TRAIL LEAD PROGRAM

IDENTIFICATION, EVALUATION AND SELECTION OF REMEDIAL OPTIONS

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PREFACE

Trail, British Columbia has been the site of a major lead and zinc smelting facility for over 80 years. In 1975, children's blood lead levels in Trail were found to be significantly higher than those in a nearby comparison community. A 1989 study found that although the average blood lead level had declined since 1975, 39% of the Trail children tested in 1989 were above the U.S. Environmental Protection Agency's "level of no concern" of 15 µg/dl. The 1989 study prompted the formation in 1990 of the Trail Community Lead Task Force.

The Task Force was composed of representatives from the provincial and municipal governments, Cominco Limited, the general public, the local School District, the United Steelworkers of America, and a network of environmental groups. The Trail Lead Program was the operational arm of the Trail Community Lead Task Force. BC Environment, the Ministry of Health, Cominco Ltd. and the City of Trail shared responsibility for funding the program.

In 1990, the Task Force embarked on comprehensive programs of community education and case management, as well as investigations of lead exposure pathways and intervention options. The reporting and decision-making process is shown in the chart on the following page.

In 1997, the Task Force began studying whether any other smelter-related contaminants might represent potential health risks. A separate, comprehensive human health risk assessment of other contaminants (focussing on arsenic and cadmium) was concluded in early 2000. That assessment is also summarized in this report.

The purpose of this report is to present, in one coordinated volume, the information which the Trail Community Lead Task Force and the public used in making decisions regarding future remedial actions to be taken in Trail. The report answers important questions about the blood lead issue, such as:

- how has environmental lead contamination occurred?
- why is lead contamination a health concern?
- how and when was the concern identified in Trail?
- why are we only concerned about children?
- where are the highest lead levels in Trail?
- how does the lead get into children?
- how high are children’s blood lead levels in Trail compared with other sites?
- what actions have been taken so far and how successful have they been?
- what are the options for dealing with the lead contamination in the future?

Framework for Development and Evaluation of Remedial Options

(need to print this page separately from Excel)

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GLOSSARY

The terms listed below have the following meanings in this report:

ppm	parts per million - a ratio of contaminant level to unit amount of medium contaminated (e.g. 500 micrograms of lead in a gram of soil = 500 ppm)
µg/dL	micrograms per decilitre - a microgram is one thousandth of a gram and a decilitre is one tenth of a litre
$\mu g/m^3$	micrograms per cubic metre
abatement	remedial measure involving a lasting alteration of the physical environment (e.g. soil or paint removal, soil treatment)
arithmetic mean	the commonly-used “average” (sum of values divided by number of values) - appropriate for expressing the average of normally-distributed data
bioavailable	the fraction of ingested lead which actually enters the bloodstream
biokinetics	the processes affecting the movements of chemical substances in the body
concentrates	raw materials used in the smelting process (e.g. lead/zinc ores which have already been milled to remove much of the non-metal rock)
concentration	the amount of a substance in some sampled medium, expressed as a ratio (e.g. 300 mg of lead in 1 kg of soil represents a soil lead concentration of 300 mg/kg, or 300 ppm)
confounding	confusion of the apparent effect of one factor with another (e.g. smoking was associated with higher blood lead levels, but the association may be due to confounding with proximity to the smelter, as people who live in the neighbourhoods near the smelter may tend to smoke more)
contamination	the presence of some substance in the environment in concentrations that are in excess of normal background levels

correlate	a factor which is associated with the variable under consideration (e.g. soil lead concentration may be a correlate of blood lead level)
dispersion	the scattering of smelter emission particles into the valley air
dustfall	particulate (including smelter emission particles, dust, pollen, etc.) which has settled out of the air (expressed as mg particulate per m^2 per day)
exposure	contact of children with lead in their environment (expressed as the amount of lead available at the digestive tract and lungs)
geometric mean	the nth root of the product of n numbers - appropriate for expressing the average of log-normally distributed data
intervention	a remedial measure designed to interrupt an exposure pathway (e.g. behavioural modification, nutritional advice, continued dust control)
loading	the amount of a substance in some sampled medium, expressed as a mass per unit area (e.g. 0.30 mg of lead per m^2 of carpet area)
pathways model	a diagram and/or set of equations which depicts the means by which lead moves from sources to children (usually derived by collecting paired measurements of blood lead in children and levels of lead in their environments)
pica	a behaviour characterized by an abnormal craving for, and consumption of, non-food items (e.g. soil, paint)
quality assurance	an overall program designed to ensure the reliability of monitoring data
quality control	procedures followed and samples analyzed as part of a quality assurance program
re-entrainment	the picking up and transporting by wind of smelter emission particles that were previously deposited on the ground or other surfaces
remediation	any action taken to reduce risk of exposure to some contaminant (includes both intervention and abatement)

risk model	a set of equations which allows the calculation of health hazard based on environmental lead levels (output may be predicted blood lead levels or some other expression of hazard)
statistically significant	greater than 95% chance that difference is real, not due to random variability
stratified	sorted into a number of categories
suspended particulate	particulate (including smelter emission particles, dust, pollen, etc.) which is supended in the air at the time of sampling (expressed as µg of particulate per m^3 of air)

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The various members of the Task Force Technical, Education, Finance and Case Management Committees over the years have all contributed to the planning of programs and investigations described in this report. The Rotary Club of Trail organized and performed much of the community dust abatement work described herein, with financial assistance from the Task Force and the Environmental Citizenship Initiative (Environment Canada).

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EXECUTIVE SUMMARY

Background

Lead is a heavy metal that has had a long history of use by humans. Documentation of the effects of excessive lead exposure dates back as far as the early Greek and Roman civilizations. Lead exposure has long been recognized as an occupational health hazard at locations such as the lead/zinc smelter in Trail, which has operated since 1896. However, society has only recently become aware of the effects of lead exposure on children in residential environments. From about 1920 to 1970, large numbers of children were diagnosed with clinical lead poisoning, mostly in large U.S. cities. By the 1970s, it had become apparent that most cases of lead poisoning were due to the inadvertent ingestion of leaded paint chips and of dust contaminated by deteriorating lead-based paint. Researchers were also beginning to survey children living in smelter communities for evidence of elevated blood lead levels.

In 1975, a survey in Trail found that only 4% of children living within one mile of the smelter had blood lead levels which exceeded the standard at that time (40 µg/dL). Since local physicians had never reported any cases of lead poisoning in Trail children, the study did not result in any further action.

In the 1980s, a number of researchers found that associations between children’s lead levels and subtle health effects, such as small IQ deficits and slightly decreased growth, were measurable at blood lead levels much lower than 40 µg/dL. In 1989, a more detailed study was initiated in Trail by Cominco and the B.C. Ministry of Health. By that time, the U.S. Environmental Protection Agency had lowered its “level of no concern” to 15 µg/dL. Although the average blood lead level in Trail children was found to have declined from 22.4 µg/dL in 1975 to 13.8 µg/dL in 1989, 39.4% of the children tested in 1989 were above 15 µg/dL. The 1989 study also found that soil lead concentration and, secondarily, house dust concentration, were the principal environmental determinants of elevated blood lead levels in children.

The 1989 study's recommendations prompted the formation of the Trail Community Lead Task Force. The Task Force, which was composed of representatives from Cominco, the government of British Columbia, local government and numerous community groups, was given responsibility for developing a strategy to reduce Trail children's lead exposures. Communities with inactive smelters or mine sites have often implemented large clean-up programs to permanently reduce lead exposures. By contrast, the strategy for Trail was expected to help the smelter and the community to continue to co-exist by focussing on actions that would be ongoing.

The Task Force estimated the cost of residential soil replacement in Trail proper alone at over $55,000,000 and expressed concern that excavation and soil transport might result in a transient increase in lead exposure. The Task Force was also advised that massive soil removal might not be rational until after the smelter emissions had been reduced. In addition to the financial deterrent and questions of efficacy, soil removal appeared to be socially unacceptable in Trail. For all of these reasons, the Task Force chose not to undertake any immediate soil replacement. Instead, the Task Force embarked on ambitious programs of community education and case management, as well as environmental assessment aimed at better understanding lead exposure pathways.

Although the Task Force philosophy was that remediation should not be conducted without evidence that it would be effective in reducing blood lead levels, it felt that some actions which could be taken at relatively low cost should not be delayed. In particular, there was wide support for a program to "green" public areas by planting grass and shrubs. The premise was that covering areas of bare, high-lead soil with vegetation would reduce children's direct contact with the soil and decrease movement of dust by wind. A host of similar projects was considered, including dust control on unpaved alleys, street cleaning and provision of seed and fertilizer to householders. It was recognized, however, that it would be virtually impossible to measure an impact on blood lead due to any one of these projects. The Task Force accepted that such projects would help to educate and involve the community and that they would be evaluated in terms of practicability in Trail, rather than in terms of impact on blood lead.

Sources and Pathways of Lead Exposure

In order to develop a remedial action plan for reducing children's exposures to lead, it was first necessary to determine the relative importance of the various sources, pathways and routes of exposure which can impact on children.

It is important to know whether children are predominantly exposed to lead by ingestion or inhalation, and whether particular sources and pathways are dominant. Answering these questions allows remedial action resources to be focused on corrective measures that are most likely to provide the greatest benefit at the lowest cost.

Most lead contamination reaching the living environments of people in Trail has been transported by air. For this reason, the levels of lead contamination in soil and dust decrease as one moves away from the smelter. Also, the highest concentrations of lead in soil are found in the top few centimetres of the soil profile. The average soil lead level in Trail is about 720 parts per million, while the standard for residential properties is 500 parts per million.

Concentrations of lead in house dust are also generally higher near the smelter than further away. The amount of lead dust inside the entryways of homes is on average about six times higher than that within the house interior, suggesting that track-in is an important mechanism for lead transfer into homes.

The annual average level of lead in air measured at four stations in Trail has generally been below the provincial objective since 1985. There is considerable evidence that the source of present day air lead in Trail is primarily current losses from the smelter, rather than re-entrainment of historically-deposited emissions by wind.

Lead levels in Trail tap water have been found to be acceptable in 98% of samples tested. There is also no tendency for Trail children with elevated blood lead levels to have higher tap water levels. Therefore, drinking water is not considered to be a significant source of lead exposure in Trail.

Most cases of elevated lead levels in locally grown produce appear to be related to inadequate washing of soil/dust from the external surfaces of the produce. There is no tendency for Trail children who eat locally grown produce to have higher blood lead levels than those who do not. This is consistent with findings at five mining or smelting sites in the U.S.

Lead in paint may be a significant factor in individual cases of elevated blood lead, but it does not appear to be a significant contributor to blood lead levels on a community-wide basis.

A comprehensive study of lead exposure pathways conducted in Trail in 1992 found that interior house dust lead is the dominant source of lead exposure for Trail children. This finding is also consistent with similar studies at other sites. The relative importance of indoor versus outdoor exposure appears to vary with age. For children less than 18 months of age, interior house dust is by far the most significant source of lead exposure. For children 18 months of age or older, current blood lead level is determined mostly by prior blood lead level. Time spent outdoors daily and yard soil lead concentration are also significant predictors of blood lead in children aged 18-35 months, which suggests that continued exposure at that age occurs mainly outdoors.

The exposure pathways model suggests that lead in dustfall, exterior dusts and soil is transported into houses, where it becomes available for ingestion by children while they are indoors. For a child in Trail with an average blood lead level (about 6 µg/dL), only about 2% (0.1 µg/dL) of his/her blood lead is due to inhalation of airborne lead and 98% is due to ingestion of lead in dust, soil, and diet. For children with higher blood lead levels, the proportionate contribution of inhalation is even less because compared with ingestion, inhalational lead exposure is relatively uniform from one child to another.

There appears to be no difference in blood lead levels between children whose parents work in a lead industry (primarily the smelter) and those children whose parents do not. Children do tend to have higher blood lead levels if their parents smoke cigarettes or if they have a dog or cat as an indoor/outdoor pet. Children who live on properties with a higher percentage of bare soil tend to have higher blood lead levels.

A higher frequency of children's mouthing behaviours (e.g. chewing fingernails, putting dirt in their mouths) has been associated with higher blood lead levels, but only in areas near the smelter, where soil lead levels are over 500 ppm.

Additional data suggest that track-in of dust is a dominant mechanism for transfer of lead into houses, and the rate of track-in may be at least four times that of settling from air. Therefore, continued use of measures which have been shown to be effective in reducing dust track-in (such as the use of entrance “walk-off” mats, removing shoes at the door and yard maintenance) is strongly recommended.

In December 1996, Cominco completed construction of a new lead smelter in Trail. The new smelter has been running on its own, with the old smelter on standby only, since June 1997. However, there were some difficulties operating the new smelter in conjunction with other integrated plant processes. The difficulties resulted in periodic shutdowns and upsets in lead production from June to November 1997. In November, the smelter was shut down for several weeks to allow for upgrades to the integrated processes. Once the new lead smelter began operating smoothly at regular capacity (January, 1999), a one-year monitoring period for the evaluation of new lead smelter performance was triggered. This smelter performance evaluation was a requirement under Cominco's air discharge permit. The new state-of-the-art smelter reduced lead emissions from stacks by about 75%. In addition, the new smelter dramatically lowered fugitive emissions through the replacement of several existing plants with a closed process. The reduction in lead emissions has had a significant effect on children’s blood lead levels, which was expected since most of the lead dust which moves about the community had been determined to be derived from current smelter emissions.

Data from the Sentinel Homes monitoring project show that there were also substantial reductions in the amount of lead in outdoor dustfall, indoor dustfall, and street dust samples after the new lead smelter started up. The greatest improvements in these measures occurred in areas nearest the smelter. The change in amount of lead in floor dust was not as clear. The "microvac" samples from 30 homes showed no change, while the HEPA vac samples from 8 homes showed only slight changes in loading and concentration.

Community Blood Lead Trends

The University of British Columbia, as part of the 1989 Trail Lead Study, conducted a survey of Trail children's blood lead levels and the Trail Lead Program has conducted annual surveys since 1991. Blood lead testing allows the program to:

- identify and follow children with elevated or rising blood lead concentrations (case finding and case management)
- define high risk geographical areas
- provide a summary assessment of the community-wide impact of various remedial actions
- evaluate outcomes in specific studies and programs.

From 1989 through 1996, average blood lead levels of children aged *6 months to 4 years*, tested for the first time, declined at an average rate of 0.6 µg/dL/year, while blood lead levels in Canadian children not living near point sources of lead emissions appeared to level off following the phase-out of leaded gasoline in 1989. The year-to-year variability in average blood lead levels during this period appeared to be related to weather conditions during the month preceding the fall blood testing clinic. Specifically, when August was relatively dry, blood lead levels, and air lead levels, tended to be higher.

From 1996 to 1999, the average blood lead level of children tested for the first time fell by 54% - from 11.0 µg/dL to 5.1 µg/dL. The average annual rate of decline during this three year period was 1.9 µg/dL/year. The rapid decline appears to be attributable to the replacement of the old lead smelter in May of 1997. Air lead levels in Trail during the summer of 1997 were already about 50% lower than during the summers of 1994-1996. By 1998, summer air lead levels were 75% lower than during the last years of the old lead smelter.

In 2000, the average blood lead level of children tested for the first time increased to 6.3 µg/dL. The increase from 1999 appears to be mostly due to weather differences. August 2000 was one of the driest Augusts in the last decade, while August 1999 was one of the wettest. Air lead levels in August 2000 were actually slightly lower than in August 1999.

Trail children's blood lead levels in 1999 and 2000 were very similar to levels measured in Silver Valley, Idaho and Herculaneum, Missouri in 1999 and 2000. Silver Valley is the location of the Bunker Hill Superfund Site, where lead smelting and mining occurred on a collosal scale in the 20th century. The smelter was permanently shut down in 1982 and very limited mining occurs in the area today. As of 1999, contaminated soil had been removed from approximately 1500 residential yards in the Silver Valley. In 1999, the average blood lead level for children aged *9 months to 9 years* was 3.9 µg/dL. Herculaneum is the site of an operating lead smelter, where very limited soil replacement and considerable ground cover improvement have been carried out in recent years. In 2000, the average blood lead levels for children aged *6 months to 5 years* was 5.4 µg/dL. The average blood lead levels of children living in other communities around the world with active lead smelters were generally considerably higher in the same years.

In Trail, as at most other sites, children's lead levels generally rise rapidly from birth to crawling age and peak at 18 to 24 months of age. This is mainly due to exposure to lead in house dust and the frequent hand-to-mouth activities of infants and toddlers. As children get older, their blood lead levels gradually decline, as their hand-to-mouth activity decreases. If Trail children do not experience elevated blood lead levels by their third birthday, they very rarely develop elevated blood lead levels later.

Risk Assessment - Lead

The British Columbia Contaminated Sites Regulation under the *Waste Management Amendment Act* contains numerical soil standards that are to be used in determining whether sites are contaminated. The geometric mean soil lead concentration in Trail residential areas is approximately 720 ppm, while the maximum allowable soil lead concentration for residential land is 500 ppm (matrix numerical soil standard for protection of human health in a residential scenario).

The regulations currently state that soils at contaminated sites must be remediated so that contaminant concentrations do not exceed the standards, or the site must be managed so that the calculated Hazard Index or estimated incremental lifetime cancer risk (see below) is acceptable. There has not been any official determination that Trail is a "contaminated site" under the Contaminated Sites Regulation. However, it is possible that the area will be listed as a "Wide Area Site", once Cominco's ecological risk assessment work has been completed. Therefore, this report must also address how the requirements of the Contaminated Sites Regulation can be satisfied by the Task Force's recommendations.

The U.S. Environmental Protection Agency has developed a risk model for lead, which predicts community blood lead levels based on environmental lead levels, with a heavy emphasis on soil and house dust concentrations. The US EPA model was used with 1992 Trail data and was found to be very effective in predicting the mean blood lead level in Trail children aged 6 to 72 months. The model confirmed that the risk of a child in Trail having a blood lead level of 10 µg/dL or higher was slightly greater than 50%. On the other hand, the model was not effective at predicting blood lead levels in individual children or in specific neighbourhoods. Since 1992, soil lead concentrations have not changed by any measurable amount, nor have house dust lead concentrations. Therefore, if a new set of paired environmental and blood lead data were available to run the model today, the model would greatly over-predict present day blood lead levels.

The US EPA lead model may be used for predicting the effects on blood lead levels of certain types of remedial actions. However, the model is not capable of predicting the effect of some other types of remedial measures, such as reductions of lead dust loadings through house de-dusting or education interventions designed to bring about changes in mouthing behaviour, hygiene or nutrition. It is necessary to use a combination of risk models and the results of real-world experiences to estimate the effects of such actions.

The following approach to lead remediation and risk assessment was adopted by the Lead Task Force:

1. Remedial options were evaluated in terms of such factors as technical feasibility, probable efficacy in reducing lead exposure risk, cost-effectiveness and public acceptability.

2. A preferred set of remedial options (based on the criteria in 1. above) was assessed as a group to ensure that remediation has a reasonable probability of achieving the Task Force's goals.

3. The preferred and approved set of remedial options is being recommended for implementation as a remedial action plan.

4. Remedial actions will be re-evaluated through follow-up monitoring of blood and environmental lead levels to determine if the Task Force's goals have been achieved. **Actual post-remedial blood lead levels will be the primary criterion for determining whether an acceptable level of lead exposure risk has been achieved.**

5. If an acceptable risk level has not been achieved, the remedial action plan should be revised to incorporate more protective measures.

The remedial action plan should continue to be re-evaluated and revised until the goals been reached.

Risk Assessment - Other Smelter Contaminants

The aim of the human health risk assessment, conducted from 1997 to 1999, was to determine whether any smelter-related contaminants other than lead pose a potential health concern to Trail residents.

A comparison of soil, air and water sample results matched against health-based standards determined that arsenic, cadmium and antimony were the only smelter-related contaminants requiring detailed risk assessment (other than lead, which was already being intensively studied).

The risk assessment addressed:

- How much arsenic, cadmium and antimony are people in Trail likely to ingest or inhale?
- How much arsenic, cadmium and antimony consumption does it take to produce adverse health effects, based on current knowledge from studies of people and lab animals?
- Based on answers to the above questions, are any adverse health effects due to arsenic, cadmium and antimony likely in Trail?

Estimated antimony exposures were found to be below levels associated with any health effects. Estimated cadmium exposures for Trail residents are below levels associated with kidney disease, with the possible exception of people who are heavy smokers.

Estimated lifetime cancer risks due to arsenic and cadmium exceed the BC "default" standard of 1 in 100,000. However, in the Trail population, exposure to smelter contaminants might result in no more than:

- 1 case of lung cancer every 60 years or so
- 1 case of skin cancer every 200 years or so

These preliminary results are based on a number of health-protective assumptions and therefore likely overestimate actual health risks.

The study authors concluded that for chemicals other than lead, there is no imminent (short-term) threat to human health and very limited potential for adverse effects from long-term residence in Trail.

Remedial Goals

The primary objective of remedial actions recommended by the Lead Task Force is to protect the sensitive population (children under 5 years of age) against lead exposure. This objective will be achieved through a combination of actions, which will either:

a) reduce sources of lead (e.g. soil treatment or removal, house de-dusting), or

b) break pathways of exposure to lead (e.g. ground cover improvement, behavioural modification)

The BC Contaminated Sites Regulation currently defines "acceptable risk level" to mean a lead hazard index of less than one. However, Section 18 of the regulation provides for deviation from the default standard based on the recommendations of a local medical health officer. In addition, a pending amendment to the CSR will allow for the use of blood lead levels (rather than hazard indexes) in risk assessments and in the evaluation of remedial actions.

A Federal-Provincial Committee on Environmental and Occupational Health has recommended that a community program to identify and reduce sources of lead exposure be considered if the proportion of children aged 6 to 72 months with blood lead levels above 10 µg/dL is double that of the general population. Currently, it is estimated that approximately 5% of Canadian children have blood lead levels over 10 µg/dL. Therefore, the long-term goal would be to have no more than 10% of Trail children with blood lead levels over 10 µg/dL.

The Trail Community Lead Task Force has therefore formulated a long-term goal statement: "At least 99% of children should have blood lead levels under 15 µg/dL or and at least 90% of children should be below 10 µg/dL by 2005.

With respect to other smelter contaminants, the Task Force goal statement is that "potential health risks from other smelter contaminants (i.e. cadmium and arsenic) should be reduced to the levels required by provincial regulations, without shutting down the smelter or conducting widespread soil replacement in the area". The phrase "levels required by provincial regulations" allows the goal to be set in terms of either the default acceptable risk levels, or some other levels as recommended by the Medical Health Officer. In setting this non-specific goal for other metals, the Task Force recognises that lead is the main contaminant of concern and that blood lead levels will be the main criterion for measuring the success of the remedial program. Levels of lead, arsenic and cadmium in local air will be the second most important criteria for monitoring the progress of remedial efforts.

Remedial Options: Identification

In this report, remedial options that are potentially applicable to the reduction of childhood lead exposure (and community exposure to other smelter contaminants) in Trail are presented and evaluated.

Long-term remedial options that were considered for continuation or implementation are presented. These options included:

- continuation of blood lead testing clinics, case management program, community education program, early childhood education program, community dust abatement program and HEPA vacuum loan program
- a new program for relocation assistance
- creation or expansion of "buffer-zones" through establishment of barriers and/or re-zoning
- soil remediation measures
- comprehensive house dust remediation measures
- expanded assistance with lead-based paint remediation
- programs to enhance public health in other ways

Remedial Options: Evaluation

This section of the report provides an assessment of remedial options, generally based on the following criteria:

- purpose
- effectiveness
- scope
- estimated costs
- permanence

A sixth important criterion, community acceptance, is discussed in the subsequent section on selection of remedial options.

First, difficulties associated with studying the effects of remedial actions on blood lead levels are reviewed, as are the limitations of pathways models and risk models.

Next, experience in Trail, as well as at other sites around the world, with testing or implementing the remedial actions is reviewed. Comments on the expected effect of remedial actions based on both pathways modelling and risk assessments are also included.

Community education and case management (measures which are intended to reduce mouthing behaviours, improve hygiene and nutrition and reduce lead levels in the home environment) are likely to be effective in reducing blood lead levels. Pathways models suggest that mouthing behaviours, house dust lead loadings and ground cover conditions in yards are important factors in childhood lead exposure. Risk models also suggest that the soil/dust ingestion rate and house dust lead levels are influential parameters in the determination of lead exposure. Assessment of actions taken in Trail and at other sites also suggests that education and home interventions can have an effect on blood lead levels. There is evidence that the benefits of such actions may be short-term and that vigilance and sustained effort are required to avoid relapses.

Community dust abatement can also be expected to result in reductions in blood lead levels, based on pathways and risk models. However, no communities have implemented community dust control programs in a way that would allow measurement of their effects on environmental levels or blood lead levels.

Relocation of children from higher risk to lower risk areas is one action that is certain to reduce blood lead levels. A study in Australia found that, in a setting where education, case management and community dust control were being conducted, permanent relocation was the only factor significantly associated with a lowering of blood lead level.

Pathways models and risk models both suggest that soil remediation should produce reductions in blood lead levels. However, the effect of removing lead contaminated soil and replacing it with “clean” soil has been studied at several sites with generally disappointing or inconclusive results. Other methods of soil remediation, such as on site treatment to reduce the bioavailability of lead in the soil, are currently being investigated.

The pathways model for Trail, as well as those developed for numerous other sites, suggest that reducing the amount of lead dust in homes should have a very significant impact on children’s lead exposure. There have now been several trials of house dust remediation, including a controlled trial in Trail. Two well-designed studies have demonstrated an effect on blood lead levels due to house cleaning. The first involved children with very high blood lead levels (average of 38 µg/dL) in a large U.S. city in the early 1980s. The second involved children with only moderately elevated blood lead levels (12.0 µg/dL on average). In both studies, vacuuming and wet-mopping every two weeks, combined with education, resulted in a 17% reduction in blood lead levels. Our own well-designed study found no impact on children's lead exposure as a result of conducting very thorough vacuuming once every six weeks. Several other less rigorous studies have suggested that house dust removal can have an impact.

The pathways model for Trail suggests that abatement of lead-based paint might have a significant impact on children’s blood lead levels in some individual cases. There have been numerous studies to evaluate the effectiveness of lead-based paint abatement combined with dust control measures. These studies have produced very mixed results, with some finding that attempts to remediate homes with lead-based paint can actually increase lead exposure to the occupants.

Remedial Options: Selection

Public Consultation Process

Although the Trail Community Lead Task Force has been a community-based group, chaired by the mayor and having no less than 5 active community representatives at any time, the Task Force decided to seek even broader public input as it developed and finalized its long-term recommendations. Also, the Task Force hoped that its consultation process would satisfy the Medical Health Officer's need for public consultation under the Contaminated Sites Regulation.

A Public Consultation sub-committee was struck and two local consultants were hired to help develop and facilitate the process. The process involved the following steps:

- A media release and meeting with Trail City Council were used to "kick-off" the public consultation process.
- Key sub-communities and stakeholders within the community were contacted to provide background information, to generate interest in the process and to ask the community how it preferred to participate.
- A newsletter and advertising were used to promote a series of five public meetings held in spring 2000.
- Following the public meetings, another newsletter was mailed out to describe the results of the meetings.
- In October 2000, a facilitated community workshop was held with key invited community stakeholders and opinion leaders. The workshop was also open to the general public.
- The Task Force's proposed recommendations were revised to reflect community input.
- In December 2000, a brochure and postage-paid survey were mailed to everyone in the community to provide one more chance for everyone to review and comment on the proposed recommendations.

The consultation process generated comments from hundreds of people in the community and assisted the Task Force tremendously in selecting remedial options. The public comments will also serve to emphasize the importance of the proposed Trail Health and Environment Committee and the need to ensure that the recommended actions are implemented in a coordinated manner with continued public communication and involvement.

Task Force Recommendations

The goals stated under "Remedial Goals" (above) form part of the Trail Community Lead Task Force's final recommendations.

Public Health Unit (Kootenay Boundary Community Health Services Society)

The Health Services Society, with financial support from the BC Ministry of Health has agreed to implement the following actions, as recommended by the Task Force:

- Continue blood lead testing, but with a reduced age scope of 6 - 36 months in order to focus on children who are most at risk. *(Parents of older children who are new to the area or who have had an elevated blood lead level previously* *will still be encouraged to have their children tested. Also, any parent with an older child will not be denied testing if they feel strongly that it's important to them.)*

- Continue counseling and services for families with children who have elevated or rising blood lead levels.
- Continue community and pre-school education about preventing and reducing lead exposure. (The education program is not proposed to include school-age children, as they are not at risk of lead exposure.)

Cominco

Cominco Ltd. has agreed to implement the following actions, and to support the Health Services Society and City of Trail financially in their efforts as needed:

- Pursue further reductions in plantsite emissions, with increased reporting to the public and plans and progress.
- Continue greening - to improve the buffer zone within the Cominco property by planting trees as stockpiles are consumed and to continue other revegetation efforts around the property and community.
- Continue environmental monitoring of air and street dust.
- Continue addressing soil on a case-by-case basis (coordinated with the counseling and services program operated by the Health Services Society).
- Implement a new program to advise and assist people doing excavation, construction, demolition or renovation (e.g. disposal of contaminated topsoil and free replacement soil for someone putting in a new vegetable garden) (Work Project Assistance Program)

City of Trail

- Flush and sweep the streets according to recommended protocols.
- Continue dust control on alleys and other unpaved areas.
- Continue greening of bare public areas.

Coordination/Monitoring

- A Trail Health and Environment Committee, appointed by the City of Trail, similar to the current Trail Community Lead Task Force, will be established to monitor, coordinate and advise on the implementation of the Task Force's recommendations.

Projections for Achievement of Remedial Goals

The average blood lead level in Trail children is currently acceptable and is expected to decline further over the next few years as the effects of the new lead smelter continue to be realized. Future improvement in air lead levels would lead to further substantial reductions in the average blood lead level.

Based on assessment of the main available risk model for lead (IEUBK) and experiences elsewhere with soil removal, it does not appear that removing soil on a community-wide basis would be an effective way to deal with children's lead exposure.

Stepping up the case-by-case approach to dealing with bare soil, house dust and deteriorating lead-based paint can further reduce the proportion of children with elevated blood lead levels. It's very difficult to predict the amount of impact this will have. It's seems, though, that it will be realistic to achieve the goals of 90% of children with blood lead levels under 10 µg/dL and 99% under 15 µg/dL by 2005.

Potential health risks from arsenic and cadmium will continue to be reduced primarily through further reductions in smelter stack and fugitive emissions and community dust control.

1. INTRODUCTION

1.1 Brief World History of Lead Production and Human Exposure

Lead is a soft, heavy, dull grey metal that is found in the earth's crust, most commonly in the sulphide mineral galena. Lead is a non-essential element in humans - it does not provide any known benefits. Thousands of years ago, before humans began extracting metals from ores, people had very low amounts of lead in their bodies. Today, lead is a widely-used metal and its production and use have resulted in world-wide human exposure to lead in air, food, drink, soil and dust.

Because lead accumulates over a lifetime in bones and teeth, and because bones and teeth stay intact for a long time, it is possible to estimate the lead exposures of ancient peoples. Shapiro (1975) compared tooth lead levels in ancient populations with those in current urban and remote populations. Table 1 shows that ancient Egyptians had tooth lead levels that were only about 1/20th of those of the contemporary urban dweller. The Peruvian Indians in the 12th century had slightly higher levels than the ancient Egyptians. The fact that even people living in remote northern regions have had tooth lead levels higher than those of the ancients indicates that present-day lead contamination affects the entire world to some extent.

Table 1 - Comparison of Past and Present Human Exposures to Lead

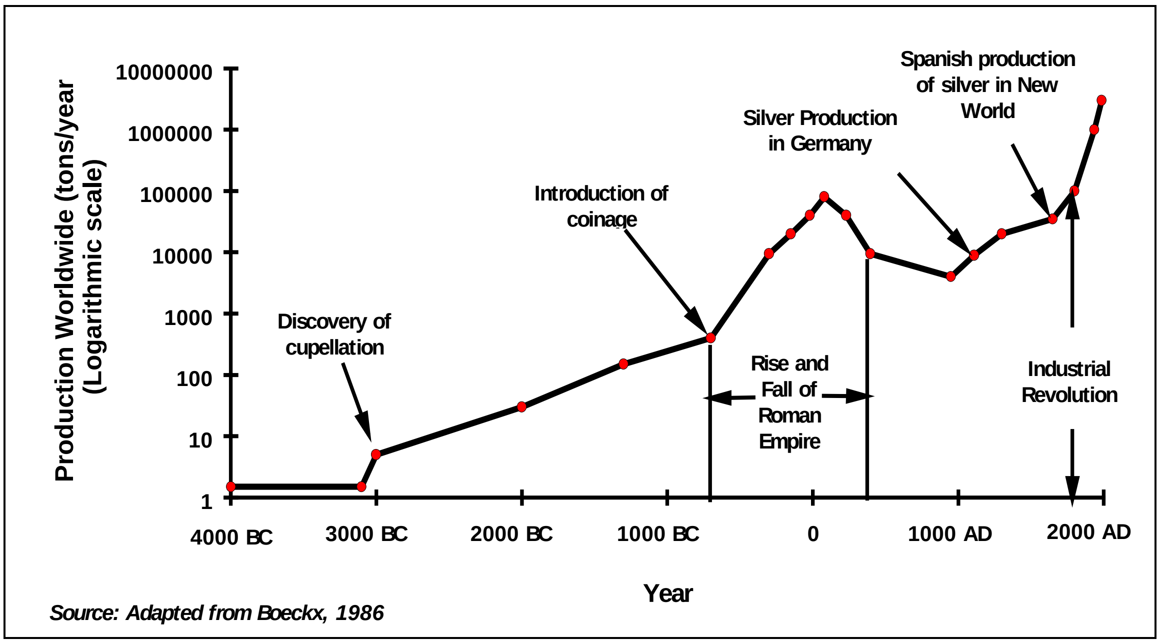
Population Studied	Tooth Lead Level (μg/g dry weight)
Ancient Egyptian	9.7
Peruvian Indian (12th century)	13.6
Alaskan Eskimo (1970s)	56.0
Philadelphian (1970s)	188.3

History of the use of lead by humans dates back almost 9000 years. Lead objects from 5000-6000 B.C. have been found in ruins in the Middle East (Boeckx, 1986). Interest in extracting silver from lead ores resulted in the production of lead oxide, which was used as a glaze in ceramics as early as about 5000 B.C. (Kazantzis, 1989). By about 2500 B.C., significant amounts of lead were being mined and smelted in southwest Asia and Europe (Lin-Fu, 1985). However, the use of lead was still limited to such applications as making statuettes, improving the quality of glass and preparing cosmetics.

It was the Roman civilization which brought the use of lead to more industrial proportions. The Romans used lead for a wide variety of purposes, including transporting and storing water in lead-lined aqueducts and cisterns, cooking with lead utensils or in lead-lined pots, making coins, and even using lead as a flavouring agent in wines. There are records indicating that the ancients were aware of the risks associated with producing and using lead. Several of the early Greek physicians (Hippocrates, Nicander, Dioscorides) had recorded observations of the signs of acute lead poisoning in persons who had ingested or inhaled lead (Lin-Fu, 1985). Symptoms noted included abdominal pain, pallor, constipation and paralysis. Interestingly, knowledge of the risks did not stop the Roman aristocracy from consuming copious amounts of lead-tainted wine. It has been estimated that Roman aristocrats ingested as much as 1500 µg of lead per day (Boeckx, 1986). (By comparison, the lead intake of a typical Canadian adult in 1986 was about 13 µg/day (Wallace and Cooper, 1986).) Records show that the rulers of the Roman Empire during its two declining centuries suffered from symptoms consistent with fairly serious lead poisoning (Nriagu, 1983). Many historians feel that lead exposure played a significant role in the decline of the Roman civilization.

After the fall of the Roman Empire, the production and use of lead fell off considerably (see Figure 1), but the continued use of lead in cooking vessels and in wine production resulted in continued cases of lead poisoning through the Middle Ages. In fact, a number of outbreaks of lead poisoning occurred from the 7th through 19th century, mostly due to contamination of drinks or food (Lin-Fu, 1985).

