in soil to its origins, investigating bioavailability factors, intensively mapping the depth and consistency of soil leads in the target neighborhoods (primarily area 3), and integrating information regarding other metals which may be expected to be found in the soil. A preliminary survey of these metals is being carried out on available soil samples as part of a process of further evaluation.

6. The question of whether or not to begin remediating soil before the sources of its contamination have been thoroughly evaluated and controlled is a very difficult one. Areas of remediated soil will likely become recontaminated if the primary sources of exposure are not controlled concurrently. Thus, it is clear that massive soil removal may not be rational until primary sources of exposure have been controlled. However, a case might be made for selected soil removal in areas of especially high lead contamination. These seem to occur sporadically throughout neighborhoods with high average concentrations of soil lead. Thus, it might be supposed that if these were removed, they would recontaminate gradually and not come to exceed the average concentration in the surrounding area. Unfortunately, this strategy suffers from several difficulties. First, identifying the hot spots comprehensively will still require further environmental assessment, and so cannot be done immediately. Secondly, it is likely that the average concentration of soil lead in children's home, play, and school environment together determine their cumulative exposure. Therefore, isolated spots of extremely high lead (for instance, greater than 4,000 ppm) will tend to be relatively insignificant unless they happen to fall in the middle of a play area, or unless they are very large. On balance, I would recommend that soil remediation strategies be developed for entire neighborhoods following

completion of a more intense environmental assessment, and that hot spots be remediated as part of the comprehensive strategy.

7. The ultimate objective of a Trail Lead Remediation program should be to control soil lead exposures so that they effectively meet the residential criteria proposed for British Columbia. The present study has allowed us to identify priority neighborhoods where evaluation and intervention need to be focused most intensively. Over time, with resurvey of blood lead levels of children, priority areas will likely change. Also, a large volume of information about the lead exposure status of children in Trail will be created. This will prove to be very fortuitous as the acceptable level of blood lead has tended to decline over time, as new studies of the toxic effects of lead have been published.

8. In the short term, it would be important to offer information and education to families with young children and to pregnant women about ways in which they can individually avoid lead exposure. Such programs are always difficult because they create the impression that individuals are expected to take primary responsibility for environmental exposures which are, in principle, outside of their control. Intensive programs, if they backfire, can produce excesses of cynicism or anxiety in different people, depending on their personal philosophy and outlook. Yet, the cumulating evidence of the effects of lead on the developing nervous system are such that targeted programs are likely warranted. If these programs occur in the context of an energetic program of environmental control, they will likely be effective and, as well, appreciated.

9. Although our study did not identify the eating of local produce as an important determinant of blood lead among children, this would still appear to be an area requiring further investigation. Because of difficulties with the analytic procedures associated with vegetables, and uncertainties regarding eating patterns, the investigators are not confident that our understanding of the role of vegetables in contributing to body burdens of lead is complete at this time.

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TRAIL LEAD STUDY REPORT

by

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The Trail Lead Study was carried out by the Division of Occupational and Environmental Health, Department of Health Care and Epidemiology, University of British Columbia upon request of the Ministries of Health and Environment of B.C. The study was conducted in response to concerns that environmental exposures to lead among children in Trail might be unacceptable. A previous study, conducted in 1975, identified an average blood lead level of 22.5 micrograms per deciliter (µg/dl) in 1 - 3 year olds and an average of 22 µg/dl in Grade 1 children in Trail. Neighbourhood soil lead levels and the proximity of the household to the Cominco lead-zinc smelter were identified as the principal determinants of elevated blood lead at that time (1). Since the mid-1970's, the standards for "acceptable" levels of blood lead have declined in North America as new knowledge about the health impact of low doses of lead on children has become known (2). In the 1986 Royal Society of Canada Report on Lead in the Canadian Environment, Trail was specifically identified as an area of potentially higher lead exposure, due to the factors identified in the previous study (3). Because of the tendency for lead to persist in soil, and the important role of soil in mediating childhood exposures to lead (4,5), it was reasonable to be concerned that lead exposures to children in Trail might be persistently high, despite a marked reduction in the use of leaded fuels in Canada during the 1980's. Moreover, because of the disproportionate exposure of young children under the age of 6 through passive soil ingestion (4,5), it was reasonable to target this age group for investigation.

This background, combined with community concerns regarding reports of sporadic high blood lead levels among children in Trail in the late 1980s, led to the initiation of the Trail Lead Study in the summer of 1989. The study was meant to provide a scientific and objective basis for future policy-making in relation to lead pollution in Trail, through the following objectives:

1) to identify modifiable factors which are determinants of elevated blood levels in pre-school children in Trail.
2) to compare the current situation with past information to determine historical trends in environmental lead contamination in Trail.
3) to review relevant experience, standards or guidelines from authorities/experts in other jurisdictions which may be applicable to the situation in Trail.
4) in consultation with the steering committee, to recommend appropriate precautions and protective actions as warranted by the findings of the study.

METHODS

Overview:

The study was undertaken in two phases. In the first phase, all children past their second birthday but before their sixth at the time of blood sampling (August/September, 1989) were identified, through multiple sources, in the twelve neighbourhoods of the Trail area identified in Table 8. Blood samples drawn from this group were analyzed for lead, then divided into approximate "quartiles" by concentration. The lower and upper quartile, that is, the highest and lowest quarter of the lead levels, were selected for further followup in order to maximize the cost-efficiency of environmental sampling. A questionnaire survey of factors potentially related to childhood blood lead exposure (Appendix A) was administered to a head of each of these households (usually female). Samples of soil, window dust, floor dust, water, paint, and, where possible, home-grown vegetables were also taken for lead analysis. These samples were supplemented by soil lead samples from 28 parks within the twelve neighbourhood area. The environmental lead levels and the questionnaire variables were analyzed in a "case-control" fashion to identify which of the factors were associated with children being among the top, versus the bottom quartile of blood lead in Trail.

Detailed Methodology: The study sample was restricted to children between the ages of two and six because of well-known difficulties in obtaining blood samples among younger children and because of the fact that their limited mobility would potentially reduce their contact with environmental sources of lead. In making this choice, the investigators acknowledge that they excluded a very important group of toddlers less than two years old. Blood sampling took place in August and September when maximum exposures were expected because of the prospect of dusty conditions during the summer and the increased opportunities for children to be at play at this time.

Each child was invited to the study centre in Rossland, B.C. where the skin on their hands was meticulously cleaned to remove potential lead contamination and a capillary blood sample was collected using a finger stab method. These samples were sent to the local laboratory at Cominco for analysis. In a random 10% of cases, a second sample was taken for analysis at the laboratory at Children's Hospital in Vancouver. Both laboratories use a Graphite furnace atomic absorption and participate in the CDC Atlanta Proficiency Testing Program for blood lead. Children were excluded from the study if they had not been resident in the study area at least five out of seven days for three continuous weeks before sampling. This cut-off was meant to exclude those children who had spent a sufficiently large proportion of time out of town during the summer to have allowed a "washout time" for lead.

All parents of participants received a brochure which made suggestions on how to reduce environmental exposure to lead. The parents of children with blood lead levels less than 15 μg/dl were advised that there was very little risk of any effect on the child's health and that no special action need be taken. For children with a level between 15 and 20 μg/dl the parents were advised that the risk of any noticeable effect was very low but a brochure was included which made suggestions on how to reduce environmental exposure. Parents of children with levels of 20 - 25 μg/dl were advised that the level was higher than desirable, and to have a repeat analysis on blood collected by venipuncture done for their child. Those parents whose children's lead levels were greater than 25 μg/dl were told that a prolonged period at this level is associated with harmful effects on the health of the child. A repeat blood test was strongly recommended. These recommendations were based on the protocol of Dr. Andrew Jin (6) which was based on the U.S. Centres for Disease Control criteria for responding to individual blood tests (7). Sample letters to parents are included as Appendix B of this report.

Environmental samples were collected from each case and control household. An attempt was made to obtain two composite soil samples, two house dust samples, two paint samples, at least one home grown food sample, and a water sample from the first draw of the day, from each household. Additional soil samples were collected from potential common sources of exposure such as school yards and playgrounds.

Environmental lead levels were determined by Quanta Trace Laboratories and a 10% random quality assurance sample was analyzed at Cominco's Laboratory in Trail. Soils were oven dried and sieved (80 mesh). Vegetables were washed with deionized water, oven dried, ground and sieved, (80 mesh). Paint was ground and sieved (80 mesh). Then all samples were digested/acidified and diluted to the appropriate volume. Analysis was done by inductively coupled Argon plasma-optical emission spectroscopy. Blanks, duplicates, and standard reference materials were analyzed concurrently with the samples.

Detailed protocols describing collection, storage, transport, and analysis of soil, blood, water, paint, and produce samples are found in Appendix C.

Results

Response rates for Phase 1 of the study are identified in Table 1. A total of 435 children were identified in Trail, which we believed to be a complete census of those of the appropriate age. After excluding the 3.4% of children who were out of town for the balance of the summer, the response rate is either from 87.6 or 91.5% depending on whether or not the children who could not be contacted are included as missed respondents or not. In either case, this is an excellent response rate, representing 368 Trail children. Table 2 identifies the age distribution of the respondents based on their year of birth (1983-1987). Not all of those born in 1983 or 1987 were eligible for study, since some would be either under two or over six at the time of sampling. Thus, the proportion of the sample born in these years is less than in the intervening years. Table 3 reveals that there were slightly more female than male study subjects in the final sample of 368.

Table 4 gives the test-retest reliability of the serum lead levels. These are calculated two ways, using absolute differences between Cominco and Children's Hospital Laboratory, and, second, using relative differences in terms of the percentage of the Cominco value. It was decided that the level of agreement between the two laboratories was acceptable on the basis of these results. In this regard, only one of the samples subjected to reliability testing would have been classified as a case (that is in the upper quintile of lead levels) by one laboratory and a control (lower quintile of lead levels) by the other. For further details, see the reliability report in Appendix D.

Table 5 shows the distribution of serum lead levels among the study subjects. It reveals a geometric mean level, or median, of 13.8 μg/dl with a range of 4 to 30 ug/dl. In all, 60.6% of the samples were below the U.S. Environmental Protection

Agency "no effect level" of 15 μg/dl (8). 11.4% were above the recommended interventional level of 20 μg/dl suggested by the Royal Society of Canada report of 1986 (3). A further 1.6% were above the U.S. Centres for Disease Control level for clinical intervention of 25 μg/dl(7).

Table 6 puts these blood lead results in historical perspective through a geographic comparison with samples obtained in 1975. Serum lead values were grouped according to 5 digit postal codes for each of the surveys and analyzed for evidence of a statistically significant change over the 14 year period. In 18 postal code areas, statistically significant declines occurred, and in the other 23 postal codes for which information was available, the direction of change was also downward, although not statistically significantly so. While this would seem to be convincing evidence of a real decline in lead exposure over time, two cautions must be borne in mind. First, we are comparing a split sample of those less than 3 years old and greater than 6 years old (1975) with a sample of 2 - 6 year olds (1989). Thus the age distribution is not strictly comparable. Secondly, it is commonly believed that techniques of skin decontamination, sample collection, laboratory analysis, and laboratory decontamination have improved in recent years. It is possible that these changes would have the effect of lowering the measured serum lead level today as compared to fourteen years ago, but there is no way to be certain of this. Nonetheless, the strength and consistency of the apparent decline makes it difficult to dismiss.

Figure 1 gives a comparison of blood lead levels in Trail and Vancouver. The samples in Vancouver were taken at the same time using the same collection and analysis methods as were used in the Trail Study. Indeed, the measured values for Vancouver were analyzed at the Children's Hospital laboratory which did the reliability checks for the Trail Study. In Vancouver the sample consisted of approximately 180 randomly selected children, age two years, who lived within the

City limits. This sample was drawn during the autumn, after it had been demonstrated by repeat soil testing that high lead levels were confined to narrow bands along heavily travelled roadways. Thus, it was expected that the serum lead levels would be low. In Vancouver, the geometric mean value was 5.3 µg/dl and only two values exceeded 15 (9). Thus, while the lead levels in Trail have likely declined substantially over the last decade and a half, they are still relatively high in relation to a community such as Vancouver which has no major point sources of lead exposure. Further comparisons with other population-based lead studies are made in the Discussion section of this report.

According to protocol, the 368 study respondents were divided into quarters by serum blood lead level, in order to determine the sample for the case control study. A total of 86 "cases" were identified, with blood lead levels of 18 µg/dl or greater. The controls consisted of 75 subjects, including all those with serum leads of 9 µg/dl or less and a random 50% sample of those whose lead level was 10 µg/dl. If all those with a value of 10 µg/dl had been included, the sample would have exceeded our budgetary constraints. Thus, the case control sampling was based on quartiles, modified slightly for practical reasons. The validity of the analysis would not be affected by this modification of protocol.

Table 7 gives the response rates for the case control study. Depending upon how we count those we were unable to contact, the response rate for cases was between 93 and 98%, and for controls it was between 97 and 100%. This is excellent by population survey standards. Moreover, the overall response rate (combining non-response rates from both phases of the survey) is between 83 and 90%. Thus, we can have full confidence in the generalizeability of these results to the population of Trail aged 2 to 6.

Figure 2 shows the distribution of the serum lead levels by the case and control status of those who responded to Phase 2 of the study. It shows that the majority of controls had serum lead levels between 7 and 10 μg/dl and the majority of cases had lead levels between 18 and 22 μg/dl.

Table 8 shows how the cases and controls were concentrated in the twelve neighbourhoods which comprised our study. The neighbourhoods broke down naturally into three groups: those where there were at least twice as many cases as controls; those where the numbers of cases and controls were approximately equal; and those where the controls outnumbered the the cases by at least five to one. In other words, there was a strong tendency for children with high blood lead levels to be found living near one another and an equally strong tendency for those with low blood leads to be found living close by each other. This is represented graphically on the map which is Figure 3 of this report. Table 8 also reveals a strong relationship between the geometric mean soil lead level in each neighbourhood and the relative number of children with high blood lead levels (cases) and low ones (controls). Because of the strong geographic clustering, the data has been analyzed two ways: once by case and control status and a second time by area according to the three areas outlined in Table 8.

Table 9 presents the questionnaire variables by the case and control status of the respondents. This table includes variables which were statistically significantly associated with case-control status or else had an inherent interest despite their lack of statistical association. All other questionnaire responses not listed in this table failed to show an association with case and control status. (These can be found on the questionnaire in Appendix A.) Table 9 reveals that the strongest association related to proximity to the Cominco smelter in Trail and the number of gas stations within six blocks. Other statistically significant correlations were found with the average educational level of parents, the number of smokers in the household, whether or not the child put dirt in its mouth, whether or not auto repairs were done at home, and the frequency with which the child's clothes needed changing due to soiling during the summer. Only weak correlations were seen with the sex of the child (males being more likely to be cases and females more likely to be controls), father's work exposure to lead, father's job group, eating produce grown in the neighbourhood, and the age of the residence. The age of the child and the source of drinking water had little impact on case control status.

Factors potentially explaining the role of parental education and of children putting dirt in their mouth were further evaluated. Table 10 reveals that parental educational level was strongly associated with the possibility of the father being exposed to lead in the workplace, while those with lower educational attainment were disproportionately likely to live near the Cominco Trail smelter. Taken together, these observations suggest that the educational status of parents is relevant only in so far as it affects the choice of father's occupation and place of residence. For statistical reasons, it was preserved as a potential independent risk factor in the multivariate analysis to follow.

Table 11 confirms the fact that the tendency for children to put dirt in their mouths diminishes with age but that boys did not tend to mouth dirt more or less than girls.

Table 12 presents a parallel analysis of the questionnaire data, this time by area of residence of the child. Area 3, the area with the highest blood lead levels, had the largest number of study subjects reporting 2-6 gas stations within six blocks of their residence. The age of the residences in area 3 tended to be older. There were also strong associations between both drinking water source and fathers' occupational group with the area of residence, but with these factors it was not a simple matter of area 3 differing from areas 2 and 1. Area 2 has the greatest proportion of fathers who reported working at Cominco as well as the highest proportion of those reporting municipal water supply. A correlation was also seen between the area of residence and the tendency to do auto repairs at home. Here, the highest proportion was in area 3 and the lowest proportion in area 2. These factors seemed to have relatively little significance for children's lead exposure because they did not show a step-by-step increase or decrease from area 1 to area 3, which would be expected of factors which explained stepwise increases in lead levels.

Table 13 shows the environmental measurements by case and control status. It reveals that floor and window dust lead levels, average soil lead levels, and garden produce lead were all markedly higher in the case than the control households. However, house paint and water samples showed no statistically significant differences between the two groups. From Table 13, it can be seen that the counts of cases and controls differ for each analysis. This is because useable samples were not available from all households for all environmental variables. For instance, in some houses insufficient quantities of floor and window dust were available for analysis. Some individuals refused to provide paint chips for house paint samples. Soil values could not be obtained for those living in apartment buildings and produce was only available from those who grew their own fruit and vegetables. Finally, a small number of water samples were not obtained before the end of the study period.