Figure 1 - World-wide Lead Production During the Past 6000 Years



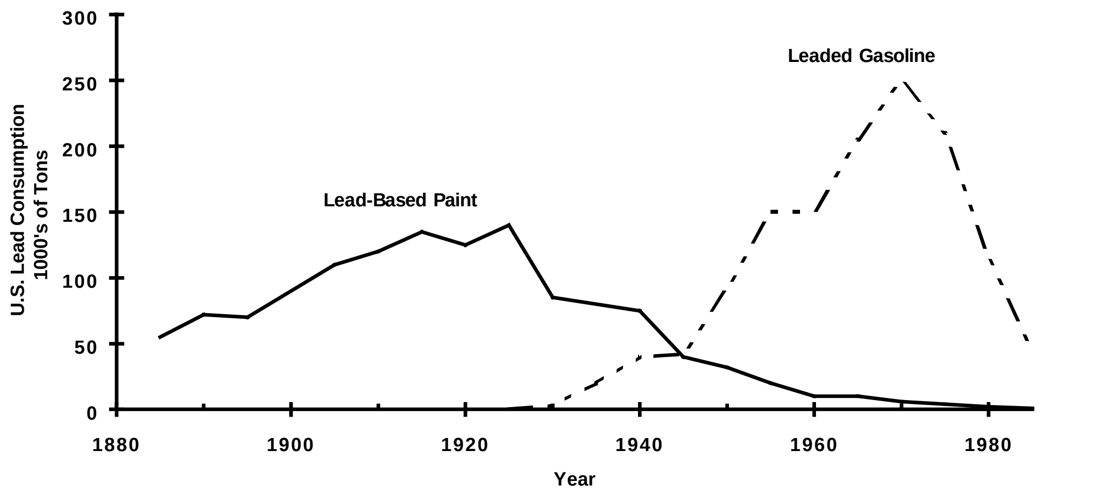
The Industrial Revolution saw a tremendous increase in the production and use of lead. By the early 19th century, lead poisoning among workers had become a serious problem. Many women and children were employed in the manufacture of lead paints, smelting of lead ores and in ceramic glazing. Studies of occupational lead exposure were conducted and much was learned about the effects of high level lead exposure on human nervous, gastrointestinal and reproductive systems. By the late 19th century, some measures to reduce lead exposure in workplaces had begun to be introduced, particularly in Great Britain and Germany (Lin-Fu, 1985). To this day, worker exposures to lead continue to be lowered, driven by repeated reductions in the blood lead levels believed to be safe.

In the late 19th century, lead carbonate (white lead) began to be added to paint to improve its performance and durability (See Figure 2). The use of lead in paint peaked in the 1920s and its use was phased out in North America in the late 1970s. Lead paint poisoning in children was first observed in Australia by Gibson et. al. (1904). Dr. Gibson and colleagues ingeniously noted the importance of house dust as a source of lead and the role of hand-to-mouth activity in childhood lead exposure. Unfortunately, the discoveries reported by Gibson were promptly forgotten, to be rediscovered only in the early 1970s (Lin-Fu, 1985).

From the 1920s through 1960s, increasing numbers of lead poisoned children were reported in large U.S. cities. In those days, lead poisoning was diagnosed by noting visible symptoms (e.g. stomach ache, headache, fatigue, paralysis, coma, even death) in children who had a history of recent lead exposure. There was no knowledge then of the more subtle effects of lower levels of lead exposure (see Section 2). By the 1960s, it had become apparent that childhood lead poisoning due to peeling paint was common in old inner-city slums of major U.S. cities. It was noted that eating paint chips was a common factor in these cases of obvious lead poisoning and that children between 1 and 3 years of age were at greatest risk.

Mass screening of children to allow early identification of children with elevated blood lead levels began in the early 1970s, under the Lead-Based Paint Poisoning Prevention Act (Lin-Fu, 1986). The data collected revealed that moderately elevated blood lead levels were not always associated with eating paint chips. At the same time, it was found that soil and house dust around heavily travelled roadways and lead smelters had high lead concentrations (NAS, 1972). Several studies of lead on children's hands showed that in contaminated areas, normal hand-to-mouth activities could result in ingestion of hazardous amounts of lead (Lin-Fu, 1973; Sayre, 1974).

Figure 2 - U.S. Lead Consumption in Paint and Gasoline

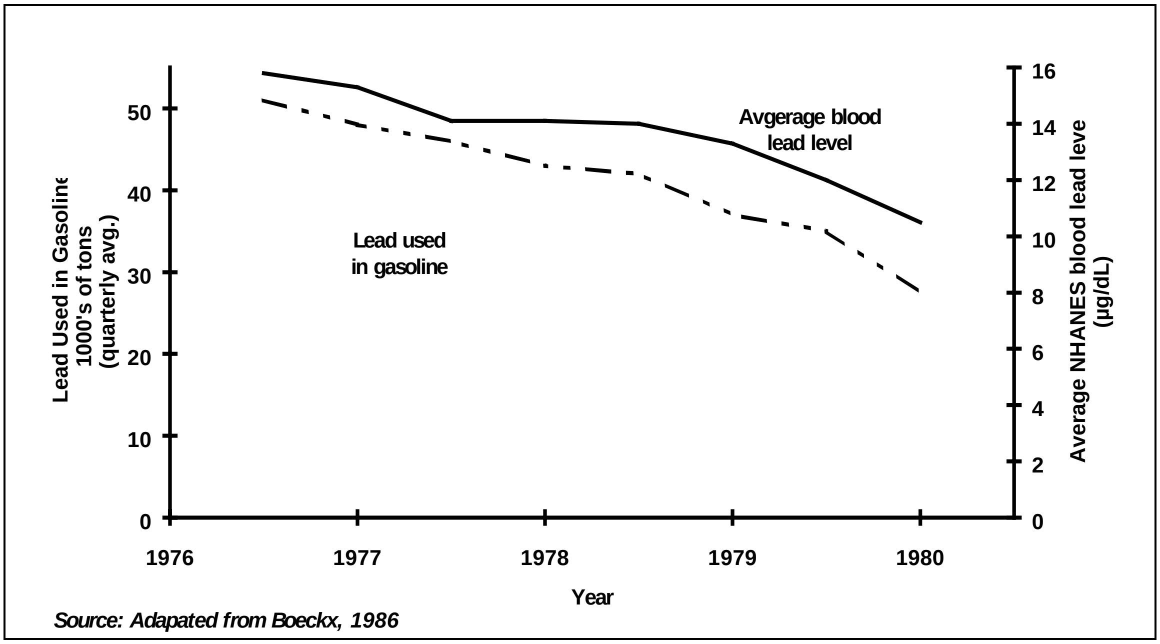


Source: Adapted from Clark et. al., 1991

The high lead concentrations in soil and dust near busy roadways are believed to be due to emissions from automobiles burning leaded gasoline. Tetraethyl lead has been used as an anti-knock additive in gasoline all over the world since about 1930 (See Figure 2). It was phased out of use in many countries during the 1980s. Figure 3 shows that the reduction of lead in gasoline in the U.S. during the 1970s was accompanied by a parallel decline in average children's blood lead levels. During the same time, there were also general reductions in the amount of lead in air due to emissions control improvements at lead smelters, and reductions in lead in food due to the decreased use of lead solder in tin cans. The decline in blood lead levels during the 1970s and 80s was observed around the world, with levels generally dropping 5-10% per year. For example, blood lead levels in Swedish children in both urban and rural areas fell by 7% per year from 1978 to 1988 (Schutz et. al., 1989).

Today, elevated blood lead levels in adults occur mostly in lead-industry workers and in people who have renovated older homes with lead-based paint. However, millions of children around the world continue to have unacceptable blood lead levels, due to their greater ingestion of dust and soil and to their higher susceptibility to lead (see Section 2 for more details on differences between children and adults).

Figure 3 - Blood Lead Declines in U.S. Children During Lead in Gasoline Phase-Out



1.2 Brief History of Lead Exposure in Trail

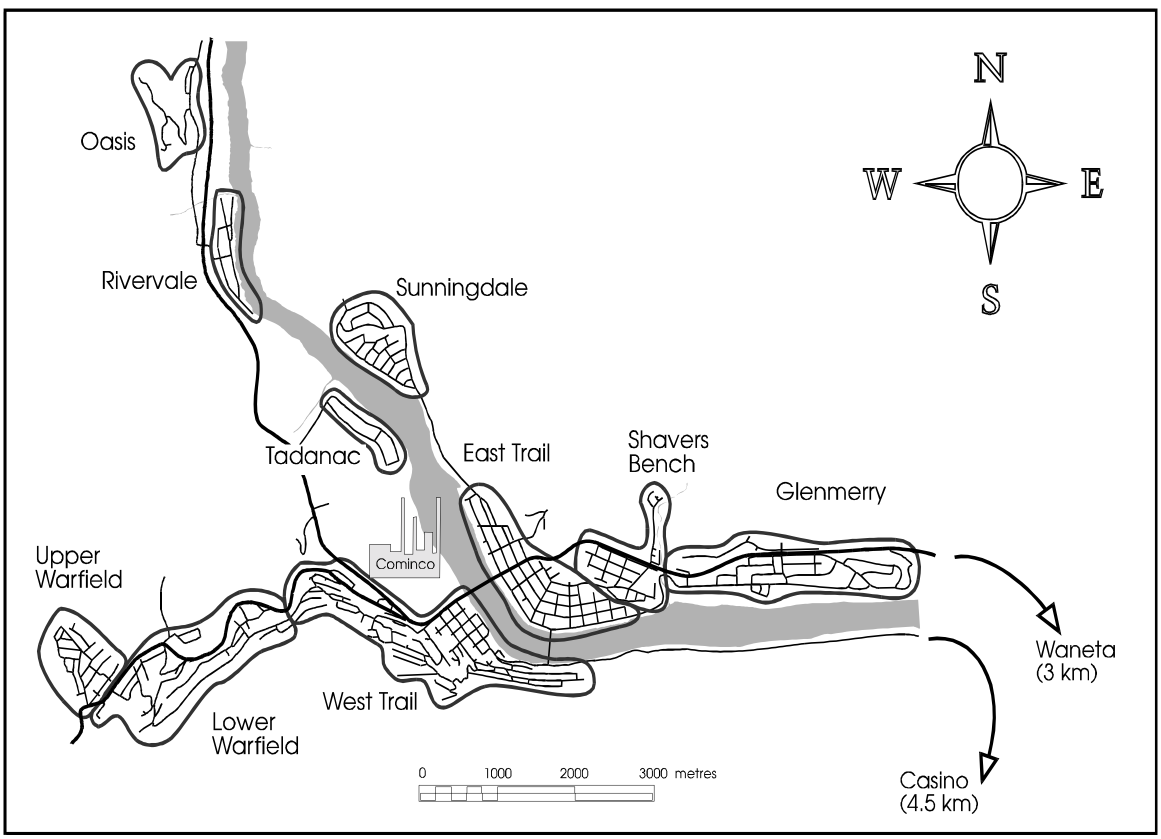
Trail is located in the West Kootenay region of British Columbia on the banks of the Columbia River and has always been a mining/smelting town. The first mining claims were filed for the Red Mountain ore bodies in 1890 and a gold/copper smelter started operation in Trail in 1896. The smelter was located on the same site as the present day lead/zinc operations, on the west bank of the Columbia. A lead blast furnace and hand roasters were built at the Trail smelter in 1899 and electrolytic refining of lead began in 1902. By 1916, zinc and copper were also being refined electrolytically at Trail. Lead production at the Trail smelter during 1916 totalled 20,000 tonnes. The lead smelter and refinery were expanded to their present capacity (about 150,000 tonnes of lead per year) during the 1920s. The concentrates processed in Cominco Ltd.'s Trail operations have come from mines all over the world. This diversity has resulted in a continuity of supply, operations and employment, which has made Trail a stable community in a traditionally unstable industry.

Before 1912, there was no road or rail access to the east side of the river, so the workers built their homes in West Trail, within easy walking distance of the smelter. After a bridge was constructed, house construction began immediately across the river in East Trail. During ensuing decades, new residential developments sprang up at increasing distances from the smelter, as the inner areas filled up and the automobile became more common. This process of concurrent smelter and town development has resulted in a major industrial facility (processing some 1,000,000 tonnes of material annually) being situated in the middle of the town. It is inevitable that there would be some contamination of the surrounding area by a facility of this size and in this case, the affected area is home to about 10,000 people. The locations of the major neighbourhoods of Trail and the Cominco Smelter Complex are shown in Figure 4.

Contamination of the community has occurred through aerial transport of pollutants. Lead bearing particles are introduced to the atmosphere by stack emissions, upsets in the blast furnaces (prior to construction of the KIVCET smelter in 1997), other "fugitive" process emissions, or by general dust picked up by the wind. The natural movement of the air carries the lead bearing particles from the smelter and deposits them in places where children can make contact with them. Examples of sources of exposure are:

- house dust in the children's homes
- surface dust in the children's yards
- soil in which the children play

Figure 4 - Location of Trail Neighbourhoods



Between 1896 and 1916, smelting operations were primitive at best. Initially, the concentrates were burned in open piles to remove the sulphur. Later, enclosed combustion chambers were used but without smoke or emission controls. At that time, smelting operations were a tremendous source of particulate contamination. In the 1920s, fume collectors, acid plants and tall stacks were constructed to remove sulphur dioxide and disperse emissions from the plants. In 1931, Cominco built the Warfield fertilizer plant to create a use for the previously emitted sulphur dioxide gas. This also resulted in a dramatic improvement in overall smelter emissions because the acid generation procedures required clean gas; therefore, most of the particulate (including the lead bearing particles) in the gas stream had to be removed for that process to work.

Since the 1930s, additional emission control equipment has been installed as new smelting technologies were implemented and as new treatment methods became available. In 1977, a major modernization of the lead, zinc and fertilizer plants was begun. The zinc plant modernization, substantially completed by 1984, resulted in some reductions in lead emissions. Unfortunately, the lead smelter modernization was delayed due to problems with the technology first selected. A new lead smelter using Russian KIVCET technology began operating in May, 1997. The new lead smelter eliminated the old sintering plant and blast furnaces and reduced lead stack emissions by about 75%.

The first investigation of children's blood lead levels in Trail was conducted in 1975 (Neri et. al., 1978). The study was prompted by published findings of high lead concentrations in soil and dust in areas surrounding other smelter sites (see Section 1.1) and by reports of widespread blood lead elevations in children in two U.S. smelter cities. Landrigan et. al. (1975) had reported that 62% of children up to age 10 living within one mile of a smelter in El Paso, Texas had blood lead levels greater than 40 µg/dL - the established upper limit for lead in blood at that time. A 1974 survey in Kellogg, Idaho had found that 99% of children aged 1-9 living within one mile of a smelter had blood lead levels above 40 µg/dL (Yankel et. al., 1977). By comparison, the 1975 Trail study found that only 4% of 1-3 year olds and grade 1 students who lived within one mile of the Cominco smelter had blood lead levels over 40 µg/dL. The study also found children's blood lead levels in Trail were significantly higher than those in the nearby comparison community of Nelson, B.C, but only in the younger age groups (see Table 2). The authors suggested that the higher lead levels in young children were due to increased ingestion of soil and dust at that age. The study did not result in any further action, as it appeared that 96% of children were at no risk of adverse effects of lead. Also, local physicians had not reported any diagnosed cases of lead poisoning.

Table 2 - Arithmetic Mean Blood Lead Levels in 1975 (Trail & Nelson)

Age	City	Blood Lead (µg/dL)	Number
1-3 years old	Trail	22	96
	Nelson	14	55
Grade 1	Trail	22	113
	Nelson	14	96
Grade 9	Trail	11	141
	Nelson	10	103

In 1989, a more detailed follow-up study was initiated by Cominco and the B.C. Ministry of Health. By that time, more research into the subtle, and usually unnoticeable, effects of lower levels of lead exposure had resulted in the U.S. Environmental Protection Agency lowering its "level of no concern" to 15 µg/dL (US EPA, 1986). The 1989 study found that soil lead concentration and, secondarily, house dust lead concentration, were the principal environmental determinants of elevated blood lead levels in Trail children (Hertzman et. al., 1991). Although the average blood lead level had declined from 22.4 µg/ in 1975 to 13.8 µg/dL in 1989, 39.4% of the children tested in 1989 were above 15 µg/dL .

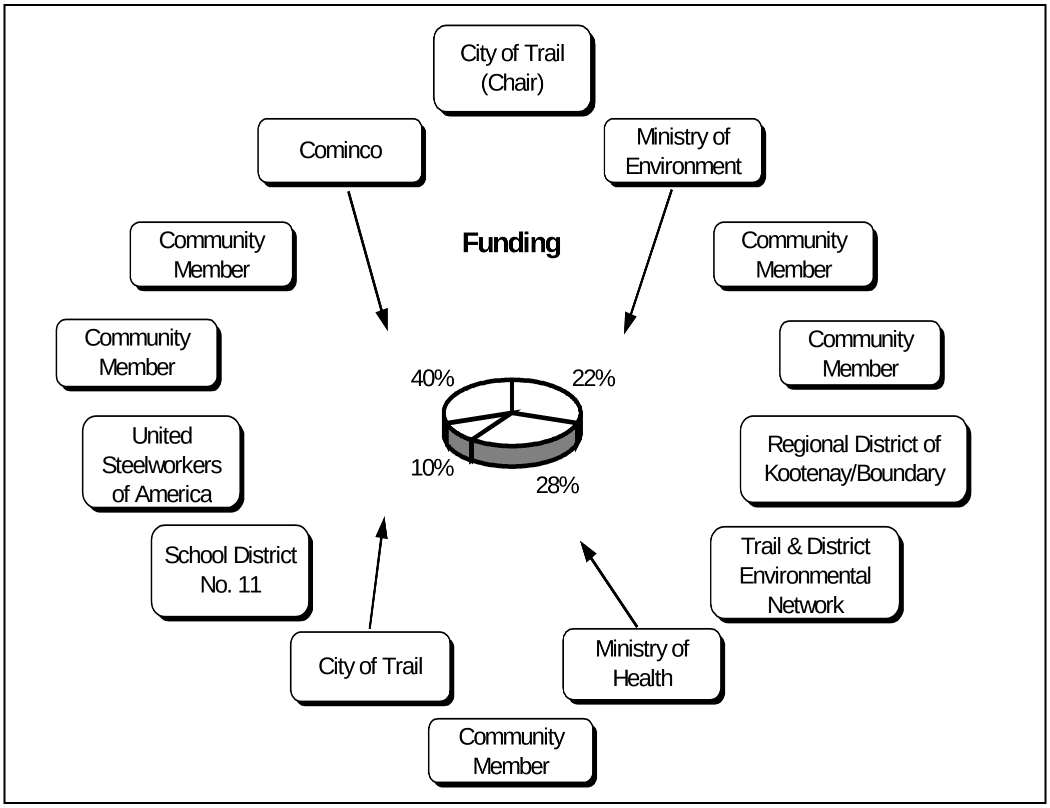
The 1989 study's recommendations prompted the formation of the Trail Community Lead Task Force in 1990. The study authors recommended that the Task Force focus its environmental assessment efforts on tracking lead in soil to its origins, investigating bioavailability factors and intensively mapping the depth and consistency of soil leads. The Task Force was cautioned, however, that massive soil removal might not be rational until after smelter emissions had been controlled. The study also recommended that a comprehensive awareness and education campaign be implemented.

The Task Force was composed of representatives from the smelter company (Cominco, Limited), the government of British Columbia, local government and numerous community groups as shown in Figure 5. Task Force spending from 1991 through 2000 totaled approximately $5,000,000. The Provice of British Columbia contributed 50% of the total, Cominco 40% and the City of Trail 10%.

The Task Force began developing a strategy for reducing Trail children's lead exposures. Communities with inactive smelters or mine sites have often implemented large clean-up programs to permanently reduce lead exposures. By contrast, the strategy for Trail was expected to help the smelter and the community to continue to co-exist by focussing on actions that would be ongoing.

The Task Force estimated the cost of residential soil replacement in Trail proper alone at over $55,000,000 and expressed concern that excavation and soil transport might result in a transient increase in lead exposure. In addition to the financial deterrent and questions of efficacy, soil removal appeared to be socially unacceptable in Trail. Until 1997, the lead smelter relied on outdated process technology and, despite efforts to control emissions, the amount of lead discharged to the environment was about 300 kg/day (Cominco Ltd., 1993). Smelter emissions, and therefore soil contamination rates, were expected to continue at fairly high levels for a number of years. For all of these reasons, the Task Force chose not to undertake any immediate soil replacement. Instead, the Task Force embarked on ambitious programs of community education and case management, as well as environmental assessment aimed at better understanding lead exposure pathways. The philosophy adopted by the Task Force was that environmental remediation should not be conducted without evidence that it would be effective in reducing blood leads. Remediation options would be considered in light of new information on exposure pathways and then tested for effectiveness.

Figure 5 - Trail Community Lead Task Force Structure



In mid 1991, after work had begun on community education and case management, it became apparent that it would take several more years before the exposure pathways assessment and other environmental groundwork could be completed. At the same time, members of the Task Force and Lead Program staff began to receive feedback that the community wanted something done to improve conditions.

The Task Force felt that some actions which could be taken at relatively low cost should not be delayed. In particular, there was wide support for a program to "green" public areas by planting grass and shrubs. The premise was that covering areas of bare, high-lead soil with vegetation would reduce children's direct contact with the soil and decrease movement of dust by wind. A host of similar projects was considered, including dust control on unpaved alleys, street cleaning and provision of seed and fertilizer to householders. It was recognized, however, that it would be virtually impossible to measure an impact on blood lead due to any one of these projects. The Task Force accepted that such projects would help to educate and involve the community and that they would be evaluated in terms of practicability in Trail, rather than in terms of impact on blood lead.

2. HEALTH EFFECTS OF LOW LEVEL LEAD EXPOSURE

2.1 Exposure, Absorption and Distribution in the Human Body

Children take lead into their bodies primarily through ingestion, and to a lesser extent, through inhalation of fine particles of lead. The amount of lead absorbed into the blood depends on many variables such as; the amount inhaled or ingested (i.e. the exposure); the chemical and physical form of the lead (i.e. the bioavailability); and dietary factors (e.g. the presence of calcium and iron, and fasting) (Saadi et al, 1991). In Trail, young children are exposed to lead particles from various sources including dust, soil, deteriorating paint, and food, with ingestion of interior house dust lead representing the dominant pathway as presented in later Section 3. The behavioural characteristics of the child determine the way in which each child interacts with his or her environment and the amount of lead ingested.

With the exception of occupational environments, ingestion is the major route of lead exposure for both children and adults. In adults, approximately 8-10% of ingested lead is absorbed (US EPA, 1986). Young children may absorb from 40-50% (Ziegler et. al., 1978). Studies have shown that absorption of lead is greatly increased during periods of fasting (Rabinowitz et al., 1980; James et al., 1985), and when intakes of dietary calcium, phosphorus and iron are low (Mahaffey, 1985; Calabrese and Dorsey, 1984; Six and Goyer, 1970).

Absorption of lead from the lung is a function of particle size and pulmonary deposition pattern (Maynard et. al., 1993). Of the very small particles that reach the lowest part of the lungs, a very high proportion is absorbed (Mahaffey, 1991). In adults, the deposition rate is considered to be around 30 - 50 percent (US EPA, 1986a). Theoretical reasoning suggests children probably have a higher retention of inhaled lead than do adults; however, little data is available to support this theory.

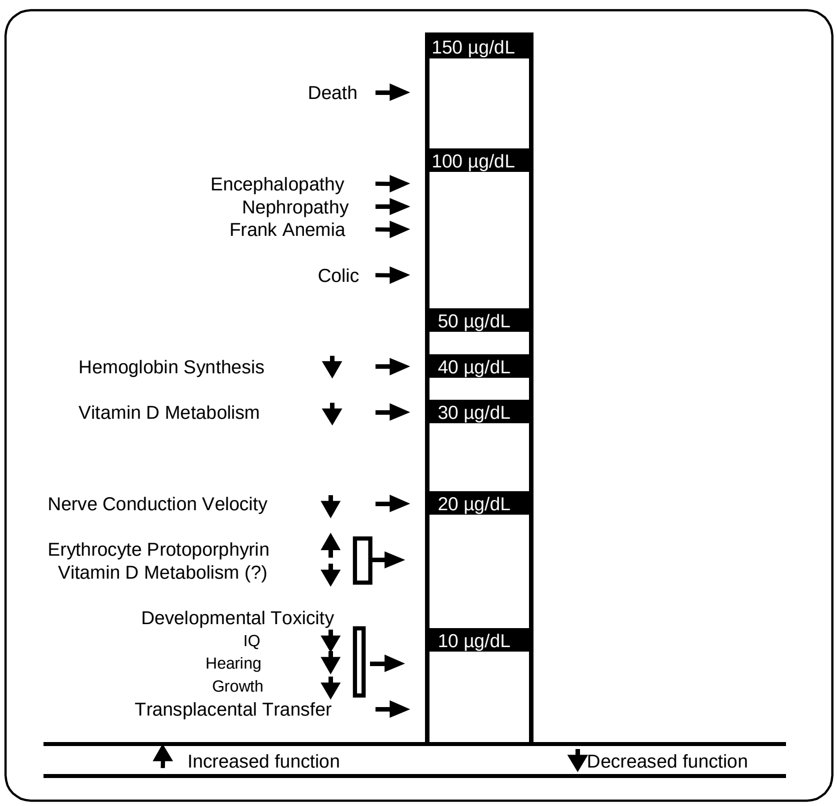
During pregnancy, lead is transferred from the mother to the developing fetus by freely crossing the placenta. There is no apparent maternal-fetal barrier to lead (Goyer, 1990), and it appears that blood lead at birth is approximately 85 - 90% as high as the mother's blood lead concentration (Mahaffey, 1991).

Once absorbed, lead enters the blood stream, where it is then distributed to other tissues and organ systems of the body such as the liver, kidney and bone. Some lead is excreted from the body in urine and feces. Remaining lead may continue to circulate in the blood stream or may be stored in bone and other tissues. The amount of lead stored in the body is known as the body burden of lead. Lead stored in bone tissue is not static, but moves in and out of bone as bone mineral is redeposited and mobilized to meet normal physiological processes, such as growth (Mahaffey,1991), and in response to reductions in lead exposure. Lead appears in several compartments in bone, and these vary in their ability to release lead to the bloodstream (National Academy of Sciences, 1993). Generally, blood lead half-life is highly variable because of such factors as age, metabolic variability, total body burden, and the concentration and duration of exposure.

2.2 Adverse Health Effects

Lead accumulates in human tissues and affects a number of organ systems including the nervous system, blood-forming system and kidneys. Both adults and children are affected by lead. Young children are at greatest risk because their nervous systems are rapidly developing, they have increased exposure through normal hand-to-mouth activity, they ingest and absorb larger amounts of lead per unit body weight and they absorb lead more efficiently (US CDC, 1991). The lowest blood lead levels associated with various observable health effects in exposed children are shown in Figure 6.

Figure 6 - Lowest Observed Effect Levels of Lead in Children



Note : The blood lead levels in this diagram do not necessarily indicate the lowest levels at which lead exerts an effect. These are the levels at which studies have adequately demonstrated an effect. **Source: US CDC, 1991.**

No clearly defined threshold has been found below which deleterious effects of lead are absent. The level of lead exposure recognized as producing an adverse health effect decreases as methodologies for measurement of effects become more sensitive (Provincial/Federal Task Force, 1991 draft).

2.3 Neurologic Effects in Infants and Children

Lead is known to have toxic effects on the human nervous system, especially in children, as they are much more sensitive than adults to the neuropathic effects of lead. Noticeable neurobehavioural signs of acute lead poisoning include irritability, short attention span, restlessness, headaches, muscle tremor and loss of memory, with encephalopathy (brain dysfunction) occurring at blood leads of 80 to 100 µg/dL in children (US CDC, 1991).

The effects on the central nervous system of children are of particular concern because they can occur at lower exposure levels. The history of research on lead has shown a progressive decline in the lowest exposure level at which neurotoxic and other effects can be detected. Thus, attention has been shifted largely to the more subtle effects of chronic low level exposure (ATSDR, 1988).

The concern about adverse effects on central nervous system functioning at blood lead as low as 10 µg/dL is based on a large number of epidemiologic and experimental studies. Over the past 15 years, cross-sectional and prospective studies in many countries have demonstrated associations between lead exposure and child development. The strength of the causal relationship between exposure and development has been the subject of considerable scientific debate. The key question appears to be whether, on a population basis, the observed results provide evidence that children's intake of lead causes deficits in intellectual attainment.

A recent meta-analysis was done to quantify the magnitude of the relation between full scale IQ (intelligence quotient) in children aged five or more and their body burden of lead (Pocock et al., 1994). The authors conducted a systematic review of 26 epidemiological studies since 1979. Overall, the evidence shows a small but potentially important deficit in full scale IQ among children with raised body lead burdens. A typical doubling of body lead burden (from 10 to 20 µg/dL blood lead or from 5 to 10 µg/dL tooth lead) is associated with a average deficit in IQ of around 1 - 2 IQ points. However, the authors point out that uncertainty remains as to the real impact of lead on children's neuropsychological development, due to the inherent limitations of observational epidemiology. That is, an observed association between two measures does not prove that one causes the other. One must also have clinical evidence in order to *prove* cause and effect (e.g. subjects must be fed lead experimentally to prove that lead exposure actually produces IQ deficits).

Animal studies do provide support for a causal relationship between lead and nervous system effects, reporting deficits in thinking functions at blood lead levels as low as 11-15 µg/dL. For example, primates experimentally exposed to sufficient lead to produce a blood lead concentration of 25 µg/dL or less do develop a variety of memory, learning, and attention deficits resembling those observed in humans. These deficits appear to be permanent (National Academy of Sciences, 1993).

2.4 Other Effects of Lead

While the neurotoxic effects of lead on children are the focus of greatest attention, lead also affects many other organ systems. For example, lead causes anemia by interfering with the activity of several of the major enzymes involved in the biosynthesis of heme, and by shortening the life span of red blood cells. This occurs in children at blood lead in excess of 40 µg/dL (US EPA, 1986). Other findings suggest that blood lead levels close to 25 µg/dL are associated with depression of hematocrit in young children (Schwartz et al., 1990). Other effects may begin at blood lead as low as 10 µg/dL, including decreased stature or growth (Bornschein et al., 1986), decreased hearing acuity (Schwartz and Otto, 1987), and decreased ability to maintain a steady posture (Bhattacharya et al., 1988), but these effects require further investigation to fully define their nature and the levels at which they begin to occur.

Neither children nor adults need any lead in their bodies, since it provides no measurable physiological benefit. Since individual children affected by undue lead exposure usually display no symptoms when exposed to lead chronically at low levels, blood lead monitoring is the only means to identify those children at risk for possible adverse health effects.

3. SOURCES AND PATHWAYS OF LEAD EXPOSURE

In order to develop a remedial action plan for reducing children's exposures to environmental lead, it is first necessary to determine the relative importance of the various sources, pathways and routes of exposure which can impact on children.

The term *"sources"* refers to both the originating processes or materials that discharge lead into the environment, as well as to the intermediate storage points for lead in the environment. Examples of originating processes or material are primary lead smelting, lead-based paint, lead plumbing or ceramic glazes. Examples of intermediate environmental storage points are soil, street dust, water and food.

The term *"exposure pathways"* refers to the ways by which lead moves from sources to children, and can include settling of dust particles from the air onto surfaces in the home, transport by track-in of dust from the yard to interior floors, or uptake of dissolved lead from the soil by vegetables.

"Exposure routes" are components of exposure pathways and are the means by which lead actually enters children's bodies. Possible exposure routes consist of ingestion (eating lead contaminated material), inhalation (breathing in particles containing lead) and absorption through the skin. In the case of inorganic lead, absorption through the skin is negligible due to the metal's low solubility.

It is important to know whether children are predominantly exposed to lead by ingestion or inhalation, and whether particular sources and pathways are dominant. Answering these questions will allow remedial action resources to be focused on corrective measures that are most likely to provide the greatest benefit at lowest cost.

3.1 Sources of Lead Exposure (Site Characterization)

This section discusses how lead has moved from the smelter to children’s immediate environments and shows where lead levels are highest in Trail. A separate report (Trail Lead Program, 1995a) provides details of various study protocols and results.

3.1.1 Contaminant Migration

As mentioned in Section 1, most lead contamination reaching the living environments of people in Trail has been transported by air. Airborne contaminants are either removed from the air by precipitation or dispersed by air movement until they fall to the ground.

The deep valley of the Columbia River at Trail provides a channel which influences the dispersion of air emissions from the smelter. In general, winds in the valley bottom are of much lower velocity than the upper level regional winds. Winds in Trail average only about 8 km/h and seldom exceed 30 km/h. Additionally, winds which do occur in the valley are restricted to two main directions (SE and NW).

A wind of about 5 kph will transport 1 µm particles for several kilometres or more, but will not pick up and move dust from the ground. On the other hand, strong winds - which will blow the small particles right out of the valley - can pick up and move larger dust particles from the smelter site and from within the town.

Another important atmospheric phenomenon, in terms of dispersion of contaminants, is the inversion - where air temperature increases with elevation (normally it decreases). An inversion layer (which is very common on clear nights in the Trail area) consists of calm, stable air, which has very limited dispersive capability. During an inversion, many of the small particles emitted from the smelter would remain in the immediate area (in the calm air mass) for long enough to settle out.

The reader should keep in mind a number of points from the preceding discussion:

- Lead contamination resulting from fallout originating from the smelter will decrease with distance from the smelter.
- Dispersion of smelter emissions by wind can occasionally result in high levels of fine lead particles suspended in the air several kilometres from the smelter.
- Measurements of lead in dustfall and in the suspended particulate load of the air should give an indication of the rate of transport and contamination.

Environmental data (measurements of the amount of lead in soil, house dust, dustfall, air, etc.) may be used to determine the mechanisms by which lead arrives in children's environments. Historical data is of great importance in understanding the present situation in Trail. Ideally, one would track the changes in lead levels in the soil, dust and atmosphere through time and correlate such changes with changes in operations or emissions from the smelter. This type of monitoring has been carried out in recent years, but sufficient data was not been collected in the more distant past.

3.1.2 Environmental Standards

In the 1980s, the concept of an "acceptable" level of soil contamination was developed. This was based on the idea that a contaminant of concern (e.g. lead) could be present in the living environment of a population (e.g. the children in Trail) but at such low levels that there would be no impact to that population.

The passage of the Contaminated Sites Regulation under the *Waste Management Amendment Act* on April 1, 1997 marked the first time that acceptable levels of soil contaminants (including lead) have been linked to land use(s) in provincial regulations. If the standards are exceeded the land owner has clear legal obligations: either clean up the site to match the criteria or demonstrate through risk assessment that risk posed by exposure to contaminants at the site is acceptable.

The acceptable standards for the media which are relevant to the Trail Lead Program are presented below.

3.1.3 Soil

Soil lead levels are often regulated through a series of critical levels. If a soil exceeds a critical level, then further investigation or remedial action will be required. Table 3 shows the critical levels and required actions for several areas around the world, with the trigger level for residential land use in BC highlighted.

Table 3 - Trigger Levels for Soil Investigation or Remediation in Various Jurisdictions

Soil Lead Concentration	Required Action	Jurisdiction
375 ppm	remediate to this level or conduct a health risk assessment (agricultural use)	Province of B.C.
400 ppm	screening level for residential or park use - undertake a risk assessment above this	US Environmental Protection Agency
500 ppm	**remediate to this level or conduct a health risk assessment (residential or park use)**	**Province of B.C.**
	provide exposure reduction advice	State of South Austratlia (Port Pirie)
1000 ppm	remediate to this level or conduct risk assessment (commercial or industrial use)	Province of B.C.
2500 ppm	place barrier over soil	State of South Australia (Port Pirie)
10000 ppm	remove & replace top 20 cm of soil	State of South Australia (Port Pirie)
Sources:	Australia: Farrel and Calder, 1988 Province of B.C.: BC Environment, 1995 U.S. Environmental Protection Agency: US EPA, 1994	
Note:	The Australian trigger levels are not as high as they appear. The analytical method used in Port Pirie results in over-estimation of lead concentration by a factor of 2 (Hilts et.al., 1992).	