Table 14 repeats the analysis of the environmental measures by area. Also included in Table 14 are the average soil lead levels from parks, by their respective areas. For seven of the nine variables listed, area 3's levels were higher than area 2's which, in turn, were higher than area 1. Once again, this pattern included all variables except paint chips and water. However, the strongest gradient was found for average soil level. Here, there was not only a stepwise increase from area 1 through area 3, but also the mean values in each area differed in a statistically significant fashion from one another. Moreover, the gradient in average soil level was greater than six-fold across the three areas. A gradient of similar magnitude was seen for carrot lead levels, but only 37 of 153 respondents provided carrot samples.

One notable feature of Table 14 is that the average park soil lead level is much below the average residential soil lead level in each of the three areas. Table 15 identifies the soil lead levels measured in the different parks. It reveals widely variable lead levels within each park, depending on the site at which the sample was taken. Beyond this observation, it is not clear why lead levels should be so much lower in neighbourhood parks than in the residential areas surrounding them. In principle, there were no differences in the methods of collection of the soil samples. This is an issue which requires further investigation in follow-up studies.

In order to tell which of the factors are truly important in determining children's blood lead level, it is necessary to perform certain forms of "multivariate analysis". In multivariate analysis, all the factors are entered into a statistical model in which a computer program tests various combinations of them, to determine which combination of factors best segregates the "case" children from the "controls". These are the important factors and the rest can be dismissed as minor.

In preparation for multivariate analysis, we constructed a "correlation matrix" of all relevant questionnaire and environmental factors. This was necessary because factors which correlate very strongly with each other create statistical confusion in identifying the most important factors. In fact, few correlations exceeded a value of .2, which would suggest little interference in the multivariate analysis. Table 16 identifies the correlations of 4 key variables with soil lead. These include the three highest correlations (with floor dust, window dust and house paint), and reveal that soil lead, as expected, is an important determinant of house dust lead level. However, it is interesting to note that the correlation between measured levels of floor and window dust were weak, suggesting that, while both are related to soil lead level in some way, the pathways might, indeed, be quite different. Despite the correlations of .42 and .38 between soil lead and window and floor dust respectively, these correlations were not strong enough to interfere with multivariate analysis.

Table 17 presents multivariate logistic regression analyses using two outcome measures: first, case and control status and second, area of residence. In both cases age and sex were "forced into" the model to make sure that their effects, however trivial, were taken into account. In both analyses, the log of the soil lead level was, by far, the strongest risk factor. The analysis by case and control status could be interpreted to mean that each ten fold increase in soil lead level would increase the relative proportion of cases to controls by 14.25 fold. An analogous comparison between area 3 and area 1 would result in a 13.59 fold difference. In both analyses, the window dust was the next most important risk factor, but its effect was much weaker than soil level. In relation to case and control status, there was a slight negative relationship between paint lead level and case control status. However, this relationship is likely a statistical artifact, since it is a physical impossibility for lead in paint to provide a protective effect for overall lead exposure to children. In relation to the area of residence, the floor dust level seemed to have an effect which was independent of window dust and nearly as strong. It is important to understand that all of the other environmental and questionnaire variables failed to enter the multiple logistic regression equation. In other words, their importance as risk factors was overwhelmed by the soil and house dust lead levels. Thus, it is fair to conclude that soil lead level and its subsidiaries, floor and window dust lead levels, are the principal determinants of children's blood lead levels in Trail.

From Table 13, it will be recalled that the mean soil lead level was 1172 ppm at case households and 351 ppm at control households. Figure 4 further explores the soil lead levels by case and control status. It demonstrates how the ratio of cases to controls rises dramatically as the soil lead levels in the household rise by various increments. The order of the ratio of cases to controls is .31, .39, 3.0, 2.3, 5.0, and infinity (as there are no controls with the highest soil levels) with each increment shown. Figure 5 further subdivides the cases and controls by blood lead level. From this table it can be seen that as the soil lead levels increase the mixture of controls tends to increasingly favour those with relatively high blood leads for controls (9 or 10 μg/dl rather than 8 ug/dl or less) and the mixture of cases also increasingly favours those with high blood leads for cases (that is, greater than 20 ug/dl).

Table 18 gives an historical perspective through a comparison of soil lead levels by 5-digit postal code from the 1975 and 1989 samplings. Overall the table reveals that the soil lead levels did not change significantly across the average of comparable local areas. However, it can be seen that there are large changes within several postal code areas over time. The most likely explanation for this is that soil lead levels often vary a great deal within short distances. Thus, an estimate of an area's average soil lead level based on a small number of samples will tend to be unstable. The finding of relatively unchanged soil lead levels overall is a more reliable observation than the variations seen within specific postal code areas. Given what is known about the persistence of lead in soils, this is not a surprising conclusion. However, it is somewhat difficult to reconcile with the observation that soil lead level was a strong predictor of serum lead in both surveys and the fact that the serum lead levels appear to have dropped by nearly 50% over the fourteen year period. This observation brings into question the comparability of the serum lead levels, and, indirectly, of the soil lead levels, too. Generally speaking, the methods of soil collection and analysis were similar, however our samples were taken at two inches depth, while the previous ones were taken at one inch.

Table 19 shows lead levels for a variety of residential soil sources. On average, it appears that there were strong differences in the lead levels found at each of these sites. However, the variation between houses was so great that the 95%

confidence limits for the geometric mean of each source overlapped with one other. The only exception to this was sandbox lead, which was statistically significantly lower than all other sites aside from "miscellaneous sandy areas". This finding is somewhat ironic when we consider that the highest park lead level was found in the sandbox in Tadanac Park.

Figures 6 and 7 separate the cases and controls by those who did and did not supply us with samples of home grown produce. These figures seem to show that there is a somewhat stronger association of soil lead levels and blood lead levels among children in households where produce is grown than where it is not. Figure 7 also shows that eight out of the ten "cases" from households with soil lead levels less than 250 ppm were found among families that did not grow produce. These results seemed to affirm the importance of home grown produce as a source of lead exposure in areas of high soil lead. Therefore, we returned to our multivariate analysis and introduced an "interaction term" between the fact of growing produce and the soil lead level to see whether or not it would serve as an important risk factor like soil lead level. It turned out that, after taking account of other important factors, this interaction term had no additional explanatory power. That is to say, growing vegetables in high soil lead areas seemed to have less effect than common sense would suggest. This may be due to the fact that our knowledge of the quantities of home grown produce eaten by the children is very limited.

Discussion

Table 20 puts the Trail lead results in context through comparison with the blood lead studies from several other places across Canada during the late 1970s and 1980s. The closest concurrent comparison is with Rouyn-Noranda, a smelting town in Quebec where the blood lead distribution was slightly lower than in Trail (10). It is important to note that this study was a repeat of a smaller sample of two to five year olds done in 1979. At that time the mean blood lead was 21.5 µg/dl. Like Trail, it has dropped in half since then. Moreover, the soil lead levels have dropped in half from an average of 840 ppm in 1979 to 438 ppm in 1989. The Vancouver study of 1989 (9) is grouped with the results of three studies from people living in non-industrial environments in Venezuela, Nepal, and Papua New Guinea (11). It can be concluded from this comparison that both industrial and non-industrial sources of exposure in Vancouver are becoming negligible. Data from Kamloops, various places in Ontario, and the urban hot spot of South Riverdale, Toronto, are presented (12,13). Because of the dramatic decline in the use of leaded gasoline during the 1980s, obvious differences in sample collection, the age groups and rationale for selection of the respondents, etc., it is difficult to draw firm conclusions from the comparison of these studies with Trail. It would appear that the mean blood lead value among children in Trail in 1989 was among the highest in Canada, but as can be seen through comparison with Smelterville, Idaho, is certainly exceeded in comparable smelting towns elsewhere in North America. Finally, the table presents the Canada Health Survey blood lead data from 1978. This was a random sample taken around the country and not in areas of special concern. It is interesting to note that, despite the fact that this study was done twelve years ago, there was a very high proportion of both males and females with blood lead levels below 10 μg/dl and no females above 20 μg/dl.

Since Trail is a region of relatively high lead levels among children and soil is the primary determinant of high lead, it is important to consider how large a reduction in blood lead levels might be achieved by soil remediation. This is best done by directly experimenting with soil remediation and tracking the decline of children's blood lead levels after remediation has occurred. However, a statistical model is available for predicting what might happen, and the following part of the discussion describes our attempts to learn what we could about soil remediation in Trail using this model.

Table 21 shows the relationship between mean blood lead levels and predicted mean soil leads for male and female children in Trail based on the multivariate analysis developed for the case-control comparison in this study (Table 17a). A word of caution must be exercised here. The equations in Table 21 were were based on those children who were selected for the case-control study, not for the 50% of children from the original blood lead survey for whom no soil lead values were taken. Thus, the distribution of blood leads in this analysis leaves out all values between 11 and 17 ug/dl, which violates the underlying assumptions for this type of analysis. Nonetheless, the analysis is useful for comparison with other studies, in preparation for planning remedial action.

From the equation specified at the bottom of table 21, it can be seen that separate relationships were generated for males and females. This is because there was a statistically significant difference in the blood lead-soil lead relationship between boys and girls. Assuming a soil lead of 0, the intercept blood lead for girls would be -2.91 µg/dl and -1.13 for boys. These are nonsensical values, because they suggest that if there was no lead in the soil, the blood leads would be less than zero! This is awkward statistically, but does not mean we cannot learn other useful things from the model. It should be noted that the model proposed by the International Lead Zinc Research Organization (14) uses a background base line blood lead of 4 µg/dl, when soil lead levels are zero.

Part (a) of table 21 shows that a mean blood lead concentration of 15µg/dl corresponds to a mean soil level 742 ppm for girls and 385 ppm for boys in Trail whereas 20 µg/dl is associated with soil leads of 4693 and 2433 ppm, respectively. Similarly, Part (b) of the table shows a rapidly increasing mean blood lead for males and females across the first 1000 ppm of soil lead. In other words, blood lead levels seem to rise very quickly with increasing soil lead levels. Are these observations similar to previous studies? Bornschein (15) compiled a list of 24 relevant slope calculations looking at the relationship between increasing blood lead levels and soil lead levels in children. These were taken from a variety of different studies using different types of soil lead measurements, different ages of children, and different analytic techniques. Nonetheless, the range of slopes goes from 0 - 9 µg/dl increase in blood lead for every 1000 ppm of increase in soil lead. Table 22 shows the numbers of studies with different results; identifying 6 which showed "slopes" of 0-2 ug/dl per 1000 ppm of soil lead, 10 in the 2 - 5 range and 8 in the 5 - 9 range. For Trail the comparable slope estimate was 6.9 µg/dl per 1000 ppm of soil. This is within the range of the other slope estimates, although it tends towards the high end. However, Table 22 provides four previous slope estimates for Trail, reported by Bornschein, using environmental data from 1978 and 1979, which show that our current slope estimate is consistent with past estimates.

By calculating the overall geometric standard deviation for blood lead in Trail, it was theoretically possible to make some rough comparisons with the ILZRO's nomograms relating soil lead to blood lead (14). In the case of the Trail Lead Study, the overall geometric standard deviation (GSD) for blood lead from the full sample of 368 children was 1.5. This information, combined with the slope coefficient of 6.9 µg/dl per 1000 ppm of soil lead theoretically allowed approximate calculation of soil leads at which 1% or 5% of children only would be above 15 µg/dl of blood lead. However, the answers so obtained were absurdly low. Instead, we inspected the ILZRO nomogram values for the conditions most closely approximating Trail. Thus, for a target of 99% of blood leads below 15 µg/dl, a GSD of 1.4, and an intercept of 4 ug/dl of blood lead at a soil lead level of zero, the target soil lead level would be 560 ppm for a slope coefficient of 6 µg/dl per 1000 ppm of soil lead or 375 ppm for a slope coefficient of 8. Since these slope coefficients surround the estimated value of 6.9 ug/dl per 1000 ppm calculated for Trail, the results of this statistical exercise tend to support the conclusion that a residential soil remediation level of 500 ppm would provide significant protection to children in Trail.

Recommendations[1]

General Comments: Because of the importance of soil lead as a determinant of blood lead among children in Trail, it would seem reasonable to assume that strategies to address the lead issue would focus on soil remediation. However, there are several problems which need to be overcome before an effective remediation strategy can be proposed with confidence. It is uncertain as to what proportion of current lead exposures to children is from long term deposits of lead in the soil and how much is due to recent dustfall which is being rapidly mobilized from soil deposits. Currently, there are approximately 300 kg of lead per day being emitted from the stacks at Cominco and an unknown quantity of fugitive emissions from stock piles and other sources. The relative contributions of stack versus fugitive emissions have been inadequately documented so far. Thus, we are currently unable to estimate the relative contribution of different sources of lead in specific high soil lead areas. These factors are crucial because no soil remediation strategy is likely to be effective unless the sources of lead deposition in the soil have been effectively controlled. While it is expected that stack emissions will drop to approximately to 80 kg of lead per day once the new smelting technology has been perfected, even this will not guarantee that soil remediation will be effective in the long term. Another factor of crucial interest is the acidity of the soil. It is thought that lead compounds in acidic soil may be especially bioavailable to those ingesting it and, thus, help explain the particularly the strong relationship between soil and blood lead in Trail. If so, this would raise the possibility of liming the soil as one of several strategies for remediation. We also have inadequate information regarding

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[1] The recommendations made here are those of the Principal Investigator, and do not necessarily reflect those of the other members of the study team.

the extent of the contamination of the soil itself. We do not know the depth to which the soil is contaminated nor its consistency throughout neighborhoods. For instance, Table 18 suggests that, while the average soil lead levels have not changed much between 1975 and 1989, the average levels within small neighborhoods (defined by 5-digit postal code) appear to have risen or fallen dramatically in many instances. It is possible that this observation is simply an artifact based on the small number of samples available to us from each neighborhood. But it may also reflect the prospect that lead has deposited in a very unequal manner. If so, remediation may be assisted by a program of intense soil sampling within high lead neighborhoods in order to most effectively target intervention.

Unfortunately, the question of remediation in Trail is taking place during a time in which we have limited information about the relative effectiveness of different strategies for addressing the problem. Table 23 summarizes the results of soil remediation attempts in Canada and elsewhere to date. From this table, it can be seen that a variety of methods involving soil removal, house cleaning, improving grass covers, and education programs have been attempted in other places. Each program was designed to address the particular needs of the community. However, only the Baltimore study has so far produced results based on declining blood lead levels in children. Although these are encouraging, they were based on a sample of children whose blood leads ranged from 30 to 49 micrograms per decilitre, a much higher range than in Trail. Thus, the remediation program in Trail must be developed without good evaluations available about the effectiveness of each of the potential components of a remediation strategy or about the overall effectiveness of multi strategy programs in communities similar to Trail. In general terms, this means that a remediation program for Trail should be based primarily on a strategy for ongoing consultation and feedback, and should remain open to a wide variety of interventions. At the same time, priorities should be placed firmly on control of primary exposure and soil as the major determinant of blood lead among children. This strategy should not attempt to replace a program of environmental controls with a program which focuses on personal habits and behaviours.

Specific Recommendations: It is assumed that an implementation strategy will be developed and approved by representatives of government and the local community which will oversee a lead remediation program over the next several years. The recommendations made below are meant to be helpful suggestions to those implementating a strategy and not as a blueprint for action.

1. In general terms, the implementation strategy should focus on neighborhoods rather than individuals. Priority should be given to investigating and intervening in those neighborhoods defined as area 3 in Table 8 of this report, followed by area 2, then area 1. This approach recognizes the fact that opportunities for exposure to lead are not just based on the individual residence but on the opportunities for exposure throughout the neighborhood in which children live and go to school.

2. Periodic blood screening will be necessary to follow the progress of the remediation strategy in Trail. When this occurs, it should involve capillary blood samples taken in the same manner as the previous study and at the same time of year. Moreover, it should involve a similar age cross section as did the 1989 sample. Conducting followups this way will insure that seasonal variations, age related changes in exposure, and systematic differences between capillary and venous blood lead levels will not distort comparisons over time and lead to inconclusive evidence of whether or not the remediation strategy is effective in lowering children's blood lead levels. Thus, whenever a resurvey is done, it will need to be conducted on a group of children somewhat different from the original study, in that new children

who have reached age two would be included and children in the previous study who were now over six would be excluded.

3. For the purposes of followup of individual children with elevated blood lead levels, venous samples should be collected, and the children should be followed until their blood lead levels are consistently below 15 micrograms per decilitre, regardless of their age. Thus, followup for individual health reasons and surveying to determine the success of environmental monitoring programs follow different principles.

4. Followup of individual children identified with high blood lead levels should be a continuous process. However, I would recommend that a resurvey of capillary blood lead levels not be carried out again until some environmental measures have been taken.

5. Carrying out a detailed environmental assessment of the community is an immediate priority. It should concentrate on tracking lead in soil to its origins, investigating bioavailability factors, intensively mapping the depth and consistency of soil leads in the target neighborhoods (primarily area 3), and integrating information regarding other metals which may be expected to be found in the soil. A preliminary survey of these metals is being carried out on available soil samples as part of a process of further evaluation.