Soil lead concentration is determined by dissolving a sample and measuring the lead content of the resulting solution. The depth of sampling, sieving of the sample to remove coarse material and the procedure for dissolving the soil can dramatically affect the results of soil testing. Although these procedures vary from site-to-site and from study-to-study, the procedure used in Trail has remained the same from 1989 through present.

A 1977 study in Trail (Schmitt et.al., 1979) found that soil lead levels increased dramatically as one approached the smelter, although the relationship with distance was modified by local topography. The study also compared soil lead levels in Trail with those in Nelson and Vancouver, BC. The results are summarized in Table 4. The table shows that most Trail neighbourhoods (and the high-traffic areas in Vancouver) had soil lead concentrations exceeding the criterion for residential land use in BC (500 ppm).

Table 4 - Soil Lead Levels by Neighourhood, 1977

Neighbourhood	Distance from Smelter (km)	Number of Samples	Median Soil Lead (ppm)
Upper Warfield	> 3.2	13	210
Glenmerry	> 3.2	11	389
Lower Warfield	1.6 - 3.2	13	225
Sunningdale	1.6 - 3.2	19	518
East Trail	1.6 - 3.2	29	1184
West Trail	1.6 - 3.2	11	1772
West Trail	0 -1.6	23	806
West Trail	0 -1.6	12	1215
East Trail	0 -1.6	22	1321
Nelson		55	83
Vancouver (selected high traffic areas)		37	1240

Note: There are multiple listings for East and West Trail because Schmitt et. al. delineated a number of sub-areas which fall within the 2 neighbourhoods.

A 1989 study (Hertzman et. al., 1991) found soil lead levels very similar to those measured in 1977. The geometric mean level in 1977 was 790 ppm, while the geometric mean for the same areas in 1989 was 725 ppm.

In 1990, some Trail soil samples from various depths were subjected to sequential sieving and each resulting fraction was analyzed separately. The results showed that the concentration of lead was highest in the top 2 cm of soil. This concentration of lead near the surface is common at sites where contamination has occurred through aerial deposition. Most lead was found in the fine fractions of the soil, particularly in the samples from deeper in the profile. This was also to be expected, as the smelter emissions particles settling onto soil surfaces are fine and it would be physically difficult for the larger particles to migrate down into the soil profile.

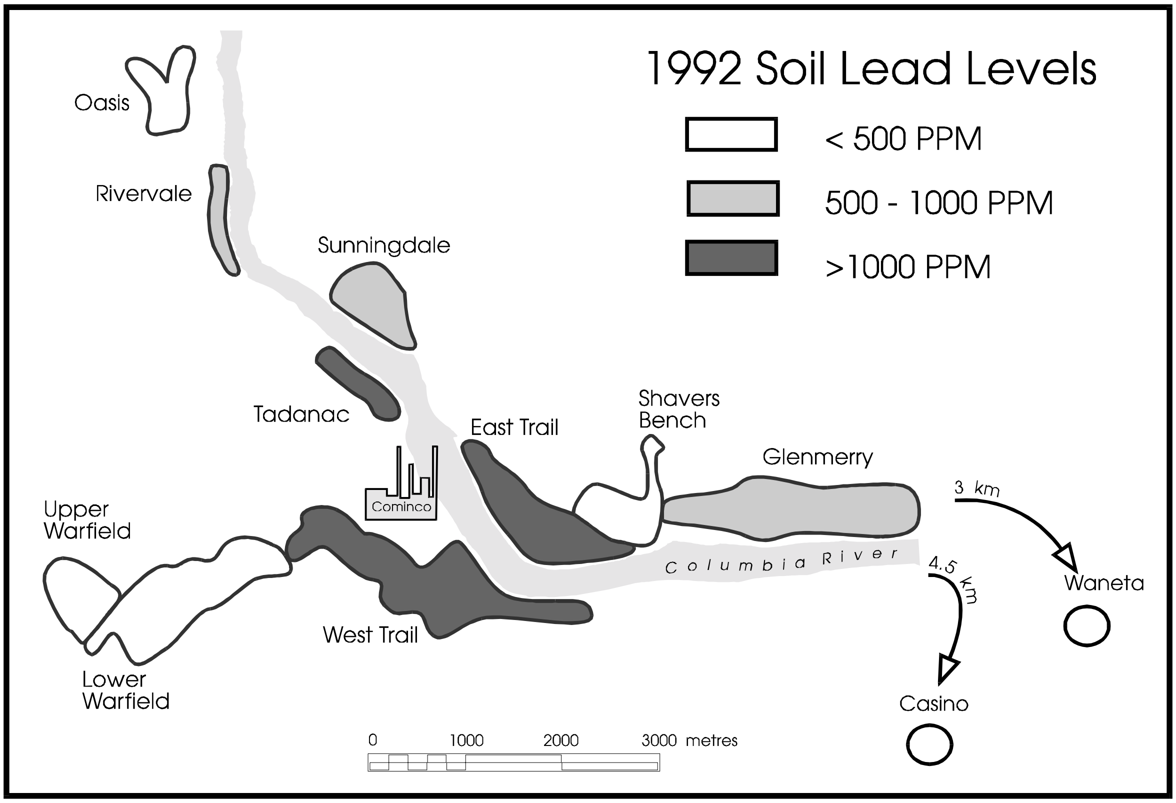
Another fairly comprehensive survey of soils was conducted in 1992, as part of the Exposure Pathways Study (Trail Lead Program, 1995b). This study found that the geometric mean soil lead concentration for the same areas as sampled in the 1977 and 1989 surveys was 713 ppm. As shown in Table 5, the average soil lead level changed little from 1977 to 1992.

Table 5 - Geometric Mean Soil Lead Concentration in Trail: 1977, 1989, 1992

Year	Soil Lead (ppm)
1977	790
1989	725
1992	713

The geographical distribution of soil lead in Trail is shown in Figure 7.

Figure 7 - Soil Lead Concentrations in Trail in 1992



3.1.4 Drinking Water

Most lead in domestic water is derived from the plumbing in the house or from old water distribution system pipes. Lead may be dissolved from the lead in solder, or from lead in the pipes themselves. Hence, "worst case" water samples would be collected after the water has been standing in the plumbing system overnight.

The acceptable standard for drinking water in Canada is 10 µg/L (Health Canada, 1992). This standard applies to water drawn from taps that have been "flushed" for several minutes to remove standing water from the plumbing system. The acceptable standard for water in the USA is 15 μg/L. This standard applies to water which has been standing in the plumbing system.

Lead levels in "first-pull" tap water in Trail were sampled in the 1989 study (Hertzman et. al., 1991). At that time, the municipal water supply in Trail was drawn from both groundwater and surface water. 98% of the 145 samples tested were below the US EPA guideline for "first-pull" water. There was no tendency for children with elevated blood lead levels to have higher lead levels in their tap water. Therefore, drinking water is not considered to be a significant source of lead exposure in Trail.

3.1.5 Paint

The US "action" levels used by Housing and Urban Development are 5000 ppm (0.5% by weight) or 1.0 mg/cm^2. In Canada, new paint for residential use cannot contain more than 5000 ppm lead (*Hazardous Products Act*, 1976). However, most paint manufacturers do not use any lead in their products anymore.

In 1992, 69 samples of flaking paint were analyzed as part of the Exposure Pathways Study (Trail Lead Program, 1995b). The geometric mean lead concentration in paint samples was 3569 ppm and the range was 100 to 93,000 ppm. It is important to remember that paint samples were only collected from peeling or flaking surfaces, so the sampling was biased toward older paints. In fact, 41 of the 69 samples were collected in the older neighbourhoods of East and West Trail.

The 1989 Trail Lead Study (Hertzman et. al., 1991) examined the lead-in-paint issue and did not find any relationship between elevated blood lead in children and lead in paint in their homes. The 1992 Exposure Pathways Study also concluded that the lead content and condition of paint had no significant independent effect on children's blood lead levels. Although paint is not a significant contributor to blood lead levels on a community-wide basis, deteriorating lead-based paint can no doubt be a factor in individual cases.

3.1.6 House Dust

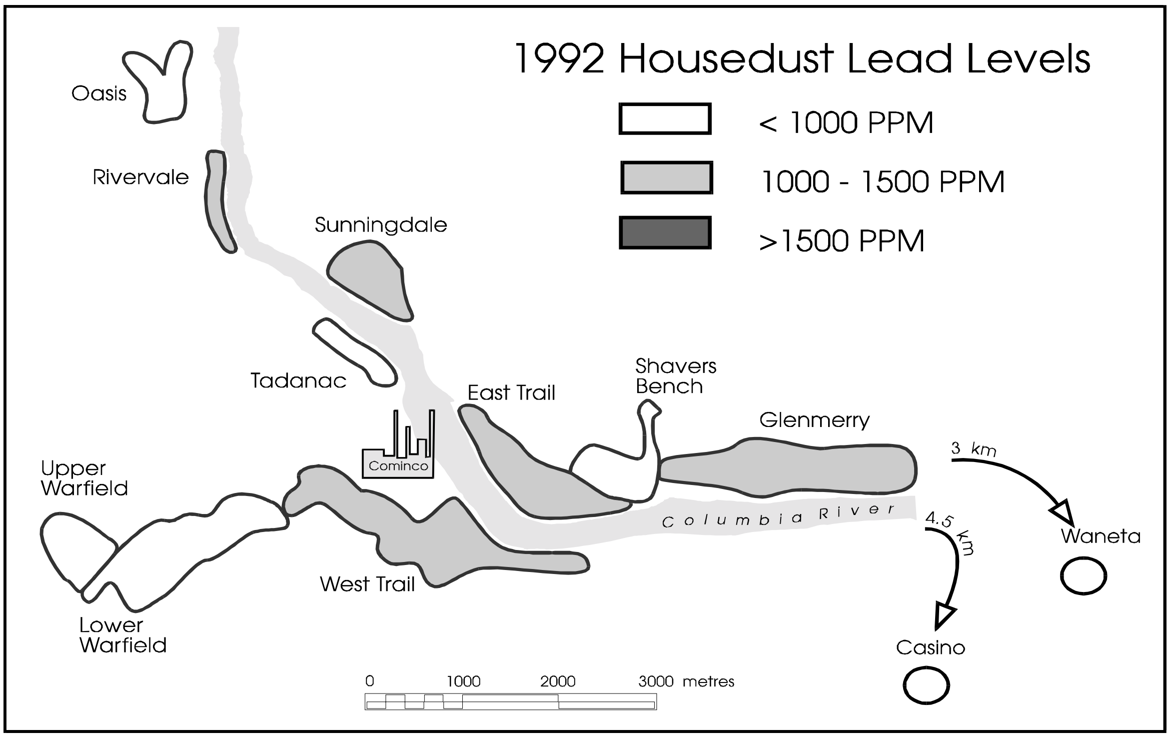
House dust samples were collected in Trail from 1989 to 2000, using the "microvac" method (Que Hee et.al., 1985). A personal air monitoring pump was used to collect dust onto a 0.8 μm filter in a plastic cassette. The method provided reliable measurements of lead loading (mg/m^2), but concentration results (ppm) were sometimes unreliable.

There are no established standards for house dust in Canada. The clearance standards (following in-home lead paint remediation) used by the US Housing and Urban Development are 200 $\mu g/ft^2$ (~ 2.0 mg/m^2) for floors, 500 $\mu g/ft^2$ for windowsills and 800 $\mu g/ft^2$ for window wells. However, these action levels will likely be lowered soon.

The 1989 Trail Lead Study (Hertzman et.al., 1991) measured only the lead concentrations in house dust, not loadings. The geometric mean lead concentration in floor dust was 2509 ppm. In 1992, the geometric mean lead concentration measured in floor dust was only 963 ppm. This result is more credible than the 1989 average, as it would result in a soil/dust lead concentration ratio of about 0.75, which is similar to ratios determined for other sites with active sources of lead deposition (U.S. EPA, 1994). The average floor dust lead loading in 1992 was 0.31 mg/m², lower than the current HUD action level. The geographical distribution of lead in house dust is shown in Figure 8.

Floor dust samples collected inside entryways of homes in 1992 showed that lead loadings at entrances averaged six times higher than those within the house interiors. This suggests that track-in is an important mechanism for lead transfer into houses.

Figure 8 - House Dust Lead Concentrations in Trail in 1992



3.1.7 Air

The environmental objectives for total suspended particulate, suspended particulate lead and dustfall published in the *Pollution Control Objectives for the Mining, Smelting and Related Industries of British Columbia, 1979* are presented in Table 6.

Table 6 - BC Air Quality Objectives

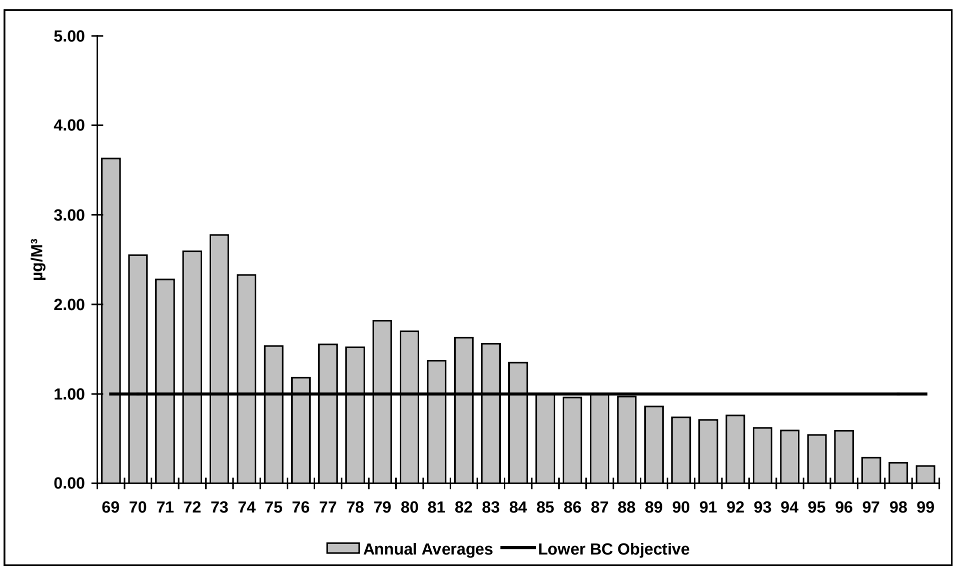
Parameter	Objective Range			
Total Dustfall	170	-	290	mg/m²/day
Lead in Suspended Particulate (annual geometric mean)	1.0	-	2.5	µg/m³
Total Suspended Particulate				
Annual geometric mean	60	-	70	µg/m³
24-hour concentration	150	-	200	µg/m³

Since 1985, annual geometric mean levels of lead in suspended particulate measured at four stations (Warfield, Glenmerry, Oasis and downtown Trail) have been below the lower objective level, as shown in Figure 9. Annual geometric mean total particulate has also been consistently below the lower objective level. Since 1997, air lead levels have been below the 1999 World Health Organization guideline of 0.5 µg/m^3.

There is considerable evidence from air monitoring data that the source of present day movement of lead about the community is primarily current losses from the smelter site, rather than re-entrainment of historically-deposited emissions:

- Analysis of one year of BC Environment's air lead and wind data by the Trail Lead Program revealed that the amount of lead suspended in the air was nearly

Figure 9 - Annual Geometric Mean Air Lead Level at Four Stations in Trail Area

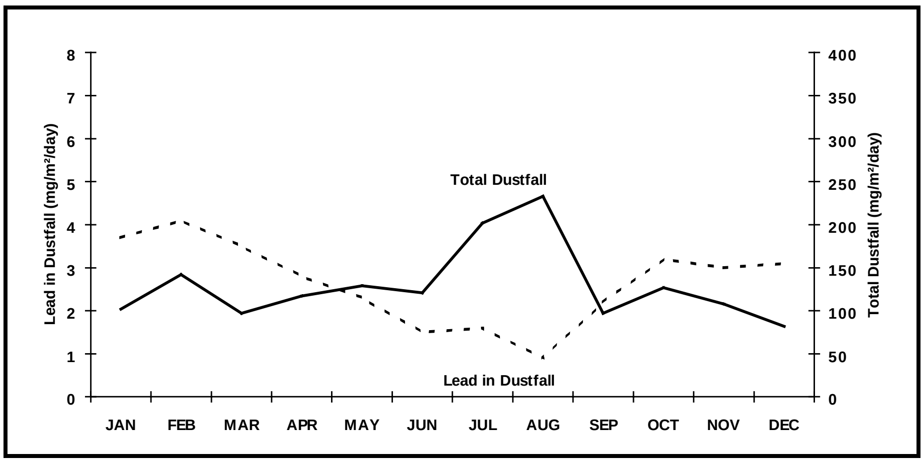


four times higher on days when the wind was blowing predominantly from the smelter toward the air sampling station than when the wind was away from the smelter.

- There is a clear seasonal trend in the dustfall data gathered at stations throughout the Trail area. Figure 10 illustrates that total dustfall increases in summer months when the ground is bare and the weather is dry. However, the amount of lead in dustfall is highest in winter months when emission dispersion conditions are poor.

- Air monitoring data from 1993 showed dramatic declines in air lead and dustfall lead during a one month shutdown of the smelter in April. Areas near the smelter experienced the greatest decreases, with both air lead and dustfall

Figure 10 - Monthly Average Dustfall at Butler Park, 1975-1987



lead dropping by 80-90%.

- Lead concentrations in dustfall are generally very high (> 10,000 ppm) - higher than the lead concentration in even the very fine fraction of soil. Therefore, soil cannot be the main contributor to lead in dustfall.

3.1.8 Vegetables and Fruits

The allowable lead content of fruit and vegetable products in Canada (*Food and Drug Act*: Regulation 15, revised 14-2-1991) is given in Table 7. It is interesting that the regulations specify certain food items without stating a universal level. In some cases, the standards are higher because people typically consume small quantities of the food type (e.g. herbs and spices), while in other cases the standard is higher due to historical use of lead arsenate pesticides (e.g. apple juice versus other juices).

Table 7 - Canadian Lead in Produce Standards

Produce Type	Maximum Lead Level (ppm)
Fresh fruits	7
Fresh vegetables	2
Dried herbs and spices	10
Apple juice, cider, beer	0.5
Fruit juices except apple juice	0.2

The lead content of vegetables grown in the Trail area was measured for many years. Cominco Ltd. found that most cases of high lead values in produce were related to inadequate washing of soil/dust from the external surfaces of the produce (Trail Lead Program, 1995a - Appendix F). Washing of vegetables (particularly leafy ones) was found to result in significant reductions in lead results. Locally grown produce generally had slightly higher levels than did commercially purchased produce.

As part of the 1992 Exposure Pathways Study (Trail Lead Program, 1995b), samples of local produce were prepared according to the families' usual methods (e.g. washing, peeling) and analyzed for lead. Results are presented by produce type in Table 8.

Table 8 - Lead Concentrations (ppm) in Vegetable Samples from Trail, 1992

Vegetable Type	Number of Samples	Geometric Mean	Minimum	Maximum
Root crops	38	0.5	0.0	2.4
Near ground crops	11	0.9	0.0	2.9
Swiss chard & lettuce	4	2.2	0.3	2.9
Excl. swiss chard &lettuce	7	0.1	0.0	0.3
Above ground crops	39	0.2	0.0	0.9

Note: Root crops include carrots, potatoes, beets, garlic.
Near ground crops include swiss chard, lettuce, cucumber, strawberries
Above ground crops include apples, apricots, peaches, oregon grape, grape, tomatoes

3.1.9 Other Metals

The mandate of the Task Force was to address lead and its impact on young children. As noted earlier, lead is transported through Trail as particulate emissions from various activities at the smelter. Given the source, it is no surprise that other components of the concentrates processed in the smelter (e.g. zinc, cadmium, arsenic) are found in close conjunction with lead in the environment (Kelly et. al., 1994). It follows that actions taken to reduce mobile lead in the environment will also reduce the levels of other metals. However, the other contaminants may impact on different segments of the population and the relative importance of exposure routes may vary from one metal to another.

From 1997 to 2000, the Task Force evaluated in detail the human health risk posed by other metals. The health risk assessment for other metals is summarized in section 5 of this report.

3.2 Pathways of Lead Exposure

In 1989, the Department of Health Care and Epidemiology at the University of British Columbia conducted a lead exposure study in Trail (Hertzman et. al., 1991). The purpose of the study was to determine the blood lead levels in young children in Trail and to identify environmental and social factors that were associated with elevated blood lead levels. Due to funding constraints, the 1989 study involved environmental sampling only at homes of children who were in the upper or lower quartiles of the blood lead distribution.

In a review of the Trail Lead Program's proposed operating plan (Clark and Bornschein, 1991), it was recommended that an exposure study involving subjects from across the full spectrum of blood leads be conducted. It was suggested that such a study would allow development of a more statistically robust, and hence reliable, "exposure pathway model". This section summarizes the procedures followed in the Exposure Pathways Investigations in 1992, presents a statistically-based model of exposure pathways in Trail and reviews the conclusions of the study. The separate study report (Trail Lead Program, 1995b) provides complete details of study protocols and results, and also includes a separate assessment of the importance of the inhalation exposure route based on air monitoring in young children’s personal breathing spaces.

3.2.1 Sampling and Analytical Methods

Blood samples were obtained by venipuncture at the Trail Lead Program Office between August 31 and October 9, 1992. Questionnaires relating to potential lead exposure risk factors were also administered at the time of blood drawing.

Environmental samples were collected between August 4 and October 26, 1992. Floor dust samples were collected from three or more carpeted areas using the "microvac" method, which employs personal air monitoring samplers as described in Que Hee et. al. (1985). Separate samples of floor dust were collected from:

- a high traffic carpet inside the main entry,
- a carpeted area where the children played regularly (often the living room)
- a carpeted area on each child's bedroom floor

The microvac was also used to collect a composite sample of windowsill dust from:

- the kitchen windowsill closest to the food preparation area
- any child-accessible bedroom windows
- any child-accessible playroom windows

Floor dust samples were collected from a standard sized area, so the results provided both loadings and concentrations. Windowsill dust was not collected from a standard area, so only concentration data were obtained.

Soil samples were collected from 2-3 areas of exposed soil where children played. Each soil sample was a composite of 5 points within a 1 metre diameter circle (where possible). A steel spatula was used to collect soil from the top 2-3 centimetres only.

Exterior dust samples were collected using a soft bristle brush to gather dust from :

- the street curb in front of the house
- the stairs, landing or walkway outside the main entry

This method provided only concentration data. A subjective visual assessment of the amount of dust on the street was recorded on the sample documentation sheet to complement the sample data.

Paint chip samples were removed from 2 cm by 2 cm areas using a new steel scalpel blade. Only chipping/peeling surfaces were sampled, and only with the householders' permission. Each peeling surface painted with a different colour was sampled.

At each home where a child ate home-grown produce, a large sample of one vegetable that the child ate was collected in a zip-loc bag. The samples were dehydrated and blended before analysis.

Dustfall samples were collected in plastic jars placed in the open for one month. The jars were half-filled with double-distilled water to trap settled dust particles. Ethylene glycol was used instead of water in winter to prevent freezing. Dustfall was collected at only 23 sites throughout the study area, not one per property. In the data analysis, each property was associated with the nearest dustfall jar.

3.2.2 Recruitment

Recruitment of participants was performed on a random-stratified basis. First, families with a child up to 72 months of age scheduled to participate in the 1992 annual blood lead clinic were stratified by neighbourhood. The target number of families was 200, which would provide good statistical power at an affordable cost. Recruitment targets for each neighbourhood were set in proportion to the percentage of families living in each neighbourhood. Families were then called randomly (progressing through lists sorted alphabetically) until the target for each neighbourhood was reached, if possible. It was not possible to recruit the desired number of families in all neighbourhoods. In total, 174 properties received environmental sampling. 241 children living on these properties had samples drawn at the blood testing clinic.

3.2.3 Quality Assurance Program

Quality assurance procedures included the use of double entry of sample tracking data, electronic transfer of lab results, blind field blanks, blind field splits, laboratory splits, blind standard reference materials and blind local reference materials.

The results of the quality assurance program indicated that environmental sampling procedures, equipment and reagents did not introduce contamination and that analytical precision was acceptable. A problem with precision and accuracy of the house dust reference material concentrations may have been due to use of insufficient masses of reference material.

The results of the rigorous quality control sampling for the blood lead monitoring provided assurance that the blood lead results were both accurate and precise.

3.2.4 Data Analysis Procedures

The final data set for exposure pathway modelling consisted of arithmetic mean values for each environmental sample type for each child. That is, each record in the data set consisted of blood lead, age and questionnaire data for one child, plus average values for lead in soil, house dust, exterior dust, paint and vegetables for his/her property.

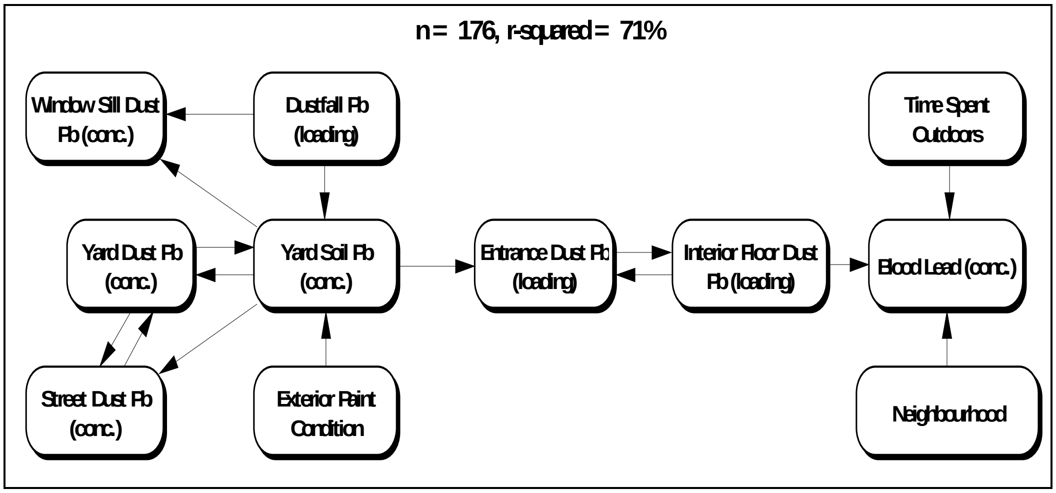
Data analyses were generally performed on log-transformed data, as the raw data were log-normally distributed. Statistical techniques used (e.g. correlation analysis, analysis of variance, multiple regression and structural equations modelling) are described in the full report (Trail Lead Program, 1995b). Statistical analyses were performed by the University of Cincinnati.

3.2.5 Results and Discussion

All analyses strongly indicated that interior house dust lead was the dominant source of lead exposure for Trail children. This finding is consistent with similar studies at other sites. Of six other studies which measured floor dust lead loadings, five found floor dust to be the strongest predictor of blood lead (Rabinowitz et.al., 1985; Bornschein et. al., 1986; Bornschein et. al., 1988; Butte-Silver Bow Hlth. Dept. and Univ. of Cincinnati, 1990; ATSDR, 1994) and only one found soil to be dominant (Univ. of Cincinnati, 1990).

The structural equations pathway model (Figure 11) suggested that lead in dustfall, exterior dusts and soil is transported into houses, where it becomes available for ingestion by children while they are indoors. The model implies that children are only indirectly exposed to lead in outdoor sources through this transport into house dust. However, children who spend time outdoors must also be directly exposed to outdoor lead sources, as the amount of time spent outdoors daily was also a significant contributor to blood lead level.

Figure 11 - Exposure Pathways Model for Trail



The relative importance of indoor versus outdoor exposure appears to vary with age, as shown in Table 9. For children less than 18 months of age, interior house dust was by far the most significant source of lead exposure. For children 18 months of age or older, current blood lead level was determined mostly by prior blood lead level. Time spent outdoors daily and yard soil lead concentration were also significant predictors of blood lead in children aged 18-35 months, which suggests that continued exposure at that age occurs mainly outdoors.

Interior or exterior paint in poor condition appeared to be associated with higher blood lead levels when examining the entire data set. However, when the data were re-analyzed by geographic area, the apparent effect of paint condition appeared to be mostly due to confounding with proximity to the smelter. (Most homes with paint in poor condition were located in the areas closest to the smelter.)

There was no difference in blood lead levels between children whose parents worked in a lead industry and those who did not. Nor was there any difference in blood lead levels between children who ate home grown vegetables and those who did not. The absence of any effect of vegetable consumption on blood lead is consistent with findings in East Helena, Leadville, Midvale, Butte, and Silver Valley (Lewis & Clark County Hlth. Dept. et. al., 1983; Colorado Dept. of Htlh. et. al., 1989; Univ. of Cincinnati, 1990; Butte-Silver Bow Hlth. Dept. & Univ. of Cincinnati, 1990; Panhandle Dist. Hlth. Dept., 1986).

Table 9 - Multiple Regression Models by Age Range

Variable Added to Forward Stepwise Regression Model[1] **(dependent variable = ln(current blood lead)) (independent variables = ln(floor lead loading), ln(soil lead concentration), time outdoors daily, ln(prior blood lead))**	**Multiple Correlation Coefficient**[2] **(r)**	**Probability that Contribution of Variable is due to Chance**
Age 4-17 months		
ln(floor lead loading)	0.66	<0.0001
Age 18-35 months		
ln(prior (1991) blood lead)	0.75	<0.0001
time outdoors daily	0.79	0.02
ln(soil lead conc.)	0.81	0.02
Age 36-53 months		
ln(prior (1991) blood lead)	0.92	<0.0001
Age 54-73 months		
ln(prior (1991) blood lead)	0.81	<0.0001

[1] In forward stepwise multiple regression, independent variables are added to the model if their contributions to the variance of dependent variable are significant. The first variable selected is always that which has the strongest simple correlation with the dependent variable.

[2] The multiple correlation coefficient (MCC) is a measure of the ability of the independent variables to predict the value of the dependent variable. When more than one independent variable is added to the model the MCC increases each time a variable is added. Independent variables which make the largest contributions to the MCC are those which most consistently affect the dependent variable.

Blood lead levels of children who live nearest the smelter (Area 3: Tadanac, West Trail, East Trail and Rivervale) tended to be higher if they spent more time outdoors and engaged in behaviours which indicate obvious ingestion of soil/dust (i.e. chewing their fingernails, putting dirt in their mouths). In contrast, blood lead levels of children who lived in the areas most distant from the smelter (Area 1: Casino, Oasis, Waneta, Warfield) were not significantly affected by soil lead concentration, mouthing of dirt, chewing of fingernails or time spent outdoors. A study in the active lead mining community of Broken Hill, Australia also found that in areas where the soil lead level was less than 600 ppm, the blood lead of children who ate dirt occasionally or often was not significantly different from blood leads of those who never ate dirt (NSW Hlth. Dept., 1994).

Children who lived on properties with a higher percentage of bare soil tended to have higher blood lead levels. A higher percentage of bare soil in the yard was also associated with higher floor dust lead loadings, even after adjusting for possible confounding by neighbourhood. This association was also observed in Broken Hill. In Silver Valley, Idaho and Leadville, Colorado, children who played on grassy surfaces tended to have lower blood lead levels than those who played on bare soil (Panhandle Dist. Hlth. Dept., 1986; Cook et. al., 1993).

Children tended to have higher blood lead levels if their parents smoked cigarettes or if they had a dog or cat as an indoor/outdoor pet. Both of these associations persist within neighbourhoods, suggesting that the effect was not due to confounding with proximity to the smelter or socioeconomic status. These associations have also been observed at numerous other sites.

The structural equations model of exposure pathways was used to calculate new equilibrium conditions that would eventually result from changes, given the statistical relationships observed for present conditions. For example, the model indicated that a 75% reduction in dustfall lead would eventually result in a mean soil lead of 216 ppm and a mean blood lead of 8 µg/dL in East and West Trail. However, the model can not estimate how long it would take for a change in one variable to effect changes in others and it is known from measurements near abandoned mining sites that lead contamination can persist in soils for centuries. [We now know that a reduction of dustfall lead on the order of 50% already appears to have resulted in mean blood lead levels of less than 8 µg/dL in East and West Trail. However, soil lead concentrations have not yet changed as a result of the reduced dustfall input.]

For a child in Trail with an average blood lead level, (about 6 µg/dL), approximately 2% (0.1 µg/dL) of his/her blood lead is due to inhalation of airborne lead and 98% is due to ingestion of lead in dust, soil, diet and drinking water. For children with higher blood lead levels, the proportionate contribution of inhalation is even less, as inhalational lead exposure is fairly uniform from one child to another.

The Exposure Pathways Investigations report (Trail Lead Program, 1995b) made the following recommendations:

- continue to reinforce good hygiene, house cleaning, use of walk-off mats, removal of shoes at entrances and ground cover maintenance through community education and individual family counselling/assistance.
- consider providing regular house cleaning services, particularly in homes of children under 18 months of age. *(This was subsequently implemented on a case-specific basis as a result of several later studies on house-cleaning.)*
- continue to reduce children's direct and indirect contact with soil and exterior dust through community greening, dust control, street cleaning and smelter emissions reductions.
- conduct further investigations to determine the sources and mechanisms of lead particle transfer into houses.

- conduct investigations and literature review to determine how quickly and to what extent blood lead would respond to changes in dustfall lead.

3.3 Historical Versus Current Emissions

The exposure pathways report (Trail Lead Program, 1995b) identified house dust as the major source of lead to which children are exposed, particularly children less than 18 months of age. We also found, in the HEPA House Cleaning Study (Hilts et al, 1995), that the floors of houses re-contaminated with lead quite quickly after they were cleaned. In order to be able to evaluate the potential effectiveness of various ways of reducing lead in dust, we need to know something about the source of lead in dust and about mechanisms for lead transfer into houses.

Most importantly, we need to know:

- Does the lead mainly arrive in a child's indoor environment shortly after emission from the smelter? If so, smelter emission reductions will help tremendously in addressing the dust ingestion pathway.

- Or, does the indoor lead come mainly from re-mobilization of particles which were deposited in the Trail area many years ago? If so, then it is most important to address historic deposition through greening, soil removal or treatment, and/or by stopping the movement of lead from soil into houses.

Information presented in Section 3.1 suggests that lead settling onto the ground is derived primarily from current smelter emissions. The evidence for this is that when suspended particulate lead levels are high, the wind is generally from the smelter site and that when the smelter is not operating, suspended particulate lead and lead in dustfall drop dramatically. Also, the lead concentration in dustfall is much higher than that in even the very finest fraction of the soil, so it is not likely that soil is a primary source of lead in dustfall. If soil were the source, then the concentration of lead in the dustfall should be no higher than the concentration of lead in the fine soil fraction.

Therefore, we are able to conclude that air transport of re-entrained historical deposits is not nearly as important as air transport of current emissions. However, track-in of historical deposits from areas of bare soil into houses may still be a significant contributor to indoor house dust lead, which leads to another important question:

Is lead dust transferred into houses mostly by track-in on shoes, or by settling of particles from air that has entered the house?

If the dominant transfer mechanism is track-in, then measures such as walk-off mats at entrances, removal of shoes at entrances, ground cover improvement and cleaning of surfaces in the yard should help reduce indoor dust lead loadings. If, on the other hand, settling from air is more important, then further emission improvements will be needed in addition to ground cover and dust control, before contamination rates can be reduced.

Data collected in the Exposure Pathways Study showed that lead loadings on mats or carpets insides entrances were on average about seven times higher than lead loadings on carpets within the interiors of houses. The HEPA vacuuming study showed that homes where shoes were removed at the door had lower floor dust lead loadings. Results from the Sentinel Homes program showed that floor dust lead loadings were significantly lower in homes where walk-off mats were used at all entrances. Also, the lead loadings on new mats provided to Sentinel Homes were about six times higher than loadings on interior carpets after only 3 months of use. A study by Roberts et. al. (1991) also found that floor dust lead loadings were lower in homes which used walk-off mats and in which shoes were removed at the door.