6. The question of whether or not to begin remediating soil before the sources of its contamination have been thoroughly evaluated and controlled is a very difficult one. Areas of remediated soil will likely become recontaminated if the primary sources of exposure are not controlled concurrently. Thus, it is clear that massive soil removal may not be rational until primary sources of exposure have been controlled. However, a case might be made for selected soil removal in areas of especially high lead contamination. These seem to occur sporadically throughout neighborhoods with high average

concentrations of soil lead. Thus, it might be supposed that if these were removed, they would recontaminate gradually and not come to exceed the average concentration in the surrounding area. Unfortunately, this strategy suffers from several difficulties. First, identifying the hot spots comprehensively will still require further environmental assessment, and so cannot be done immediately. Secondly, it is likely that the average concentration of soil lead in children's home, play, and school environment together determine their cumulative exposure. Therefore, isolated spots of extremely high lead (for instance, greater than 4,000 ppm) will tend to be relatively insignificant unless they happen to fall in the middle of a play area, or unless they are very large. On balance, I would recommend that soil remediation strategies be developed for entire neighborhoods following completion of a more intense environmental assessment, and that hot spots be remediated as part of the comprehensive strategy.

7. The ultimate objective of a Trail Lead Remediation program should be to control soil lead exposures so that they effectively meet the residential criteria proposed for British Columbia. The present study has allowed us to identify priority neighborhoods where evaluation and intervention need to be focused most intensively. Over time, with resurvey of blood lead levels of children, priority areas will likely change. Also, a large volume of information about the lead exposure status of children in Trail will be created. This will prove to be very fortuitous as the acceptable level of blood lead has tended to decline over time, as new studies of the toxic effects of lead have been published.

8. In the short term, it would be important to offer information and education to families with young children and to pregnant women about ways in which they can individually avoid lead exposure. Such programs are always

difficult because they create the impression that individuals are expected to take primary responsibility for environmental exposures which are, in principle, outside of their control. Intensive programs, if they backfire, can produce excesses of cynicism or anxiety in different people, depending on their personal philosophy and outlook. Yet, the cumulating evidence of the effects of lead on the developing nervous system are such that targeted programs are likely warranted. If these programs occur in the context of an energetic program of environmental control, they will likely be effective and, as well, appreciated.

9. Although our study did not identify the eating of local produce as an important determinant of blood lead among children, this would still appear to be an area requiring further investigation. Because of difficulties with the analytic procedures associated with vegetables, and uncertainties regarding eating patterns, the investigators are not confident that our understanding of the role of vegetables in contributing to body burdens of lead is complete at this time.

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Table 1: Response Rates for Blood Sampling

Total number tested	=	368
Refusals	=	34
Exclusions (out-of-town)	=	15
Could not contact/failed to show up	=	18
Total children	=	435

Response rate (high estimate): $\frac{368}{368 + 34}$ =91.5%

Response rate (low estimate): $\frac{368}{368 + 34 + 18}$ = 87.6%

Table 2: Age Distribution of Respondents

Age	Number	Percent
2	52	14.1
3	81	22.0
4	99	26.9
5	103	28.0
6	33	9.0

Table 3: Sex Distribution of Respondents

Sex	Number	Percent
Male	179	48.6%
Female	189	51.4%

Table 4: Test-Retest Reliability of Blood Lead Values

Absolute Differences, Lab 1 to Lab 2

Range	Percent of Samples
≤2 μg/dl	63.6
<2-5 μg/dl	21.9
>5-10 μg/dl	10.9
>10 μg/dl	3.6

Relative Differences, Lab 1 to Lab 2

Range	Percent of Samples
≤10%	40.0
>10-25%	39.2
>25-50%	14.5
>50%	7.3

Table 5: Distribution of Blood Lead Levels among Respondents

Blood Lead (µg/dl)	Number	%	Cumulative %
4-9	63	17.1	17.1
10-14	160	43.5	60.6
15-19[c]	103	28.0	88.6
20-24[b]	36	9.8	98.4
25+[a]	6	1.6	100
Total	368	100	-

a. US CDC Level
b. Royal Society Intervention Level
c. EPA Intervention Level

Range: 4-30
Mean: 13.84

Table 6: Areas with Reduced Blood Lead Level - 1975 to 1989

Postal Code	Mean Blood Lead 1975	Mean Blood Lead 1989	P(2-tailed)*	Area	Neighbourhood
1H	24.3	17.4	.0164	3	Tadanac
1L	44.0	17.6	.0132	3	East Trail
1P	22.0	12.8	.0001	3	East Trail
1S	34.0	17.5	.0039	3	East Trail
1X	30.8	18.6	.0136	3	East Trail
2V	18.9	12.6	.0006	2	Glenmerry
2W	22.0	12.0	.0167	2	Glenmerry
2Y	28.0	12.8	.0020	2	Glenmerry
3A	22.0	11.9	.0011	2	Shaver's Bench
3B	28.0	14.6	.0019	2	Shaver's Bench
3G	24.6	14.0	.0256	3	West Trail
3H	30.7	13.0	.0126	3	West Trail
3N	31.0	14.2	.0080	3	West Trail
3Z	35.7	9.30	.0004	3	West Trail
4K	25.7	11.4	.0029	3	West Trail
2H	22.3	10.9	.0007	3	West Trail
2L	19.3	11.5	.0008	3	West Trail

* Based on t-distribution

Table 7: Response Rates for Case-Control Study

	Cases	Controls
Respondents	80	73
Refusals	2	-
Unable to contact	2	2
Not Done in Time	2	-
Totals	86	75
Response Rate (high estimate)	$\frac{80}{82} = 98\%$	$\frac{73}{73} = 100\%$
Response Rate (low estimate)	$\frac{80}{86} = 93\%$	$\frac{73}{75} = 97\%$

Overall Response Rate from Blood Survey and Case Control Study

High Estimate = $\frac{368}{402} \times \frac{153}{155} = 90\%$

Low Estimate = $\frac{368}{420} \times \frac{153}{161} = 83\%$

Table 8: Neighborhoods by "AREA"

Area 3	Cases	Controls	Geometric Mean Soil Lead Level
West Trail	22	11	728
Tadanac	6	0	2002
Rivervale	4	0	559
East Trail	18	1	1605
Area 2	Cases	Controls	
Sunningdale	3	2	393
Glenmerry	11	11	542
Shavers Bench	12	10	276
Area 1	Cases	Controls	
Lower Warfield	3	16	191
Upper Warfield	1	15	167
Oasis	0	2	433*
Waneta	0	3	135
Casino	0	2	55

*Based on one value

Table 9: Questionnaire Variables by "STATUS"

Variable	Cases	Controls	Crude OR	χ^2	(p)
Sex of child					
- male	45	30	1.84	3.51	.06
- female	35	43			
Age					
- two	13	7			
- three	20	17			
- four	23	24	N A	2.38	.67
- five	18	21			
- six	6	4			
Average education of parents					
- < grade 11	9	7	N A	11.99	.007
- high school	32	16			
- some post secondary	29	30			
- university degree	5	17			
Number of smokers in household					
- two	19	7			
- one	16	9	N A	8.61	.01
- none	45	57			
Father exposed to lead at work?					
- yes	41	30	1.56	1.79	.18
- no	35	40			
Father's job group					
- cominco	49	40			
- labor	12	12	N A	5.90	.12
- service	10	5			
- professional	5	13			
Does child's clothing need changing (due to soiling) more than once a day in summer?					
- daily	13	9			
- sometimes	38	21	N A	8.04	.02
- never	29	43			

Table 9 (continued) Questionnaire Variables by "STATUS"

Variable	Cases	Controls	Crude OR	χ^2	(p)
Eats produce from the neighbourhood					
- yes	73	60	2.26	2.76	.10
- no	7	13			
Puts dirt in mouth					
- yes	23	9	2.87	6.22	.01
- no	57	64			
Industry within 6 blocks					
- Cominco Trail	29	11			
- Cominco Warfield	3	14	NA	15.18	.0005
- other	8	4			
Number of gas stations within 6 blocks					
- 2 - 6	32	13			
- one	16	38	NA	18.56	<.0001
- none	32	22			
Drinking water source					
- municipal	75	64	2.11	1.04	.31
- well/other	5	9			
Heating source					
- gas	64	46			
- electric	10	17	NA	5.45	.07
- other	6	10			
Age of residence					
- 50+	15	6			
- 41-50	14	17			
- 31-40	12	13	NA	9.95	.08
- 21-30	6	8			
- 11-20	8	7			
-<11	5	16			
Auto repairs done at home					
- yes	21	10	2.0	3.72	.05
- no	59	63			

Table 10: Correlates of Parental Education

		Father exposed to lead at work? Yes	No
Average education of both parents	< Grade 11	5	11
	Completed High School	26	22
	Some Post-secondary	36	23
	University Graduation	4	18

$\chi 2 = 14.3; p=.0025$

Which industries are within 6 blocks of residence?

		Cominco Trail	Cominco Warfield	Other
Average education of both parents	<Grade 11	8	1	1
	Completed High School	17	5	3
	Some Post-secondary	9	4	6
	University Graduation	3	6	2

$\chi 2 = 11.39; p = .08$

Table 11: Correlates of Child Putting Dirt in Mouth

Does your child put dirt or gravel in their mouth?

		Yes	No	$\chi 2$	(p)
Age	2	7	13		
	3	14	23	15.2	.004
	4	7	40		
	5	4	35		
	6	0	10		
Sex	Male	13	62	1.1	.29
	Female	19	59		

Table 12: Questionnaire Variables by "AREA"

Variable	Area 3	Area 2	Area 1	χ2	(p)
Sex of child					
- male	35	22	18	2.34	.31
- female	27	27	24		
Age					
- two	8	7	5		
- three	16	11	10		
- four	16	18	13	5.83	.67
- five	18	8	13		
- six	4	5	1		
Average education of parents					
- < grade 11	11	3	2		
- high school	26	15	7	27.68	.0001
- some post secondary	18	23	18		
- university degree	3	5	14		
Number of smokers in household					
- two	14	7	5		
- one	10	9	6	2.82	.59
- none	38	33	31		
Father exposed to lead at work?					
- yes	34	21	16	3.59	.17
- no	25	25	25		
Father's job group					
- cominco	33	34	22		
- labor	13	4	7	20.12	.003
- service	11	2	2		
- professional	2	6	10		
Does child's clothing need changing (due to soiling) more than once a day in summer?					
- daily	9	5	8		
- sometimes	26	20	13	2.39	.67
- never	27	24	21		

Table 12 (continued) Questionnaire Variables by "AREA"

Variable	Area 3	Area 2	Area 1	$\chi 2$	(p)
Eats produce from the neighbourhood					
- yes	53	44	36	.52	.77
- no	9	5	6		
Puts dirt in mouth					
- yes	17	7	8	2.98	.23
- no	45	42	34		
Industry within 6 blocks					
- Cominco Trail	38	0	2		
- Cominco Warfield	0	0	17	65.55	<.0001
- other	6	3	3		
Number of gas stations within 6 blocks					
- 2 - 6	31	14	0		
- one	4	20	30	53.91	<.0001
- none	27	15	12		
Drinking water source					
- municipal	56	49	34	9.91	.007
- well/other	6	0	8		
Heating source					
- gas	51	29	30		
- electric	6	13	8	7.56	.11
- other	5	7	4		
Age of residence					
- 50+	17	1	3		
- 41-50	12	3	16		
- 31-40	8	8	9	66.14	<.0001
- 21-30	6	10	2		
- 11-20	3	12	0		
-<11	0	9	12		
Auto repairs done at home					
- yes	17	4	10	6.73	.03
- no	45	45	32		

Table 13: Environmental Variables by "STATUS"

Variable Level	Status	Count	Mean (ppm)	S.E.	(p)*
Floor dust	case	79	4140	414	.004
	control	71	3025	441	
Window dust	case	74	8118	998	<.001
	control	69	4420	565	
House Paint	case	73	4743	1149	.93
	control	66	6507	1773	
Water	case	74	.0039	.000	.80
	control	71	.0041	.001	
Average soil	case	79	1172	112	<.001
	control	65	351	39	
Average produce	case	38	12.8	2.0	<.001
	control	38	3.6	.6	
Carrots	case	17	30.0	5.4	<.001
	control	20	6.9	1.7	
Tomatoes	case	30	7.5	1.3	<.001
	control	31	2.6	.4	

*Statistical significance "p" based on an unpaired t-test on logged (base 10) values.

Table 14: Environmental Variables by "AREA"

Variable***	Area 3	Area 2	Area 1	(p)**
Floor dust	4676*	3150	2634*	<.05
Window dust	9014*	6056	2988*	<.01
Paint chips	7781*	3423*	4969	<.05
Water	.0045	.0035	.0039	<.1
Average soil	1366*	626*	223*	<.01
Average produce	12.6*	10.4	2.4*	<.01
Carrots	30.5*	19.7	4.6*	<.01
Tomatoes	7.3*	6.0	1.9*	<.01
Average park soil	362*	245	104*	<.01

*Starred groups are significantly different from each other, based on a multiple comparisons test.

** Statistical significance "p" based on an analysis of variance F Ratio on logged (base 10) values.

***All values in ppm

Table 15: Soil Lead Levels in Parks

Number	Park name	Neighborhood	Area	Lead (ppm)	Play area
01	Gyro	East Trail	3	341	swing set
				220	slide
				1060	merry-go-round
02	Butler	East Trail	3	959	slide
				228	swing set
				510	adventure play area
03	Elizabeth	Glenmerry	2	33	play area
				33	swing set
				163	tire swing
04	Pople	Shavers Bench	2	207	swing set
				229	teeter totter
				160	slide
05	"B" Street	West Trail	3	248	swing set
				287	adventure play area
06	Austad Lane	West Trail	3	779	pool area
				585	swing set
				269	play area
				959	slide
				228	swing set
07	Upper Sunningdale	Sunningdale	2	360	swing set
				249	teeter totter
				161	swing set
08	Lower Sunningdale	Sunningdale	2	343	adventure play area
				180	ball diamond
10	Tadanac	Tadanac	3	2940	sandbox
				223	slide
				141	swing set
11	Tadanac Pitch	Tadanac	3	207	swing set
				193	slide
				275	not specified

Table 15: Soil Lead Levels in Parks

Number	Park name	Neighborhood	Area	Lead (ppm)	Play area
				28	slide
				196	teeter totter
26	Rossland Avenue	West Trail	3	50	swing set
				137	slide
				36	cable drop
27	Rivervale	Rivervale	3	403	swing set
				177	teeter totter
				84	slide
28	McBride Street	Shavers Bench	2	261	adventure play area
				93	play area
				65	tire swing
30	Muzzin	Lower Warfield	1	55	slide
			1	13	teeter totter
				10	maypole
32	Shaver's Bench Townhouse	Shavers Bench	2	354	sandbox
				747	swing set
				630	swing set
33	Webster School	Upper Warfield	1	151	slide
				157	monkey bars
				170	ball diamond
34	Central Elementary School	West Trail	3	181	home plate
				257	outfield
				563	drainage

Table 16: Relationship of Soil Lead to Other Physical Measures

Measure	Correlation with Soil Lead*	(p)
Floor Dust*	.38	<.001
Window Dust*	.42	<.001
House Paint*	.24	.004
Water	.02	.415

*Based on the log of the mean lead level for each household

Table 17: Logistic Regression Analysis

(a) Outcome = Case vs control status

Variable	Beta	p	OR	C.I.
Age	-.24	<.13		
Sex	.94	<.06		
Logged soil level	2.66	<.001	14.25	3.57-50.90
Logged window dust	1.55	<.02	4.69	1.28-17.15
Logged paint level	-.58	<.05	.56	.32-.98

(b) Outcome = Area

Variable	Beta	p	Risk Function	C.I.
Age	-.07	<.7		
Sex	.69	<.1		
Logged soil level	2.61	<.001	13.59	4.50-41.02
Logged window dust	1.37	<.01	3.95	1.49-10.44
Logged floor dust	1.32	<.03	3.76	1.19-11.93

Table 15: Soil Lead Levels in Parks

Number	Park name	Neighborhood	Area	Lead (ppm)	Play area
12	Byers Lane	West Trail	3	138	tire swing
				97	adventure play area
				40	cable drop
14	Daniel Street	West Trail	3	332	swing set
				311	teeter totter
				297	rocking horse
15	L.J. Morrish	East Trail	3	137	swing set
				206	slide
				403	sandbox
17	Glenmerry School	Glenmerry	2	251	tire swing
				209	slide
				146	play area
19	Haley	Upper Warfield	1	25	slide
				32	swing set
				39	monkey bars
20	French Street	West Trail	3	177	swing set
				202	slide
				105	monkey bars
21	Beaver Bend	Lower Warfield	1	144	swing set
				314	slide
				151	monkey bars
22	Dickens Street	Upper Warfield	1	73	slide
				77	swing set
				175	monkey bars
23	Byron Ave	Upper Warfield	1	72	swing set
				27	slide
				159	teeter totter
24	Warfield Pool	Lower Warfield	1	95	swing set
				74	slide
				52	teeter totter
25	Wolfe Drive	Lower Warfield	1	102	swing set

Table 18: Soil Lead Levels by Postal Code, 1975 and 1989.