Early data from the Sentinel Homes program (1994-95), prior to start-up of the new lead smelter, showed that the rate of settling of lead particles from indoor air was about 0.28 mg/m^2/month, while the rate of contamination of the new entrance mats was about 1.1 mg/m^2/month. It is not known how much of the indoor lead from settling is actually new lead from outdoors, versus recirculated lead already in the house.

All of the above information suggests that track-in is an important mechanism for transfer of lead into houses, and that the rate of track-in may be at least 4 times that of settling from air. Therefore, it seems that the use of walk-off mats, removal of shoes at the door and yard maintenance should be beneficial and should continue to be strongly encouraged. This work has not been repeated since start-up of the new lead smelter. However, it seems likely that track-in would be a proportionately more important dust transfer mechanism now that air lead levels have been reduced.

Very preliminary work was conducted by Cominco Research in 1995 to see if the source of lead in house dust could be determined by examination of house dust, soil and emission samples by scanning electron microscopy. Lead-containing particles in one house dust sample could not be related to any of the four stack emission sources sampled. On the other hand, the elemental composition of lead-containing particles in the house dust sample was similar to those in two soil samples.

3.4 Evidence of Improved Environmental Conditions since 1997

In 1994, a Sentinel Homes Project was started. The primary objective of this project was to measure changes in environmental conditions resulting from smelter emissions reductions and other lead remediation efforts.

Environmental data were collected quarterly from a network of 32 homes at consistent locations. Samples of carpet surface dust and indoor dustfall were collected at each home during each quarter. Street dust was sampled during snow-free quarters. Outdoor dustfall was collected monthly at each home, or at a location within one block of each Sentinel Home.

In 1995, we also began collecting soil and HEPA vacuum bag samples during the 3rd quarter of each year.

The new lead smelter commenced operation in April 1997. Therefore, the floor and street dust samples collected in June 1997, and the indoor and outdoor dustfall samples from June-Sept 1997, were the first samples from the post-new-smelter era of dramatically reduced smelter emissions. However, the start-up of the new smelter was a complicated process, and it did not operate smoothly at full design capacity until January, 1999.

Figure 12 shows that the average outdoor dustfall lead loading fell by about 50% (61 to 28 mg/m^2/month) from "before new smelter" to "after new smelter".

Figure 12 - Outdoor Dustfall Lead Before/After New Lead Smelter

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Figure 13 - Outdoor Dustfall Lead Loading by Geographic Area

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Figure 13 shows that the improvement in outdoor dustfall lead loading was most noticeable in the areas closer to the smelter (areas 2 and 3). This suggests that the smelter emission reductions might have occurred mostly in the larger sized particles, which used to settle out relatively close to the smelter.

Figure 14 - Street Dust Lead Loadings Before/After New Smelter

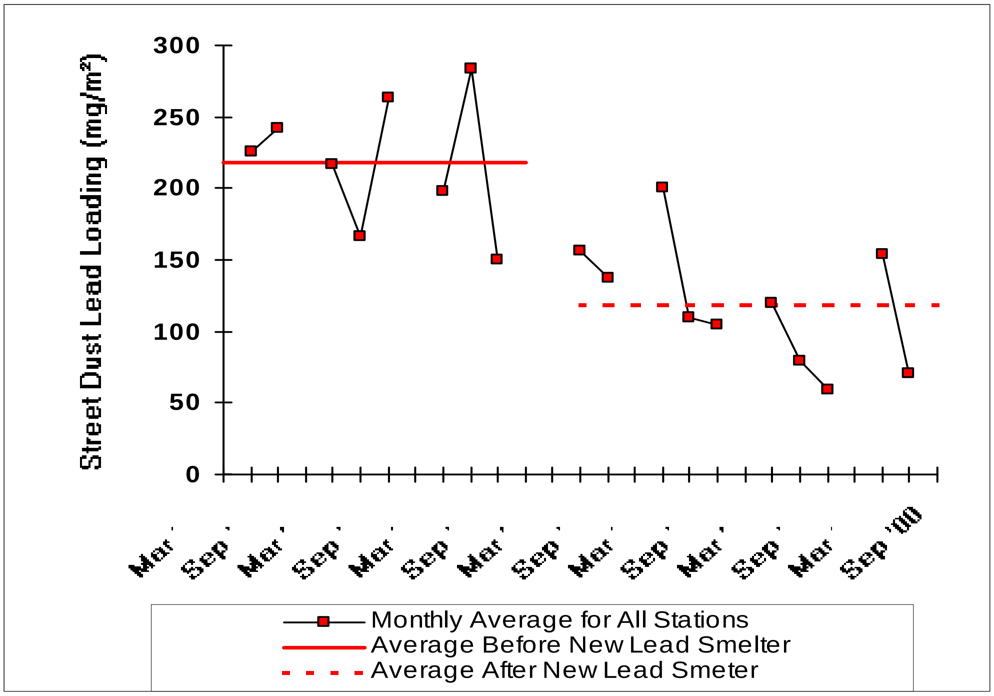
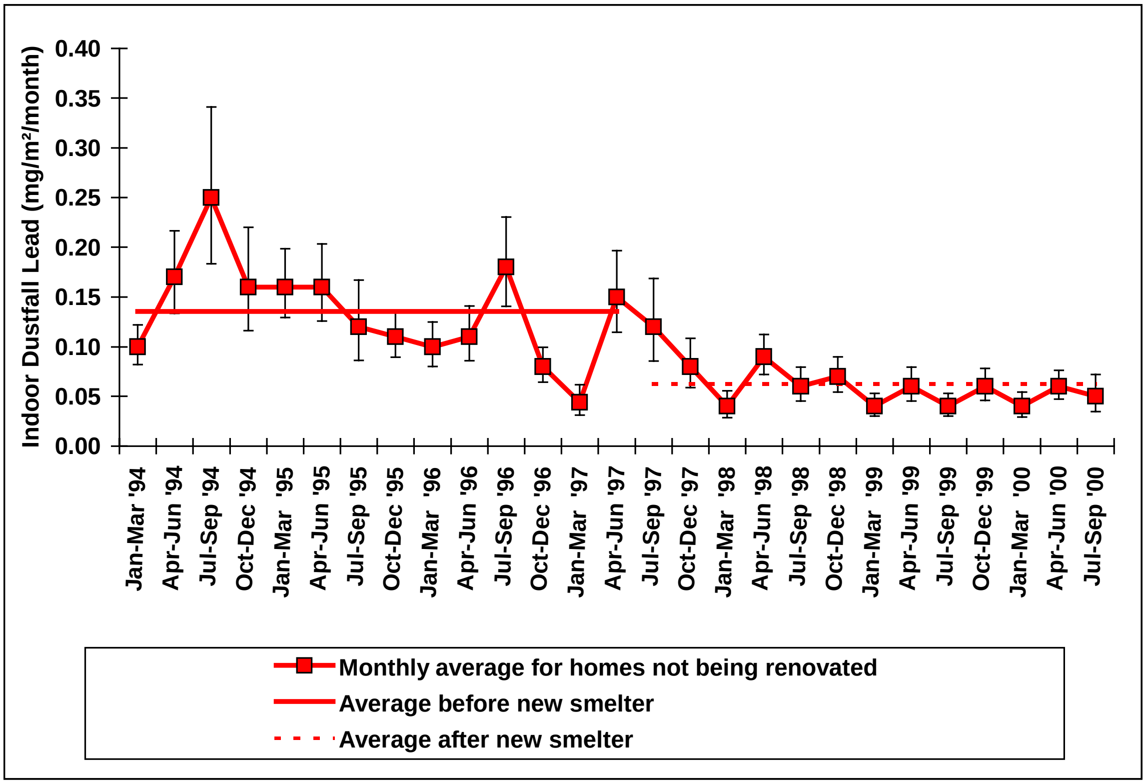


Figure 14 shows that average street dust lead *loadings* also declined by nearly 50% (218 to 119 mg/m²) since the new smelter went into operation. As with outdoor dustfall, the greatest reductions occurred in areas nearest the smelter. Average Street dust lead *concentrations* declined by about 20% (1123 to 888 part per million).

Indoor dustfall lead loadings also declined by about 50% (0.14 to 0.06 mg/m²/month) since the new smelter was started up, as shown in Figure 15. The error bars (upper and lower 95% confidence limits for the means) show that the variability between stations during any sampling period was much lower after the new lead smelter started up. This reflects that fact that indoor dustfall lead levels for stations nearest the smelter declined substantially, so that results from later years were uniformly lower across the entire sampling area.

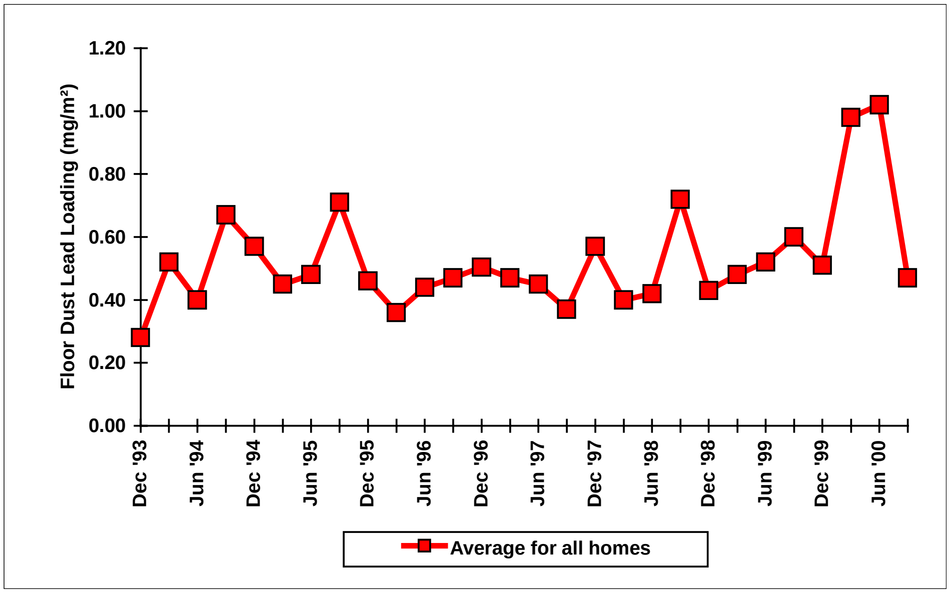
Figure 15 - Indoor Dustfall Lead Loading Before/After New Smelter



Unfortunately, the average lead loading on carpets in the Sentinel Homes did not show any improvement since the new smelter started up, as shown in Figure 16. Even when the carpet dust results were examined by geographic area, no improvement was apparent in any of the three areas. Overall, the trend from 1994-2000 seems to be toward increasing carpet dust lead loadings.

Since carpet dust lead loadings are likely quite dependent on the residents' housekeeping efforts, it is possible that a change in housekeeping practices was responsible for the slight increasing trend. Many of the Sentinel Homes participants had young children at the start of the program, but later most of their children had passed the age of greatest concern for lead exposure. Also, participants have become much more comfortable with the quarterly sampling visits to their homes. Therefore, it is possible that their parents might have become less concerned about maintaining very low dust levels during the later years of this program. Alternatively, it's possible that any carpet will show increased lead loading over time, due to constant accumulation at a rate that exceeds removal by vacuuming.

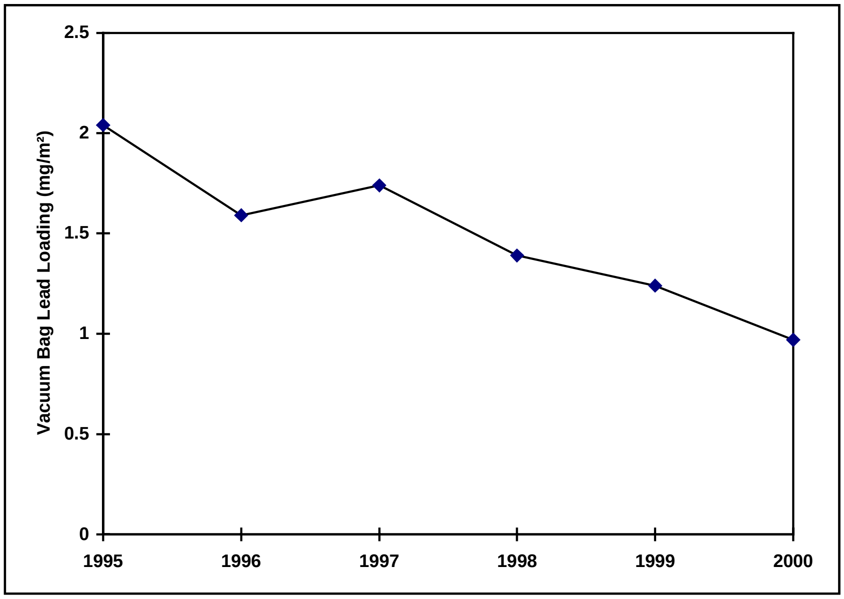
Figure 16 - Carpet Dust Lead Loading (by Microvac Method)



When the Sentinel Homes project was started, we chose to measure carpet lead *loadings* only, using the "microvac" sampling method, since the method was easy to use and loadings were better correlated with individual blood lead levels than were concentrations. In 1995, we also began collecting floor dust samples using the "whole-house" HEPA vacuum method during September of each year. This method gives reliable measurements of loadings and concentrations, but it is much more intrusive. Not all participants allowed us to collect these "whole-house" samples each year. Only 8 homes were sampled using this method in each of the years from 1995 to 2000.

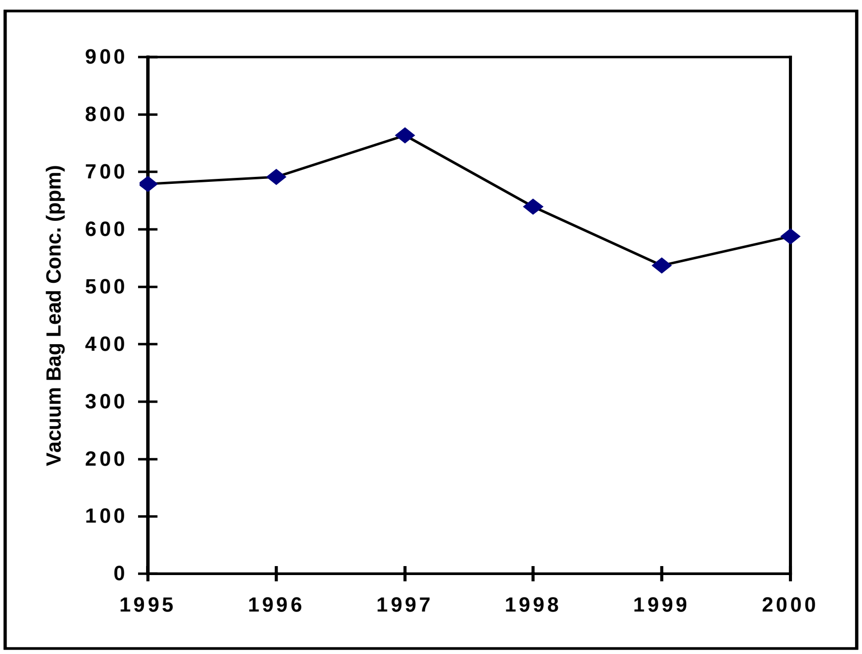
Figure 17 shows that the average lead loading measured by HEPA vacuum sampling at 8 homes declined from 1995 to 2000. However, the number of homes sampled was very small, so the difference between the 1995-96 mean (1.80 mg/m²) and the 2000 mean (0.97 mg/m²) was not statistically significant (P value for paired t-test = 0.15).

Figure 17 - Floor Dust Lead Loadings by Whole-House HEPA Vac



Average floor dust lead concentrations also declined slightly in the 8 homes which were sampled by the HEPA vac method, as shown in Figure 18. The change in mean lead concentration from 1995-96 (758 ppm) to 2000 (583 ppm) was of borderline statistical significance, despite the small number of homes sampled (P value for paired t-test = 0.08).

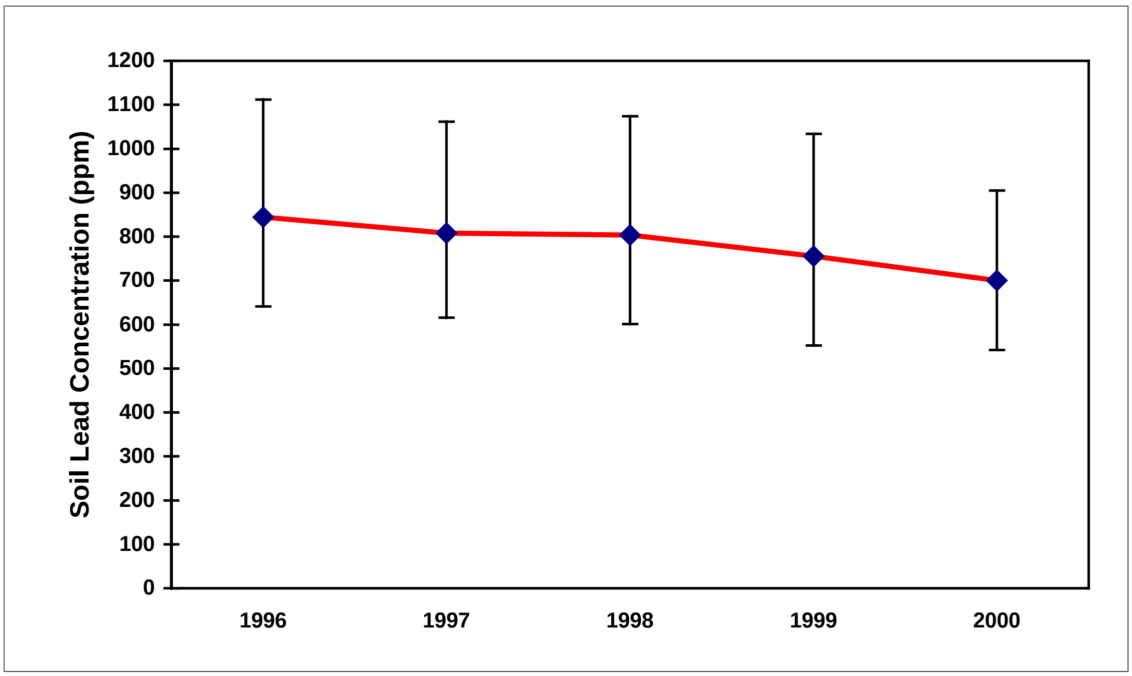
Figure 18 - Floor Dust Lead Concentrations by HEPA Vac



Samples of the top 2-3 centimetres of soil were collected from consistent locations at 29 properties in September of each year from 1996-2000. The average soil lead concentrations at these properties are shown in Figure 19. The graph suggests that soil concentrations have been trending slightly downward since 1996. However, the error bars (upper and lower 95% confidence limits for the means) clearly overlap, which indicates that the differences between years may be due to chance. When the stations were plotted individually, there was no consistent trend in soil lead concentrations over time.

Although the decrease after 1996 might possibly be expected due to the concurrent decreases in outdoor dustfall lead described above, soil lead concentrations in Trail have been previously observed to be quite stable over time. As discussed in Section 3, the average soil lead concentration changed very little between 1977 and 1992. It's quite possible that differences in average soil concentrations between years have been due to random variation in sampling and analysis.

Figure 19 - Average Soil Lead Concentrations at 29 Sentinel Homes



In summary, there were substantial reductions in the amount of lead in outdoor dustfall, indoor dustfall, and street dust samples since the new lead smelter started up. The greatest improvements in these measures occurred in areas nearest the smelter. The change in amount of lead in floor dust was not as clear. The "microvac" samples from 30 homes showed no change, while the HEPA vac samples from 8 homes showed only slight changes in loading and concentration.

4. COMMUNITY BLOOD LEAD TRENDS: 1989-2000

Lead in whole blood is considered to provide the best measure of exposure. With a half-life in blood of about 25-35 days for acute exposures, blood lead has been assumed to reflect relatively recent exposure. However, bone lead can be an important contributor to steady-state blood lead concentration, even under conditions of ordinary exposure and particularly among growing children (National Academy of Sciences, 1993). Despite not being an exact measure of lead exposure or of total body lead burden, blood lead remains the one readily accessible and convenient measurement that can demonstrate the relationship of various biological effects to increases in exposure (Maynard et al, 1993).

One of the functions of the Trail Lead Program is to monitor children's blood lead. Blood lead testing allows the program to:

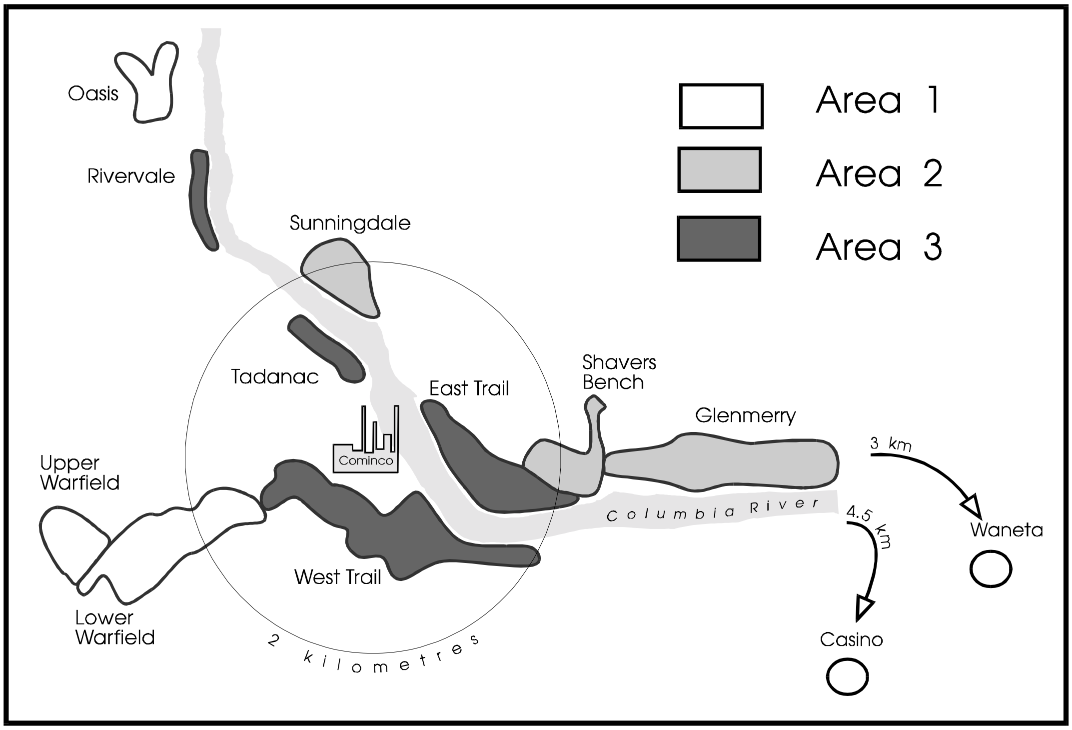
- identify and follow children with elevated or rising blood lead concentrations (case finding and case management)
- define high risk geographical areas
- provide a summary assessment of the community-wide impact of various actions
- evaluate outcomes in specific studies and programs.

The 1989 Trail Lead Study sampled children ages 2 through 6 years (Hertzman et.al., 1991), which excluded the infants and toddlers who engage in the most hand to mouth behaviours. From 1991-93, annual blood lead testing was offered to all families in the greater Trail area with children 6 to 72 months old.

In 1994, the Task Force decided to narrow the focus of the screening program so that only children at greatest risk of developing a blood lead of 15 µg/dL or higher would be tested. Children from 6 to 60 months who live in area 2 (moderate risk) and area 3 (high risk) are now routinely tested. Children in area 1 (low risk) are screened for case finding purposes only up to 36 months of age. The blood results from children in area 1 are not included in the data analysis. (See Figure 20 for locations of the areas of Trail.) This strategy has meant that testing resources can now be used to focus on higher risk children, while older children living in low risk areas are not subjected to unnecessary testing.

This section contains a summary of the “Community Blood Lead Status Report” (Trail Lead Program, 1996), plus an update on results from the 1996 - 2000 blood lead surveys. Details of protocols and results may be found in the complete report.

Figure 20 - Map of Areas and Neighbourhoods of Trail



4.1 Blood Lead Monitoring Methods

4.1.1 Recruitment

Each year, eligible children are identified through health unit immunization records, birth notices, BC Medical Services Plan data, and local day care centre and kindergarten lists. One month prior to the clinic, families are sent a letter introducing the blood lead screening program and its purpose. Phone contact is made two weeks after the letter is sent to answer questions and to offer an appointment for a blood test. A written reminder is sent one week prior to the clinic and families are reminded by phone the day before their appointment. On average, 79% of children identified have participated in the annual blood testing clinics.

4.1.2 Clinic Procedure

Families are invited to the Trail Lead Program office where venous blood samples are drawn by an experienced pediatric phlebotomist. Capillary samples are collected only in rare instances when venipuncture fails or is not acceptable to the parent or child. Blood samples are collected during September each year, immediately after maximum summer exposure conditions are known to prevail.

4.1.3 Analysis and Quality Control

Blood lead samples are analyzed using a graphite furnace atomic absorption spectrometer with zeeman background correction. Cominco, Ltd. performed the analyses from 1989 through 1992. British Columbia Children's Hospital (BCCH) laboratory provided the quality control during this time. Since 1993, BCCH has provided the analyses and the University of Alberta hospital lab has provided the quality control.

The following quality control (QC) procedures are used to verify the accuracy and precision of the blood lead measurements:

- random split samples from children are analyzed at both the study laboratory and a QC laboratory
- replicate samples from adult volunteers are submitted weekly to the two labs
- certified reference blood from the National Institute of Standards and Technology (NIST) were submitted weekly to the two labs (discontinued after 1995)
- blood collection tubes and supplies are pre-screened for contamination prior to the clinic
- all blood sample tracking data is double-entered into a computerized data base management system and cross-checked for accuracy.

BCCH also participates successfully in the US Centers for Disease Control and Quebec Toxicology proficiency programs for blood lead.

4.1.4 Results to Families

Results are reported to families and their physicians (if requested) in micrograms per decilitre (µg/dL) within three weeks of sampling. Lead results are described as being acceptable, higher than desirable, or requiring medical evaluation and follow up, depending on the child’s age and blood level. (Blood results of 15 µg/dL or greater for children 13 months of age and older, or greater than 7.9 µg/dL for children less than 13 months trigger the family's inclusion into the case management program, while a blood lead level of 20 µg/dL or higher prompts a recommendation for medical evaluation.) *See Case Management flow chart*. In the absence of Canadian lead guidelines, the case management strategy was adapted from the U.S. Centers for Disease Control's “class of child based on blood lead concentration” (US CDC, 1991). In 1995, Canada adopted the same blood lead intervention levels (Federal-Provincial Committee on Environmental and Occupational Health, 1994). See Figure 21 for CDC guidelines.

Result letters include information brochures to reinforce the messages of good hygiene, good nutrition, reducing house dust, safe renovations and safe outside play for children. Families are contacted by phone if their child has an elevated or rising blood lead. A phone call usually prompts questions about health effects and exposure reduction from parents and offers an opportunity to set up an in-home counselling appointment.

Figure 21 - Class of Child and Recommended Action According to Blood Lead Measurement

Source: Adapted from US CDC, 1991.

Centers for Disease Control and Prevention recommendations to public health agencies and physicians

Blood Lead Level	ACTION
<10 µg/dl	Regular screening at 12 and 24 months and annually in higher risk areas.
10-14 µg/dl	Rescreen child in 3 to 4 months and monitor level. Community intervention when many children are at this level.
15-19 µg/dl	Rescreen child in 3 to 4 months and monitor level. Educate parents. Test for iron deficiency. Investigate environment for source.
20-44 µg/dl	Complete medical evaluation. Identify and remove environmental lead sources.
45-69 µg/dl	Medical treatment and environmental assessment and remediation within 48 hours.
<=70 µg/dl	Medical treatment and environmental assessment and remediation IMMEDIATELY.

4.2 Blood Lead Results

4.2.1 Participation Rates

Participation in the annual blood testing clinic has been very good for a voluntary program. Table 10 shows the participation rates from 1989 to 2000. Families who have refused to have their children tested have cited reasons such as feeling that their child was too young for a blood test and not wanting to subject their child to another blood test. Some eligible families do not participate because of our inability to contact them, e.g., they have no phone or an unlisted number.

Table 10 - Participation Rates in Annual Fall Blood Screening Clinics

Year	Number of children in area 2/3	Number of children participating	Participation rate
1989	420	368	88%
1991	536	402	75%
1992	526	397	75%
1993	585	438	75%
1994	410	304	74%
1995	383	317	83%
1996	346	290	86%
1997	355	295	85%
1998	317	234	81%
1999	292	216	77%
2000	224	172	77%

[1] in 1989, children 24-72 months of age were recruited
[2] in 1991-93, children 6-72 months of age were recruited
[3] in 1994 -00, children 6-60 months in areas 2&3 and 6-36 months in area 1 were recruited

From 1991 to 1997 the participation rate increased in both the high-risk area (area 3) and the moderate risk neighbourhoods (area 2). From 1997 to 1999, following start up of the new smelter, participation dropped in area 2 but increased in area 3. In 2000, participation fell slightly in the high-risk neighbourhoods and improved slightly in area 2. Overall, there has been higher participation in area 3, which may be due to recognition that there is a higher risk of lead exposure in these neighbourhoods.

Despite the fact that a higher percentage of the children living in area 3 have been tested in recent years, the area distribution of children tested has not changed significantly from year-to-year. (The increase in the percentage of area 3 children participating has been offset by a decrease in the number of children living in area 3.) The average age and the age distribution of children tested has also not varied significantly from year-to-year. Therefore, there is no need to perform statistical adjustment of annual mean blood lead levels for the age and area covariates.

Children who have had elevated blood leads in a previous year have a higher participation rate than those whose previous lead levels were less than 15 µg/dL. These children are followed more closely and encouraged to attend for additional lead tests. The participation rates of case management (≥15 µg/dL) compared with non case management children are given in Table 11. All of the children shown in the table were tested the previous year. The children not represented in the table are those who have never been tested previously. The response rate among those children is only about 60 percent. It appears that once families have attended a blood testing clinic they tend to return for subsequent ones. Since children in the high risk neighbourhoods and children with elevated lead levels are slightly over-represented in the annual sample, the average blood lead is likely to be an over-estimate of the average for the entire community.

Table 11 - Participation Rates of Case-Management vs. Non Case-Management Children

Year	Case-Management Children			Non Case-Management Children		
	Eligible	Tested	Percentage	Eligible	Tested	Percentage
1992	119	99	83%	181	149	82%
1993	90	85	94%	264	219	83%
1994	58	55	95%	182	152	84%
1995	64	60	94%	128	116	91%
1996	97	91	95%	182	147	83%
1997	80	73	92%	192	157	84%
1998	64	55	89%	200	140	77%
1999	43	38	93%	197	138	74%
2000	24	21	88%	200	151	88%
Total	639	577	90%	1726	1369	79%

Note: Children up to 60 months of age from areas 2 and 3, tested in previous fall clinics.

4.2.2 Geometric Means and Distributions of Blood Lead Levels

There was a general decline in blood lead concentrations from 1991-96, followed by a more pronounced decrease beginning in 1997 after the old lead smelter was shut down. In 2000, there was a slight increase in blood lead concentrations. A summary of all blood lead levels obtained over ten years is provided in Table 12.

Table 12 - Blood Lead Statistics 1991-2000

Statistic	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Number tested										
Geometric Mean (µg/dL)	13.5	11.4	11.1	12.0	10.4	11.5	8.8	7.7	5.9	6.7
Geometric Std. Dev. (µg/dL)	1.45	1.51	1.48	1.48	1.54	1.55	1.63	1.72	1.93	1.92
Minimum (µg/dL)	5.0	4.0	2.5	4.7	2.2	3.6	2.5	1.4	0.6	0.7
Maximum (µg/dL)	35.0	28.0	35.6	33.3	36.2	29.9	27.2	42.6	27.7	20.3
≥ 10 µg/dL	83%	66%	62%	68%	53%	62%	41%	34%	22%	27%
≥ 15 µg/dL	42%	31%	22%	31%	21%	34%	15%	10%	6%	9%
≥ 25 µg/dL	5%	1%	2%	2%	1%	3%	0.4%	0.5%	0.5%	0%

Note: Children aged 6 to 60 months in areas 2 & 3 only

The all-age (6 to 60 months) geometric mean decreased from 13.5 µg/dL in 1991 to 6.7 µg/dL in 2000. The mean blood lead level varied from year to year due to several factors, including: changes in smelter emissions (stack and fugitive), different weather patterns (especially during summer months) and a continuously increasing level of education and intervention efforts by the lead program.

The percentage of children with lead levels of 15 µg/dL or higher (Trail Lead Program 'level of concern') has followed the same pattern as the geometric mean.

Geometric mean blood lead levels by age from 1991 to 2000 are shown in Table 13. Contrary to expectation, the greatest declines in average blood lead levels from 1991 to 2000 occurred among the 3 and 4 year old age group, rather than among the younger children. (One would expect that the blood lead levels of infants might respond more quickly than those of older children, since they do not carry a significant body burden of lead.)

In Trail, as at other sites, children's lead levels generally rise rapidly from birth to crawling age and peak at 18 to 24 months of age. This is mainly due to exposure to lead in house dust and the frequent hand-to-mouth activities of infants and toddlers. Blood lead levels gradually decline as children age, when hand-to-mouth activity decreases.

Table 13 - Geometric Mean Blood Lead Levels by Age

Age (years)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
<1	10.9	9.7	10.8	10.8	9.4	10.5	8.5	7.3	4.5	5.0
1	13.7	12.3	11.8	14.0	10.3	12.2	9.5	8.3	7.4	7.7
2	14.6	11.5	11.1	12.8	11.5	11.7	9.9	8.4	6.5	8.3
3	13.2	12.5	10.7	11.2	10.3	11.1	8.2	7.0	5.3	6.0
4	13.5	10.5	11.2	10.4	10.1	11.4	8.2	7.2	5.0	6.2

Elevated blood lead levels in Trail children almost always occur before they reach three years of age. Out of 306 children who did not have a blood lead result over 15 µg/dL when they were younger than 3 years, only 13 (4%) became elevated after their third birthday. The maximum lead level attained by these children was 18 µg/dL, compared with levels of up to 35 µg/dL amoung younger children. This finding emphasizes the importance of prevention and intervention programs targeted toward prenatal families and families with infants and toddlers.

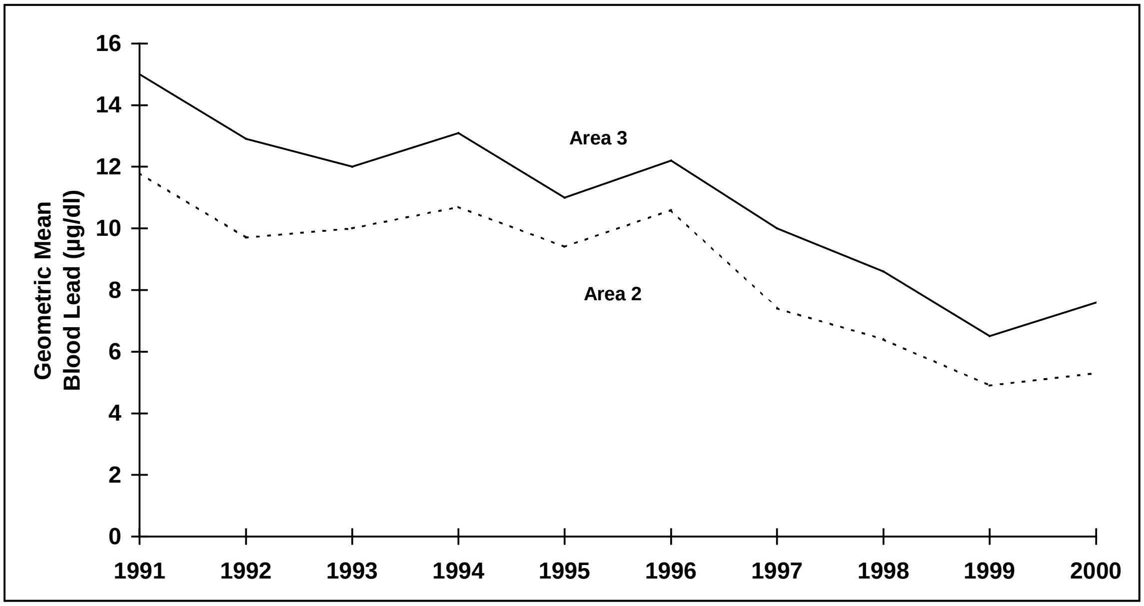
4.2.3 Geographic High Risk and Lower Risk Areas

Children living in Area 3 are at higher risk of lead exposure than are children in other areas, based on loadings and concentrations of lead in dust and soil. Environmental lead levels in Area 3 neighbourhoods (East and West Trail, Tadanac, Rivervale) are higher due to geography, wind direction and proximity to the smelter. Area 2 includes Sunningdale, Shavers Bench and Glenmerry. These neighbourhoods are at moderate risk of lead exposure because of distance from the smelter and prevailing winds. Area 1 includes the outlying neighbourhoods of Warfield, Waneta, Oasis and Casino. Children in this area are at low risk of developing an elevated blood lead. Please refer back to Figure 20 for map of areas and neighbourhoods of Trail.

Percentage-wise, the decline in average blood lead levels has been similar in the high and moderate risk areas. In area 3, the geometric mean went from 15.3 µg/dL in 1991 to 7.6 µg/dL in 2000 (50% decline). The moderate risk neighbourhoods (area 2) saw a decline from 11.8 µg/dL in 1991 to 5.3 µg/dL in 2000 (55% decline). Figure 22 illustrates the changes in blood lead geometric mean by area from 1991 to 2000.

Families from area 3 usually receive the greatest amount of attention in the form of advice, case management, blood monitoring and services because of the higher percentage of children in this area with elevated lead levels.

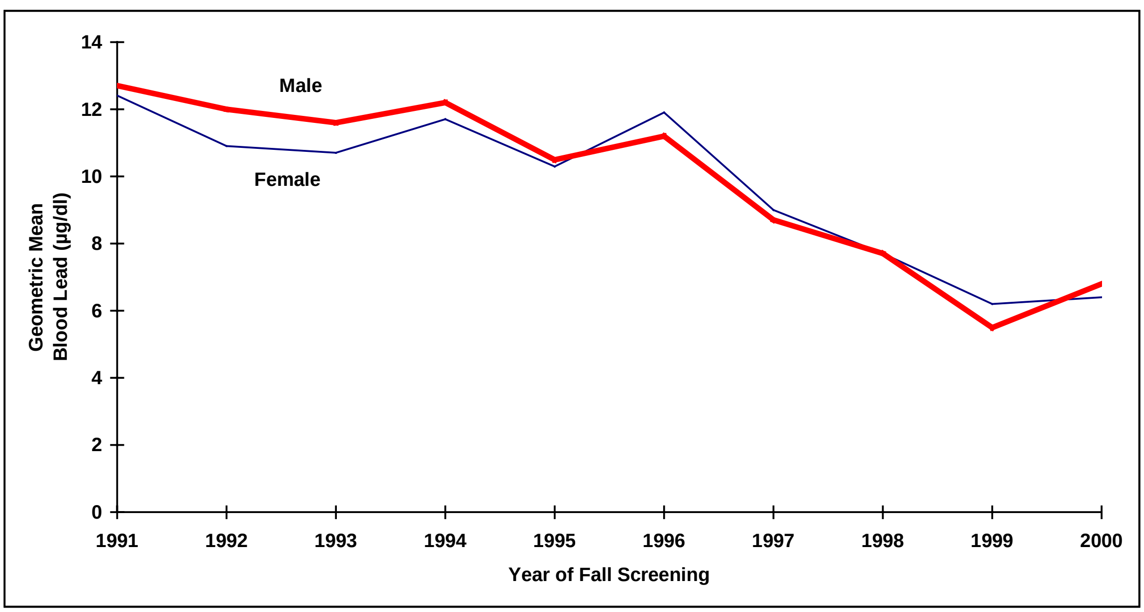
Figure 22: Geometric Mean Blood Lead Levels by Area



4.2.4 Effect of Gender on Blood Lead Levels

Trends in mean lead levels by sex are shown in Figure 23. Looking at the data from all years combined, there is no statistically significant difference between lead levels by sex.

Figure 23 - Geometric Mean Blood Lead Levels by Sex



4.2.5 Children Tested for the First Time

As noted in Section 4.2.1, children who have a high blood lead result in one year are more likely to return for testing in following years than are the children who have low blood leads. To remove the resulting positive bias from our estimates of the mean blood lead each year, we have taken a separate look at children tested for the first time.

Since there has been a change in the age and area makeup of these children from year-to-year, a statistical adjustment of the mean blood leads is performed to account for the age and area differences. Least squares regression models were developed between area and blood lead and between age and blood lead. For area, a simple linear regression provided the best fit. For age, a cubic polynomial model provided the best fit. (The relationship between age and blood lead is non-linear, with a peak at about 2 years of age.) Analysis of covariance, with age and area as covariates and dummy variables for each year, was employed to compute age and area adjusted means for "first-timers".

The age and area adjusted geometric means for "first-timers" from areas 2 &3 are shown in Table 14. The table shows that the decrease in the average blood lead level of children tested for the first time from 1989 to 2000 was 57%, whereas the decrease among all children tested was 53%.

Table 14 - Blood Lead Levels of Children Tested for 1st Time

Year	Number of "1st-timers"	Average age of "1st-timers" (months)	Unadjusted Average Blood Lead for all Children Tested (µg/dL)	Age&Area-Adjusted Average Blood Lead of "1st-timers" (µg/dL)
1989	169	43	14.2	14.8
1991	197	29	13.5	13.3
1992	118	26	11.4	11.9
1993	99	23	11.1	11.2
1994	95	23	12.0	11.9
1995	76	25	10.4	9.4
1996	46	19	11.5	11.0
1997	60	25	8.8	8.8
1998	63	23	7.7	7.4
1999	62	22	5.9	5.1
2000	67	18	6.7	6.3

4.2.6 Comparison Community Results

In 1992, blood samples were drawn from children in Beaver Valley, a semi-rural area approximately 10 km. east of Trail, for the purpose of tracking trends in blood lead levels over time in Trail and a community with lower exposure levels. Approximately 50% of eligible children from Beaver Valley participated in the blood testing clinic. The geometric mean blood lead was 6.6 µg/dL, compared with 10.8 µg/dL in Trail (see Figure 24). The largest percentage of children in Beaver Valley had lead levels in the 5-9 µg/dL range, with only 15% having levels less than 5 µg/dL.

These results suggest that there is some degree of lead exposure for these children, whether from the smelter or other lead sources. Five children (3%) in Beaver Valley had blood lead levels of 15 µg/dL or greater. Two of these children have parents that are employed at a battery recycling plant, and the children spend time at the work site. Two other children had recently moved to Beaver Valley from a high risk area in Trail. The last child was an infant whose father works in a lead-hazard area of Cominco. Following counselling from the lead program staff on separating work clothes, shoes, and lunch boxes, etc., the child's lead level dropped significantly.

Figure 24 - Blood Lead Distribution for Trail vs. Beaver Valley

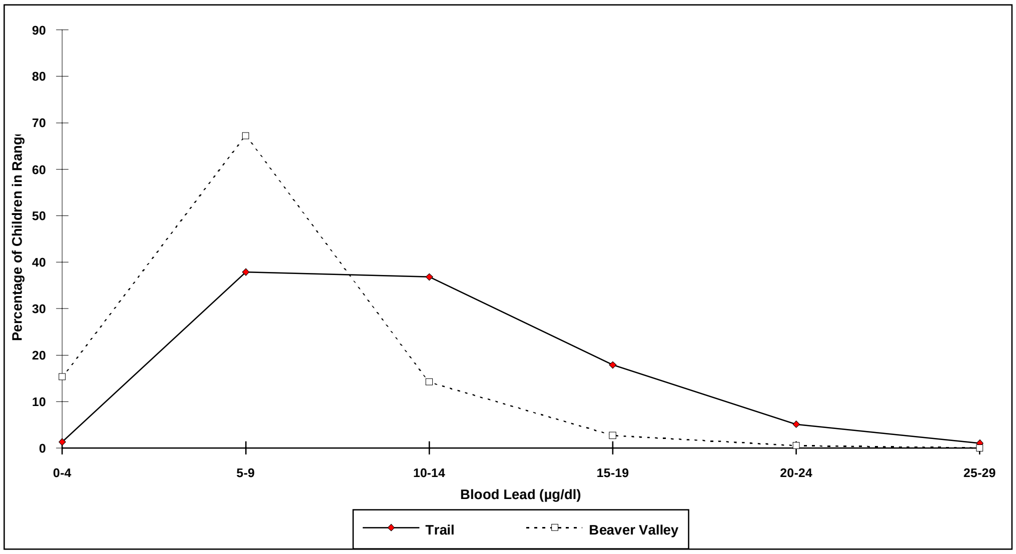


Table 15 shows results of blood lead surveys conducted in other locations around the world during the last 10 years. Although it is difficult to compare these results due to varying age ranges of children tested and differences in the nature of the sites, this table provides some approximate benchmarks against which the blood lead levels in Trail may be compared. The reference sources for this table are listed at the back of the References section of this report.

Table 15 - Comparison with Blood Lead Levels for Other Sites

Reference Number	City or Region	Country	Nature of site	No. of children tested	Age of subjects tested	Year of testing	Distance from smelter	Average Blood Lead Level (µg/dL)
1	Santo Amaro	Brazil	Operating primary lead smelter	490	1 to 9 yrs	1992	<1 km	58.9
2	Andean villages	Ecuador	Villages with lead-glazing	82	4 to 15 yrs	1996		51.0
3	Berat	Albania	Battery Plant	84	<6 yrs	1997	< 2 km	43.4
4	La Oroya	Peru	Urban		adults	1995		34.8
5	Lima	Peru	Urban		adults	1995		26.9
6	Santiago	Chile	Urban	312	<2 yrs	1997*		25.5
7	Huancayo	Peru	Urban		adults	1995		22.4
8	Berat	Albania	Battery Plant	45	<6 yrs	1997	> 2 km	15.0
9	Yaupi	Peru	Smaller urban?		adults	1995		14.0
10	Campania and Naples	Italy	Urban		children	1994		13.8
11	Pribram	Czech Republic	Operating primary lead smelter		6 to 12 yrs	1995	< 3 km	11.4
12	Port Pirie	Australia	Operating primary lead smelter	892	9 mos to 5 yrs	1999	< 4 km	10.2
13	Mexico City	Mexico	Urban	200	< 5 yrs	1994		9.9
14	Montevideo	Uruguay	Mix of rural, urban	96	2 to 14 yrs	1996		9.6
15	N. Lake Macquarie	Australia	Operating primary lead smelter	26	1-4 yrs	2000	< 4 km	9.3
16	Nordenham	Germany	Operating primary lead smelter	114	6 to 7 yrs	1982	< 2 km	8.2
17	Nordenham	Germany	Operating primary lead smelter	76	9 - 10 yrs	1985	< 2 km	7.8
18	Eastern Sydney	Australia	Urban	191	1 to 4 yrs	1993		7.2
19	Sydney	Australia	Urban	718	9 mos to 5 yrs	1994		7.0
20	**Trail**	**Canada**	**Operating primary lead smelter**	**172**	**6 mos to 5 yrs**	**2000**	**< 4 km**	**6.7**
21	Rockhampton	Australia	Rural	123	< 5 yrs	1994		5.7
22	Vancouver	Canada	Urban	172	2 to 3 yrs	1993		5.4
23	Herculaneum	U.S.A.	Primary Pb smelter	62	6 mos to 6 yrs	2000		5.4
24	Rouyn-Noranda	Canada	Operating copper smelter		1 to 5 yrs	1999	<1 km	5.0
25	Silver Valley	Idaho	Closed primary lead smelter	370	9 mos to 9 yrs	2000	< 4 km	3.5
26	East Helena	United States	Operating primary lead smelter	271	< 7yrs	1995-99	<3.6 km	4.6
27	Hettstedt	Germany	Closed primary lead smelter		5 to 14 yrs	1996		3.5
28	Northern Ontario	Canada	Rural	395	1 to 6 yrs	1992		3.1
29	Nation-wide	United States	Urban and rural (NHANES III, phs 2)	2392	1 to 5 yrs	1991-94		2.7

4.2.7 Newborn Study

The study was performed to determine the magnitude of maternal and fetal lead exposures in Trail. Although women without occupational contact with lead generally have very low current exposure, there is a concern that *in utero* lead exposure to fetuses may result from mobilization of lead stores that have accumulated in bone from prior exposures. Trail data from 1991 to 1993 showed that infants aged six to eleven months had blood lead levels averaging 10 µg/dL. A number of these infants had lead levels greater than 15 µg/dL. There was a concern that babies in Trail might be receiving a significant amount of their lead exposure *in utero*.

Between November 1993 and December 1995, satisfactory blood specimens were collected from 62 newborns (umbilical cord blood) and from 67 mothers (venous blood) two days postpartum. Of these specimens, we ultimately obtained lead levels for 48 matched maternal-infant pairs.

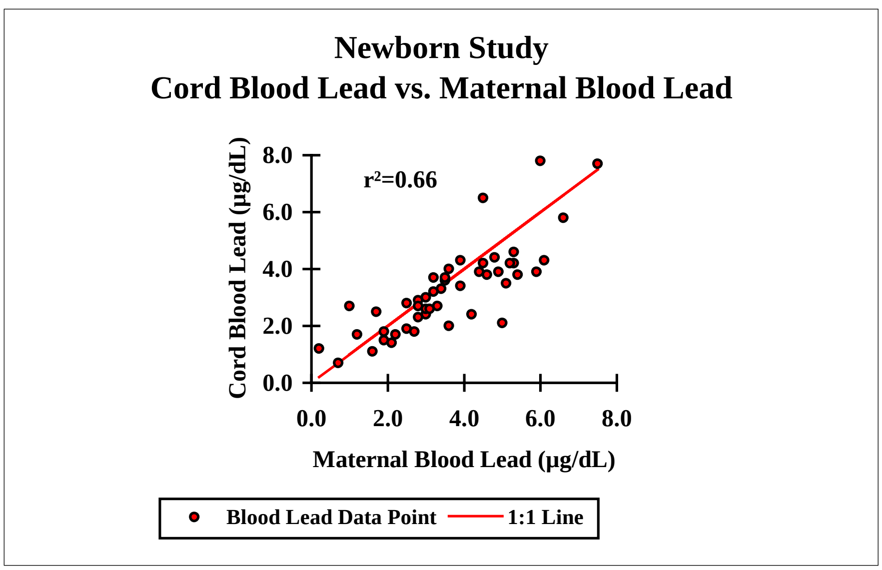
The arithmetic mean cord blood lead level for the 48 matched pairs was 3.3 µg/dL (0.16 u/mol/l). The arithmetic mean maternal blood lead level was 3.6 µg/dL (0.17umol/l). There was a significant linear correlation between maternal and neonatal blood lead concentrations ($r2= .66$, $p < 0.0001$). Results are presented in Figure 25.

The range of blood lead levels was 0.7 - 7.8 µg/dL for cord samples and 0.2 - 7.5 µg/dL for maternal samples. Maternal lead levels were generally higher than cord levels. Most (92%) of the newborns had lead levels less than 5 µg/dL, and 77% of mothers had lead levels less than 5 µg/dL.

Of the 48 mother sampled, 16 were born and raised to at least 5 years of age in Trail. The mean cord blood lead of infants born to these mothers was 3.4 µg/dL. The mean cord blood lead of infants born to mothers raised outside of Trail was 3.2 µg/dL. The difference is not statistically significant.

The results of the study suggest that in Trail, pregnant women and their fetuses are at low risk for adverse health effects due to lead exposure, based on current knowledge of lead toxicology. It appears that children born in Trail start out with blood leads close to "normal background". It is not known exactly when lead levels rise in infancy, but we suspect it occurs once babies become mobile and have greater access to house dust and exposed soil, which are recognised as the principal environmental determinants of elevated blood lead levels in smelter community children.

Figure 25- Newborn (Cord) Blood Lead versus Maternal Blood Lead



5. RISK ASSESSMENT

5.1 Regulatory Framework

The B.C. Contaminated Sites Regulation under the *Waste Management Amendment Act* contains numerical soil standards that are to be used in determining whether sites are contaminated. The geometric mean soil lead concentration in Trail residential areas is approximately 720 ppm, while the maximum allowable soil lead concentration for residential land is 500 ppm (matrix numerical soil standard for protection of human health in a residential scenario). The soil standards for arsenic, cadmium and antimony are also exceeded on some properties in Trail.

The regulations currently state that soils at contaminated sites must be remediated so that contaminant concentrations do not exceed the standards, or the site must be managed so that the calculated Hazard Index or estimated incremental lifetime cancer risk (see below) is acceptable. There has not been any official determination that Trail is a "contaminated site" under the Contaminated Sites Regulation. However, it is possible that the area will be listed as a "Wide Area Site", once Cominco's ecological risk assessment work has been completed. Therefore, this must report must also address how the requirements of the Contaminated Sites Regulation can be satisfied by the Task Force's recommendations.

Replacing all soils in Trail with lead concentrations above 500 ppm would be very costly and logistically complicated. Focusing only on soil remediation would satisfy the possible regulatory requirement to meet standards under the Contaminated Sites Regulation. However, human health would not be adequately protected, as exposure to lead in dust (not all of which is derived from soil) also occurs. Therefore, the Lead Task Force has chosen the risk management approach over the numerical standards approach.

The "Hazard Index" for non-cancer health effects is determined through quantitative human health risk assessment. The Hazard Index approach is based on the premise that non-cancer health effects will only begin to occur after a safe threshold level of contaminant exposure has been passed.

The Hazard Index (HI) is defined in the regulation as the estimated daily intake[1] from all sources (EDI) divided by the reference dose (RfD), or maximum allowable intake:

$$Hazard\ Index\ =\ \frac{EDI}{RfD}$$

[1] *The use of the term "intake" in this equation may cause some confusion. In practice, risk assessors use uptake as the numerator if there is reliable data on what portion of the contaminant is absorbed into the blood stream when administered in various media and by various exposure routes. In such cases,the RfD must also be expressed as an absorbed dose, or 100% bioavailable intake.*

The "default" value for maximum acceptable hazard index is set at one in the regulation. In simple terms, the intake of a contaminant must not exceed the recommended maximum intake, or safety threshold. Alternatively, the regulation provides for use of a site-specific risk-based standard recommended by the local medical health officer for the site following public consultation. In fact, the alternative standard may be based on "biometrics", such as blood lead levels in the resident population, rather than on calculated risks.

The incremental lifetime cancer risk (ILCR) posed by cancer-causing contaminants is also determined through quantitative human health risk assessment. The ILCR approach is based on the theory that for cancer-causing contaminants, there is no safe threshold of exposure. The relationships between exposure and cancer that have been observed at relatively high exposure levels (often in occupational settings) are extrapolated to estimate the risks associated with much lower environmental exposures.

Incremental lifetime cancer risks are calculated by multiplying estimated daily contaminant intakes by the cancer slope factors for those contaminants. The "default" value for maximum acceptable ILCR is 1 in 100,000. In simple terms, this means that the "extra" cancer risk due to a lifetime of exposure to the contaminants at the site must not exceed 1 in 100,000. Since background risks for all types of cancer are much higher than this (e.g. the background lifetime risk of lung cancer in BC is about 4 in 100), it would not be possible to measure an increased risk of 1 in 100,000 in an exposed population. As with the Hazard Index, the regulation provides for use of an alternate site-specific risk-based standard recommended by the local medical health officer for the site following public consultation.

By comparison, the Canadian Council of Ministers of the Environment (CCME) has adopted the position that site-related risks arising from human exposure to carcinogenic chemicals should be remediated to levels within the range of 1 in 10,000 to 1 in 10,000,000 (CCME 1996). The U.S. Environmental Protection Agency uses the 1 in 10,000 to 1 in 1,000,000 risk range as a "target range" within which the agency strives to manage risks as part of a Superfund cleanup. EPA generally uses the 1 in 10,000 risk level as an approximate cut-off level for decisions on whether risk management action is required at a site (U.S EPA 1991).

This section discusses the risk assessments for lead and other metals, and considers whether risk models can be used for estimating the risk reductions that should result from remedial actions that are being recommended for Trail.

5.2 Components of Risk Assessment

5.2.1 Exposure Evaluation

The exposure evaluation component of risk assessment involves estimating the magnitude and duration of exposure of susceptible persons to the contaminant of concern.

In general, the following information is required in order to estimate daily intakes of contaminants:

- accepted tables of body weights by age
- accepted tables of inhalation rates by age
- accepted tables of ingestion rates for water, food, soil, etc. by age
- concentrations of contaminants in the media of concern (e.g. soil lead concentrations)
- default or site-specific information regarding the fraction of ingested or inhaled contaminant that is taken up by the body (i.e. bioavailability).

Exposure evaluation generally involves calculating intakes (or uptakes - see footnote 2) for each pathway of potential concern. Generally, exposures are estimated for persons with "reasonable maximum exposure". The US

A typical, simplified equation for an individual pathway is:

$$Uptake = \frac{CC \ X \ CR \ X \ BF}{BW}$$

Where,

Uptake = amount of contaminant absorbed into blood stream (mg/kg/day)
CC = contaminant concentration (mg/kg) *(e.g. soil/dust lead concentration)*
CR = consumption rate (mg/day) *(e.g. how much soil/dust does a child ingest in a day?)*
BF = bioavailability factor *(e.g. fraction of ingested lead absorbed into blood stream)*
BW = body weight (kg)

5.2.2 Toxicity Assessment

The toxicity assessment component of risk assessment involves selection of toxicity values for the contaminants being assessed. The toxicity values for non-carcinogenic contaminants such as lead are expressed as "reference doses", which are maximum allowable chronic daily intakes. Reference doses are set by regulatory agencies such as the US EPA, the World Health Organization or Health Canada on the basis of toxicologic studies. Generally, safety factors of 10 to 1000 are built into such reference doses.

The toxicologic database for lead differs from that for most other contaminants. Lead health effects have been related to blood lead levels in human subjects, whereas low dose health effects of other contaminants are generally related to doses calculated for humans in high exposure situations or to doses administered to animals in experimental settings.

The toxicity values used for assessing cancer risks are "cancer slope factors", which are estimates of the cancer risk associated with an uptake or dose of 1 mg/kg/day

5.2.3 Risk Characterization

The final step in risk assessment is risk characterization, which for non-carcinogenic contaminants such as lead involves calculation of the Hazard Index using the total estimated daily intake for all pathways and the reference dose as described in Section 5.1. (Often, the calculated intakes for each pathway are divided by the reference dose to determine pathway-specific "Hazard Quotients" (HQ). The HQ's for all pathways are then summed to obtain the Hazard Index.)

Given the extent of knowledge of lead health effects at various blood lead levels, it is more appropriate to base risk assessment for lead on blood lead levels, rather than on doses. This provides an opportunity for validating risk assessments by comparison with actual biological measurements in the population at risk - an opportunity that does not exist with most other contaminants.

Therefore, the U.S. Environmental Protection Agency (US EPA) has developed an Integrated Exposure Uptake Biokinetic (IEUBK) model for lead which goes beyond the calculation of hazard index to predict blood lead concentrations using biokinetics.

For assessing cancer risks, the estimated upper-bound estimates of uptake for the site are multiplied by the cancer slope factors to calculate the probability that an individual with reasonable maximum lifetime exposure will develop cancer due to that exposure. These estimated risks can be put in perspective of the local population by calculating how often, on average, a case of cancer due to exposure to carcinogenic contaminants at the site would occur in the local population, if everyone were exposed at that level.

5.3 Risk Assessment for Lead

5.3.1 The IEUBK Model

The IEUBK model is a computer model which integrates simulations of exposure, uptake and biokinetics for lead (U.S. EPA, 1994). The Integrated Exposure Uptake Biokinetic (IEUBK) Model (currently available as release 0.99d) uses complex equations based on animal studies to simulate human biokinetics and allow prediction of blood lead levels when exposure information is available. The uptake portion of the IEUBK model uses standard risk assessment techniques and may be used to calculate estimated daily uptake for input into the Hazard Index formula.

5.3.2 Baseline Risk Assessment for Childhood Lead Exposure

In 1992, a lead exposure pathways study (summarized in Section 3.2) involving subjects from across the full spectrum of blood leads was conducted in Trail. The exposure pathways study was conducted in 1992 and is described in a separate report (Trail Lead Program, 1995b). This section describes the use of the 1992 Trail data set with the U.S. EPA's IEUBK version 0.99d (U.S. EPA, 1994) as a means of assessing baseline risk from lead exposure in Trail. Full details of the risk assessment may also be found in a separate report (Trail Lead Program, 1995d).

Methods

Participant recruitment, sampling methods and quality control procedures have been summarized in Section 3.2 of this report.

The final data set for input into the IEUBK model consisted of arithmetic mean values for each environmental sample type for each child. That is, each record in the data set consisted of blood lead and age for one child, plus average values for lead in soil and house dust for his/her home.

Each record also contained one of two possible values for air lead (0.5 µg/m3 for outlying neighbourhoods or 1.0 µg/m3 for Trail neighbourhoods). These values were selected on the basis of geometric mean results for lead in suspended particulate as measured in 1992 at four stations operated by Cominco Limited. The geometric mean air leads for the downtown and Glenmerry stations in Trail were 1.11 and 0.94 µg/m3 respectively, while the geometric means for Oasis and Warfield were 0.46 and 0.52 µg/m3 respectively.

The IEUBK model was run with most other parameters set to default values. As the model was designed and validated at smelter sites, it is appropriate to use the default values in Trail. Default values of all parameters are provided in Appendix C of the separate report (Trail Lead Program, 1995d), as well as in the IEUBK Guidance Manual (US EPA, 1994b). A summary of key defaults follows here:

Air Lead

Ventilation rates and hours spent outdoors daily are specified for each age range. The values of both parameters increase with age. The percentage of air lead particles reaching the lungs is assumed to be 42% for smelter sites and 100% of particles reaching the lungs is assumed to be absorbed into the bloodstream.

Indoor air lead concentration is set to 30% of the outdoor concentration. This ratio is based on investigations conducted at various sites and referred to by U.S. EPA in its air quality criteria document for lead (U.S. EPA, 1986). There is concern that air lead measurements by stationary monitors might under-estimate children's personal exposures, as their activities might increase air lead concentrations in their personal breathing spaces. The BC

Ministry of Health sponsored an investigation of children's personal exposures to air lead in 1993 (MacFadgen, 1993). The study found that children in several Trail neighbourhoods who wore personal air samplers during the day were exposed to an average of 0.50 µg/m^3 of lead in air. The average fraction of time spent outdoors during personal air monitoring was 29%. Applying the typical outdoor air lead level in Trail, the default ratio of indoor to outdoor air lead concentration and the portion of time spent outdoors yields the following estimate for personal exposure:

$$Air\ lead = (1.0\ \mu g/m^3 \times 0.29) + ((1.0\ \mu g/m^3 \times 0.30) \times 0.71) = 0.50\ \mu g/m^3$$

which concurs exactly with the average personal air monitor result above. Therefore, it appears appropriate to use the default assumption in this analysis.

Diet Lead — The IEUBK model specifies dietary lead intake for each age group based on U.S. Food and Drug Administration Market Basket samples to 1988. The fraction of dietary lead absorbed into the bloodstream is set to 50%.

Water Lead — The default value for lead in drinking water is 4 µg/L. The 1989 Trail Lead Study (Hertzman et.al., 1991) measured lead in drinking water in 161 homes and found that the mean concentration was about 4 µg/L. Daily water consumption values increase with age and are taken from the US EPA's Exposure Factors Handbook (US EPA, 1989). The fraction of drinking water lead absorbed into the bloodstream is set to 50%

Soil/Dust Lead — Soil and dust ingestion values range from 85 to 135 mg/day, are age-dependent and are based on a number of recent investigations (Binder et.al., 1986; Clausing et.al., 1987; Calabrese et.al., 1989, 1991; van Wijnen et. al., 1990; Davis et.al., 1990). It is assumed that 45% of soil/dust ingested is derived from soil, 55% from indoor dust.

The IEUBK model uses an active/passive non-linear uptake model to determine the fraction of ingested lead that is absorbed into the bloodstream. The model assumes that 30% of the soil/dust is bioaccessible and apportions this into a nonsaturable (passive absorption) component of 6% and a saturable (active absorption) component of 24%.

Maternal Blood Lead — Set to 4.0 µg/dL, based on 27 samples collected in 1993/94 at time of birth.

Other Lead	Direct lead intake from other sources such as paint or hobbies defaults to 0. (Indirect intake of lead from other sources via contribution to dust is accounted for in the soil/dust concentrations.)

The reference dose for lead used in this analysis (3.57 µg/kg/day) is based on a provisional tolerable intake for lead in children of 25 µg/kg/week, developed by the World Health Organization (WHO, 1987).

5.3.2.2 Results and Discussion

Validation of the IEUBK Model against Observed Blood Leads

Prior to using the IEUBK model to determine lead hazard index, or to estimate risk under various remedial scenarios, it is useful to validate the model against a properly conducted survey of blood lead levels in the population of concern. The blood lead surveys conducted in Trail from 1991-94 (see Section 4) have been appropriately conducted to provide reliable and representative data:

- the preferred method of sample collection (venipuncture) has been used
- analyses have been performed by a sensitive, preferred method (graphite furnace atomic absorption spectrometry)
- a rigorous quality assurance/quality control program (including use of blind quality control samples) has been followed
- blood samples have been collected from large subsets of the population (e.g. 77%, or 426 children in 1992)
- the most susceptible age group (6 to 72 months) has been tested
- blood samples have been collected at the time of year when blood leads are known to peak in response to higher exposures (late summer)

Therefore, the results are expected to accurately characterize the lead exposure risk of children in the community. In 1992, 61% of Trail children aged 6 to 72 months had a blood lead level of 10 µg/dL or higher.

The IEUBK model was run in batch mode to predict blood lead for each of the 241 children in the 1992 Trail data set on the basis of age, soil, dust and air lead concentrations and default values for all other parameters.

The statistical program, PbSTAT, included with the IEUBK model, was used to produce descriptive and inferential statistics to compare predicted and observed blood lead. Table 16 shows that the geometric means and distributions of observed and predicted blood leads are very similar (p-value > 0.05).

Table 16 - Statistical Comparison of Observed and Predicted Blood Leads

IEUBK v. 0.99d Batch Mode Run, Entire 1992 Trail Dataset

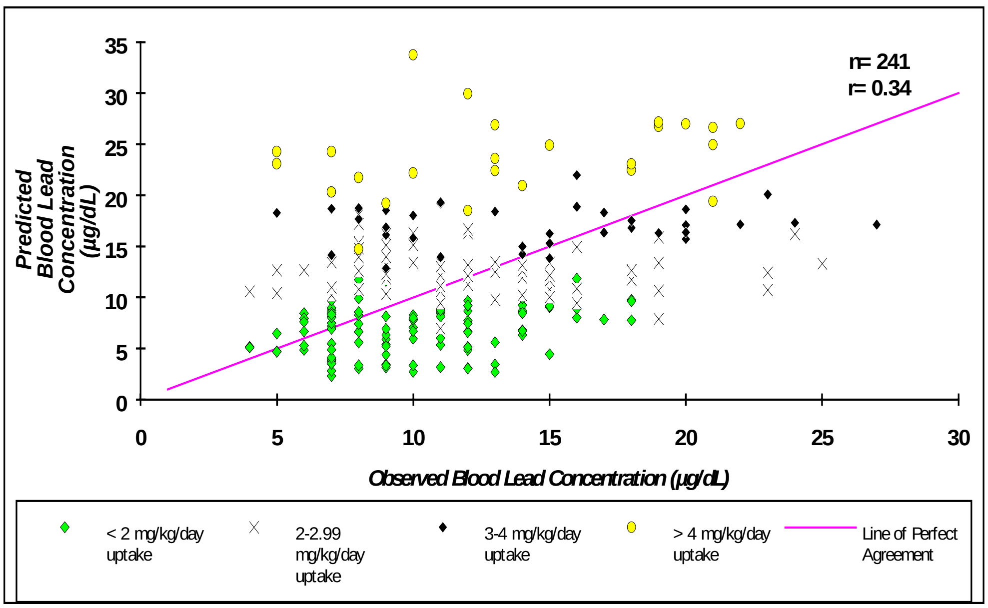
	Predicted	Observed
Number of Cases	241	241
Blood Lead Conc. (µg/dL)		
Minimum	2.3	4
Maximum	33.8	27
Geometric Mean	10.3	10.8
Paired T-test for difference in geometric means (p-value)	0.21	
25th Percentile	7.5	8
50th Percentile	10.8	11
75th Percentile	15.8	14
90th Percentile	19.4	19
Standard Deviation	6.1	4.6
Geometric Standard Deviation	1.74	1.49
Soil/Dust Lead Conc. (ppm)		
Geometric Mean Soil		635
Geometric Mean Dust		791

The IEUBK Model v. 0.99d was very effective in predicting the mean blood lead level in Trail children aged 6 to 72 months. The model confirmed that the risk of an individual child in Trail having a blood lead level of 10 µg/dL or higher in 1992 was slightly greater than 50%. The fact that the model accurately predicted the distribution and mean of blood lead levels in the population suggests that the default values for model parameters are appropriate for use in Trail. However, it is possible that compensatory errors in the default values may be responsible for the general agreement of predicted and observed blood lead means. For example, an over-estimation of soil/dust lead bioavailability could be offset by under-estimation of soil/dust ingestion rates.

Figure 26 shows that the IEUBK model is not a reliable predictor of individual blood lead levels on the basis of environmental levels. The maximum difference between individual observed and predicted blood lead was 23.7 µg/dL. The plot also shows that the IEUBK model tends to over-predict blood lead levels at high calculated uptake and to under-predict at low uptake. This implies that either the model is over-estimating uptake when soil and dust concentrations are high, or that the biokinetic portion of the model is over-estimating blood lead when uptake is high.

Figure 26 - Scatter Plot of Observed vs. Predicted Blood Leads

US EPA IEUBK v. 0.99d Batch Run, 1992 Trail Data set



The failure of the model to accurately predict blood lead levels for individual children is not surprising. The default values for physiological and behavioural parameters such as fractional absorption and soil/dust ingestion are based on typical children. Even if the default values appropriately describe the average child in Trail, these parameters are known to vary highly among individual children. For example, a child who eats a regular and adequate diet that is high in calcium, vitamin C and iron will tend to absorb a much smaller fraction of ingested lead into his bloodstream than would a child who skips meals and is deficient in iron or calcium.

The IEUBK model was also run for a neighbourhood close to the smelter (East Trail) and a neighbourhood more distant from the smelter (Village of Warfield). As shown in Table 17, the model over-predicted the mean blood lead for the high risk area and under-predicted for the low risk area. This also suggests that the model tends to over-estimate blood lead when the soil/dust concentrations are high. One possible explanation might be that the default partitioning of soil/dust ingestion is not attributing a large enough fraction to indoor dust. (The default assumption is that 45% of soil/dust ingested is soil and 55% is dust.) However, even if the contribution of soil is set to zero, the model still over-predicts for the high-risk area (13.8 µg/dL predicted versus 12.9 µg/dL observed) and under-predicts for the low-risk area (6.8 µg/dL predicted versus 9.2 µg/dL observed). A second possibility is that the model itself may be flawed.