Postal Code	Number of Households 1975	Number of Households 1989	Average Soil Lead 1975	Average Soil Lead 1989	Area
1A	2	1	743	87	Sunningdale
1G	2	2	2545	583	Glenmerry
1H	2	4	764	1912	Tadanac
1J	5	1	409	1000	East Trail
1K	2	1	614	3053	East Trail
1L	8	3	1085	1796	East Trail
1S	4	3	3961	3049	East Trail
1T	4	3	994	2673	East Trail
1V	2	3	750	1447	East Trail
2A	2	2	766	191	Upper Warfield
2B	5	4	238	312	Upper Warfield
2E	1	3	113	155	Upper Warfield
2G	3	2	175	412	Lower Warfield
2H	4	4	2506	268	Lower Warfield
2J	2	1	1102	124	Lower Warfield
2L	1	3	450	350	Lower Warfield
2S	3	2	2573	646	Glenmerry
2T	1	1	443	1594	Glenmerry
2V	4	7	413	508	Glenmerry
3A	2	3	205	543	Shaver's Bench
3B	5	3	1188	883	Shaver's Bench
3C	2	6	327	891	Shaver's Bench
3E	1	2	4989	340	Shaver's Bench
1M	4	1	3350	1406	West Trail
3H	2	1	1393	974	West Trail
3L	1	3	1213	1082	West Trail
3M	3	1	1180	755	West Trail
3N	5	2	1196	1340	West Trail
3P	2	1	1697	676	West Trail.
3Z	8	2	1420	742	West Trail
4G	4	2	261	1140	West Trail
4H	3	3	244	1038	West Trail
4J	3	1	206	1660	West Trail
4K	2	2	1316	584	West Trail

Geometric Mean Soil Lead 1975 = 790
1989 = 725

Paired t-test=0.40;p=0.69

Table 19: Household Soil Lead Levels by Source

Source	Geometric Mean	CI95*
Bare Soil	1044	604 - 1805
Back yard	938	440 - 2000
Drainage	707	249 - 2006
Front yard	496	230 - 1072
Garden	441	334 - 584
Play area	358	233 - 550
Swing set	347	229 - 526
Sandy area	323	82 - 1262
Sandbox	107	75 - 154

*95% Confidence interval of mean, based on log-normal distribution

Table 20: Summary of Recent Blood Lead Surveys in Canada and Elsewhere*

1. Canada Health Survey, 1978 (percentage of samples within the given ranges)

	Blood Lead (µg/dl)							
	Males				Females			
Age Group	0-10	1 -15	16-20	21-35	0-10	11-15	16-20	21-35
0 - 4	90.3	4.4	0.0	4.4	100.0	-	-	-
5 - 9	80.1	16.3	2.1	1.4	79.5	17.3	3.2	-

2.	Toronto: South Riverdale		Mean Blood Lead	%>20 ug/dl
	(>6 years old)	1982	14.0	13.3
		1983	15.8	18.6
		1984	15.5	18.5
		1986	10.6	4.3
3.	Rouyn-Noranda	1989	11.1	6.0
	(children 2 - 5)		Blood Lead	% of Subjects
			≤10.0	48.7%
			10.1 - 15.0	32.5%
			15.1 - 20.0	12.8%
			20.1 - 25.0	4.3%
			≥25.1	1.7%
4.	Ontario (children)		Mean Blood Lead	% >20 ug/dl
		Urban, 1984		
		Windsor	12.02	4.7
		Toronto	12.02	7.7
		Suburban, 1984		
		Scarborough	10.36	4.2
		Etobicoke	9.74	3.2
		Peel (1987)	7.9	0
		Rural, 1984		
		Nanticoke/Walpole	9.95	5.2
		Longwoods	7.67	1.2
5.	Kamloops (children 2-12,1984)		10.8 - 12.4	0
6.	Vancouver, 1989		5.3	0
7.	Venezuela, Yanomano Indians		0.8	0
8.	Nepal, children		5.2	0
9.	Papua New Guinea, children		5.2	0
10.	Trail (children 2-6) 1989		13.8	11.4
11.	Smelterville, Idaho, 1983		21.0	(26% >25 ug/dl)

*see References 10, 11, 12, 13, and 25

Table 21: Prediction of Mean Soil and Blood Lead Levels from a Data-based Multiple Linear Regression*

(a)	Mean Blood Lead	Mean Soil Lead (ppm) Female	Male
1.	5.0 µg/dl	19	10
2.	15.0 µg/dl	742	385
3.	20.0 µg/dl	4693	2433

(b)	Mean Soil Lead	Mean Blood Lead (µg/dl) Female	Male
1.	100 ppm	9.6	11.4
2.	500 ppm	13.9	15.7
3.	1000 ppm	15.8	17.6

*Based on best fit equation: blood lead = -2.91 + 1.78 (1 if male, 0 if female) + 6.24 ($\log_{10}$soil); r=0.52, r^2=0.27

Table 22: Slope Estimates of the Linear Regression Relationship of Blood Lead in Children to Soil Lead*

	Range of Slopes (µg/dl per 1000 ppm)		
	0-2	>2-5	>5-9
Number of Estimates	6	10	8

Trail, 1989 =	6.9	µg/dl per 1000 ppm**
Trail, 1979 =	4.6 - 7.2	µg/dl per 1000 ppm
Trail, 1978 =	7.6 - 8.5	µg/dl per 1000 ppm

*From Bornschein, 1989.

**based on the anti-log across the range 100-1000 ppm of the relationship between logged soil lead levels and unlogged blood lead levels.

TABLE 23

Summary of Results of Soil Remediation Attempts in Canada and Elsewhere

Ref	Area	Target	Abatement	Results
24, 16	Toronto, (S. Riverdale) 1988-89	soil >500 ppm or housedust >500 ppm	dry vacuuming, (8 houses) steam cleaning, duct cleaning.	dust from 2016 ppm to 1786 ppm airborne from 0.3 ppm to < .1 ppm Removed 2-29 g Pb in .9-10.8 kg dust
18.	Toronto, (S. Riverdale) 1974-79	Soil >2600 ppm	soil removal to 15 cm (48 houses) soil replacement	80% soils <500 ppm 4.1% > 2000 ppm
18.	Kingston, Ontario 1977-84	former lead smelter site soil up to 11,600 ppm	soil removed soil replaced	not stated
18, 19	Winnipeg, 1981-83	soil >2600	soil removed to 15 cm (26 houses) soil replaced	not stated
20.	Quebec 1989-present	mean blood lead 11.1 ug/dl (range 2.3-26.9 ug/dl) smelter area	"wet" clean households personal hygiene education program soil decontamination program (not specified)	in progress
21.	S. Australia, (Port Pirie) 1984 present	1) soil 500-2500 ppm	1) homeowner encouraged to seal with grass or gravel	in progress
		2) soil 2500-10,000 ppm	2) government supplies a cover of grass or gravel.	in progress
		3) soil >10,000	3) Cover must be >200 mm deep or Remove and replace soil	
22.	Baltimore, USA 1983	blood 30-49 ug/dl	"wet" clean house twice monthly frequent washing of children's hands	blood levels decreased 6.9 ug/dl
24.	Baltimore, Boston and Cincinnati	blood 8-24 ug/dl in children <6 years	soil removal and replacement loose paint removal interior dust removal exterior dust removal (Cincinnati only)	in progress

Figure 1

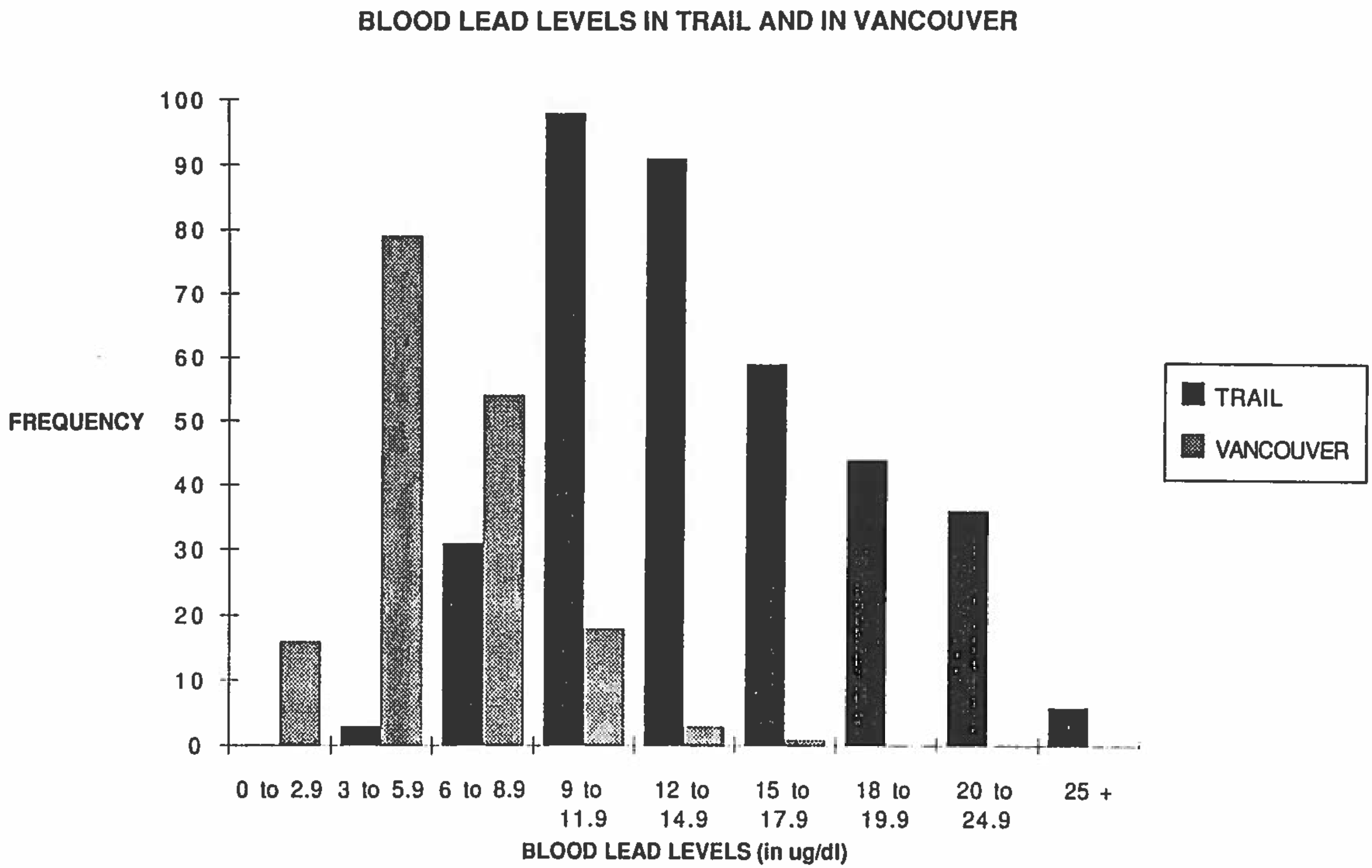

BLOOD LEAD LEVELS IN TRAIL AND IN VANCOUVER
FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
0 to 2.9
3 to 5.9
6 to 8.9
9 to 11.9
12 to 14.9
15 to 17.9
18 to 19.9
20 to 24.9
25 +
BLOOD LEAD LEVELS (in ug/dl)
TRAIL
VANCOUVER

Figure 2

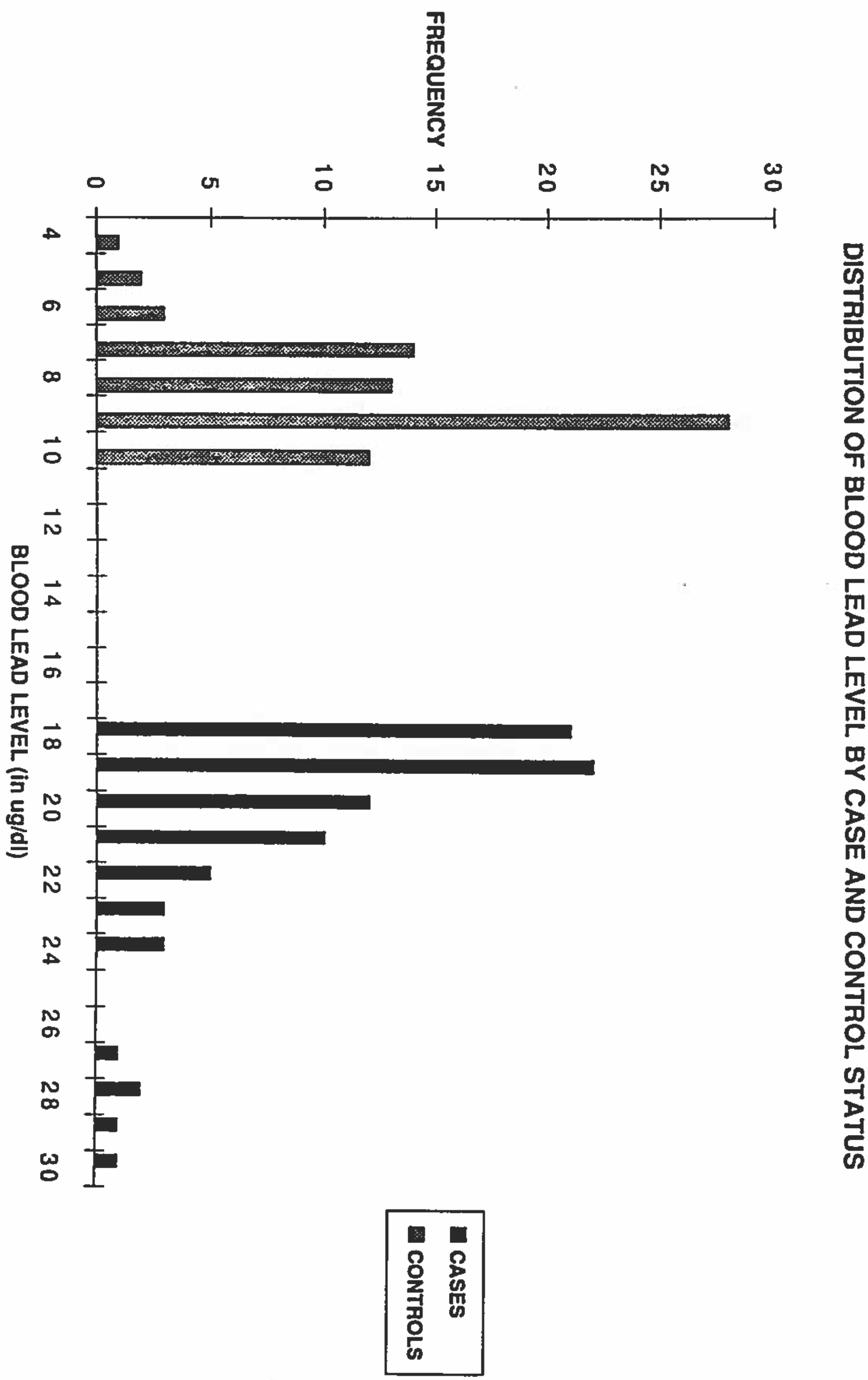
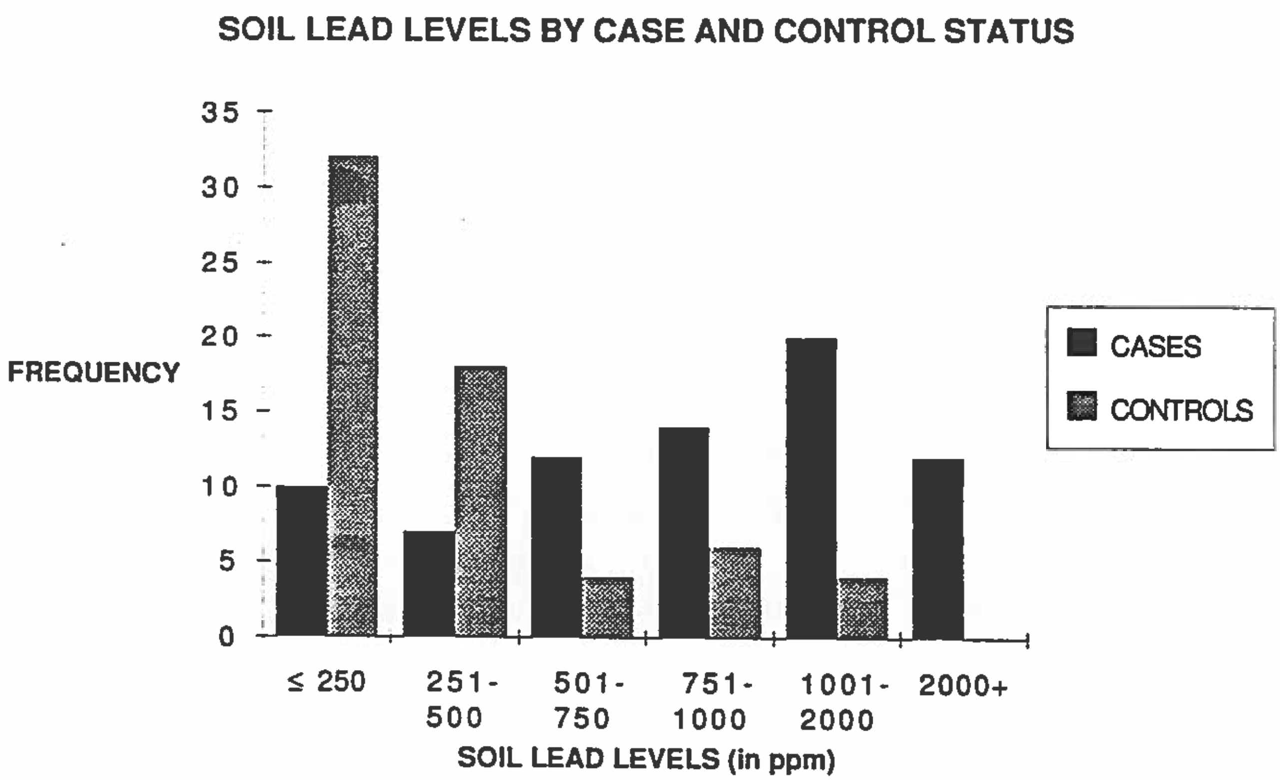

DISTRIBUTION OF BLOOD LEAD LEVEL BY CASE AND CONTROL STATUS
FREQUENCY
0
5
10
15
20
25
30
4
6
8
10
12
14
16
18
20
22
24
26
28
30
BLOOD LEAD LEVEL (in ug/dl)
CASES
CONTROLS

Figure 4



SOIL LEAD LEVELS BY CASE AND CONTROL STATUS
FREQUENCY
35
30
25
20
15
10
5
0
≤ 250
251-500
501-750
751-1000
1001-2000
2000+
SOIL LEAD LEVELS (in ppm)
CASES
CONTROLS

Figure 5

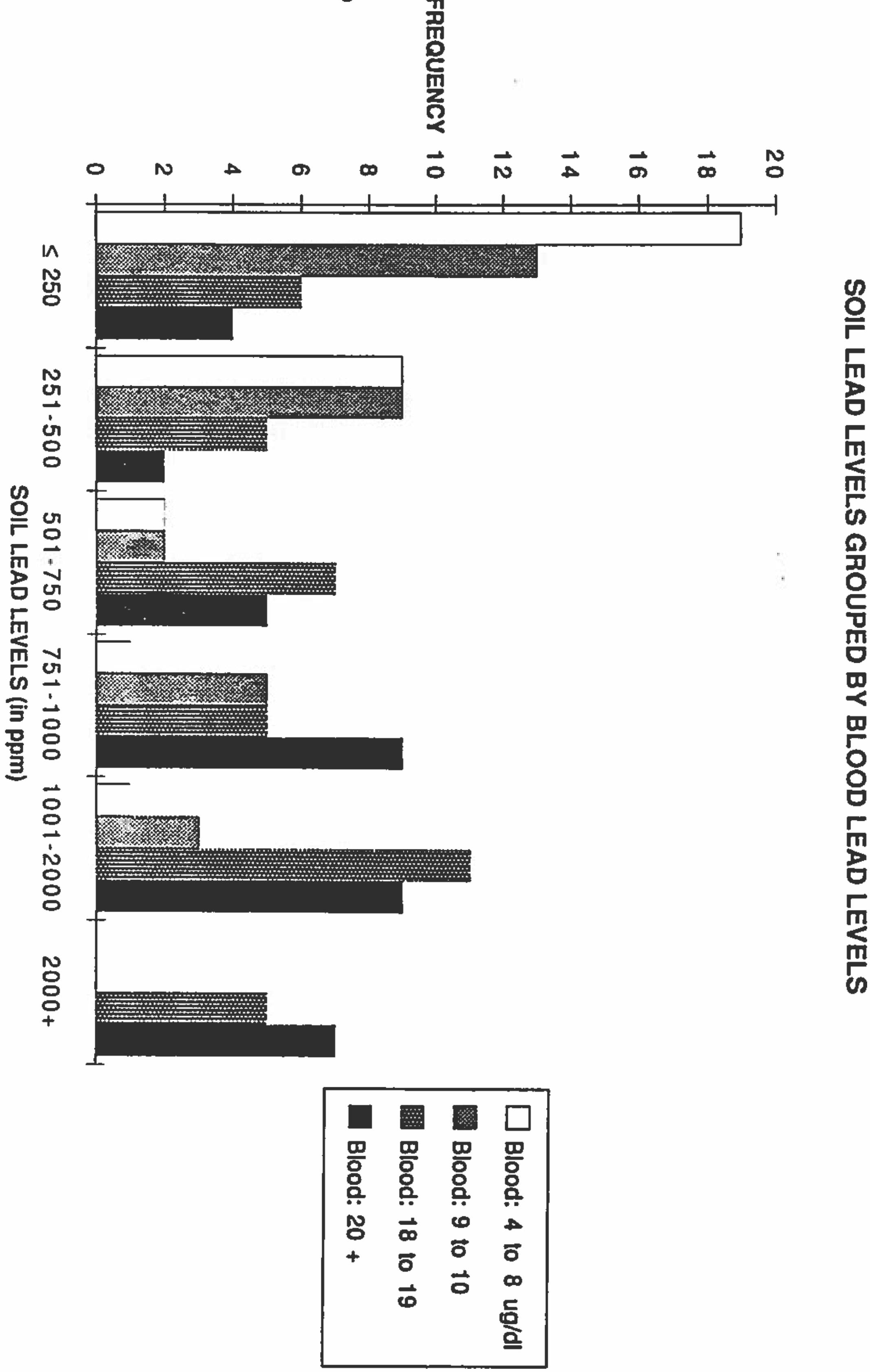

SOIL LEAD LEVELS GROUPED BY BLOOD LEAD LEVELS
FREQUENCY
0
2
4
6
8
10
12
14
16
18
20
≤ 250
251-500
501-750
751-1000
1001-2000
2000+
SOIL LEAD LEVELS (in ppm)
Blood: 4 to 8 ug/dl
Blood: 9 to 10
Blood: 18 to 19
Blood: 20 +

Figure 6

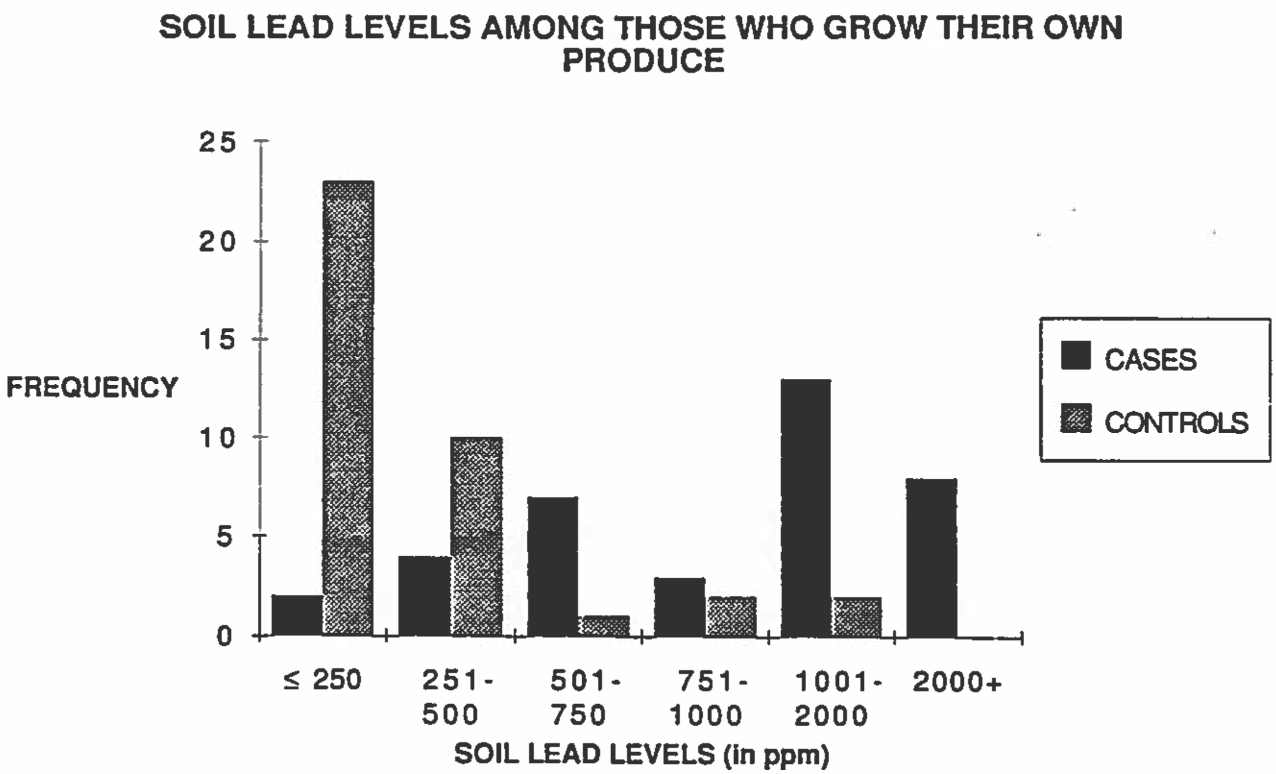
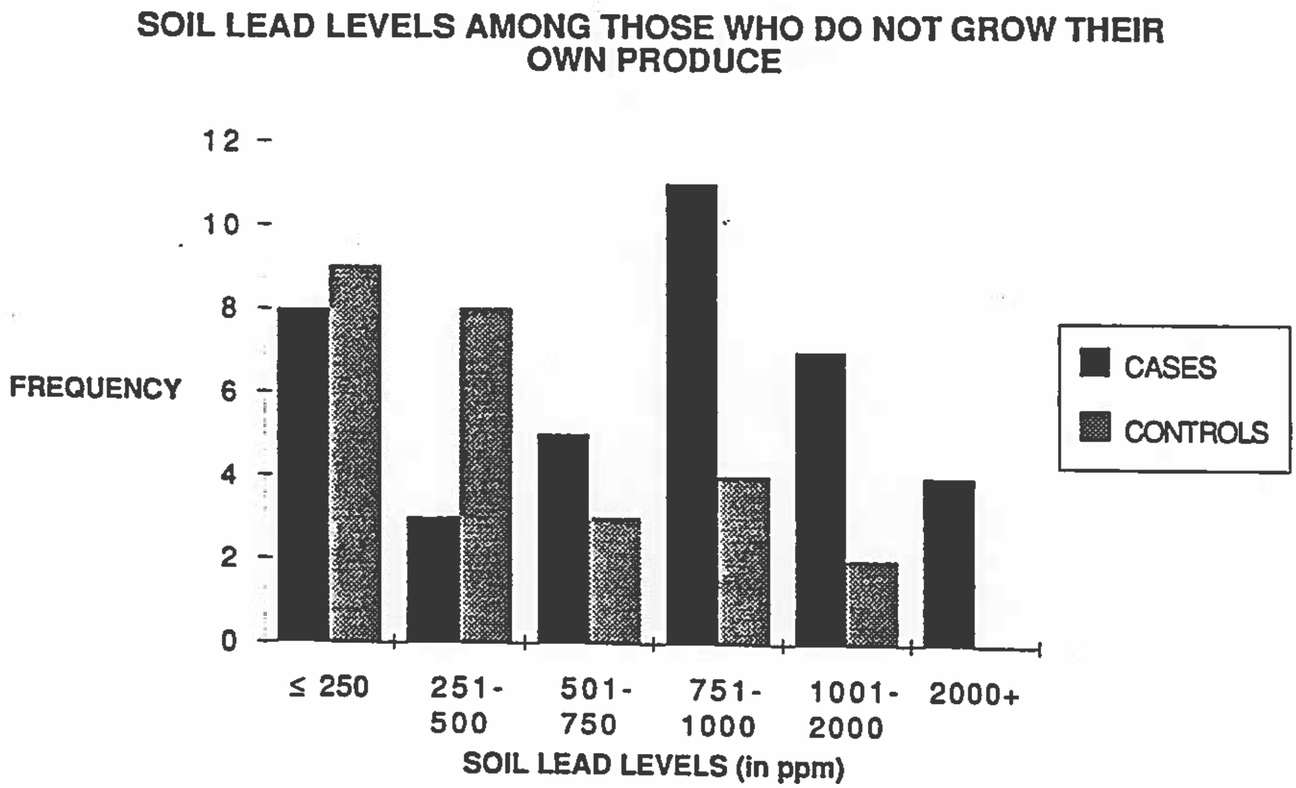
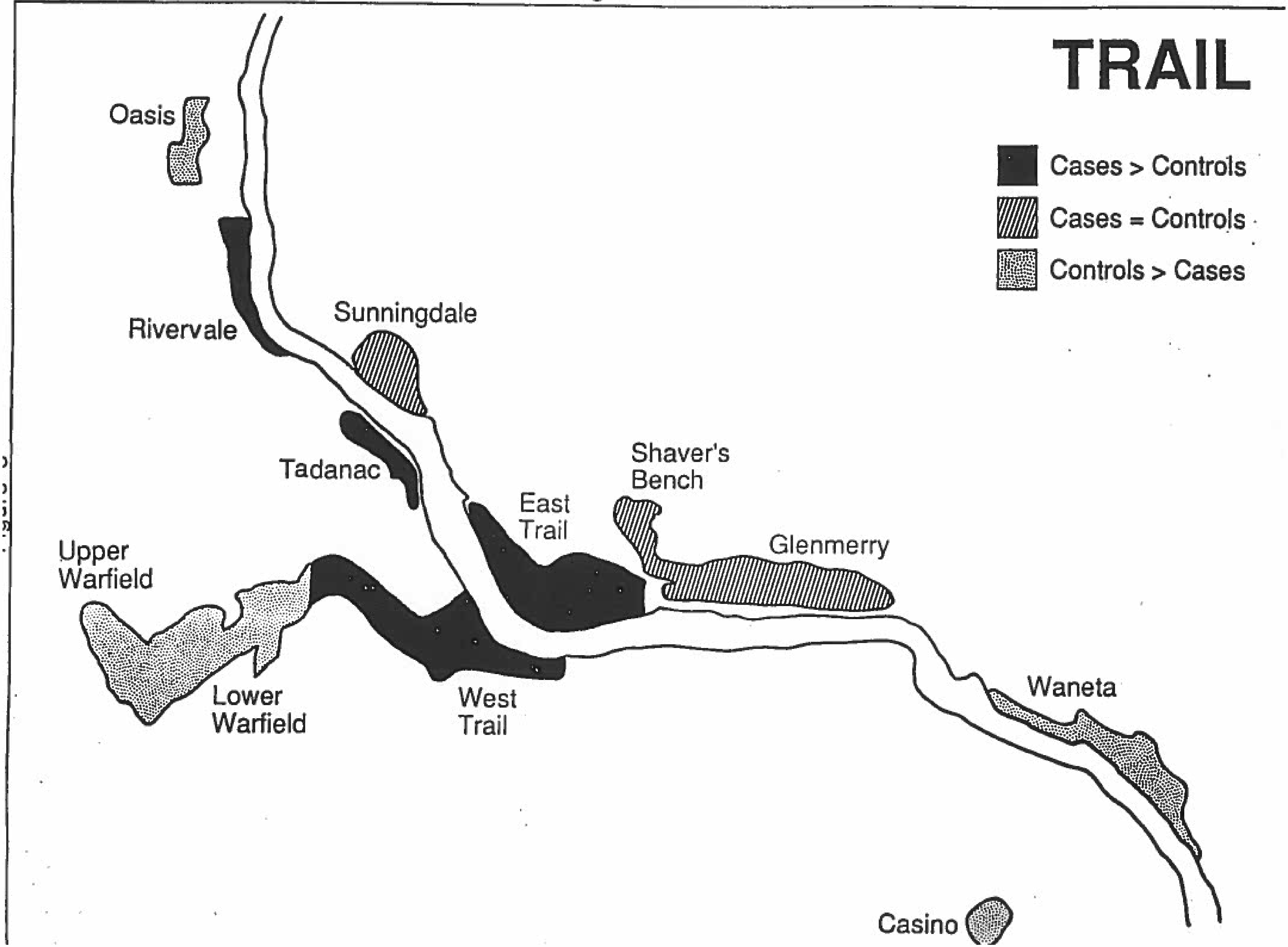

SOIL LEAD LEVELS AMONG THOSE WHO GROW THEIR OWN PRODUCE
25
20
15
10
5
0
FREQUENCY
≤ 250
251-500
501-750
751-1000
1001-2000
2000+
SOIL LEAD LEVELS (in ppm)
CASES
CONTROLS

Figure 7


SOIL LEAD LEVELS AMONG THOSE WHO DO NOT GROW THEIR OWN PRODUCE
12
10
8
6
4
2
0
FREQUENCY
CASES
CONTROLS
≤ 250
251-500
501-750
751-1000
1001-2000
2000+
SOIL LEAD LEVELS (in ppm)


TRAIL
Cases > Controls
Cases = Controls
Controls > Cases
Oasis
Rivervale
Sunningdale
Tadanac
Shaver's Bench
East Trail
Glenmerry
Upper Warfield
Lower Warfield
West Trail
Waneta
Casino

APPENDIX A

QUESTIONNAIRE

BLOOD LEAD QUESTIONNAIRE

For Office Use Only	
Identity	#☐☐☐☐
Interviewer	☐

Date of Interview ☐☐☐☐☐☐
D M Y

1. a) Name of Tested Child: ____________________ ☐☐☐☐☐☐☐☐

   b) Date of Birth ____________ ☐☐☐☐☐☐
   D M Y

   c) Sex 1) Male____ 2) Female_____ ☐

   d) Mailing Address: ____________________ ☐

   ____

   ____

   e) Note next address if planning to move before Dec/89

   ____

   ____

   ____

2. a) Name of person interviewed ____________________

   b) 1) Male________ 2) Female________ ☐

   c) 1) Parent________ 2) Step-parent__________ ☐

   3) Grandparent__________ 4) Sibling_________ 5) Child Care Provider________

3. How many of the following people have lived with the child since May 1/89?

a) Mother ______ ☐
b) Father ______ ☐
c) Step-parents or Guardians ______ ☐
d) Grandparents or other Relatives ______ ☐
e) Unrelated others ______ ☐
f) Siblings ______ ☐

g) TOTAL ______ ☐☐

4. How many of the people in the residence have smoked daily since May 1/89? ☐☐

5. Were any other children in this residence tested for lead in this study?

1) Yes______ 2) No_ ☐

if yes please list name(s):

a)________________________

b)________________________

6. b) Is the child in "day" care at all during a typical week?