<u>Use of the IEUBK Model to Determine Hazard Index</u>

Table 17 - Observed and Predicted Blood Leads for Two Areas of Trail

IEUBK v. 0.99d Batch Mode Run, Partial 1992 Trail Data set

	East Trail		Warfield	
	Predicted	Observed	Predicted	Observed
Number of Cases	41	41	37	37
Blood Lead Conc. (µg/dL)				
Geometric Mean	17.3	12.9	5.9	9.2
Paired T-test for difference in geometric	<0.001		<0.001	
Standard Deviation	6.3	5.8	2.9	2.7
Geometric Standard Deviation	1.44	1.58	1.55	1.33
Soil/Dust Lead Conc. (ppm)				
Geometric Mean Soil		2224		192
Geometric Mean Dust		1276		435

The IEUBK model was run for each of the 241 children in the 1992 data set to determine total daily lead uptake (µg/day). A standard table of median body weights by age was used to calculate daily uptake per unit body mass (µg/kg/day). The geometric mean uptake was determined to be 2.00 µg/kg/day. Therefore the Hazard Index for a typical child is:

$$\text{Hazard Index} = \frac{EDI}{RfD} = \frac{2.00\ \mu g / kg / day}{3.57\ \mu g / kg / day} = 0.56$$

The Contaminated Site Regulation does not specify whether the hazard index is to be calculated for a typical individual within the population of concern or for a "most exposed individual". However, draft BC Environment guidance for human health risk assessment

(Zapfe-Gilje, et.al., undated) refers to the U.S. EPA's goal in deterministic risk assessment, which is to estimate the 95th percentile of the risk distribution (U.S. EPA, 1992).

The geometric standard deviation of uptake was determined to be 1.83 µg/kg/day. Therefore, the 95th percentile of the uptake distribution (1.64 standard deviations above the mean) may be estimated as:

$$95th\ percentile\ uptake = 2.00\ \mu g / kg / day \times 1.83^{1.64} = 5.37\ \mu g / kg / day$$

The Hazard Index corresponding to a most exposed individual is then:

$$Hazard\ Index = \frac{5.37\ \mu g / kg / day}{3.57\ \mu g / kg / day} = 1.50$$

On individual runs, the IEUBK model provides calculated uptakes for each pathway. In order to apportion the Hazard Index for a "most exposed individual" into individual Hazard Quotients for each pathway, the model was run once using the 95th percentile of the soil and dust lead concentration data and the outdoor air lead concentration for sampling stations closest to the smelter. For the average age (38 months) and weight (15.1 kg) of the children in the data set, the model calculates a total uptake of about 5.21 µg/kg/day (and therefore an HI of 1.46). Therefore, the Hazard Index may be approximately apportioned as:

Soil/Dust Ingestion: $HQ = \frac{(75.52/15.1)\ \mu g/kg/day}{3.57\ \mu g/kg/day} =$ 1.40 (95% of total)

Lead in Diet: $HQ = \frac{(1.85/15.1)\ \mu g/kg/day}{3.57\ \mu g/kg/day} =$ 0.03 (2% of total)

Drinking Water: $HQ = \frac{(0.63/15.1)\ \mu g/kg/day}{3.57\ \mu g/kg/day} =$ 0.01 (1% of total)

Inhalation: $HQ = \frac{(0.67/15.1)\ \mu g/kg/day}{3.57\ \mu g/kg/day} =$ 0.01 (1% of total)

Assuming that the IEUBK model is as effective in estimating lead uptake as it is at predicting the final result (blood lead level) then the model is an acceptable tool for estimating community hazard index distribution. The estimated hazard index for a "most exposed individual" in 1992 (1.50) exceeds the default maximum of one and therefore confirms the results of annual blood lead surveys which indicated that the risk posed by exposure of children to lead in Trail was unacceptable.

5.3.3 Update to Current Conditions

The preceding section 5.3.2 described the use of a complete environmental and blood lead data set from 1992 to assess baseline risk of lead exposure. The US EPA IEUBK model was found to be very effective in predicting community mean childhood blood lead levels at that time. The model confirmed that, in 1992, the risk of an individual child having a blood lead level of 10 µg/dL or higher was slightly greater than 50%. The fact that the model agreed with measured blood lead levels suggested that the model might also be helpful in predicting the changes in blood lead levels that would be likely to result from environmental remediation.

As presented earlier in this report, significant decreases in community air and dust lead levels have occurred since the new lead smelter commenced operation in 1997. It seems appropriate now to compare the observed reductions in blood lead levels since 1996 with the reductions that the IEUBK model would predict.

We do not have available a new, paired environmental and blood lead data set as was collected in 1992. However, it is possible to run the IEUBK model using average values for the various input parameters, such as soil, dust and air concentrations.

As presented in section 3, soil lead concentrations did not change significantly from 1975 to 1989 or 1992. Also, soil samples collected from the same locations at our Sentinel Homes over the past 4 years are not showing any significant change. Therefore, it's reasonable to assume that soil concentrations remained the same from 1992 to 1999.

Air monitoring data from hi-volume suspended particulate samplers in areas 2 and 3 of Trail show that the annual arithmetic mean air lead levels declined from 1.0 µg/m3 in 1996 to about 0.30 µg/m3 in 1999.

As reported in section 3, monitoring of floor dust concentrations in 8 Sentinel homes suggests that the average house dust concentration has dropped from 758 in 1996 to 588 in 1999 (22% decline).

The average soil lead level in areas 2 and 3 (the area from which children are currently tested) was 830 ppm, according to the 1992 data set. The average house dust concentration in the same area in the 1992 data set was 1060 ppm. If we assume that the average house dust concentration declined by 22%, as indicated by our limited data from 8 Sentinel Homes, the average house dust concentration in 2000 would be 827. If we also assume that the average soil lead concentration has declined by 17%, as indicated by the (non-significant) trend in results from 29 Sentinel Homes, the average soil lead concentration in 2000 would be 689 ppm.

Input data and results for 1996 and 1999 IEUBK model runs are summarized in Table 18.

Table 18 - 1996 and 2000 Model Run Data/Results

Input Parameter	1996	2000
Soil lead concentration (ppm)	830	689
House dust concentration (ppm)	1060	827
Air lead concentration (µg/m^3)	1.0	0.30
Water lead concentration (ppb)	4	4
Actual geometric mean blood lead level (µg/dL)	11.5	6.7
Predicted geometric mean blood lead level (µg/dL)	11.8	10.0

Even if we assume that the average house dust concentration declined by 50% (similar to observed indoor dustfall declines), the IEUBK model would predict a geometric mean blood lead level of 8.4.

5.3.4 Implications for Remediation Planning

The Contaminated Site Regulation states that if a site is not to be remediated to the proposed numerical standards, the site must be managed such that the hazard index for the site is reduced to less than one. There are three general ways of reducing the lead hazard index in Trail:

1. Reduce the amount of lead in the environment. (e.g. reduce smelter emissions)

2. Reduce the amount of soil/dust taken up by children. (e.g. behavioural/nutritional intervention)

3. Reduce the toxicity of the lead in the soil. (e.g. reduce soil lead solubility)

Specific remedial options for Trail are described in Section 7. Once a set of remedial options has been accepted on the basis of such important factors as cost-effectiveness, technical feasibility and public acceptability, it is necessary to estimate whether implementing those options will achieve the required reduction in risk.

The IEUBK model has been used to determine soil lead clean-up goals at a number of U.S. sites. The effect of soil replacement or establishment of soil barriers can be simulated by altering the soil lead concentrations input to the model. The model can be run using progressively lower soil lead concentrations until the desired distribution of blood lead levels (or hazard index) is achieved. Although the IEUBK model now appears to have been validated for Trail as a whole, it would be necessary to independently verify the relevancy of key default parameters (such as bioavailability) before using it to estimate the impact of soil abatement on blood leads, especially within neighbourhoods. However, as noted in the previous section, measured blood lead levels have declined dramatically in recent years with no change in soil lead levels. In addition, the experience with soil abatement trials at other sites has generally been that the impact on blood lead has not been as large as expected. (Occupational Health Centre at Queen's University, 1991; Weitzman, et.al., 1993). This is perhaps because soil is not, as assumed in risk models, the key source of lead exposure in all situations.

The IEUBK model could perhaps be used to estimate the impact on blood lead (or hazard index) of changes in soil lead bioavailability brought about by treatment. Results of animal feeding studies or validated in vitro tests using treated soils may be used to adjust the soil lead absorption parameters in the model. Once again, though, it cannot be assumed that reducing the toxicity of soil lead will effect a dramatic reduction in the overall outdoor soil/dust ingestion pathway, if the relative importance of dust versus soil ingestion is unknown.

It is more difficult to use the model to estimate the impact of remedial actions taken to reduce air lead emissions or house dust levels or the amount of soil/dust ingested by children. When air lead emissions are reduced, the impacts on lead exposure are both direct and indirect. As demonstrated in the previous section, the direct impact of reduced emissions may be modelled by inputting anticipated new values for air lead concentrations into the IEUBK model. This allows estimation of the impact on blood lead via the inhalation exposure route only. As the proportion of childhood lead exposure due to inhalation is relatively small, the direct impact on blood lead or hazard index is negligible. The indirect, but more important, impact of reduced air emissions is reduced deposition of lead particles on surfaces in the environment. This indirect impact is more difficult to model, as it is not known how long it will take for soil/dust loadings and concentrations to drop, nor what the magnitude of the drop will be.

Investigations of exposure pathways in Trail indicate that ingestion of house dust is a dominant source of childhood lead exposure, particularly for children under 18 months of age (see Section 3.2 and Trail Lead Program, 1995b). Remedial actions such as HEPA vacuuming that may be taken to reduce house dust lead exposure will not affect the concentration of lead in the house dust (Hilts et. al., 1995; CH2M Hill, 1991; Ewers et.al., 1994). Any reduction in exposure to lead in house dust as a result of remediation will arise from reductions in lead loadings, rather than concentrations. As the current IEUBK model accepts only concentrations as inputs for house dust lead levels, it is not possible to estimate the effects of reduced loadings through clean-up of dust. There is discussion of incorporating loading in a future version of the model.

Educational interventions designed to bring about changes in mouthing behaviour, personal hygiene or nutrition are also difficult to evaluate with the IEUBK model. Behavioural modification would be expected to impact on soil/dust ingestion rates and nutritional intervention would impact on soil/dust lead gut absorption rates. However, the magnitude of change that can be expected in these parameters is unknown.

Alternate methods had to be used to allow estimation of the effect of air emissions improvements and behavioural/nutritional interventions. It has been necessary to use a combination of risk models and real-world intervention trials results to estimate the effects of remedial actions. A recent literature review concluded that trials of soil abatement, dust control and education measures have usually produced at least some measurable reduction in children's blood lead levels (US EPA, 1995).

It was recommended in the baseline risk assessment report that a phased, iterative approach to remediation and risk assessment in Trail be adopted. The Task Force proceeded according to the following plan:

1. Remedial options were evaluated in terms of such factors as technical feasibility, probable efficacy in reducing lead exposure risk, cost-effectiveness and public acceptability.

2. A preferred set of remedial options (based on the criteria in 1. above) was assessed as a group to ensure that remediation has a reasonable probability of achieving the Task Force's goals.

3. The preferred and approved set of remedial options is being recommended for implementation as a remedial action plan.

4. Remedial actions will be re-evaluated through follow-up monitoring of blood and environmental lead levels to determine if the risk-based goals have been achieved. Actual post-remedial blood lead levels will be the primary criterion for determining whether an acceptable level of lead exposure risk has been achieved.

5. If an acceptable risk level has not been achieved, the remedial action plan should be revised to incorporate more protective measures.

The remedial action plan should continue to be re-evaluated and revised until the goals have been reached.

5.4 Risk Assessment for Other Smelter Contaminants

5.4.1 Project Purpose & Background

The aim of the human health risk assessment was to determine whether any smelter-related contaminants other than lead pose a potential health concern to Trail residents.

The work was performed by Exponent Environmental Group of Boulder, CO and Bellevue, WA, under the direction of the Trail Lead Program. Exponent is a leading international consultant in metals exposure and toxicity assessment.

The complete report consists of three volumes (Exponent 1997, 1998, 2000a)

5.4.2 Comparisons against Standards (Problem Formulation Phase)

A comparison of soil, air and water sample results against health-based standards determined that arsenic, cadmium and antimony were the only smelter-related contaminants requiring detailed risk assessment (other than lead, which was already being intensively studied).

5.4.3 Risk Assessment

The risk assessment addressed:

- How much arsenic, cadmium and antimony are people in Trail likely to ingest or inhale?

- How much arsenic, cadmium and antimony consumption does it take to produce adverse health effects?

Based on answers to the above questions, are any adverse health effects due to arsenic, cadmium and antimony likely in Trail?

5.4.4 Risk Assessment Methods

All available data on the amounts of arsenic, cadmium and antimony in local soil, dust, produce and air was assembled and evaluated.

Information on human environmental exposure was gathered from Trail, or from approved Canadian or international sources. (e.g. For how many months is the ground covered with snow? How much time do Canadians spend indoors? How much soil and dust do children ingest through hand-to-mouth behaviour?)

Information on toxicity was gathered from approved Canadian or international sources. (e.g. What are the health effects of concern for the 3 chemicals? What are “acceptable” levels of human intake for the 3 chemicals?)

For non-cancer health effects, estimated intakes of arsenic, cadmium and antimony were compared with “acceptable” amounts.

For cancer (applicable only to arsenic and cadmium), estimated intakes were multiplied by “slope factors”, to estimate the probability of someone living in Trail their entire life developing cancer due to site contamination.

5.4.5 Risk Assessment Results

Estimated antimony exposures are below levels associated with any health effects.

Estimated cadmium exposures are below levels associated with kidney disease, with the possible exception of heavy smokers.

Estimated lifetime cancer risks due to arsenic and cadmium exceed the BC “default” standard of 1 in 100,000

- In Trail population, exposure to smelter contaminants might result in:
    - no more than no more than 1 case of lung cancer every 60 years or so
    - no more than 1 case of skin cancer every 200 years or so

These preliminary results are based on a number of health-protective assumptions and are likely to overestimate actual health risks.

6. REMEDIAL GOALS

6.1 Contaminants of Concern

Previous work (including Kelly et.al., 1994) has identified that other metallic constituents of the concentrates processed in the smelter (e.g. zinc, arsenic and cadmium) are also present in the Trail environment in concentrations that exceed normal background levels. Zinc, arsenic and cadmium have been found to be distributed in the environment in conjunction with lead (i.e. where lead is high, zinc, arsenic and cadmium also tend to be high). Therefore, any measures designed to reduce human exposure to environmental lead are likely to also reduce exposure to associated metals. However, the other contaminants have the potential to impact different segments of the population and the relative importance of exposure routes may vary from one metal to another.

Until recently, the mandate of the Trail Community Lead Task Force has been to address lead and its impact on young children. In February of 1997, the Task Force began evaluating in detail the human health risk posed by other metals. This evaluation, which is fully documented in three separate reports and summarized in section 5 of this report, was completed in early 2000.

The estimated health risks of other smelter contaminants have been perceived by the Task Force, and by the community in general, to be very minimal. Therefore, the Task Force's remedial goals and recommendations focus mainly on addressing childhood lead exposure. As noted later in Section 9.2, the Task Force is recommending that potential health risks from other smelter contaminants be reduced to the levels required by provincial regulations, without shutting down the smelter or conducting widespread soil replacement.

6.2 Media of Concern

The media of potential concern with respect to childhood lead exposure are soil, dust, air, paint, drinking water, and diet. High concentrations in any of these media can result in excessive intake of lead by young children.

<u>Soil, dust and air</u>: As presented in Section 3.1 - Sources of Lead Exposure, the concentrations of lead in soil, dust and air are high throughout most neighbourhoods of Trail.

<u>Paint</u>: Lead concentrations in paint are often high in the older neighbourhoods close to the smelter. Therefore, lead in paint is of

concern in individual cases where old lead based paint is in deteriorating condition.

Drinking water — Drinking water may be ruled out as a medium of concern, as 98% of 145 tap water samples tested were below the US EPA's guideline for "first-pull" water.

Diet — The main potential concern with respect to diet is the consumption of vegetables grown in lead-contaminated soil. However, as presented in Section 3.1 - Sources of Lead Exposure, vegetables grown in Trail usually have acceptable lead levels. Most cases of high lead levels in local produce have been related to inadequate washing of soil/dust from the external surfaces of the produce. Also, as reported in Section 3.2 - Pathways of Lead Exposure, there is no difference in blood lead levels between Trail children who eat home-grown produce and those who do not.

All foods prepared in the home can of course be contaminated by dust during preparation, or by leaving them stored in the open. Advice regarding minimizing this exposure pathway is included in the Trail Lead Program messages regarding hygiene and housekeeping.

6.3 Sensitive Population

As presented in Section 2.2 - Adverse Health Effects, young children are at greater risk of lead health effects because:

1. They have higher intakes of lead through their normal hand-to-mouth activity.
2. They absorb lead more efficiently (young children may absorb 40-50% of ingested lead, whereas adults typically absorb only 10%).
3. The amount of lead they absorb is greater per unit body mass.
4. Their nervous systems are rapidly developing and their blood-brain barriers are not yet fully developed.

As presented in Section 4.2 - Blood Lead Results, monitoring of Trail children under 5 years of age showed that, in 1999, about 6% had blood lead levels above the individual level of concern (15 µg/dL).

Between 1992 and 1995, 39 adults residing in the Trail area, including 16 pregnant women, volunteered for blood lead testing. None of these adults were employed at the smelter. The geometric mean blood lead level among these adult volunteers was 4.8 µg/dL and the maximum was 10 µg/dL.

The Trail Lead Program also analyzed 48 pairs of maternal and cord blood samples collected at birth at Trail Regional Hospital between 1993 and 1995. The arithmetic mean cord blood lead level was 3.6 µg/dL and the maximum was 7.8 µg/dL. The average ratio of cord blood lead level to maternal lead level was 0.93, with a correlation between the two measures (r) of 0.78. These data indicate that pre-natal lead exposure is not a concern under present environmental conditions in the Trail community.

6.4 Primary and Secondary Exposure Routes

There are three routes by which lead might be absorbed by humans: ingestion, inhalation or skin absorption. Absorption of lead through skin is negligible, compared with uptake through the ingestion and inhalation routes (US EPA, 1986). In turn, uptake of lead via inhalation is significantly lower than uptake through ingestion of dust, soil and food, particularly in young children who engage in frequent hand-to-mouth behaviour (see Section 5.4.2.2 - Use of the IEUBK Model to Determine Hazard Index).

6.5 Exposure Pathways

The dominant pathways of childhood lead exposure in Trail have are ingestion of house dust and soil. The relative importance of these key pathways varies with age, as described in Section 3.2 - Pathways of Lead Exposure.

The pathways between measured environmental lead sources and children's blood have been presented in Section 3.2. The pathways diagram from Section 3.2 has been expanded to include air lead and to show the sources which can contribute to air lead (smelter emissions or re-entrainment of historically-deposited emissions.) The diagram includes only the media of concern identified in Section 6.1.2 - soil, dust, air and paint. (See Figure 27.)

6.6 Remedial Goal

The main objective of remedial actions recommended by the Lead Task Force will be to protect the sensitive population (children under 5 years of age) against lead exposure. This objective will be achieved through a combination of actions which will either:

a) reduce sources of lead (e.g. soil treatment or removal, house de-dusting), or

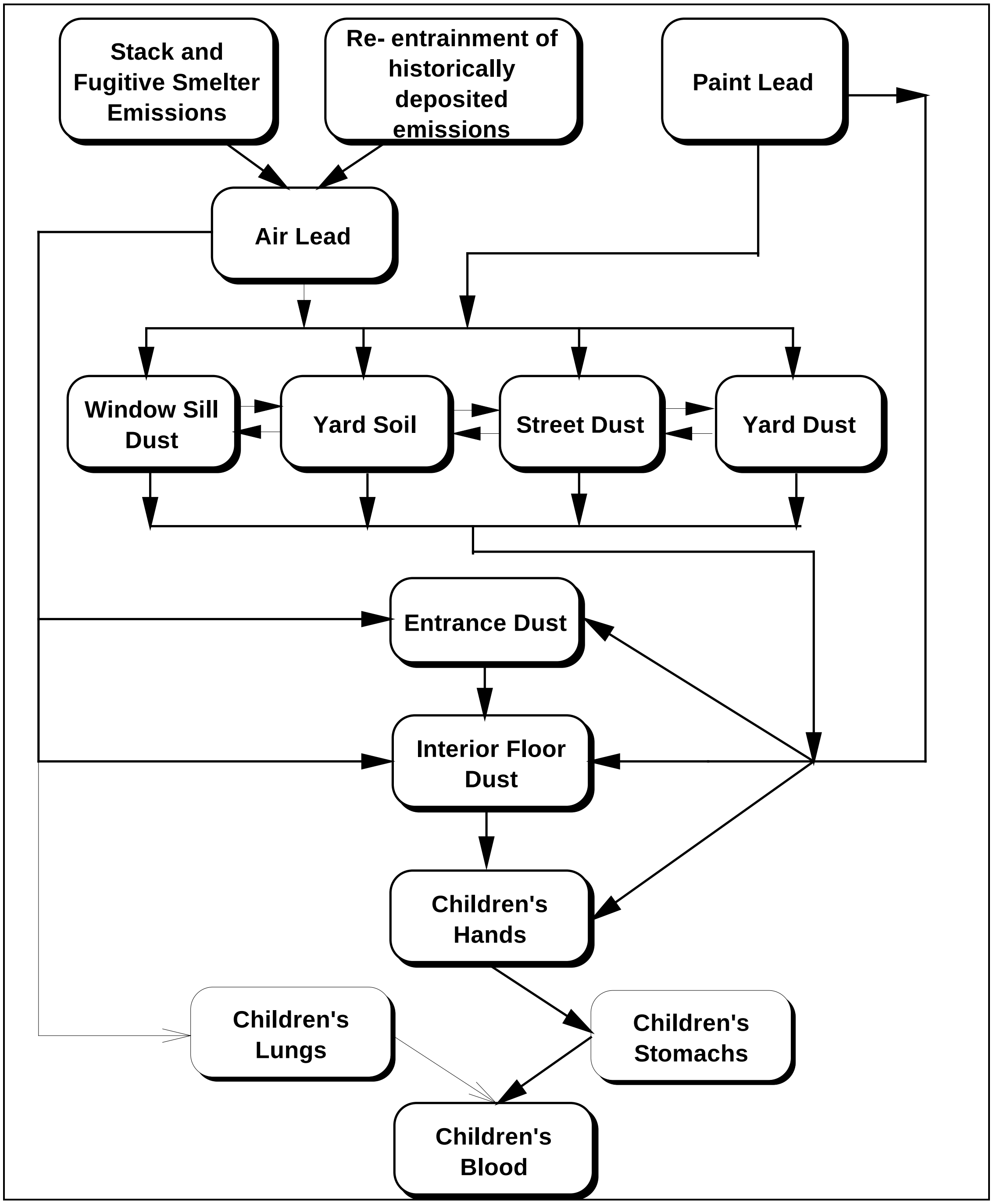
a) break pathways of exposure to lead (e.g. ground cover improvement, behavioural modification)

A report of the Federal-Provincial Committee on Environmental and Occupational Health (1994) recommends that a community program to identify and reduce sources of lead exposure be considered if the proportion of children with blood lead levels above 10 µg/dL is double that of the general population. Currently, it is estimated that approximately 5% of Canadian children have blood lead levels over 10 µg/dL. Therefore, the long-term goal is to have 90% of children age 6-60 months with blood lead levels under 10 µg/dL. The Trail Community Lead Task Force has also recommended that 99% of children should have blood lead levels under 15 µg/dL.

6.8 Summary of Issues and Remedial Action Objective

Main contaminant of concern:	Lead
Media of concern:	Dust, soil, air, paint
Sensitive population:	Children under 60 months of age
Primary exposure route:	Ingestion
Secondary exposure route:	Inhalation
Exposure pathways:	As per Figure 27.
Remedial Goal:	To reduce sources of exposure or break pathways of exposure to achieve an acceptable risk level. (Less than 10% probability of an individual child having a blood lead level greater than 10 µg/dL)

Figure 27 - Lead Exposure Pathways in Trail



7. REMEDIAL OPTIONS: IDENTIFICATION

The purpose of this section is simply to present and briefly describe remedial options, as they were identified in 1998. Evaluations of remedial options are presented in Section 8. All costs are estimates only, and are given in 2000 dollars.

Only those remedial measures that are potentially applicable to the reduction of human lead exposure in Trail are presented here. That is, remedial measures which do not apply to the relevant media and exposure pathways have been excluded. For example, measures designed to address drinking water are not considered, as drinking water has not been identified as a medium of concern. Therefore, the options presented in this chapter have essentially been “pre-screened“ for applicability, based on ten years of site investigations and interactions with those involved in the remediation of other sites.

7.1 Continuation of Current Actions

7.1.1 Annual Blood Lead Testing Clinic

All young children have been invited for blood lead testing in early fall each year since 1991. In 1994, the focus of the blood testing program was narrowed so that only children at greatest risk of developing a blood lead level of 15 µg/dL or higher would be tested. Children from 6 to 60 months of age who live in area 2 (moderate risk) or area 3 (high risk) are now routinely tested. Children in area 1 (low risk) are tested for case finding purposes only, up to 36 months of age. Blood lead levels for area 1 children are not included in the data analysis. The changes have meant that testing resources can now be used to focus on higher risk children, while older children living in low risk areas are not subjected to unnecessary testing.

The blood lead testing program could be institutionalized into the local public health system. Voluntary testing for blood lead elevations could be integrated with existing immunization programs.

Blood lead data could be used to make decisions about further narrowing of the scope of testing. That is, blood lead data might indicate that the upper age limit and geographic area for blood lead testing could be further reduced.

Annual blood lead testing would likely be continued even after the remedial goals have been achieved, in order to ensure ongoing protection of children in Trail.

Continued blood lead testing each fall would allow:

- identification of children with elevated or rising blood lead levels for follow-up (case finding and case management)
- summary assessment of the community-wide impact of various remedial measures
- determination of whether the remedial goals have been achieved

Approximate cost: $30,000 per year (declining if focus of testing is narrowed further)

7.1.2 Case Management

Blood lead results of 15 µg/dL or greater for children two years of age and older, and greater than 10 µg/dL for children under two years old currently trigger the family's inclusion in the case management program. The current case management program consists of:

- more frequent blood lead testing (depending on child's age and blood lead level)
- in-home counselling (on exposure reduction measures such as dust control, hygiene, nutrition and yard care)
- environmental assessment (sampling of bare ground, dust, painted surfaces, etc., to highlight areas that need attention)
- provision of walk-off mats
- provision of sandboxes with clean sand and lids
- provision of house cleaning services (regular HEPA vacuuming, wet-wiping and wet-mopping)
- for families in financial need:
    - assistance with ground cover improvement
    - assistance with paint abatement
    - provision of cleaning supplies (mops, buckets, detergent, vacuum cleaners)
- if a child has blood lead level of 40 µg/dL or higher:
    - the child's family is offered all regular case management services, including a home visit to assess the child's environment within 72 hours of receipt of the blood lead result.
    - if the home requires extensive paint abatement or renovations and the family needs to be temporarily relocated until the work is completed, a special sub-committee of the Task Force (composed of the members of the Finance Committee and one community member) is informed of the family's circumstances.
    - the sub-committee decides whether the case warrants Task Force assistance to pay for temporary housing and/or assistance with contractor costs.

Approximate cost: $20,000 per year, assuming no children with blood lead ≥ 40 µg/dL. Cases involving children with blood lead levels of 40 µg/dL or higher might be expected to cost $2000-$20,000 per case.

As with the annual blood lead testing, most components of the case management program could be institutionalized into the local public health system. In-home counselling on exposure reduction measures and in-home environmental assessment could be integrated with the "well baby" visits. Public health staff could identify those families in need of house cleaning services, ground cover, paint abatement or relocation and could refer those families to the party carrying out physical remediation measures (Cominco).

The cost of the case management program would likely decline over time, as fewer children would be expected to fit the case management criteria each year. Eventually, after the remedial goals are achieved, there would be very few children requiring case management in most years.

Approximate cost: $20,000 per year (declining)

7.1.3 Community and Early Childhood Education

The Lead Program's exposure reduction messages, as well as news about program activities and progress, are communicated to the general public through:

- distribution of a semi-annual newsletter to all residential mailing addresses
- advertisements in local print and radio media
- billboards, public displays
- storybook available to all play schools, day care centres, elementary schools, libraries and other educational resources

The community and early childhood education programs could be continued, with institutionalization of some components into the local public health and pre-school systems, plus transfer of other components to the party responsible for implementing the long-term remedial plan. It could be argued that these education programs should be continued even after the remedial action objective has been achieved, as continued delivery of these programs may be necessary to maintain lower blood lead levels in children.

Approximate cost: $25,000 per year.

7.1.4 Community Dust Abatement

Street Cleaning

In early 1995, the City of Trail and Emcon Services volunteered to perform more frequent and thorough cleaning of city streets and highways. In future, these actions could continue to be performed voluntarily by the City of Trail and Emcon Services.

In at least three other lead smelter towns (East Helena, MT, Herculaneum, MO and Torreon, Mexico), the streets are cleaned regularly by the smelter company using their own top quality street sweepers. In East Helena and Torreon, the state governments have instituted street lead loading standards which must be met by the company. In East Helena, the standard is 30 mg/m^2 and in Torreon, the standard is 600 mg/m^2. In Trail, street dust lead loadings have averaged about 120 mg/m^2 since the new lead smelter went into operation.

Dust Control on Alleys

Since 1993, the unpaved alleys in Trail have been sprayed with magnesium chloride dust suppressant in early summer. Magnesium chloride is an odourless, colourless salt brine which soaks into the road surface and forms a hard layer that resists erosion by rain, wind and traffic. The coating also attracts a thin film of moisture which helps keep the road surface wetted. Each year, the dust suppressant is applied after the alleys have been re-graded by the City of Trail.

During the first few years, the cost of this program was covered by the Rotary Club of Trail, with funding received from the Task Force and from Environment Canada's "Environmental Citizenship Initiative" program. From about 1997-1999, the City of Trail and Cominco shared the cost of alley spraying.

Beyond 2000, this action could be performed/paid for by the party formally responsible for implementing long-term remedial actions (Cominco), or it could continue to be performed by the City, with cost-sharing by Cominco. There may be an indefinite requirement for continuing these actions, unless the historical reservoir of lead in alley and public area soils is permanently addressed through paving and/or soil removal or treatment.

Approximate cost: $8000 year.

Greening of Public Areas

From 1992 through 1996, the Rotary Club of Trail completed a substantial amount of seeding and planting in public areas that were identified by the Trail Lead Program as having high lead levels (Trail Lead Program, 1999). Most of the bare areas identified as priority sites for greening were successfully revegetated through hydro-seeding or application of turf, or covered with asphalt, concrete or gravel. There are still some bare public areas, and areas of Cominco property near the plant, that Cominco continues to address with hydro-seeding, tree-planting and application of composted pulp mill biosolids residue.

7.1.5 Provision of Loaner HEPA Vacuum Cleaners

The Trail Lead Program currently has 4 HEPA vacuum cleaners, which are available to any member of the local community on a free loan basis for up to 48 hours per use. The machines are in use quite regularly by parents of young children, as well as by people doing renovations on their homes.

The HEPA vacuum cleaners and other types of vacuum cleaners (e.g. Eureka HEPA with "imbedded dirt finder") could continue to be made available to the public on a free loan basis, perhaps from the local public health service outlet.

Approximate cost: $1000 per year for maintenance, parts and supplies

7.1.6 Provision of Nutrition Information/Counselling and Nutritious Foods

Currently, parents receive advice through the Community Education and Case Management Programs about how to feed their children in order to minimize lead absorption. Pre-schoolers are taught about healthy eating through the Early Childhood Education Program. The Lead Program advises that children should eat a balanced diet that is high in fibre, vitamin C, calcium and iron, and low in fat. Children should also eat regularly to avoid going for extended periods on an empty stomach (the importance of breakfast is stressed).

This nutritional advice was expanded in 1997 by providing high risk families with nutritious foods and additional nutrition counselling through the Building Beautiful Babies program under the Ministry of Families and Children. The service includes:

- a focus on pregnant women and high risk families with infants aged 0-6 months
- provision of a new brochure on lead and nutrition to parents of young children
- weekly drop-in sessions which include nutrition info and a free, healthy lunch
- provision of vouchers for milk, eggs, vegetables and vitamin supplements if needed
- approximately 50 families participated in this program in 1999

Approximate cost: $1,000 - $2,000 per year.

7.2 Options for New Long-Term Actions

7.2.1 Relocation

As described in Section 7.1.2, the case management program currently includes a mechanism for providing financial support to families who need to relocate temporarily while lead abatement work is performed in their homes. This mechanism applies only to children with a blood lead level of 40 µg/dL or higher.

Lead Program staff have encountered a few families with children who seem to be particularly prone to lead exposure. That is, these children's blood lead levels do not respond to in-home counselling about exposure reduction measures, nor to the services provided through the case management program. Usually, such families live in the highest risk areas. Their homes are generally in need of significant work to improve ground cover, address deteriorating paint or remove lead dust from floors and furnishings. Therefore, an option for remedial action is to provide financial assistance for permanent relocation of families who have a low probability of success in reducing their children's blood lead levels if they remain in their current location. Financial assistance for relocation might consist of reimbursement of costs of: selling a house; breaking a lease or moving furniture and other belongings. In a typical year, there might be one family requiring such assistance.

Approximate cost: $15,000 per year?

7.2.2 Re-zoning

Buffer Zones

Buffer zones with no residential development can serve two purposes. First, the buffer zones can prevent families from living adjacent to the smelter. Secondly, if the buffer zone is planted with trees, it can help to shelter residential areas from smelter emissions.

Consideration could be given to expanding the undeveloped buffer zone around the smelter property in Tadanac. Many sections of the Tadanac neighbourhood are already buffered from the smelter site by parkland containing a strip of mature trees. However, some residences in the northwest quadrant of Tadanac are located across the street from the smelter property and are not buffered against wind transport of stockpiled materials. (The stockpiled materials are either covered or coated. However, when the materials are handled, there is a potential for generation of fugitive dusts.) Once most of the stockpiled materials have been consumed, it may be possible to expand the vegetated buffer strip within the Cominco property.

Cominco owns the four houses which are located closest to its stockpiles and currently will not rent the homes to anyone with children. The former Children's Development Centre (a facility which provided assessment and education services for children with developmental delays, as well as regular day care services) is also located across the street from the stockpiles and has now been vacant for several years.

The Columbia River provides a buffer strip between the lead smelter and East Trail. Although this buffer has prevented the construction of housing adjacent to the lead smelter, the river does not buffer against the air transport of smelter emissions to East Trail. Unfortunately, establishing a wider strip of trees along the east bank of the river would not help, as the smelter is located on a terrace approximately 200 metres higher than the East Trail neighbourhood. Smelter emissions would easily be carried over the tree tops, to be deposited in the East Trail residential area at the base of Mt. Heinz.

The West Trail neighbourhood is buffered from the smelter property by a highway, railway, and several other right-of-ways. A number of older homes located in the Trail Creek gulch below the smelter site terrace were actually demolished in the 1980's when the new highway was constructed. As with East Trail, the West Trail neighbourhood cannot be sheltered from emissions dispersing from the smelter site, as the residences are situated on a hillside facing the smelter terrace from across the Trail Creek gulch.

Therefore, buffer zone expansion might only be helpful in a portion of the Tadanac neighbourhood. In this area, several buildings could be demolished and the lots planted with large species of trees.

Approximate cost: $300,000+?

<u>Changes in Zoning</u>

In order to restrict the number of children living in the highest risk area (the portion of East Trail bounded by Bailey Street to the west, the Columbia River to the south, Highway 3B and Shavers Bench banks to the north and Gardener Street to the east), a portion of the area could be re-zoned as "no new residential development". This area is presently a commercial and recreational sub-core of the City of Trail, containing a major supermarket, aquatic centre, baseball park, tennis courts, senior citizens home, numerous small retail and service outlets and several professional practices.

Simply zoning the area as "no new residential development" would result in a gradual relocation of children from the highest risk area to lower risk areas. The process could be accelerated by purchasing and demolishing existing older homes, then covering over the lots with a layer of clean soil and vegetation.

Approximate cost: No cost for re-zoning (except for possible impacts on property values).
$85,000 - $125,000 per property if demolition of homes occurs.