1) Yes______ 2) No__________ ☐

If yes to a) answer b to d

b) How many hours per day? ☐☐
c) How many days per week? ☐
d) Where is the child cared for? ☐

____
____
____

7. a) Has Father (including stepfather) lived with this child since May 1/89?
1) Yes________ 2) No_______ ☐

If the answer to a is Yes, answer b-f. If No, go to 8.

b) Current occupation (job title and company; describe job duties)________________________

____

____

____

____

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c) Does his job bring him into contact with dusts or fumes which may contain lead?

1) Yes_______ 2) No_______

d) Is he tested for lead at work?

1) Yes_______ 2) No_______

If the answer is Yes to either c or d, answer e. If No to c and d go to f.

e) Does he wear his protective work clothes home or bring them home for washing?

1) Yes_______ 2) No_______

f) Does he have another part-time job outside the home? 1) Yes_______ 2) No_______

if yes describe ____

____

g) How many years did he complete at school?

1) Grade 1 - 7
2) Grade 8 - 11
3) High School Graduation
4) Some College, University or technical training after high school.
5) College or University degree

8. a) Has Mother (including stepmother) lived with this child since May 1/89?

1) Yes__________ 2) No____________ ☐

If the answer to a is Yes, answer b-f. If No, go to 9.

b) Current occupation (job title and company; describe job duties)__________________________

____

____

____

☐☐☐☐
☐☐☐☐
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c) Does her job bring her into contact with dusts or fumes which may contain lead?

1) Yes________ 2) No_______ ☐

d) Is she tested for lead at work?

1) Yes________ 2) No_______ ☐

If the answer is Yes to either c or d, go to e. If No to c and d go to f.

e) Does she wear her protective work clothes home or bring them home for washing?

1) Yes________ 2) No_______ ☐

f) Does she have another part-time job outside the home? 1) Yes________ 2) No_______ ☐

if yes describe ____

____

g) How many years did she complete at school? ☐

1) Grade 1 - 7
2) Grade 8 - 11
3) High School Graduation
4) Some College, University or technical training after high school
5) College or University degree

Are there other adults living in this residence since May 1/89?

if Yes go to question 9) *if No go to question 12)*

Considering the first of these other adults:

9. What is their relationship to this child?

a) 1) Male______ 2) Female______ ☐

b) 3) Grandparent _____ 4) Sibling________ ☐

5) Child Care Provider________ 6) Other-specify______________________________

c) Current occupation (job title and company; describe job duties)________________

____

____

____

☐☐☐☐
☐☐☐☐
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d) Does their job bring them into contact with dusts or fumes which may contain lead?

1) Yes_______ 2) No_______ ☐

e) Are they tested for lead at work?

1) Yes_______ 2) No_______ ☐

If Yes to d or e answer f if No go to g

f) Do they wear their protective work clothes home or bring them home for washing?

1) Yes_______ 2) No_______ ☐

g) Do they have another part-time job outside the home? 1) Yes_______ 2) No_______ ☐

if yes describe ____

____

Are there other adults living in this household since May 1/89?

If Yes go to question 10
If No go to question 12

Considering the second of these other adults:

10. What is their relationship to this child?

a) 1) Male______ 2) Female_______ ☐

b) 3) Grandparent _____ 4) Sibling_________ ☐

5) Child Care Provider_________ 6) Other-specify_______________________________

c) Current occupation (job title and company; describe job duties)______________________

____

____

____

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d) Does their job bring them into contact with dusts or fumes which may contain lead?

1) Yes________ 2) No________ ☐

e) Are they tested for lead at work?

1) Yes________ 2) No________ ☐

if Yes to d or e answer f if No go to g

f) Do they wear their protective work clothes home or bring them home for washing?

1) Yes________ 2) No________ ☐

g) Do they have another part-time job outside the home? 1) Yes________ 2) No________ ☐

if yes describe ____

____

Are there other adults living in this household since May 1/89?

If Yes go to question 11
If No go to question 12

Considering the third of these other adults:

11. What is their relationship to this child?

a) 1) Male_____ 2) Female_______ ☐

b) 3) Grandparent _____ 4) Sibling________ ☐

5) Child Care Provider_________ 6) Other-specify________________________

c) Current occupation (job title and company; describe job duties)____________________

____

____

____

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d) Does their job bring them into contact with dusts or fumes which may contain lead?

1) Yes_______ 2) No_______ ☐

e) Are they tested for lead at work?

1) Yes_______ 2) No_______ ☐

if Yes to d or e answer f if No go to g

f) Do they wear their protective work clothes home or bring them home for washing?

1) Yes_______ 2) No_______ ☐

g) Do they have another part-time job outside the home? 1) Yes_______ 2) No_______ ☐

if yes describe ______________________________

____

Residential Data

12. a) Have you lived at this address since January 1/89?

    1) Yes________ 2) No________ ☐

    b) if no, give answers for the residence in Trail you have lived in for the longest period of time since Jan/89.

    Record address ______________________________ ☐
    ____
    ____

13. How would you classify this residence?

    1) Single detached home 2) Town house 3) Apartment 4) Mobile Home ☐

14. How old is this residence? _____ years ☐☐☐

15. How long have you lived in this residence?

    (round up to next) _______ years and _____ months ☐☐ ☐☐

    Y M

16. Which of these describes the main construction material on the exterior of your residence? ☐

    1) Aluminum
    2) Duroid Shingles
    3) Masonry
    4) Stucco
    5) Vinyl siding
    6) Wood
    7) other (describe)____________________________

17. Is the exterior of your home painted?

    1) Yes 2) Trim 3) No

If the answer to 17 is 3, go to question 19.

18. When was the exterior of your house last painted?

    year ______________ ☐☐

19. Has any of the following been added to the surface of your yard for any reason in the last 6 years?

    a) Top soil?

    1) Yes 2) No ☐

    b) Fill?

    1) Yes 2) No ☐

    c) Mining or Smelter tailings?

    1) Yes 2) No ☐

20. Is there a flower/vegetable garden? 1) yes 2) no ☐

21. Do you grow vegetables or fruits for home consumption?
    1) Yes 2) No ☐

22. a) Does the child eat table prepared produce grown at this residence or anywhere close by in this neighbourhood?
    1) Yes 2) No ☐

    b) Does the child help themselves to produce directly from the garden?
    1) Yes 2) No ☐

    c) if yes to a or b, list the 3 vegetables/fruits he/she most commonly consumes from these sources.

    i) ____________ ☐☐

    ii) ____________ ☐☐

    iii) ____________ ☐☐

If Yes to question 22, go to question 23. If No, go to question 24.

23. How often does your child eat produce grown at this residence or anywhere close by in this neighbourhood?

    a) During Summer
    1. Daily
    2. Several times/week
    3. Weekly
    4. Monthly
    5. Never
    ☐

    b) During Winter
    1. Daily
    2. Several times/week
    3. Weekly
    4. Monthly
    5. Never
    ☐

24. At what local Park does your child most often play when outdoors?
    Name ____________________ ☐☐

25. a) What is the main source of heating used in your home? ☐
    1. Oil
    2. Gas
    3. Electric
    4. Wood stove
    5. Other (specify) ______________

    b) 1) forced air
    2) radiator ☐

26. a) Do you have an <u>open</u> fireplace/wood stove?
    1) Yes 2) No ☐

    b) if yes, when used for heating how often is it used?

    1) Daily ☐
    2) Several times/week
    3) Weekly
    4) Monthly
    5) Never

27. Does your house have an air purifying device, (for example, filter or electrostatic filter; including those on forced air systems)

    a) 1) Yes_____ 2) No_____ ☐

    b) 1) Central _______ 2) Individual Room _________ ☐

28. Does your home have an air conditioner?

    a) 1) Yes_____ 2) No_____ ☐

    b) 1) Central _______ 2) Individual Room _________ ☐

29. a) Have there been any major renovations to your residence in 1989?

    1) Yes 2) No ☐
    if yes, did these include
    b) Sanding or sandblasting
    1) Yes 2) No ☐
    c) Removal of walls
    1) Yes 2) No ☐
    d) Plumbing work involving the installation or repair of pipes
    1) Yes 2) No ☐
    e) Other (describe)

    ____

    ____

30. What is your source of drinking water?

1) Municipal/city
2) Well
3) Other (specify) ______________________

31. Do you import canned food from other countries for your family's use? ☐

1) Yes 2) No

32. When food is served to this child, is it ever served in homemade clay pottery or ceramic dishes

1) Yes (2 No ☐

33. Within six blocks (1/2 mile) of your residence how many of the following are there?

a) gas stations number ____ ☐

b) major industries number ____

describe ______________________ ☐

____

34. Within 1 block of your residence, how many of the following are there?

a) gas stations number ____ ☐

b) major industries number ____

describe ______________________ ☐

____

Family Activities

35. Does any family member take part in the following hobbies at home?

a) Soldering, e.g., jewelry making	1) yes	2) no	☐
b) Oil based artistic Painting	1) yes	2) no	☐
c) Stained Glass	1) yes	2) no	☐
d) Pottery Glazing	1) yes	2) no	☐
e) Auto Repairing	1) yes	2) no	☐
f) Furniture Refinishing	1) yes	2) no	☐
g) Casting lead, e.g. fishing sinkers, shotgun shells	1) yes	2) no	☐

36. a) Do you use an electric kettle?

1) Yes 2) No ☐

b) if yes, brand name? ______________________

c) how old is it? ______________________ (years) ☐☐

37. a) Do you have any pets that go in and out of the residence?

1) Yes 2) No ☐
if yes

b) Number of cats + dogs ______________ ☐☐

c) Other number ____
describe______________________ ☐

Many children put some things other than food in their mouth.

38. Since May 1/89 are you aware of your child having sucked or chewed on their own fingers/hands? ☐

1) Daily
2) Several times/week
3) Weekly
4) Monthly
5) Never

39. a) Since May 1/89 are you aware of your child having sucked or chewed on non-food items inside the residence such as toys, blankets, pencils, crayons, pets, window sills, furniture, keys, soother, etc?

☐

1) Daily
2) Several times/week
3) Weekly
4) Monthly
5) Never

40. Since May 1/89, are you aware of your child having sucked or chewed on non-food items outside the residence such as toys, lawn furniture, tools, garden equipment, etc?

☐

1) Daily
2) Several times/week
3) Weekly
4) Monthly
5) Never

41. Does your child put dirt or gravel in their mouth?

☐

1) Daily
2) Several times/week
3) Weekly
4) Monthly
5) Never

42. a) Since May 1/89, has your child taken any vitamins or medication?

1) Yes ☐
2) No

b) Describe ______________ ☐

43. During the summer, do you have to change your child's clothing due to soiling more than once per day?

1) Daily
2) Several times/week
3) Weekly
4) Monthly
5) Never

44. Is the tap run for at least 30 seconds before the child takes drinking water in the morning?

1) Yes
2) No

45. Does the child often take some food or a bottle with (him/her) outside to play?

1) Daily
2) Several times/week
3) Weekly
4) Monthly
5) Never

____
Interviewer's Signature

Start Time: __________

Finish Time: __________

Comments ______________________________

____

____

APPENDIX B

SAMPLE LETTERS TO PARENTS

The University of British Columbia
Faculty of Medicine
Department of Health Care and Epidemiology
5804 Fairview Avenue
Vancouver, B.C.
V6T 1W5
Telephone: (604) 228-5550
Fax: (604) 228-4994

November 30, 1989

address
Trail, B.C.
V1R

Dear Mrs. *Parent*:

Re: *Child's Name*

Thank you for your recent participation in the Trail Lead Study. Your child's blood was tested at the Cominco Laboratory and a quality control check was performed on random samples by Children's Hospital Laboratory in Vancouver.

Your child's lead level was # micrograms per deciliter. This is within the expected range for children living within a city environment. With a lead level less than 15 there is very little risk of any effect on your child's health. There is no special action that you need to take because of this blood lead test result.

As you have also volunteered to have your home environment tested for lead in dust, soil, vegetables, water and paint, these results will be forwarded to you later this winter. Included with them will be an interpretation of their significance.

If you have any questions about your child's blood test results, please call Cheryl Yates at 362-5062. If you consented at the time of enrollment, your family physician will also receive a copy of the test results.

Please find enclosed information about how to minimize your family's exposure to environmental lead.

Thank you for participating in this study. Your cooperation will lead to a better understanding of what the lead levels are in the children of Trail and how existing routes of exposure may be reduced.

Yours sincerely,

Clyde Hertzman, MD MSc FRCPC
Director, Division of Occupational
and Environmental Health

CH/vc

letter 1

The University of British Columbia
Faculty of Medicine
Department of Health Care and Epidemiology
5804 Fairview Avenue
Vancouver, B.C.
V6T 1W5
Telephone: (604) 228-5550
Fax: (604) 228-4994

November 30, 1989

address
Trail, B.C.
V1R

Dear Mrs. *Parent*:

Re: *Child's Name*

Thank you for your recent participation in the Trail Lead Study. Your child's blood was tested at the Cominco Laboratory and a quality control check was performed on random samples by Children's Hospital Laboratory in Vancouver.

Your child's lead level was # micrograms per deciliter. This is within the expected range for children living within a city environment. With a lead level less than 15 there is very little risk of any effect on your child's health. There is no special action that you need to take because of this blood lead test result.

If you have any questions about your child's blood test results, please call Cheryl Yates at 362-5062. If you consented at the time of enrollment, your family physician will also receive a copy of the test results.

Please find enclosed information about how to minimize your family's exposure to environmental lead.

Thank you for participating in this study. Your cooperation will lead to a better understanding of what the lead levels are in the children of Trail and how existing routes of exposure may be reduced.

Yours sincerely,

Clyde Hertzman, MD MSc FRCPC
Director, Division of Occupational
and Environmental Health

CH/vc

letter 2

The University of British Columbia
Faculty of Medicine
Department of Health Care and Epidemiology
5804 Fairview Avenue
Vancouver, B.C.
V6T 1W5
Telephone: (604) 228-5550
Fax: (604) 228-4994

November 30, 1989

address
Trail, B.C.
V1R

Dear Mrs. *Parent*:

Re: *Child's Name*

Thank you for your recent participation in the Trail Lead Study. Your child's blood was tested at the Cominco Laboratory and a quality control check was performed on random samples by Children's Hospital Laboratory in Vancouver.

Your child's lead level was # micrograms per deciliter. With a blood level less than 25, the risk of any noticeable effect on your child's health is low, but such a lead level is still higher than is desirable.

We recommend a repeat of your child's blood lead test. As fingerprick blood specimens sometimes get contaminated with lead from dust and dirt already on the surface of the skin, the measurement of the blood level can be falsely high. By repeating the blood test we can be more sure the test result is correct. If you consented at the time of enrollment, your family physician will also receive a copy of your child's test result. Please request that he obtain the repeat blood lead test which will be billed to your Medical Services Plan.

If your child's blood lead level is confirmed by a repeat test, we would recommend that you take steps to reduce your child's exposure to lead. Please find enclosed suggestions about how you can reduce your child's exposure to environmental lead. If you have any further questions about your child's blood test results or the recommendations suggested, please call Cheryl Yates at 362-5062.

As you have also volunteered to have your home environment tested for lead in dust, soil, vegetables, water and paint, these results will be forwarded to you later this winter. Included with them will be an interpretation of their significance.

Thank you for participating in this study. Your cooperation will lead to a better understanding of what the lead levels are in the children of Trail and how existing routes of exposure may be reduced.