7.2.3 Soil Remediation

It was important to decide how much emphasis should be placed on remediation of the historical store of lead in soil. Soil contaminated by lead smelter emissions may be remediated by a variety of methods. Currently, soil remediation activity in Trail consists of the assistance provided to householders with improving their ground cover under the case management program, as well as the community greening and dust abatement actions on public areas. A possible pitfall associated with conducting costly soil remediation in a community with an active smelter is that the soils might become recontaminated quite quickly.

Options for longer term soil remediation are:

- voluntary remediation of residential yards in higher risk areas by householders (not restricted to case management families), through:

    - provision of materials, such as clean topsoil, turf, seed and fertilizer, landscape fabric, clean rock, bark chips, concrete, etc.

    - provision of construction and/or landscaping services

  This type of remediation has been tested previously in Trail (See Section 8 or Trail Lead Program (1995c)). Based on participation in the pilot program, it is expected that about 30 families from areas 2 and 3 would participate in a given year.

  Approximate cost: $30,000 per year ($1000 per property times 30 properties)

- soil mixing above a specified level of lead contamination:

    - as soil lead contamination in Trail is generally highest in the top 5 cm, tilling the soil to a depth of 30 cm or greater could result in acceptable concentrations of lead in surface soils in many locations. Of course, soil mixing would also involve the removal and replacement of turf, trees, shrubs, fences, etc.

  Approximate cost: $2500-$20,000 per property, depending on level of existing landscaping

- chemical soil treatment above a specified level of lead contamination:

    - studies have suggested that inducing lead in soil to alter to low solubility lead phosphate by adding phosphate amendments may be effective in reducing bioavailability (Rabinowitz, 1993; Ma et. al., 1993; Ruby et. al., 1994; Ma et. al., 1995)

    - other studies have shown that lead and other metals may be removed from soil by acid leaching or chelation (Elliot and Brown, 1989; US EPA, 1994; Fristad et. al., 1996; Abumaizar and Khan, 1996)

- acid leaching or chelation would require *ex situ* treatment (excavating the soil, placing it in a reactor vessel with the necessary reagents, then replacing the soil after it has been "cleaned"), whereas amendments might be effectively applied *in situ*

Approximate cost: not yet fully explored for Trail, depends heavily on whether *in situ* application (e.g. mixing into the soil or surface application) would be effective. (Potential for success of soil amendments appears to be very limited - see Section 8.)

- extraction of lead from soil using hyperaccumulator plants (phytoextraction)

  - a potential advantage of phytoextraction over *in situ* immobilization using chemical amendments is that it results in an actual removal of metals from the contaminated soil, which provides better assurance of longevity of risk reduction. Under ideal circumstances, hyperaccumulator plants can actually take up so much metal that they can be harvested and sent to smelters for economical recovery of the metals.

  - the key disadvantage of phytoextraction is that it takes longer to achieve risk reductions. A particular disadvantage with respect to lead is that no plant species has yet been found that is capable of accumulating enough lead to make its use effective and reasonably quick. To compensate for this, some people are adding chelators, such as EDTA, to lead-contaminated soil in order to accelerate plant uptake. Of course, the chelator would also temporarily make the lead more available in the human gut.

  - In general, it seems that phytoextraction is promising, but the technique requires a great deal more development before it will receive widespread operational use. Also, phytoextraction may not very practical for residential yards.

- soil removal and replacement above a specified level of lead contamination:

  - removing the top 30 cm of soil and replacing with "clean" soil (e.g. lead level < 100 ppm) would permanently address surface contamination (barring recontamination by smelter emissions). As with mixing, soil removal and replacement would also involve removal and replacement of fences and landscaping. This option would also involve high costs for disposal of the contaminated soil at an acceptable site and for replacement with clean soil.

Approximate cost: average of $13,000 to $47,000 per property, based on experiences elsewhere (Toronto: $13,000/property (Boehnke, 1991); Silver Valley, ID: US$19,000/property (Cobb, 1991); Midvale, UT: US$47,000/property (Nieveen, 1994); Bartlesville, OK: US$20,000/property (Bennett, 1995))

7.2.4 House Dust Remediation

Currently, house dust remediation activity consists of the assistance provided to householders under the case management program (provision of walk-off mats, house cleaning services and cleaning supplies). A pitfall associated with conducting comprehensive, one-time remediation of house dust in an active smelter town is that the homes become recontaminated quite quickly (Hilts, et.al., 1995). In such cases, it might be wise to continue with repeated house cleaning efforts as outlined below:

- provision of walk-off mats (not restricted to case management properties)
- provision of regular HEPA vacuuming services (not restricted to case management properties)
- provision of regular wet-mopping and wiping services (not restricted to case management properties)
- purchase of HEPA vacuum cleaners for day care centres

Approximate cost: $250 per property (to clean every two weeks from June through August and monthly during rest of year, plus provide one walk-off mat per year). If these services were offered to all families with children under 5 years of age in areas 2 and 3, the number of families participating would be about 150. Total cost would therefore be about $37,500 per year.

Purchase of HEPA vacuum cleaners for 6 day care centres would cost about $8000.

If it is determined at some point that house interiors are no longer rapidly contaminating with leaded dust, then it would be appropriate to consider conducting comprehensive, one-time de-dusting of homes.

Comprehensive house de-dusting would include the following components, as applicable:

- HEPA vacuuming of carpets, smooth flooring, attics, furniture, drapes
- steam cleaning or shampooing of carpets, soft furniture, drapes
- removal of old carpets
- wet mopping or wiping of smooth surfaces using detergent
- replacement of old soft furnishings
- vacuuming of furnace ducts

Approximate cost: Toronto experience - $1500 per home (Boehnke, 1991)
Port Pirie experience - $700 per home (calculated from Hilts et.al. (1992) and Maynard et.al. (1993))

7.2.5 Lead-based Paint Abatement

Most homes in Trail do not have significant amounts of deteriorating lead based paint. Most deteriorating lead-based paint is found on trim areas such as door or window casings or baseboards, where replacement is often safer and less costly than paint abatement. Currently, paint remediation activity consists of the assistance provided to householders under the case management program (provision of safe chemical paint strippers, paint, scaffolding or other materials). Options for expanding on this activity are:

- provision of materials for use in paint abatement (e.g. safe chemical paint strippers, paint, scaffolding), not restricted to case management properties. Approximately 5-15 families might make use of this program each year, based on case management program experience.

Approximate cost: $200 per property ($1000 - $3000 per year)

- provision of paint abatement or renovation services through qualified contractors (to case management and/or non-case management families) Approximately 3-5 families might require this service each year.

  Approximate cost: $3000 per property ($9000 - $15,000 per year)

Lead-based paint abatement could also be integrated with house dust remediation and/or soil remediation. That is, the long-term remedial plan could provide for each property to receive remediation of house dust, soil, and paint according to criteria for each type of action. For example, a property with an average soil lead level of 800 ppm and deteriorating lead-based paint present might qualify for paint abatement as well as ground cover work and house de-dusting.

7.2.6 Smelter Operations and Materials Management

Management of smelter operations to minimize losses of lead dust due to stack and fugitive emissions, wind transport and materials handling is a Cominco responsibility. Cominco's pollution prevention efforts are overseen by the Nelson regional office of BC Environment. The Trail Community Lead Task Force is kept informed by Cominco about its efforts and Task Force members have opportunity to comment and make recommendations on Cominco practices and plans. This section is included simply to provide the reader with an overview of current practices and future issues.

Stack and Fugitive Emissions

Cominco is continuously working toward further reductions in stack and fugitive emission, using an Environmental Management System. They are also working toward ISO 14000 environmental certification, which requires companies to develop and implement procedures for minimizing waste production and optimizing waste control.

Further improvements are still possible by, for example:

- improving emission control systems (e.g. baghouses, smoke eliminators)
- making changes to plant processes so less waste products are produced
- conducting research to identify specific sources of stack and fugitive emissions

Further emission reductions are likely still the most effective action available for reducing risks, both from breathing air and ingesting dusts.

Vehicle Wash Station and Traffic Routing

Cominco has now constructed an enclosed wash facility for year-round use and requires that all vehicles use the facility before exiting the property, regardless of where they have driven on site.

Materials Management

Many measures have been implemented by Cominco to reduce dust losses due to materials handling and storage, including:

- covering stockpiles
- spraying dust suppressant on stockpiles
- bagging stockpiled materials

- relocating stockpiles to minimize hauling distances
- inspecting tailgates, boxes, etc. on haulage equipment
- maximizing consumption of stockpiled materials

Now that the new smelter is operating at full capacity, some of the materials currently stockpiled (e.g. zinc plant residues) are being consumed. This has resulted in increased excavation and hauling of these stockpiled materials. Expansion of dust control actions has become especially important at this time.

Other Dust Control Measures

Other actions which Cominco carries out to minimize the transport of contaminated dusts from its property to the community include:

- frequent road washing with sweeper and flusher trucks
- grass seeding, tree planting and berm construction
- installation of irrigation systems

7.2.7 Enhancing Public Health in Other Ways

A new approach that could be considered is to take actions that offset the efffects of exposure rather than reducing exposure. Such actions would not be directed at the cause of the problem but may address the problem most effectively.

Examples include:

- supporting general health promotion programs (e.g. the Waddell cancer prevention project)
- helping people who want to quit smoking
- supporting child development (e.g. supporting pre-school programs)

The first two examples would be aimed more at offsetting potential effects of other smelter contaminants, while the third would be specifically relevant to childhood lead exposure.

8. REMEDIAL OPTIONS: EVALUATION

This section provides an assessment of the remedial options presented in Section 7, based on their probable effectiveness in reducing children's blood lead levels. The collective world experience with testing or implementing the remedial options is reviewed in this section. A report on soil remediation cost estimates for Trail is summarized in this section. Comments on the expected effect of remedial actions based on pathways modelling or risk assessment are also included here.

8.1 Design of Remedial Trials

Before launching into a review of the studies that have been conducted in Trail and elsewhere, it is important to consider the design requirements and limitations of such studies.

8.1.1 Experimental Design

The first step in scientifically evaluating the effectiveness of remedial actions is the formulation of a hypothesis to test. A hypothesis generally takes the form:

> "[*Action*] will result in a change in [*Outcome Measure*]."

Ideally, the effectiveness of remedial actions would be measured in terms of changes in the health outcomes described in Section 2. That is, one would prefer to measure improvements in children's learning abilities, intelligence quotients and motor coordination resulting from remedial action. However, knowledge of those health effects due to low level lead exposure is based on studies of very large numbers of children which have found small differences in these outcome measures between groups of lead-exposed and non lead-exposed children. It would be very difficult and costly to perform studies of remedial actions on such large groups of children. Therefore, in practice blood lead levels have become the most commonly used outcomes measure in the assessment of remedial actions.

To conclusively prove that a change in the outcome measure is due to the action, the study design must ensure that no factors other than the action being tested can affect the outcome measure. For example, if children's blood lead levels drop following frequent street cleaning, the drop could be due not only to cleaner streets but to wetter weather, lower smelter emissions, different wind patterns, the children getting older, or even a number of other factors.

The only way to ensure that other factors do not confound the effect of the action under study is to compare changes in a *treatment* group with changes in a *control* group. The treatment group receives the intervention while the control group does not. The two groups must be matched with respect to all other factors that might affect the outcome measure and assignment to groups must be random. To test the effectiveness of frequent street cleaning, the children in the two groups would need to have the same distribution of age, gender and initial blood lead. The two groups would also have to be located in the same geographical area, so that weather and emissions fallout would be the same.

The randomized, controlled trial may be thought of as the “gold standard” - it is the only way to prove cause and effect, but not everyone can afford the time and money required to conduct their trials in this manner. Therefore, some remedial trials measure changes only in the group receiving the “treatment”. In these cases, conclusions about the effectiveness of the action may be drawn only by using available knowledge to estimate what changes might have occurred in a control group. For example, it might be possible to use information such as: expected average declines in blood lead as children age; a comparison of weather conditions before and after remediation and a comparison of smelter emissions fallout before and after remediation to estimate the amount of change in blood lead experienced by a treatment group that is due to the remedial action.

8.1.2 Sample Size

Another important aspect of study design requirements to consider is sample size. In order to conclude that an effect on an outcome measure is not due to chance, the treatment and control groups must contain a sufficient number of subjects. Required sample size is calculated during study design based on what is known about the populations being studied and the expected size of the effect.

In lead epidemiology, the chances of finding a conclusive effect on blood lead can be maximized by selecting study groups most likely to experience the greatest changes in blood lead. Since comparisons are being made between treatment and control groups, the blood lead change of interest may be either a greater reduction or a lesser rise. For example, in designing the HEPA House Cleaning Pilot Project, the Task Force Technical Committee considered that if the study focused on children with higher blood leads, the treatment group might be expected to drop more than the control group. On the other hand, if the focus were on infants, the treatment group might experience a lesser rise in blood lead than the control group. The decision made was to focus on young children in an effort to prevent a rise in blood lead. Unfortunately, it was necessary to recruit children up to six years of age in order to achieve the required sample size. Any future intervention study in Trail would also be up against this problem. That is, for statistical reasons, it will always be necessary to work with the whole population, rather than a segment which might maximize the chance of finding an effect.

The HEPA House Cleaning Pilot Project, with 55 treatment homes and 56 control homes, had the *statistical power* to conclude that a blood lead difference between groups of at least 1.5 µg/dL was real and not due to chance. Any other intervention trial in Trail using the same number of subjects would have about the same statistical power.

An effect size of 1.5 µg/dL may not seem significant at first. However, the average blood lead in Trail children (approx. 6 µg/dL) is now only about 3 µg/dL above normal background. That means a change of 1.5 µg/dL would represent about a 50% change in that portion of children's blood lead which is due to the smelter contamination. Considering that blood lead is determined by many factors (e.g. house dust lead, soil lead, outdoor dust lead, mouthing behaviour, diet, age, body burden of lead) in a number of locations (e.g. child's home, relative's homes, day care centre), it seems optimistic to think that any single action could result in an average blood lead reduction of 50%.

8.1.3 Bone-lead Mobilization

When using blood lead levels as the outcome measure in a remedial trial, it is also very important to be aware of the delay effect that bone-lead mobilization has on the reduction of children's blood lead levels following reductions in exposure. As described in Section 2 of this report, lead stored in bone tissue is not static. Instead, lead moves in and out of bone as part of normal physiological processes, such as growth, and in response to changes in lead exposure.

When a child's lead exposure is reduced, the resulting lower blood lead level is no longer in equilibrium with the lead stored in bone, so lead is mobilized from the bone into the bloodstream to restore equilibrium. This effect has been demonstrated in a study which measured lower bone-lead levels following an intervention consisting of paint abatement and chelation therapy (Rosen et.al., 1991; Markowitz et.al., 1993; Ruff et.al., 1993). Other studies have shown that blood lead levels rebound following completion of chelation therapy (Shannon, et.al., 1988; Graziano et.al., 1988; Graziano et.al., 1992).

A bone-lead mobilization model suggests that bone-lead stores can maintain children's blood lead levels at 75% of pre-intervention levels for up to 6 months after the complete elimination of new lead exposure, depending on the children's ages (US EPA, 1995). If the intervention only eliminates 50% of new exposure, blood lead levels might be maintained at 75% of pre-intervention levels for over one year.

The length of time required to reduce bone-lead stores emphasizes the importance of intervening at as early an age as possible and also implies that it may take more than one year for proper evaluation of the response in blood lead levels to improvements in environmental conditions.

8.1.4 Use of Environmental Measurements in Remedial Trials

An alternative to proving that remediation has an effect on blood lead is to look for an effect on a measurement of environmental lead which is closely related to blood lead. Of course, the principles of experimental design outlined above would apply here as well. To glean as much information as possible from a carefully designed trial, the HEPA House Cleaning Pilot Project also looked for an impact on the amount of lead on floors or on children's hands.

Unfortunately, finding a conclusive effect on an environmental lead measure is about as difficult as proving an effect on blood lead. There are well-accepted protocols for drawing samples from children that are representative of the blood in their entire bodies and that are measures of exposures over extended periods. In contrast, it is very difficult to collect environmental samples that are representative of the child's whole living environment and consequently the samples collected are merely "snapshots" of the exposure in a portion of the child's environment at an instant in time. Therefore, measurements of lead levels in an individual's environment are subject to greater random variability than are blood lead measurements. This greater variability might increase the effect of “regression to the mean” [2]. In a remedial trial, the effect of regression to the mean must be accounted for by examining a matched control group.

The reality is that proving the effectiveness of interventions or remediations requires carefully designed studies which consume considerable time and money and cannot guarantee conclusive results.

8.2 Use of Pathways Models and Risk Models

Another means of assessing the probable impact of a remedial measure on children’s blood lead levels is to estimate the relative or absolute magnitude of the impact using:

1. observed associations between environmental measures and blood lead levels (pathways models, such as described in Section 3.2), or

2. equations for determining the blood lead levels that should result, given the concentration of lead in environmental media such as soil, dust and water (risk models, such as the IEUBK model employed in Section 5)

Pathways models are primarily useful for expressing the relative magnitude of the impact of remedial actions taken to address various pathways. For example, the pathways model developed for Trail indicates that action taken to reduce house dust lead loadings will have a greater impact on children’s blood lead levels than would action taken to reduce street dust levels.

Pathways models also illustrate the dependency of one pathway on others. For example, if house dust lead loadings were reduced in Trail, the pathways model suggests that house dust would be replenished by street dust and soil, unless those sources are remediated. Likewise, unless lead fallout from emissions is reduced, soil and street dust lead levels are likely to rebound following remediation.

The relationships between variables in pathways models (e.g. the house dust lead/blood lead slope) can be used to estimate the reduction in blood lead that should occur if the lead level in a particular source is reduced, or if certain exposure pathways are

[2] Regression to the mean occurs when a set of measurements is repeated. Individuals or sites with high values in the first measurement will tend to have lower values in the second measurement, simply due to random variability.

interrupted. However, these relationships are based on an equilibrium that has developed over an unknown period of time, and they provide no guarantee that higher levels in a particular source actually cause higher blood lead levels. A number of researchers have conducted remedial trials, expecting substantial reductions in blood lead, only to be disappointed with the real world returns.

Risk models can also be used to prioritize pathways for actions and to estimate the magnitude of reduction in blood lead levels that should occur if action is taken on particular sources or pathways. As with pathways models, risk models are only a mathematical approximation of a complex real world situation. Risk models can be another useful tool for selecting the best remedial options, but again, the results of risk modelling provide no guarantee that actions taken will produce the predicted impacts.

8.3 Community Education and Case Management

8.3.1 Expectations Based on Pathways or Risk Models

The pathways modelling exercise for Trail (described in Section 3.2) found that the blood lead levels of children who live in areas near the smelter tend to be higher if they engage in behaviours which indicate obvious ingestion of soil/dust (i.e. chewing fingernails, putting dirt in mouths). Higher amounts of house dust were also strongly associated with higher blood lead levels. Children who had higher percentages of bare soil in their yards or who had dogs or cats also tended to have higher blood lead levels. The HEPA House Cleaning Study in Trail (Hilts et.al., 1995) found that families who removed their shoes at the door tended to have children with lower blood lead levels. These associations have also been observed at many other sites. (e.g. NSW Hlth. Dept., 1994; Panhandle Dist. Hlth. Dept., 1986; Cook et.al., 1993; Roberts et.al., 1991).

Many studies have documented the beneficial effect that proper nutrition can have in reducing lead absorption or toxicity. Total food intake, percent dietary fat and dietary intakes of calcium, iron, phosphorus, zinc and various vitamins have been shown to influence susceptibility to lead (Mahaffey, 1990).

Risk models, such as the US EPA's IEUBK model described in Section 5, also suggest that soil/dust ingestion rate and house dust lead levels are influential parameters in the determination of lead exposure and blood lead levels.

Therefore, parental and child education about reducing house dust, playing on "lead-safe" surfaces, reducing mouthing behaviours, reducing dust track-in into homes, and nutrition can be expected to have a significant beneficial impact on children's blood lead levels, *provided that the education efforts actually produce changes in behaviour*.

It is not possible at this time to use risk models to quantify the impact that education efforts and their resulting behavioural modifications should have on blood lead levels. No research has been done to determine to what extent soil/dust ingestion rates can be lowered by education. It seems that the assessment of effectiveness of educational efforts should be based primarily on the results of the real world applications described below.

8.3.2 Assessment of Actions Taken in Trail

Community education and case management programs began in earnest in Trail in 1991. It is not possible to quantify the specific impact that these programs have had on children's blood lead levels, as the educational messages and home counselling visits were not withheld from a matched control group. However, average blood lead levels of Trail children tested for the first time declined at an average rate of 0.6 µg/dL/year from 1989 through 1996. A decline in blood lead levels was observed at numerous locations around the globe during the period from about 1976 through 1994 (Annest et.al., 1983; Pirkle et.al., 1994; Bornschein et.al., 1988; Stromberg et.al., 1995; Schutz et.al., 1989). This global decline is thought to be due to such actions as the phase out of lead in gasoline and paint, the discontinued use of lead solder in food tins, and reduction in air emission from industrial plants. In Canada, where leaded gasoline was eliminated by 1990, the Ontario Blood Lead Study found that average blood lead levels in children not living near point sources declined by about 1.3 µg/dL/year from 1984 to 1990, and then appeared to level off (Langlois et.al., 1996). Therefore, it appears that the decline in blood lead levels in Trail from 1991 through 1996 must be at least partly due to local changes.

Changes in local environmental lead levels and weather conditions were investigated to determine whether the 0.6 µg/dL/year decline in average blood lead levels might be due to improvements in local conditions. As mentioned earlier in Section 3, average soil lead levels in Trail did not vary significantly from 1977 through 1992. It may be safely assumed that soil levels also did not vary significantly from 1992 through 1996.

In infants and toddlers, where skeletal lead contributes a relatively small portion of total blood lead concentration, lead in blood is generally thought to reflect fairly recent exposure (i.e. past 30 days) (National Academy of Science, (1993)). Many of the children tested annually in Trail, particularly those aged 3-5 years, have been chronically exposed to lead for several years and their present blood lead levels are much more dependent upon longer term past exposures. However, the year-to-year variability in average blood lead levels in Trail might be expected to correlate with exposure conditions during the summer months prior to each annual blood testing clinic. We therefore chose to look at environmental and weather conditions during the summers preceding each of the annual blood lead clinics.

Possible relationships between blood lead and air lead, dustfall lead and number of days without rainfall in the June-August period were examined. In multiple regression, no statistically significant correlations were found between average blood lead level and air lead, dustfall lead or number of dry days for either the whole summer period or for any subset of it. Table 19 shows that there clearly has not been any trend in August values for ambient air lead, dustfall lead or number of dry days over the 1989-96 period. Therefore the decline in blood lead levels from 1989-96 does not appear to be due to changes in summer air lead, dustfall lead or weather conditions.

Table 19 - Blood Lead Levels and Concurrent Environmental Conditions

Parameter	1989	1991	1992	1993	1994	1995	1996
Blood Lead (µg/dL)							
No. of children tested	169	197	118	99	95	76	46
Age and area-adjusted geometric mean	14.5	13.4	11.9	11.3	12.1	9.5	11.0
Lead in Suspended Particulate (µg/m^3)							
Geometric mean (August)	0.98	1.1	2.7	0.51	1.5	0.71	1.8
Lead in Dustfall (mg/m^2/day)							
Geometric mean (August)	NA	2.6	1.7	1.4	1.4	0.81	2.4
Weather							
No. of days without rain (August)	13	22	25	19	27	19	24

Another way of examining the effect of case management efforts is to look specifically at the children whose families received personal attention, in the form of home counselling visits and assistance with exposure reduction actions.

Table 20 shows that personal contact with families appears to have an impact on children's blood lead levels on one year follow-up.

Table 20 - Children's Blood Lead Levels Following Case Management Intervention

Year Children Received Intervention	Number of Children in Group	Average Age at enrollment (mos.)	Average Initial Blood Lead[1] (µg/dL)	Average Change in Blood Lead in Group 1 Year Later (µg/dL)	Paired *t*-test *p*-value for change
Chidren receiving intervention[2]					
1991	77	39	19.8	-4.0	<0.0001
1992	34	33	18.4	-3.1	<0.0001
1993	14	21	20.4	-2.3	0.10
1994	25	27	18.2	-3.1	0.0001
1995	14	30	17.4	+0.5	0.71
Children who did not receive intervention					
1989	55	48	19.8	+1.2	0.16

[1]All data in this table are for children who had an elevated blood lead level (≥ 15 µg/dL) prior to intervention.
[2] Data in this section are for children whose families received case management intervention for the first fime.

From 1991 through 1995, parents of children with elevated blood lead levels have been offered in-home counselling on how to reduce their children's exposure. Virtually all of the families who were offered counselling accepted, so there is no way to compare the change in blood lead in the counselled group with changes in an uncounselled group. The best available comparison is with the children who did not receive counselling in 1989. (In 1989, no exposure reduction counselling was provided to the families of children with elevated blood lead levels). Despite the high average age of these children at the time of their 1989 test (4 years), they showed an average increase of 1.2 µg/dL when tested one year later. (Children's blood lead levels generally increase to about 3 years of age, then decline steadily thereafter.) In contrast, when the blood lead levels of counselled children have been re-checked one year later, the average has declined significantly in 3 years out of 5. Curiously, there is no significant relationship between age and change in blood lead level among the children counselled from 1991-94. Therefore, despite the declining average age of children counselled for the first time, there is no need to age-adjust the blood lead data.

[The assessments presented in this section may reviewed in more detail by referring to an article published by the Trail Lead Program (Hilts et.al., 1998).]

8.3.3 Assessment of Actions Taken Elsewhere

Port Pirie, Australia

Luke (1991) conducted an analysis of predictors of reduced blood lead levels in 59 children in the active lead smelter town of Port Pirie. The children were from 59 different families who had received case worker intervention in the form of in-home counselling on lead exposure reduction. Unfortunately, there was no control group not receiving the intervention for comparison.

The study included measurement of lifestyle changes following case worker intervention. The changes most predictive of reduced blood lead levels were:

1. Improved dust related hygiene practices
2. A more substantial and nutritious early morning diet
3. A reduction in an easily enforced hand-to-mouth activity (mouthing of objects such as toys, stones and sticks).

Persons involved in the implementation and evaluation of the Port Pirie Lead Program feel that it is doubtful whether most of the behavioural modifications discovered to be effective could be maintained in the longer term (Maynard et.al., 1993). In particular, it is felt that substantial changes to dust hygiene practices and to mouthing activity would be very difficult to maintain. Advice regarding the consumption of adequate breakfasts has been better received in Port Pirie and, therefore, better longer term compliance might be expected in this area.

Milwaukee, Wisconsin

The effectiveness of in-home education efforts in Milwaukee from 1991-94 was studied by the Milwaukee Health Department (US EPA, 1995). The study examined 431 children up to 6 years of age with blood lead levels of 20-24 µg/dL. Of these, 195 children received in-home educational visits and 236 children did not receive visits, either because the family could not be contacted after three tries or because the children were identified before the educational program was started.

The visits lasted about one hour and included advice on nutrition, behaviour change and housekeeping. Post-intervention blood lead samples were obtained 2-15 months after the initial blood lead samples. Blood lead levels were adjusted for age and seasonal differences.

The arithmetic mean decline in the group which received visits was 4 µg/dL (from 22 to 18 µg/dL), while the decline in the control group was only 1 µg/dL (from 22 to 21 µg/dL). The difference between these declines was highly statistically significant ($p=0.001$). These results, which are of about the same magnitude as those reported for Trail in Section 8.2.1, suggest that educational intervention does produce some decline in children's blood lead levels, at least in the short term.

Another study in Milwaukee involved 28 children with initial blood lead levels of 25-40 µg/dL (US EPA, 1995). These children's homes were scheduled for lead-based paint abatement, but the abatement had not been conducted at the time of the home visit and follow-up blood lead test.

Children in this group received the same home visit as in the above study, plus an additional visit from a public health nurse, who conducted a child health assessment and answered any questions about lead. Follow-up blood samples were collected 2-6 months after the initial sample. There was no control group in this study, as virtually all eligible families were contacted.

The arithmetic mean decline in this group was 6 µg/dL (from 29 to 23 µg/dL). The larger decline in this group suggests that greater declines may be achieved when initial blood lead levels are higher, or that the second visit by the public health nurse may have provided additional benefit.

Silver Valley, Idaho

In-home counselling on lead exposure reduction also appears to have been successful in the former lead smelting community of Silver Valley. From 1985-93, about 80 children received some combination of in-home investigations, parental counselling and pathway-specific remediation of lead sources in their immediate environments (Terragraphics, 1993). These services were not withheld from a matched control group. More than 70% of these children responded positively (defined as a decline in blood lead level of at least 5 µg/dL after one year). Average blood lead level declines were about 50% (10 - 16 µg/dL) and were usually achieved in less than one year. Counselling alone, counselling combined with relocation, and remediation all produced about the same magnitude of blood lead declines on average. Concurrent counselling and remediation produced marginally higher declines.

Granite City, Illinois

A 1991 study in the former secondary lead smelting town of Granite City involved 78 children under age 6 who had blood lead levels greater than 9 µg/dL (Kimbrough et. al., 1993). The parents of these children received in-home counselling visits lasting about 30 to 45 minutes. The visits included advice on hand washing, nutrition, housekeeping, hand-to-mouth activity and simple paint abatement where indicated. There was no control group.

At one year follow-up, the average blood lead level had declined by 5 µg/dL (from 14.6 to 9.6 µg/dL), which is quite an astounding decrease given the relatively low initial blood lead levels.

St-Jean-sur-Richelieu, Quebec

A health education campaign was part of a comprehensive decontamination program carried out in a residential area surrounding a battery reclamation plant in St-Jean-sur-Richelieu, Québec in 1989-91 (Goulet et.al., 1996). The campaign included meetings with parents of young children living near the plant, distribution of pamphlets, visits to prenatal classes, provision of a telephone hotline and publication of articles in local newspapers. Surveys of parents conducted in 1989 before the campaign began and again in 1991 showed significant declines in the percentages of parents who reported that their children had pica or put things in their mouths. The percentage of children reported to have pica fell from 35.5% in 1989 to 18.8% in 1991 (p=0.004). The percentage of children reported to put things in their mouths fell from 46.2% in 1989 to 31.7% in 1991 ($p=0.03$).

Table 21 - Summary of Experiences with Community Education/Case Management

Intervention Year	Number Participating	Av. Initial BlPb (µg/dl)	Average Change within 1 yr (µg/dl)	City	Reference
1991-95	164	19.1	-3.1	Trail	EHP, 1998
1991-94	195	22.0	-4.0	Milwaukee	US EPA, 1995
1991-95	28	29.0	-6.0	Milwaukee	US EPA, 1995
1985-93	16	15-59	-15.0	Silver Valley	Terragraphics, 1993
1991	78	14.6	-5.0	Granite City	Kimbrough et.al, 1993

8.4 Community Dust Abatement

Pathways investigations in Trail and elsewhere have found that children who live in yards with poor ground cover, or who often play on bare ground, tend to have higher blood lead levels (Trail Lead Program, 1995b; . NSW Hlth. Dept., 1994; Panhandle Dist. Hlth. Dept., 1986; Cook et.al., 1993). The pathways model for Trail also indicates that soil may be a dominant source of both direct exposure for children ingesting soil and indirect exposure through it's contribution to house dust. Risk models indicate that interrupting the soil ingestion pathway should have significant impact on children's blood lead levels.

It would be difficult to use soil lead/blood lead relationships or risk models to estimate the amount of reduction in blood lead levels that would be expected from greening and dust control on bare public areas alone. Models can be used to quantify the expected impact of covering soil in a child's immediate environment. However, covering soil in public areas not only reduces direct contact by children in those areas, but also decreases the movement of dust around the community from those sources. This latter effect would be very difficult to model.

While many communities with lead contaminated soils and dusts have implemented community greening and dust control programs, none have set up such programs as experiments to quantify an effect on blood lead levels or environmental lead levels. To do so would require selection of a large area (at least 6 city blocks) to receive dust control and another area of the same size with similar characteristics to act as a control. Also, greening and dust control programs have always been implemented in conjunction with other actions.

Therefore, it is essentially impossible to determine the impact that community dust abatement programs have had on either blood or environmental lead levels. Generally, it is assumed that measures such as frequent street cleaning, greening of public areas, and paving will contribute to the reduction of blood lead levels, provided that the immediate objective is achieved effectively (i.e. that bare ground is adequately revegetated, street dust levels are reduced, etc.).

8.5 Relocation

Relocation of children from higher risk to lower risk areas is one action that is certain to reduce blood lead levels. This assumption has been confirmed in Trail by tracking a number of children who have relocated.

The effectiveness of relocation was also documented in Port Pirie by Luke (1991), who found that permanent relocation was the only environmental factor significantly associated with a lowering of blood lead level.

8.6 Soil Remediation

8.6.1 Expectations Based on Pathways or Risk Models

The pathways modelling exercise for Trail (described in Section 3.2) found that the blood lead levels of children who live in areas near the smelter tend to be higher if they engage in behaviours which indicate obvious ingestion of soil/dust (i.e. chewing fingernails, putting dirt in mouths). Higher concentrations of lead in yard soil were also associated with higher blood lead levels, particularly in children over 18 months or age. Children who had higher percentages of bare soil in their yards and who spent more time outdoors tended to have higher blood lead levels. These relationships, which have also been observed at numerous other sites, suggest that soil remediation or interruption of the soil ingestion pathway would be effective in reducing children's blood lead levels.

Risk models, such as the IEUBK model employed in Section 5, also suggest that soil ingestion plays an important role in childhood lead exposure. It is fairly straight forward to use risk models to estimate the effect of some types of soil remediation, but more difficult with others. For example, removing and replacing soil results in lower concentrations of lead in soil, which can then be input into soil ingestion model. In contrast, it would be difficult to model the effect of barriers which may be only partially effective in breaking the soil ingestion pathway. For example, a good grass cover might be expected to substantially reduce children's direct contact with soil, but not to eliminate it entirely. To date, the state-of-the-art of soil ingestion rate studies is not sufficiently precise to enable measurement of the reduction in soil ingestion rate that would result from establishing good grass cover.

8.6.2 Assessment of Actions Taken in Trail

To date, there have been no trials of soil remediation in Trail that would allow an assessment of impact on blood lead levels. However, there has been one qualitative study of occupant-performed residential ground cover improvement and there is an ongoing study of the effect of phosphate soil amendment on lead bioavailability.

Establishment of Ground Cover (Barriers)

In 1993/94, a trial of financially-assisted voluntary remediation of residential yards was conducted (Trail Lead Program, 1995c). The objective of the yard remediation was to provide barriers to reduce children's physical contact with soil and to reduce movement of dust by wind and human activity. The objectives of the trial were to determine the level of participation in a voluntary program of yard remediation by householders and to qualitatively assess the success of the householders' projects in establishing barriers between bare soil and children.

Families with children under 6 years of age who participated in the Trail Lead Program's blood screening program were invited to submit applications for a rebate on ground cover improvement projects. Operators of 7 licensed day care centres were also invited to submit applications. Based on a previous survey of parents, it was anticipated that 66% of the 299 properties would have areas of soil in need of ground cover and that about 63% of those would apply for financial assistance with projects (total of about 124 applications were expected). In fact, only 55 applications were received (effective application rate of about 28%).

The 43 families and one day care centre which completed their projects received reimbursement for 50% of their material costs (up to a maximum of $400) following final inspection of their projects. A total of $10,314.61 was paid out in reimbursements. Projects using predominantly concrete or asphalt for driveways, patios or retaining walls accounted for 15 of the projects and $4602.92 of the total cost. Projects using sod accounted for 12 projects and $2235.23. Other materials (such as top soil, gravel, landscaping fabric, landscape ties, lawn seed, fertilizer or bark chips) accounted for 17 projects and $3476.46.

Unfortunately, participation was lowest in the higher risk areas near the smelter, where improved ground cover would actually be of most benefit. A number of eligible parents in the higher risk areas remarked that, even with 50% of the materials costs being rebated, they still could not afford to undertake ground cover improvement projects. It was also noted that even when projects were completed as planned, there often remained additional areas on the properties that were in need of further ground cover work.