Yours sincerely,

Clyde Hertzman, MD MSc FRCPC
Director, Division of Occupational
and Environmental Health
CH/vc

letter 4

The University of British Columbia
Faculty of Medicine
Department of Health Care and Epidemiology
5804 Fairview Avenue
Vancouver, B.C.
V6T 1W5
Telephone: (604) 228-5550
Fax: (604) 228-4994

November 30, 1989

address
Trail, B.C.
V1R

Dear Mrs. *Parent*:

Re: *Child's Name*

Thank you for your recent participation in the Trail Lead Study. Your child's blood was tested at the Cominco Laboratory and a quality control check was performed on random samples by Children's Hospital Laboratory in Vancouver.

Your child's lead level was # micrograms per deciliter. This is within the expected range for children living within a city environment. With a lead level between 15 and 20 the risk of any noticeable effect on your child's health is very low. There is no special action that you need to take because of this blood lead test result. However, if you want to be extra careful, we have enclosed some suggestions on how you can reduce your child's exposure to lead in the environment.

If you consented at the time of enrollment, your family physician will also receive a copy of the test results. If you have any questions about your child's blood test results please call Cheryl Yates at 362-5062.

Thank you for participating in this study. Your cooperation will lead to a better understanding of what the lead levels are in the children of Trail and how existing routes of exposure may be reduced.

Yours sincerely,

Clyde Hertzman, MD MSc FRCPC
Director, Division of Occupational
and Environmental Health

CH/vc

letter 3

The University of British Columbia
Faculty of Medicine
Department of Health Care and Epidemiology
5804 Fairview Avenue
Vancouver, B.C.
V6T 1W5
Telephone: (604) 228-5550
Fax: (604) 228-4994

November 30, 1989

address
Trail, B.C.
V1R

Dear Mrs. *Parent*:

Re: *Child's Name*

Thank you for your recent participation in the Trail Lead Study. Your child's blood was tested at the Cominco Laboratory and a quality control check was performed on random samples by Children's Hospital Laboratory in Vancouver.

Your child's lead level was # per deciliter. A blood level of 25 or more is a cause for concern. Such a level, if sustained for a prolonged period, may be associated with harmful effects on the health of children.

We strongly recommend that you have a repeat blood test arranged by your family doctor. It is possible that the lead test result is wrong. Fingerprick blood specimens sometimes get contaminated with lead from dust and dirt on the surface of the skin. If this happens, measurement of the blood lead level will be falsely high. The repeat blood test will be covered by the Medical Services Plan. Your child should also be checked to make sure that there is not some other illness or condition which is making him or her more susceptible to lead. Your family physician can arrange these tests and may want to do other tests as well.

As you have also volunteered to have your home environment tested for lead in dust, soil, vegetables, water and paint, these results will be forwarded to you later this winter. Included with them will be an interpretation of their significance.

Enclosed are some suggestions for ways you can reduce your child's exposure to environmental lead. If you have any further questions about your child's blood test results or the recommendations suggested, please call Cheryl Yates at 362-5062.

Thank you for participating in this study. Your cooperation will lead to a better understanding of what the lead levels are in the children of Trail and how existing routes of exposure may be reduced.

Yours sincerely,

Clyde Hertzman, MD MSc FRCPC
Director, Division of Occupational
and Environmental Health
CH/vc

letter 5

APPENDIX C

DETAILED PROTOCOLS FOR ENVIRONMENTAL SAMPLES

TRAIL LEAD STUDY

PROTOCOL FOR BLOOD LEAD SAMPLE COLLECTION

(A) The sampler's hands will be washed with soap, rinsed with water, and dried with a paper towel not made from recycled paper; a sample of which has been pretested for lead.

(B) The sampler will wear talc free gloves for all contacts with subjects and, will rewash the same pair of gloves with soap and water between subjects.

(C) Wash the subject's hands with soap and rinse with tap water. The subject's hands may be dried with the same paper towel described in (A) above. Then have the subject steeple their fingers in front of their chests, in order to prevent contact with contaminated surfaces prior to sampling.

(D) Place hand to be sampled (non-dominant side) in a bath of warm deionised water for 2-3 minutes to increase blood flow.

(E) Grasp the hand to be sampled with the subject's palm upward and the sampler's thumb across the middle of the fingers to control movement.

(F) Clean the lateral portion of the distal phalanx of the third finger by scrubbing with an isopropyl alcohol swab for 10 seconds.

(G) Allow 15 seconds for the finger to air dry.

(H) Strike the lateral portion of the distal phalanx with a B-D Minilance or Microtainer Brand Safely Flow Lancet. Establish a free flowing blood sample.

(I) Invert the subject's hand so the first droplet hangs from the finger.

(J) Discard the first drop of blood by lightly touching only the drop to a gauze swab.

(K) Then collect up to 500 uL. of blood into a B-D HEPINARIZED microtainer.

Minimum volume of whole blood = 100uL.
Optimal volume of whole blood = 300uL.

Do not expose the sample to the air for any longer than necessary because of possible lead contaminants in the clinic environment.

(L) Mix thoroughly by inverting the container several times to prevent clot formation.

(M) Store samples at 0-4 degrees Celsius during sampling clinic, and then transport on ice to the laboratory.

A SAMPLE OF ALL THE SUPPLIES AND EQUIPMENT USED IN THE ABOVE PROTOCOL WILL BE TESTED FOR LEAD CONTAMINATION PRIOR TO THEIR USE IN THE BLOOD TESTING CLINIC

TRAIL LEAD STUDY PROTOCOL FOR HOUSE DUST; COLLECTION, STORAGE, AND TRANSPORT.

For this study, household dust samples are defined as samples that represent the dust most likely to come in contact with a child's hands during indoor activity. This would include dust on upfacing surfaces accessible to a child, such as bare or carpeted floors, window sills, furniture, as well as toys and other objects likely to be handled by children. For reasons of feasibility and consistency, floor and windowsill samples only will be collected.

In order to more fully describe where samples have been collected, a rough sketch of the internal residence layout will be made. This sketch should show the primary features of the residence such as window and door placement, the direction of the residence in relationship to the nearest street, and the relationship of the various rooms to each other. Rooms should be labeled according to their apparent function. The placement of the sample areas should be noted. This sketch will be an important aid if additional samples are required at a later date.

CALIBRATION AND MAINTENANCE OF THE SURFACE DUST SAMPLING PUMP.

The sampling apparatus is a personal air monitoring pump with a 3-piece air sampling cassette attached by tubing to the pump. The cassette holds a 37 mm diameter 0.8 um polycellulose acetate filter (Nuclepore). The accompanying figure shows the entire apparatus in its sampling configuration. The object is to collect a minimum of 50 mg of dust; an amount that is clearly visible in the cassette.

For the collection of surface dust, the only piece of equipment that requires calibration is the personal air monitoring pump. The Gilian HFS 513 pump is equipped with a rotometer flow indicator which should be used to set and monitor a pump flow rate of 2.5 litre/min. With the sampling train in place, the flow rate will be calibrated using a wet test metre provided courtesy of Cominco.

The pump flow rate should be checked and adjusted as part of the equipment check before a day's sampling. In practice, the flow rate should not change during a day's sampling operation.

The sample pump should be charged after every other day of sampling, and allowed to completly discharge and recharge (not trickle charge) at least once a week.

CHOOSING SAMPLE SITES.

A weight of dust is collected over a composite of measured areas so that three measures are obtained:

Dust loading = mg dust/square metre.
Lead loading = ug/square metre.
Lead concentration = ug lead/g dust or PPM lead.

Plastic templates, 25 by 25 cm. will be used to outline the standarized area to be sampled. One template will be four sided and the other three sided to facilate collection of samples adjacent to walls.

Composite household dust samples will be collected from two types of sources in the residence.

(A) Floors: a composite sample of the following floor areas,
1) A high traffic area just inside the entry to the residence.
2) A floor area where the child regularly plays.
3) A floor area in the child's bedroom.
If carpet is present in the residence, it will be the first choice of sampled area. If carpet is not present, a composite of non-carpet floor areas will be sampled.

(B) Windowsills and window wells:
A window well is that part of the window frame that the moving part of the window fits into and occludes when it is closed. It would only be accessible when the window is open. The combined windowsill and well area should be measured. A sample will be a composite of at least 3 window areas (windowsills and window wells of opening windows), including but not limited to a window in the main living area and a window in the child's bedroom.

TO OBTAIN A SAMPLE.

With the template in place, turn the pump on and check the flow rate. Sample the area by holding the filter attachment at a 45 degree angle to the surface and drawing the nozzle over the area in one direction at about 1 cm/sec until the area is completly covered. Repeat the process twice for a total of three passes. Check the filter and flow metre occassionally to see if the filter has become clogged. If the flow rate drops below 2 litres/min., then replace the cassette and continue, labeling the cassettes as one sample.

Care should be taken to avoid running the pump during non-sampling periods. At the end of each sample, turn the pump off and disconnect the sample cassette. Plug the outlets with the plugs provided and label the cassette(s). Store and transport the completed sample cassettes in the manufacturer's boxes provided at ambient temperature.

TRAIL LEAD STUDY PROTOCOL FOR PAINT SAMPLING; COLLECTION, TRANSPORTATION, AND STORAGE.

The use of interior lead based paint was discontinued in 1971. Even if the residence has been repainted with low lead paint since that time, leaded paint may be exposed in areas of increased wear. Paint chip samples will be collected from two discrete functional areas in all residences.

Note the sites selected for paint sampling on the internal residence layout sketch described in the house dust sampling protocol. If possible, pick sampling sites that are readily accessible to the child. Give consideration to the height off the floor and the functional areas of the residence. Likely areas for sampling would include entry ways, eating areas, play areas and the child's bedroom.

With the occupant's permission, use a new scalpel blade to remove surface paint chips from several sites in each of the two discrete functional areas. If taken from areas of surfacing chipping, the samples taken for analysis should be taken from the intact paint and therefore represent the missing paint. Ideally, without affecting aesthetics an area equivalent to 2 cm. square of composite paint sample should be obtained. Samples of greater and lesser size are analyzable and should still be sent for anaylsis.

Place the paint chips in the vials provided and label them. The vials containing the paint samples require no special storage or transportation measures.

TRAIL LEAD STUDY PROTOCOL FOR PRODUCE; COLLECTION, STORAGE, AND TRANSPORT.

The type of produce to be sampled will be selected from the list of the three most common fruit/vegetables consumed by the child and grown at this residence or at an adjacent residence. If the child consumes produce from a yard immediately adjacent to the residence rather than from their own residence, this should be used as the source of sampling. The most frequently consumed fruit/vegetable that is still in season at the time of sampling will be sampled.

Obtain approximately three portions of the produce to be sampled. For example, three carrots or apples, etc. If the produce favored by the child does not occur in individual units, then sample approximately 100-200g.

The produce should be collected with talc free gloved hands. If any cutting is neccessary, use a disposable stainless steel scalpel blade which should be changed after each sampling procedure. The produce should be placed in the plastic containers provided and kept refrigerated but not frozen for storage and transport.

Samples should be transported by overnight courier to Quanta Trace lab no more than 48 hours after sampling.

TRAIL LEAD STUDY PROTOCOL FOR SOIL; COLLECTION, STORAGE, AND TRANSPORT.

GENERAL SITE DESCRIPTION.

For each property, a detailed drawing should be made that shows the boundary of the lot, the position of the main building and any other buildings such as storage sheds or garages, the position of the sidewalks, driveway, and other paved areas, the position of the play areas if obvious, and the position and approximate size of areas with exposed soil. Show down spouts and general drainage patterns. Identify each soil sample area by I.D. number.

SAMPLE SITE SELECTION.

Sampling sites on residential properties should consist of discrete, easily identifiable areas. Two sites per residential property will be sampled. Overall priority will be given to sampling areas that the child frequents. Look for objective evidence of child related activity, or failing this ask the adult responsible for the child where they most often play in the yard. The following is a guide to priority ordering for site selection.

(1) If an area of exposed soil, such as a garden, a child's play area or a sand box is present it will constitute at least one of the samples.

(2) If children play near rain downspouts this area will be sampled.

If none or one of these two areas is sampled, then pick another functional area used regularly by the child.

For each of the two soil sampling areas identified on the general site description, describe the category of land use; for example, adjacent to the foundation/downspout, front yard lawn, backyard lawn, vegetable garden, or child's play area. Exposed soil and grass or sod covered samples must be so identified.

Sampling of school yards and parks should focus on identifiable sites frequented by children, such as playing fields, beaches, and areas under playground equipment. A minimum of three sites per park or school yard should be sampled.

SAMPLING SCHEMES.

For front and back yard area samples and samples from school yards and parks estimate the approximate centre of the discrete functional area, and draw a circle one metre in diameter. Subsamples will be taken from five locations on the circle; one each at the four compass points and one at the centre and composited to form a single sample.

If it is not possible to take a sample because of an obstruction, move one metre to the right while facing the main building and/or away from the street and proceed with sampling. In the event it is not possible to draw a circle, measure and collect five subsamples from a rectangular configuration one-half (.5) metres by two (2) metres. Soil collected at each corner and the centre of the rectangle will be composited identically to those collected from sampling the circle.

When sampling the area near a downspout, draw the one metre circle one half metre from the foundation so it includes the downspout outlet within its circumference. This should yield one subsample immediately adjacent to the foundation, two subsamples half a metre from the foundation and the fourth subsample one full metre from the foundation.

In multiple dwelling housing units, it may not be possible to obtain two composite soil samples for each eligible child. However, the identified areas held in common by the residents and available to the children must be sampled, using the methods described.

SAMPLE COLLECTION.

The corer, a JMC 18" Zero Contamination Tube with PETG liners and caps, will be used to collect the soil samples. The core makes a composite of five subsamples identified as a single sample.

Vegetation and debris must be removed at the point of insertion with a talc free gloved hand and by dissection using a scalpel blade. Discard the scalpel blade and replace with a clean blade after sampling all five subsamples. Try not to remove any soil or decayed litter.

The corer should be driven in the ground with the JMC Backsaver N-2 Handle to a depth of five (5) cm. for each subsample; fifteen (15) cm. for vegetable gardens. If the prespecified depth can not be reached, the corer should be extracted and another attempt made nearby. There is no need to redraw the circle etc. Where hard-packed, coarse or loose, sandy soil is encountered, a stainless steel trowel may be used to collect the samples to a minimum depth of two (2) cm and the depth should be specified.

The cores should be examined for debris, artifacts, and any other evidence of recent soil disturbance. These should be noted on the sample code sheet along with a brief description of soil colour and type.

Samples collected with the corer should be sealed in the tubes with the caps provided and labelled. Samples collected with the trowel should be placed into clean labelled plastic bags suitable for prevention of contamination and loss of the specimen. Soils can be stored and transported in a dry environment at ambient temperature.

A field blank should be taken on each sampling day. A sample container with clean quartz sand will be taken to the field, opened and exposed for a period of time representative of normal sampling procedures, and then returned to the lab for analysis in the same manner as the other soil samples.

TRAIL LEAD STUDY PROTOCOL FOR WATER SAMPLING; COLLECTION, TRANSPORTATION, AND STORAGE.

WHERE TO SAMPLE.

The samples should be taken from the cold water kitchen tap in all residences.

WHEN TO SAMPLE.

A first morning draw of water is taken after standing in the pipes overnight or at least 8 hours. Don't flush toilets or run other taps prior to collecting the sample.

HOW TO SAMPLE.

Remove the cap from the plastic bottle provided. Then carefully open the cold water tap and collect the first water obtained immediately after opening the tap into the 250 ml. bottle provided. A full bottle (250 ml.) of water is required, without wasting or spilling any water. Then shut off the tap and replace the cap.

Please place the full water bottle in a prearranged location outside your residence for pick up by study personnel later in the day. If the person taking the sample encounters any difficulty in obtaining the sample please have them contact THE TRAIL LEAD STUDY, at 363-5062 for assistance. A repeat sample is preferable to analyzing an improperly collected one.

Water sample bottles may be stored and transported at ambient temperatures but must not be allowed to freeze.

quanta trace laboratories inc.

401·3700 Gilmore Way, Burnaby, British Columbia, Canada. V5G 4M1 Telephone·(604) 438·5226

July 5, 1989

UBC Health Care & Epidemiology
5804 Fairview Cres.
James Mather Bldg.
Vancouver, B.C.
V6T 1W5

Attn: Dr. Nelson Ames
Re: Determination of Lead in Samples from Trail, B.C.

The following quote for the above project is based on 600 soils, 155 waters, 150 vegetables, 310 paints and 310 dusts:

COLLECTION:

Quanta Trace will prepare and supply all collection containers.

Soils	Collect in soil collection bags - fill completely.
Water	Collect in acid washed 250 ml plastic bottles.
Vegetables	Collect 100-200 g in plastic bags.
Paint	Collect in acid washed 16 dram viles.
Dust	Collect in acid washed 16 dram viles.

PREPARATION:

Soils	Oven dried (100 C), sieved (80 mesh).
Vegetables	Washed with DI water, oven dried (100 C), ground and sieved (80 mesh).
Paint	Ground and sieved (80 mesh).

..../2

DECOMPOSITION:

Soils	1 to 2 g digested with HNO3/HClO4/HCl then to 100 ml.
Water	Acidified (HNO3/HCl) then 100 ml concentrated to 10 ml.
Vegetables	4 g digested with HNO3/HClO4/HCl then to 100 ml.
Paint	As for soils - if small samples, final vol adjusted.
Dust	As for soils - if small samples, final vol adjusted.

ANALYSIS:

All samples analyzed by Inductively Coupled Argon Plasma - Optical Emission Spectroscopy (ICAP-OES) for lead. Our ICAP incorporates a high pressure, mass flow controlled cross flow nebulizer; low flow, mass flow controlled torch; high resolution echelle grating spectrometer; coupled directly to a mini computer (pdp 11/23). Detection limits as follows:

Soils	5.	ug/g
Water	0.002	ug/ml
Vegetables	0.5	ug/g
Paint	5.	ug/g
Dust	5.	ug/g

QUALITY CONTROL:

Blanks, duplicates and Standard Reference Materials (SRM's) will be analyzed concurrently with the samples. All values will be reported along with the accepted values for the SRM's. This represents a 20% QC level as specified by the US Environmental Protection Agency. The following SRM's will be analyzed:

CANMET SO2	Podzolic B Horizon Soil	Pb = 21	ug/g
IAEA Soil-5	Peruvian Soil	Pb = 129	ug/g
NBS 1570	Spinach	Pb = 1.2	ug/g
NBS 1571	Orchard Leaves	Pb = 45	ug/g
EPA WS 378	Water	Pb = 0.034	ug/ml
EPA WP 287	Water	Pb = 0.100	ug/ml

If you have any questions, please contact me.

John Davidson,
Technical Director

quanta trace laboratories inc.

401-3700 Gilmore Way, Burnaby, British Columbia, Canada. V5G 4M1 Telephone-(604) 438-5226

July 10, 1989

UBC Health Care & Epidemiology
5804 Fairview Cres.
James Mather Bldg.
Vancouver, B.C.
V6T 1W5

Attn: Dr. Nelson Ames
Re: Determination of Lead in Samples from Trail, B.C.

Further to our proposal of July 5, 1989 and to your request for additional information on quality control, I submit the following:

1. Copy of First Intercomparison Exercise for Trace Metals in Marine Sediments NRC MS1/TM by Shier Berman and Victor Boyko. My only critisism of the report is the method of averaging the data. All values were averaged no matter what the digest technique. For example, if most labs used a weak acid leach and a few labs used a total digest, the average could be slanted to the low side and the possibility exists that some of the total digest data would be rejected even though the data was "correct". For some metals that are very soluble, the digest technique would cause very little variation, but for other metals (Cr, Be for eg.), the variation would be considerable.

   I have included the lead data only since the report is 50 pages. If you need more data, please call me.

2. Copy of a paper by J.W. McLaren and S.S. Berman of the NRC. They state that lead results from ICP and GFAAS were in good agreement even with the aluminum interference present near the 220.353 nm line. This interference would be of concern only in soils and sediments, not in vegetation or water where the Al concentration in solution would be minimal.

3. I have no interlab published data for Pb in vegetation or water. We routinely determine Pb in EPA QC water samples (attached) and we always are within the acceptable range. The SRM vegetation we will run with your samples will guarantee accuracy of the vegetation data.

..../2

Re: Determination of Lead in Samples from Trail, B.C.

Our detection limit for Pb in solution is in the range of 0.006 to 0.012 ug/ml (3 times standard deviation of base line). A paper recommended by Dr. Berman states that the error introduced by background correction must be added to the detection limit. I have calculated that error and added the result to the 0.012 ug/ml Pb detection limit for water and vegetation matricies. The resulting detection limit is still under our set detection of 0.02 ug/ml. For soils, I have set the detection limit at 5 ug/g to allow for the greater background in these matricies which is conservative even by Dr. Berman's standards since in another paper he gives Pb detection at 3 ug/g in sediments using the same weight to volume ratio and the same instrument as ouselves.

Our detection limit for Pb is reasonable given the superior stability of the mass flow controlled, high pressure, cross-flow nebulizer and the high resolving power of the Echelle Spectrometer which minimizes background correction uncertanties.

Please call me if you have any other questions.

John Davidson,
Technical Director

APPENDIX D

RELIABILITY REPORT FOR BLOOD SAMPLES

A Reliability Analysis of Blood Lead Samples;

Results from the Trail Case Control Study of Lead Exposure Among Pre-School Children.

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A total of 55 split samples of capillary blood were obtained from two sources:

(1) Study participants, who were Trail residents, 2 to 6 years of age and;

(2) Adult volunteers residing in the same community.

The blood lead samples were first analyzed at the study laboratory, located at the Cominco Smelter in Trail, (herein referred to as COMINCO) and were then sent to the British Columbia's Children's Hospital (referred to as CONTROL) between August 8th and October 5th, 1989.
All values of blood lead levels are expressed in micrograms per decilitre (ug/dl).

Measured blood lead levels found in each laboratory are depicted in the histograms shown in figures 1 and 2. The distributions for each of the labs had a high kurtosis coefficient, indicating that the values were clustered around the mean such that the peak of the normal curve was broadened. The most extreme value measured by COMINCO was 44 compared to the CONTROL'S measurement of 57. A small difference was found for the means of these two groups, which were 14.6 for the COMINCO lab and 15.1 for the CONTROL lab. For the median value, which falls in the 50th percentile, a value of 13 was found in both instances. When the CONTROL values were subtracted from each respective COMINCO value, the average of the summed differences was -.56 with a standard deviation of 4.3. When the absolute values of the differences for each pair were summed and averaged, the resultant difference was 2.86. The range of value were from 0, which is perfect agreement, to a difference of 14. The paired t- test procedure was applied to test for the significance of the differences between the two laboratories and the result was non-significant (p>.333).

Table 1: The Distribution of Absolute and Percentage Differences in Laboratory Measurements

Absolute Differences	% Total	Percentage Differences	% Total
>2 ug/dl	36.4	>10%	60.0
>5 ug/dl	14.5	>25%	21.8
>10 ug/dl	3.6	>50%	7.3

Table 1 shows the percentages of the total sample where the lead levels measured by the COMINCO and CONTROL labs differed by greater than 2, 5 or 10 ug/dl. Percentage differences, calculated as the absolute difference divided by the COMINCO value (x 100%), are categorized by levels of greater than 10, 25 and 50 percent.

Less than 15% of the measurement pairs were greater than 5ug/dl apart. Absolute differences of greater than 25% of the original Cominco measures were evident in less than 25% of the cases. For 45.5% of the sample pairs, the measurement by the control lab was greater than that of the Cominco laboratory, while for 38.2%, the reverse was true. Exact agreement was found among 16.4% of the sample pairs.

The blood lead levels measured by COMINCO and the CONTROL laboratories for each individual were plotted on the accompanying scattergram (figure 3). The value of the number plotted indicates how many replicant values were found at that same position. A perfect correlation would have resulted in all the values falling on a straight line at a 45° angle from an origin of 0. The correlation of .88 found is significant and indicates good agreement.

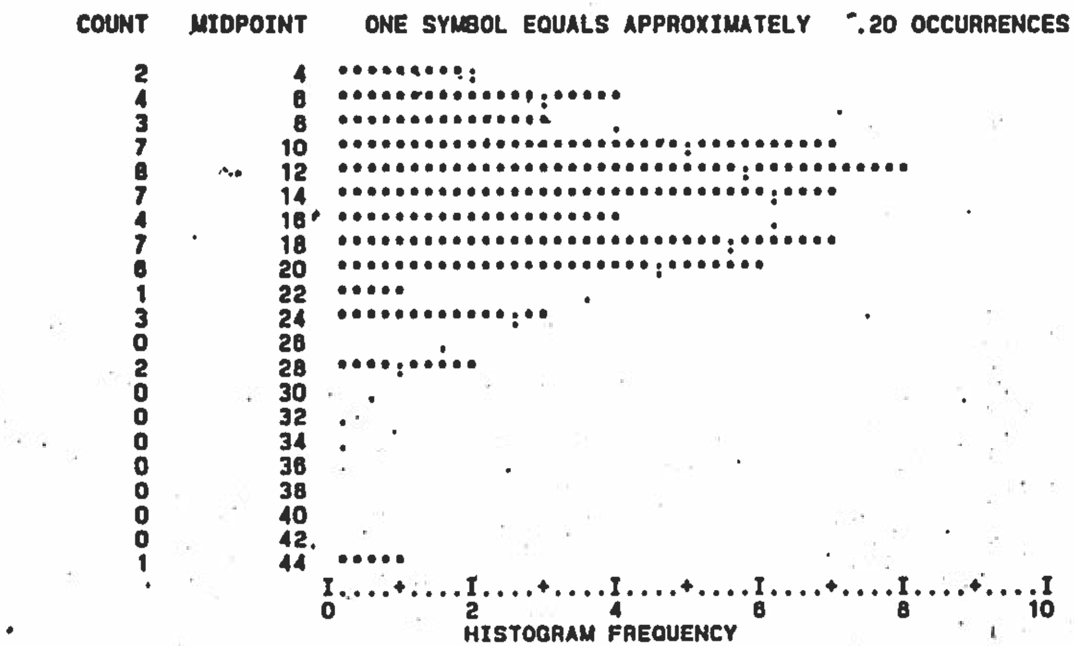
The degree of scatter of the individual values increased with higher measured concentrations. This variable degree of scatter is reflected in the standard deviations of the absolute differences in the measurements which were found to be 1.6, .8, 3.0, and 4.2 for each 25th percentile. An aberrant value (which is circled) found for the lower end of the scale of values as measured by the CONTROL laboratory, contributed to the higher standard deviation found for the first quartile of values.

A contingency table, shown in table 2, provides a means of evaluating the potential for misclassification if individuals with the measured values were grouped as cases and controls. For this exercise, cases were defined as those individuals having blood lead levels above 17ug/dl, while controls were designated as those having values less than 10ug/dl. In only one instance, which was the aberrant value identified in the scattergram, would a case found by the Cominco lab measurements be classified as a control when using the Children's Hospital measurements. The cross tabulation indicates that for 44 of the 55 pairs of measurements, perfect agreement was found as to the designation of the value being a case, control or "other". The use of the COMINCO lab measurements would have resulted in 6 people being classified as either a case or control, which the CONTROL lab would have classified as an "other". The opposite situation was evident for four of the individuals' values.

In conclusion, the reliability analysis indicates no significant differences in the averages found for the split sample measurements. In a minority of cases however, there were more extreme differences in the measurements, which indicates that some misclassification of cases and controls in the Trail study data may have occurred, which might conservatively bias the study results.

FIGURE 1:

HISTOGRAM OF COMINCO BLOOD LEAD MEASUREMENTS



MEAN	14.564	STD ERR	.954	MEDIAN	13.000
MODE	17.000	STD DEV	7.073	VARIANCE	50.028
KURTOSIS	4.339	S E KURT	.634	SKEWNESS	1.462
S E SKEW	.322	RANGE	40.000	MINIMUM	4.000
MAXIMUM	44.000	SUM	801.000		

VALID CASES 55 MISSING CASES 0

FIGURE 2.

Histogram of CONTROL Blood Lead Measurements.

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COUNT   MIDPOINT   ONE SYMBOL EQUALS APPROXIMATELY   .40 OCCURRENCES

    0        0
    2        3   •••••
    5        6   •••••••••••••
    9        9   •••••••••••••••••••••••
   13       12   ••••••••••••••••••••••••••••••••
   12       15   ••••••••••••••••••••••••••••••
    1       18   •••
    2       21   •••••
    6       24   •••••••••••••••
    1       27   •••
    3       30   ••••••••
    0       33
    0       36
    0       39
    0       42
    0       45
    0       48
    0       51
    0       54
    1       57   •••
    0       60
                 I....+....I....+....I....+....I....+....I....+....I
                 0         4         8        12        16        20
                                 HISTOGRAM FREQUENCY

MEAN          15.127      STD ERR       1.206      MEDIAN       13.000
MODE          13.000      STD DEV       8.940      VARIANCE     79.928
KURTOSIS       7.768      S E KURT       .634      SKEWNESS      2.134
S E SKEW        .322      RANGE        54.000      MINIMUM       3.000
MAXIMUM       57.000      SUM         832.000

VALID CASES       55      MISSING CASES     0
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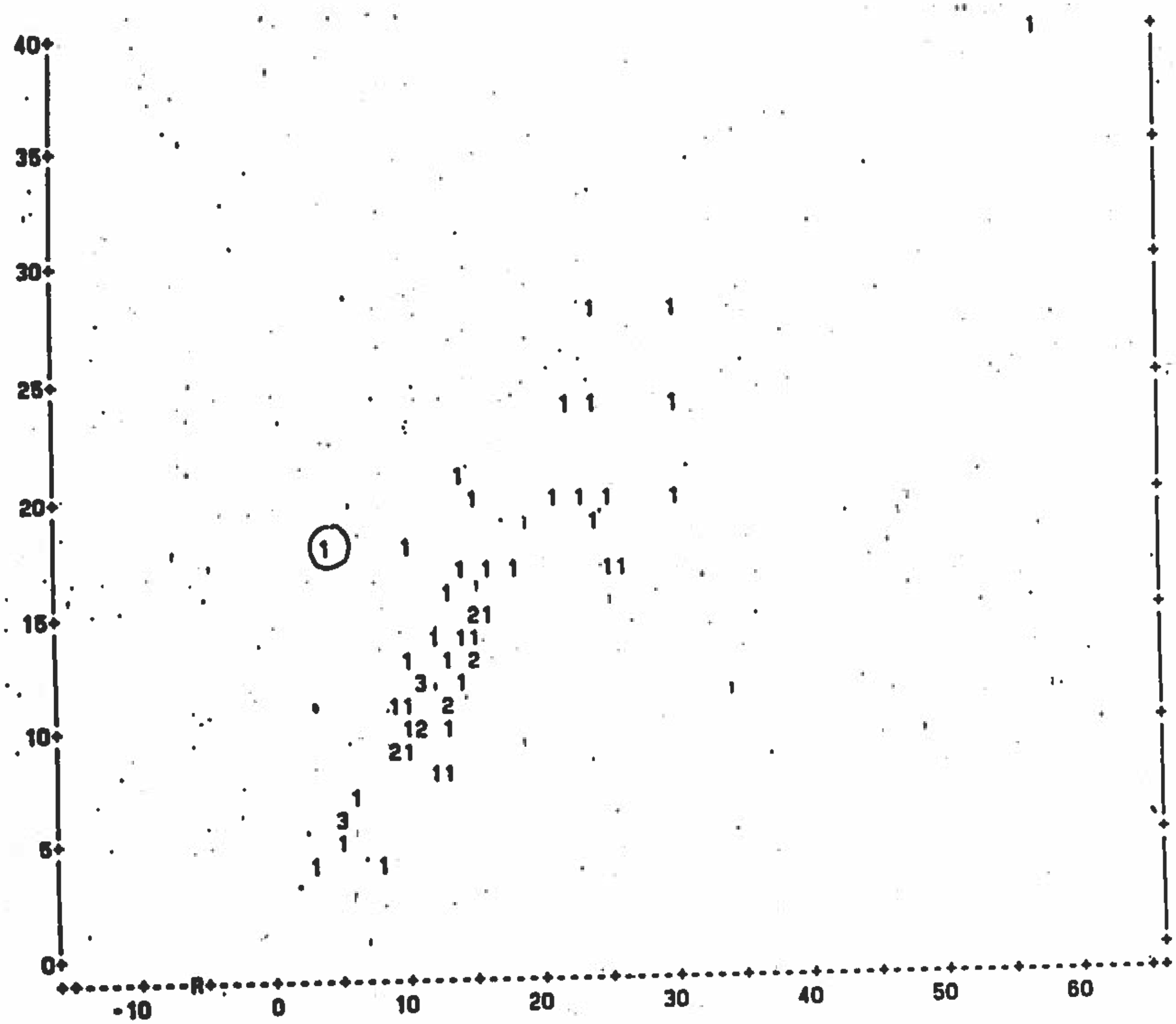

55 cases plotted. Regression statistics of PBCOM on PBCNTRL:
Correlation .88297 R Squared .77963 S.E. of Est 3.35153 2-tailed Sig. .0000
Intercept(S.E.) 3.99635(.89430) Slope(S.E.) .69856(.05101)

FIGURE 3:

Scattergram of COMINCO vs CONTROL BLOOD LEAD MEASUREMENTS.

TABLE 2

CROSSTABULATION OF COMINCO AND CONTROL CASE/CONTROL CLASSIFICATIONS

COMCC	COUNT	CNTRLCC CONTROL 1	CASE 2	OTHER 3	ROW TOTAL
CONTROL	1	9		3	12 21.8
CASE	2	1	11	3	15 27.3
OTHER	3	1	3	24	28 50.9
	COLUMN TOTAL	11 20.0	14 25.5	30 54.5	55 100.0

NUMBER OF MISSING OBSERVATIONS = 0