Several recommendations arising from this project have been implemented. The low participation rate in higher risk neighbourhoods and the inadequacy of the 50% rebate for low income families have been addressed through a Case Management Services Program introduced in 1994. The Case Management Services Program helps families who have children with elevated or rising blood lead by providing financial assistance with ground cover projects or house cleaning supplies or by providing cleaning services.

Soil Mixing

Mixing of soil to reduce the surface concentration of lead was tested at one property in Trail. Prior to roto-tilling, a composite sample from the top 2 cm of the soil contained 15,000 ppm lead. One day after roto-tilling, the lead concentration had dropped to 3,600 ppm.

Soil Treatment (Phosphate Amendment)

The health risk posed by lead contaminated soil is not determined by lead concentration alone. Factors such as the chemical form of lead, soil pH, texture and organic content all influence the bioavailability of lead in soil (Chaney et al., 1988). Investigating the geochemistry of Trail soils might provide additional options for remediation. For example, studies have suggested that inducing lead in soil to alter to low solubility lead phosphate can be effective in reducing bioavailability (Ma et.al., 1993; Ruby et.al., 1994; Ma et.al., 1995).

In 1994, the Trail Lead Task Force conducted a program to characterize Trail area soils in preparation for conducting bench-scale trials of soil amendments. The characterization work showed that the six areas sampled had similar soil geochemistry (PTI, 1995). In particular, all had relatively low clay and organic matter content, low pH and low water-soluble phosphate. These low levels suggested that soil amendment using phosphate and lime may be quite beneficial.

In 1995, bench-scale amendment trials began at the University of Colorado at Boulder, using soils from Trail (PTI, 1997). A number of possible amendments were first tested at various rates under optimum mixing and moisture conditions in order to select the amendments with greatest potential for success. Then, long-term (9 months) monitoring of soils in humidity cells was started. The amendments tested were:

1. Triple super phosphate
2. Triple super phosphate and iron in the form of ferric chloride
3. Phosphoric acid followed by lime, calcium carbonate and amorphous ferric hydroxide.

It was hoped that the addition of iron in amendments 2 and 3 would further promote the formation of lead phosphate mineral phases and might also combat the tendency for phosphate amendment to make arsenic more available. The third amendment involved the creation of a low pH environment through the addition of phosphoric acid. In the low pH environment, more lead would be liberated from existing mineral phases and hence available for subsequent formation of less soluble lead phosphates. The addition of lime or calcium carbonate in the third amendment was intended to restore the soil pH to between 6.5 and 7.0, where phosphate activity is at a maximum.

The long-term monitoring of soil in humidity cells began in October of 1995. The cells were sampled bimonthly, with the progress of the amendments being monitored through bioaccessibility and leachability testing for lead, cadmium and arsenic. The most effective amendment was the combination of phosphoric acid, calcium carbonate and amorphous ferric hydroxide, which achieved a reduction in lead bioaccessibility of about 55%. Unfortunately, that amendment (and all others) also produced an increase in the bioaccessible and leachable arsenic.

In addition to the humidity cell testing, varying solutions of phosphate and ferric hydroxide were applied to samples of Trail soil overlain by sod. These experiments were also conducted under temperature and humidity conditions designed to mimic the Trail climate. Unfortunately, the grass died following application of the amendments.

A second phase of bench-scale trials was conducted in 1997 to address the increases in arsenic bioaccessbility (Exponent, 1999a). The most successful amendment was a higher concentration of amorphous ferric hydroxide combined with lower concentrations of sparingly-soluble tri-calcium phosphate and phosphoric acid. This amendment reduced lead bioaccessibility by about 66% and actually produced decreases in arsenic bioaccessbility.

This phase of the study also involved an examination of the bioaccessbility and mineralogy of lead and arsenic in soil from the Trail area that have been amended by phosphorus historically (through application of fertilizers).

A third round of bench-scale trials was conducted in 1998 (Exponent, 1999b). This final laboratory investigation was conducted to ensure that we were not overlooking any amendments that might be even more effective than the amorphous ferric hydroxide with tri-calcium phosphate. Amendments tested in this phase included portland cement, zeolites, iron filings, steel shot, activated alumina, manganese oxide and several proprietary commercial mixtures.

Field trials of the most promising amendments commenced in the summer of 1998 (Exponent, 2000b). Unfortunately, no reductions in bioaccessibility were achieved in the field trials. It was decided not to pursue this investigation further at this time.

8.6.3 Assessment of Actions Taken Elsewhere

<u>Establishment of Ground Cover (Barriers)</u>

Mielke et. al. (1992) conducted a trial of dust control measures in inner-city neighbourhoods in Minnesota. A treatment group of 23 Minneapolis children received a dust control program, while a control group of 17 St. Paul children did not. The dust control program consisted of covering bare soil with sod or bark, provision of clean sand boxes, interior painted surface cleanup, house cleanup with a HEPA vacuum followed by mopping with high phosphate detergent, some carpet removal, , provision of household cleaning supplies and provision of dust control information. The treatment and control groups were on opposite sides of the river and there does not appear to be matching of treatment and control groups with respect to age or initial blood lead. However, the study did find a significant impact on treatment group blood lead levels in comparison with those of the control group. (It is difficult to quantify the effect here, as no mean changes in blood lead were reported.) The effect was due to some unknown combination of the abatements conducted.

<u>Soil Mixing</u>

There are no known reports of testing or use of soil mixing to reduce the surface concentration of lead at any sites where human health is a concern.

Soil Treatment

Soil treatment to reduce the bioavailability of lead to children has not yet been implemented at an operational scale at any sites. However, lab and field experiments have been conducted to assess the reduced leachability of lead phosphates and to confirm that lead phosphate formation can be induced through the addition of phosphates to soil. (Ma et.al., 1993; Ma et.al., 1995; Sellstone et.al., 1996). Experiments have also been conducted to investigate the possibility that addition of iron to soils can reduce the solubility of lead (Sellstone et.al., 1996).

Soil Removal and Replacement

US EPA Three Cities Study

The U.S. Environmental Protection Agency has conducted random controlled trials of soil lead abatement in Boston, Baltimore and Cincinnati at a total cost of over US$17 million. These studies, known as the “Three Cities Studies”, were aimed at assessing the effectiveness of lead-contaminated soil removal in a lead based paint environment. In Boston, abatement consisted of soil replacement and exterior paint cleanup. In Baltimore, soil, interior dust, interior paint and exterior paint were abated. In Cincinnati, soil, interior dust and street dust were abated in housing that had previously received lead based paint abatement. The three carefully designed studies tested the various abatements separately and in combinations. Only the results of the Boston study have been published. However, results from the Cincinnati and Baltimore studies presented at a conference in 1992 indicated that neither study had found any effect of soil abatement on children’s blood lead levels.

The first phase of the Boston study found that the effect of soil abatement on blood lead was a decline of 0.8 to 1.6 µg/dL, when the impact of potential confounders, such as water, dust and paint levels, children’s mouthing behaviours and other characteristics, was controlled for. The average pre-abatement blood lead level in the Boston study was 12.5 µg/dL and the average child age was 31.6 months.

The second phase of the Boston study involved conducting soil replacement for the two study groups which did not receive soil abatement in phase I. Interior lead based paint abatement was also offered to all three study groups. There was no control group studied in phase II, so declines in phase II had to be compared with declines in the same children during phase I, when they were one year younger. The mean decline in phase II was 3.6 µg/dL, whereas the average decline in the same study groups during phase I (no soil abatement) was 0.64 µg/dL. The decline attributable to phase II abatements appears to be about 3 µg/dL.

When the data for both phases and all three study groups were combined, the mean decline was 2.89 µg/dL, if children whose homes had paint abatement in phase II are excluded. Therefore, the soil abatement in all three groups and both phases combined appears to have resulted in a decline of 2.25 µg/dL. (2.89-0.64) However, as noted above, the phase II decline is difficult to assess due to the lack of a proper control group.

The Boston study also found that children with higher initial blood lead levels experienced larger declines. Soil abatement was not effective with children who lived in apartments with consistently elevated floor dust lead loadings throughout the study. The effect of soil abatement on floor dust lead loadings was inconsistent. In phase I, mean floor dust lead levels in the study group declined markedly from pre-abatement to 6-12 months post-abatement. In phase II, floor dust lead loadings did not change significantly in the two groups which received soil abatement.

Silver Valley, Idaho

Lamb and Kiernan (1988) reviewed the first ten years of activity at the Bunker Hill Superfund site at Kellogg, Idaho. Bunker Hill was the site of lead mining, milling and smelting from 1886 through to smelter closure in 1981. Starting in 1974, remedial action including soil replacement, resodding, paving, street washing and some relocation of families was conducted. The mean childhood blood lead level fell from 65 µg/dL in 1974 to 21 µg/dL in 1983. Whether the blood lead decline could be attributed to all or some of the remedial efforts is not known. Terragraphics Environmental Engineering(1993) has reported on intervention and abatement conducted from 1985 through 1993 at the Bunker Hill site. This report shows that from 1983 to 1993, the mean blood lead level in the area decreased by about 70%. The report attributes most of the decline in blood leads to the combination of education and soil removal activities that took place from 1985 through 1993. At various times during this period, four types of intervention responses were employed among children with blood lead levels above follow-up criteria: parental counselling followed by moving; counselling only; yard soil remediation 1-4 years after counselling; and concurrent counselling and remediation. Of 82 case-specific intervention efforts undertaken , 53 achieved at least a 5 µg/dL or 15 % reduction in blood lead in one year. Each of the intervention types achieved similar reductions in blood lead, with concurrent counselling and yard remediation being most effective by a slight margin. It is worth noting that even in the lowest risk area, where no yard remediation was conducted until 1992 (and then on only 2% of the yards in the area), the decline in blood lead from 1983-1993 was still 71%. This percentage decline is slightly better than that achieved in the higher risk areas, where yard remediation started in 1989 and about 25% of yards were cleaned up in total.

South Riverdale, Ontario

The Occupational Health Centre at Queen’s University (1991) could not find any effect on blood lead due to soil replacement in the secondary lead smelter community of South Riverdale, Ontario. However, it was felt that this analysis was based on blood screening conducted too soon after remediation for an effect to have occurred (soil replacement and house de-dusting finished in the fall of 1988 and post-abatement blood lead testing also occurred in the fall of 1988).

The Queen's University study based on 1988 blood lead data found that the decrease in blood lead was lowest in those children with the highest pre-abatement soil lead levels. Also, pre-abatement soil lead level was significantly correlated with post-abatement blood lead, but not with pre-abatement blood lead. These findings suggest that soil replacement may have been temporarily increasing lead exposure. This theory is supported by the observation that mean blood lead levels showed an increase about one month after abatement.

Blood lead levels were measured in South Riverdale and in a control area again in 1989, 19990 and 1992 (Langlois et. al., 1996). These surveys revealed that the difference in mean blood lead levels between South Riverdale and the control area had disappeared by 1992. However, it was difficult to distinguish the effect of soil replacement and house decontamination from the effects of an accelerated decline in air lead levels in 1987/88 and further smelter emission declines in 1992.

Within the South Riverdale community, children whose properties received abatment experienced slower declines in blood lead levels. The study authors suggest it is unlikely that the abatement activities themselves might have increased blood lead levels, as the transient increase in blood lead levels mentioned above was not significant, and there was no dose-response pattern (i.e. among children receiving abatment, those living on properties with higher levels of lead contamination did not experience slower declines in blood lead levels that those living on less contaminated properties. The slower decline in blood lead levels in children receiving abatement was attributed to other factors, such as selection bias (there may have been some bias in who did and did not consent to abatment and response rates for follow-up blood testing were poorer for children who received abatement), soil mixing after abatement, or localized recontamination from the smelter. Overall, it was deemed that the findings did not support nor refute a beneficial effect of soil and house dust abatement.

St-Jean-sur-Richelieu, Québec

A residential area surrounding a battery reclamation plant in St-Jean-sur-Richelieu, Québec was found in 1988 to have lead contaminated soil and dust (Goulet et.al., 1996). The geometric mean blood lead level of children aged 6 months to 10 years living within 200 metres of the plant was 9.2 µg/dL in 1989. A public health program was developed in response to these findings. The program consisted of the following measures:

- in 1989 the plant was shut down, the plant yard was asphalted and street dust was cleaned up in the surrounding area (150 m radius from the plant site)
- also in 1989, within 150 m of the plant, 10-30 cm of soil were removed and replaced, regardless of lead concentration, unless covered with grass or gravel. Areas covered with grass or gravel had soil replacement if lead concentrations

were above 500 ppm. In the area from 150-600 m from the plant, bare soil was replaced if lead concentration exceeded 400 ppm and areas covered with grass or gravel were replaced if lead levels were above 1000 ppm.

- in 1989/90 115 houses within 600 m radius of the plant site were professionally cleaned (HEPA vacuuming of ceiling, walls, floors, furniture and heating ducts; steam-cleaning of carpets and furniture, damp-mopping of floors
- in 1990-92 all homes within 150 m radius of the plant with children 0-6 years of age were offered the professional cleaning service
- in 1989/90, a public health information campaign was conducted, which included meetings with parents of young children living near the plant, distribution of pamphlets, visits to prenatal classes, provision of a telephone hotline and publication of articles in local newspapers.

The cost of the program was approximately 4 million dollars, with soil replacement being the most costly component.

A second epidemiologic survey was conducted in 1991 to evaluate the impact of the above actions. The geometric mean blood lead level had fallen from 9.2 µg/dL in 1989 to 5.0 in 1991. Although the program was successful, the actions were not carried out in a controlled way that would permit the evaluation of specific effects of each program component. As mentioned in 8.3.3, the health education campaign appeared to provided some benefit, as evidenced by significant declines in the percentages of parents who reported that their children had pica or who put things in their mouths.

Rouyn-Noranda, Québec

The town of Rouyn-Noranda has been the site of a copper smelter since 1927. In 1979, children aged 2-5 years in the district closest to smelter had an average blood lead level of 21.4 (Gagné, pers. comm.). A follow-up survey in 1989 showed that only two children had blood leads higher than 25 µg/dL (the Canadian action level at the time) and the average was 11.1 µg/dL (Letourneau and Gagné, 1992). Despite the considerable improvement over ten years, the local Department of Community Health recommended that action be taken to ensure that ultimately no child in the age group would have a blood lead greater than 10 µg/dL.

The results of the 1989 survey were released at a public meeting and a citizens' committee was formed spontaneously a few days later (Gagné, pers. comm.). The Rouyn-Noranda City Council then decided to form a task force to study the problem. The task force was composed of representatives from the City, the smelting company, the Department of Community Health, the citizens' committee and the Québec Ministry of Environment. The group was co-chaired by a citizen and a municipal councillor. After four months of study and discussion, the group reached consensus on a short term objective and a proposed set of corrective actions.

The task force's goal was to reduce the percentage of children with blood lead greater than 10 µg/dL to 10%. (In 1989, 49% of children had blood lead greater than 10 µg/dL.) The corrective measures proposed were:

- removal of all top soil in the most contaminated zone and on residential lots of all children with blood lead greater than 10 µg/dL
- removal of top soil which averaged more than 500 ppm lead from all residential lots and public areas in the less contaminated zones
- reduction of lead emissions from the smelter stack as well as from fugitive emissions
- thorough cleaning of house interiors was not judged necessary based on dust sampling
- counselling of all families with young children concerning hygienic measures to reduce lead intake
- paving of all back alleys
- monitoring of lead in suspended particulate and in dustfall
- follow-up blood lead surveys in 1990, 1993 and 1995

Soil removal took place during 1990 and 1991 at a cost of about $3,000,000 and improvements in smelter emissions were achieved from 1990 through 1993 at a cost of about $16,000,000 (Gagné, pers. comm.). The Department of Community Health has assumed all costs of blood lead screening and reporting, the smelter company has paid for all soil removal and emissions improvements, the City has paid for alley paving and community greening and the Ministry of Environment has overseen removal and disposal of soil and paid for soil testing.

Community participation in the blood screening has been extremely high - generally about 90%. By 1991, only 25% of children had a blood lead level in excess of 10 µg/dL and by 1993, the percentage above 10 had fallen to 13% (Gagné, 1993). During the period from 1991 to 1993, lead in dustfall declined by about 35%. However, there is no evidence that the blood lead decline has been greater for children living on abated properties than for those living on unabated properties (Gagné, 1992). Since the 1993 blood testing indicated that the objective of having only 10% of children with blood lead levels above 10 µg/dL was nearly reached, the community decided to skip the planned blood lead testing in 1995 in favour of an assessment of long-term success in 1999 (Gagné, pers. comm.).

The September 1999 blood lead screening in Rouyn-Noranda found that the proportion of children aged 1-5 years living with 1 kilometre of the smelter had fallen to 6%. The 1999 geometric mean blood lead level was 5.0 µg/dl (Gagné, pers. comm.).

8.6.4 Soil Remediation Cost Estimates

In 2000, cost estimates for several soil remediation alternatives were prepared for the Trail Community Lead Task Force by Western Bioresources Consulting Ltd. (Western Bioresources, 2000).

The objectives of the investigation were to:

- compile information regarding the estimated number of residential properties on which soil numerical standards would be exceeded
- review treatment strategies employed by other smelter-impacted communities
- determine the material and labour requirement for implementing selected soil treatment strategies
- develop cost estimates for carrying out this work

The investigation involved:

- Characterization of Residential Lots:
    - The number and size of residential lots in each neighbourhood were estimated using information from the City of Trail, BC Assessment Authority and the Trail Lead Program GIS system.
    - Properties with lot sizes near the 25th percentile and 75th percentile were selected to represent the upper and lower range of residences with each neighbourhood.
    - Site surveys were conducted for 42 properties selected from the set of 25th and 75th percentile properties described above. The survey parameters included:
        - Area covered by concrete or buildings, as opposed to lawn and/or exposed soil
        - Area of vegetable gardens and/or flower beds
        - Number of large trees

    - Accessibility based on four different types of equipment: dump truck, bobcat mini-loader, wheelbarrow or chain-gang.

  - The number of properties with soil lead levels exceeding the BC numerical standards, and various higher cut-off levels, was estimated for each neighbourhood using data collected by the Trail Lead Program.

- Review of Remediation Alternatives:

  - Western Bioresources conducted a review of published reports, engineering studies, public notification documents and conference proceedings from eight communities throughout the world. Key people involved in remediation projects at some of these sites were also contacted by telephone or e-mail.

- Cost Modelling:

  - A costing model was developed, which included three components:

    - Inputs (lot characteristics and material/labour unit costs)

    - Unit Operations (different combinations of unit operations, such as site assessment and preparation, excavation, soil replacement, surfacing, post-treatment assessment, for 11 remediation alternatives)

    - Outputs (cost per lot, cost per neighbourhood at different soil lead trigger levels)

The 11 remediation alternatives included in the costing investigation were:

1. Vegetable garden soil replacement
2. Vegetable garden and flower bed soil replacement
3. Garden and flower bed replacement plus lawn sodding
4. Soil excavation to 7 cm depth and replacement with clean soil and sod cover
5. Soil excavation to 15 cm depth and replacement with clean soil and sod
6. Soil excavation to 30 cm depth and replacement with clean soil and sod
7. Triple digging (mixing the top 45 cm of soil in three 15 cm lifts)
8. Soil excavation to 7 cm, replacement with clean soil and hydro-seeding
9. Soil excavation to 15 cm, replacement with clean soil and hydro-seeding
10. Soil excavation to 30 cm, replacement with clean soil and hydro-seeding

11. Soil excavation to 45 cm, replacement with clean soil and hydro-seeding

<u>Results</u>:

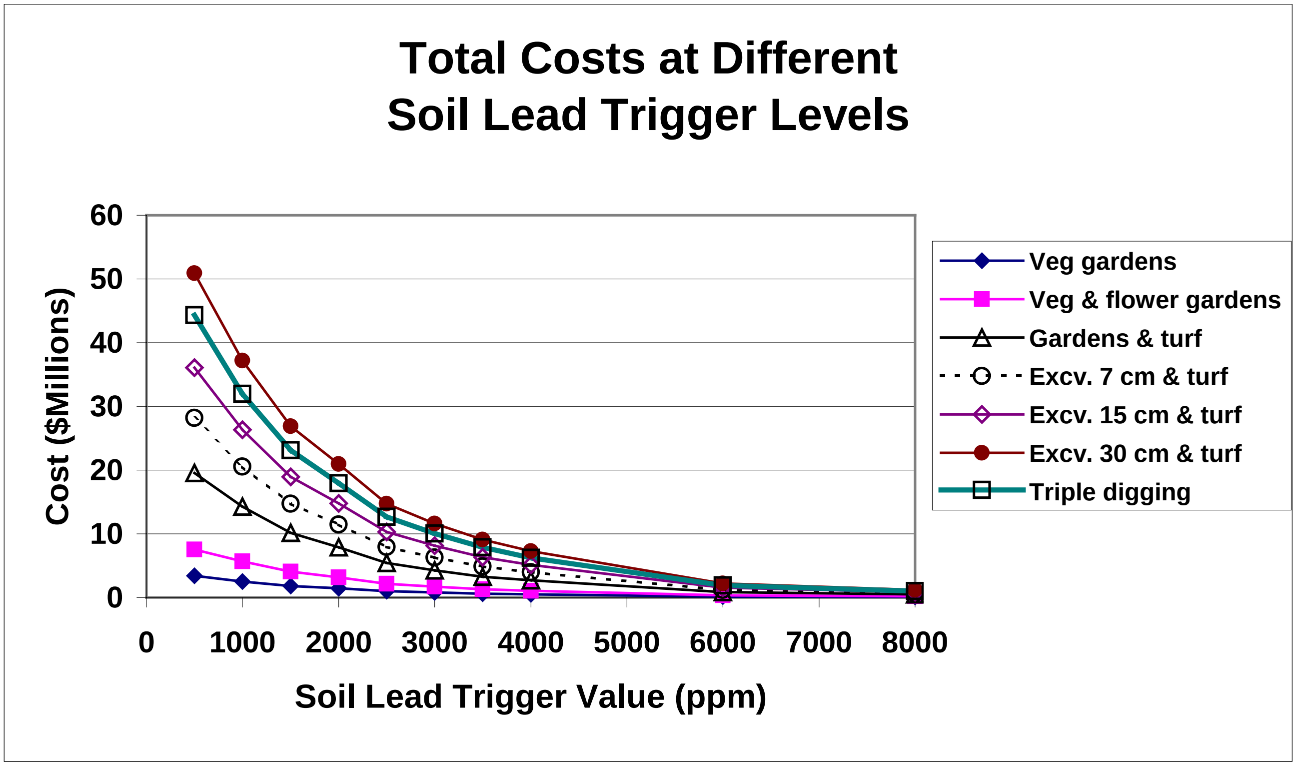
Overall costs based on a soil lead trigger level of 500 ppm are given in Table 22. It is estimated that about 2700 properties have soil lead concentrations exceeding 500 ppm.

Table 22 - Cost Estimates for Soil Remediation

Remediation Alternative	Average Cost per Lot (Canadian dollars)	Cost Estimate Based on 500 ppm Lead Trigger Level
1 (Vegetable gardens)	$1300	$3.4 million
2 (Vegetable & flower gardens)	$2800	$7.5 million
3 (Gardens and turf)	$7000	$19 million
4 (Excavate/replace & turf - 7 cm)	$10,400	$28 million
5 (Excavate/replace & turf - 15 cm)	$13,300	$36 million
6 (Excavate/replace & turf - 30 cm)	$18,500	$50 million
7 (Triple digging)	$16,300	$44 million
8 (Excavate/replace & seed - 7 cm)	$10,000	$27 million
9 (Excavate/replace & seed - 15 cm)	$13,000	$35 million
10 (Excavate/replace & seed - 30 cm)	$18,100	$49 million
11 (Excavate/replace & seed - 45 cm)	$15,900	$43 million

The Western Bioresources report includes costs per lot in each neighbourhood, and total costs per neighbourhood, for each of the 11 alternatives.

Figure 28 - Estimated Total Costs for Soil Remediation Alternatives



Caveats:

- The cost model did not include costs associating with storage and treatment of contaminated soils, which could amount to as much as $10 million (only a basic $20/m^3$ tipping fee associated with a typical modern engineered landfill was included)
- The cost model did not allow for possible economies of scale. For example, the total costs could be reduced if remediation were approached on a block-by-block or neighbourhood-by-neighbourhood basis.
- The cost model is sensitive to the high variability in accessibility to lots, sizes of lots, sizes of gardens, etc. If a decision is made to pursue one of the soil remediation alternatives, it would be wise to reduce model uncertainty by doing some further site survey work prior to commencing the remedial work.

Table 23 - Summary of Soil Remediation Alternatives - Effectiveness

Method	*Outcome*	*Source*
Ground Cover		
Trail	Final inspection ensured successful projects - low participation rate (28%) attributed to 50% subsidy	TLP, 1995
Minnesota	Significant impact on treatment group's BlPb's	Mielke et. al., 1992
Phytoextraction		
Other Sites	No plant species has been identified that accumulates enough lead to be effective in a reasonable time-frame	Various pers. comm.
Soil Mixing		
Trail	Pb conc. dropped from 15,000 to 3,600 ppm (1 property)	Trail Lead Program experience
Soil Treatment & Phosphate Amendment		
Trail	Field trials showed no reduction in Pb bioavailability	Exponent, 2000
Other Sites	Reduced leachability and bioavailability of Pb due to phosphate addition	Ma et.al, 1993; Ma et.al.1995; Sellstone et.al., 1996
Soil Removal		
Boston	Children's BlPb's declined by an avg. of 2.25 µg/dl	US EPA, 1995
Cincinnati & Baltimore	No evidence of greater BlPb declines in children living on abated properties	US EPA, 1995
South Riverdale	Findings inconclusive	Langlois et.al., 1996
Rouyn-Noranda	No evidence of greater BlPb declines in children living on abated properties	Gagne, 1992
Soil Removal plus other interventions		
St-Jean-sur-Richelieu	BlPb's reduced from 9.2 µg/dl in 1989 to 5.0 µg/dl in 1991 - isolated effect of soil removal not studied	Goulet et.al., 1996
Silver Valley	BlPb's reduced from 65 µg/dl in 1974 to 21 µg/dl in 1983 - concurrent counselling and yard remed-ation most effective intervention	Lamb et.al., 1988 Terragraphics Env. Eng., 1993

Table 24 - Summary of Soil Remediation Alternative Cost Estimates

Method	Applies to	Cost per Yard (Range)	Reference
Ground Cover (by residents, with cost subsidy)	Bare areas of yard	$250 - $1000	Trail Lead Program, 1995c
Soil Removal & Replacement	Gardens (veg. & flower)	$1300 - $4100	Western Bioresources, 2000
Phytoextraction	Gardens ---> whole yard	currently not judged feasible	Various pers. comm.
Soil Treatment & Phosphate Amendment	Gardens ---> whole yard	currently not judged feasible/effective	Exponent, 2000
Soil Mixing (roto-tilling)	Gardens ---> whole yard	$500 - $15,000	Trail Lead Program experience
Soil Mixing (triple-digging)	Whole yard	$12,000 - $48,000	Western Bioresources, 2000
Soil Removal & Replacement	Whole yard	$12,000 - $55,000	Boehnke, 1991; Cobb, 1991; Nieveen, 1994; Bennett, 1995 Doolan (2000)
Soil Removal & Replacement	Whole yard (top 30 cm)	$14,000 - $50,000	Western Bioresources, 2000

8.7 House Dust Remediation

8.7.1 Expectations Based on Pathways or Risk Models

The pathways modelling exercise for Trail (described in Section 3.2) found that the blood lead levels of children who live in areas near the smelter tend to be higher if they engage in behaviours which indicate obvious ingestion of soil/dust (i.e. chewing fingernails, putting dirt in mouths). Higher loadings and concentrations of lead in house dust were also strongly associated with higher blood lead levels, particularly in children less than 18 months of age. These relationships, which have also been observed at numerous other sites, suggest that house dust remediation or interruption of the dust ingestion pathway would be effective in reducing children's blood lead levels.

Risk models, such as the IEUBK model employed in Section 5, also suggest that dust ingestion plays an important role in childhood lead exposure. However, it is difficult to use the IEUBK model, or any other risk model, to estimate the impact of house dust remedial actions. Actions that may be taken to reduce house dust lead exposure, such as intensive HEPA vacuuming, will not affect the concentration of lead in the house dust (CH2MHill, 1991; Ewers et. al., 1994; Hilts et. al., 1995). Any reduction in exposure to lead in house dust as a result of remediation will arise from lowering of lead loadings, rather than concentrations. As current models accept only concentrations as inputs for house dust lead levels, it is not possible at this time to estimate the effects of reduced loadings through clean-up of dust. There is discussion of incorporating an option for inputting loadings in a future version of the IEUBK model.

8.7.2 Assessment of Actions Taken in Trail

HEPA House Cleaning Pilot Project

The benefit of providing repeated house vacuuming using HEPA vacuum cleaners was studied in Trail in 1993 (Hilts et. al., 1995). 55 treatment homes received thorough vacuuming of finished accessible floor areas once every six weeks for 10 months, while 56 control homes did not. Although the vacuuming typically achieved immediate reductions in carpet surface lead loading of about 40%, the study did not show any clinically significant impact on either blood lead or floor lead over its 10 month term. Therefore, regular HEPA vacuuming is not a primary component of the community-wide intervention strategy at this time. However, a survey of participants and an ancillary investigation of recontamination provided insight into factors that influence indoor lead exposure and indicate that more frequent vacuuming might be beneficial in some cases. In particular, the vacuuming service achieved greater reductions in floor lead loadings in homes where the parents did not vacuum frequently and where the children had higher blood leads at the start of the study.

A follow-up study was conducted in 17 homes located in high-risk neighbourhoods. Families in the follow-up study received HEPA vacuuming, wet-mopping and wet-wiping once every 2 weeks over the summer months. Participants also received exposure reduction advice and financial assistance with ground cover improvement. There was no random assignment to a control group in the follow-up study. The average blood lead level of children in the study group rose by 2.9 µg/dL from April to September, whereas the blood leads of 10 children about the same age, living in the same neighbourhoods, but not enrolled in the study, rose by 4.2 µg/dL over the same period. The difference between groups was not statistically significant. The average amount of lead on carpet surfaces in the study group did not change from start to finish (0.47 to 0.42 mg/m^2; p-value 0.60), whereas the lead on carpets in 14 homes in the same neighbourhoods nearly doubled over the same period (0.52 to 0.90 mg/m^2; p-value 0.01). Therefore, the interventions appeared to prevent a seasonal rise in the amount of lead on the surfaces of carpets and may have lessened the rise in blood leads.

8.7.3 Assessment of Actions Taken Elsewhere

There have been a number of studies of the ability of various methods to remove contaminated dust from homes (Ewers et.al., 1994; Milar and Mushak, 1982; City of Toronto, 1989; Saskatchewan Research Council, 1992; CH2M Hill, 1991). This section reviews only those studies which have looked for an effect of house dust remediation on children's blood lead levels.

Baltimore, Maryland

Charney et. al. (1983) published perhaps the best example to date of a highly successful intervention trial in the childhood lead exposure field. In that study, a treatment group of 14 homes in Baltimore received wet-mopping twice-monthly, while a control group of 35 homes did not. In addition to the cleaning, the treatment group parents were advised to wash their children's hand frequently, to wet-mop frequently between visits and to keep their children away from lead paint or dust "hot spots". The average blood lead in the treatment group fell from 38.6 µg/dL to 31.7 µg/dL (a drop of 6.9 µg/dL), while the control group fell by only 0.7 µg/dL. This remarkable drop occurred over one year and was possible only because of the high average initial blood leads. The researchers concluded that the drop was due to some unknown combination of house cleaning by the study team, improved house cleaning by the householders, regular hand washing and avoidance of high lead areas.

Seattle, Washington

A study by Roberts et.al. (1991) involved sampling house dust and soil in 37 Seattle homes and 5 Port Townsend homes. The data were combined with other information about the homes and their occupants and used to construct an exposure model. The authors found that homes which practised removal of shoes at the door and used walk-off mats tended to have lower amounts of floor dust lead. An attempt was made to test this association in three homes. Occupants of these homes started removing shoes at the door and one of the homes also started using a walk-off mat and vacuuming twice per week. Five months later, floor dust lead was found to be dramatically lower in the three study homes. This portion of the study not reliable, as the sample size was very small, no control group was monitored, and the final dust samples were collected in winter.

Minneapolis/St. Paul, Minnesota

As described in Section 8.6.3, Mielke et.al. (1992) found a significant drop in blood lead levels due to a combination of various indoor and outdoor dust control measures.

Rochester, New York

A randomized, controlled trial of the effect of dust control on children's blood lead levels was conducted in Rochester, New York in 1993 and 1994 (Lanphear et. al., 1996). One hundred four children were randomly assigned to either an intervention group or a control group. Families in the intervention group received cleaning supplies, information about cleaning and a cleaning demonstration. They were instructed to clean carpets thoroughly with a vacuum cleaner each week, to clean window wells each month when the windows were open, to clean interior window sills and floors near windows once each month and to clean the entire house every three months. Families in the control group received only a brochure about preventing lead exposure.

Children's blood lead levels and lead levels in house dust were assessed at baseline and again at seven months after enrolment. There was no significant difference in the change in children's blood lead levels or in dust lead levels between the treatment and control groups. These data suggest that an intervention which consists only of providing cleaning supplies and advice is not effective at reducing blood lead levels among children with low to mild elevations in blood lead levels. Even if families in the intervention group followed all instructions, it seems unlikely that the cleaning advice provided would have offered much protection against lead exposure. Non-carpeted floors were to be cleaned only once every three months or monthly if they were near windows. Certainly a great deal of dust can accumulate on floors over a month, and all of the dust which accumulates on non-carpeted floors is readily available to children's hands.

The potential preventive effect of dust control was investigated in a subsequent study in Rochestor (Lanphear et.al., 1999). In that study, 275 children were assigned to treament or control groups at 6 months of age. The treatment group received cleaning equipment and up to 8 visits by a "dust control advisor" over 18 months. The control group did not receive any lead exposure prevention education or interventions. At enrollment, the geometric mean blood lead level in both groups was 2.9 µg/dL. At 24 months after enrollment, the geometric mean blood lead level in the treatment group was 7.3 (95% confidence interval 6.6 - 8.2) and the geometric mean in the control group was 7.8 (95% confidence interval 6.9 - 8.7). The authors concluded that dust control, as performed by families and in the absence of actions to reduce ongoing contamination from lead-based paint, is not effective in the primary prevention of childhood lead exposure.

Piscataway, New Jersey

A trial by Rhoads et.al. (1999) involved 113 children aged 6 to 36 months, who were randomly assigned to either a lead dust intervention group or a control group. The intervention group received house cleaning assistance and maternal education on lead exposure prevention once every two weeks for one year. The house cleaning was performed by two trained workers who conducted wet mopping of floors, damp-sponging of walls and horizontal surfaces and use of HEPA-filtered vacuum cleaners. The study found that blood lead fell by 17% in the intervention group and did not change among controls. The authors recommended that regular house cleaning, accompanied by maternal education should be provided for lead-exposed children for whom removal to lead-safe housing is not an option.

Table 25 provides a summary of the dust control trials described in this section. The overall conclusion is that dust control has been shown to be effective in reducing or preventing childhood lead exposure only when it has been performed for families by workers or when initial blood lead levels are very high. The frequency of cleaning also must be high enough to stay ahead of recontamination.

Table 25 - Summary of Dust Control Trials

Intervention	Group	Sample Size	Blood Lead Result (µg/dl)	Significant Difference between Groups?	Reference
House cleaning service & counseling	Treatment	56	decline of 17%	Yes	Rhoads et al, 1999
	Control	57	no change		
House cleaning service & counseling	Treatment	14	decline of 6.9	Yes	Charney et.al., 1983
	Control	35	decline of 0.7		
House cleaning service, ground cover, & sand boxes	Treatment	23	decline (means not presented)	Yes	Mielke et.al, 1992
	Control	17	decline (means not presented)		
Provision of cleaning supplies and advice	Treatment	52	decline of 0.05	No	Lanphear et.al., 1996
	Control	52	decline of 0.60		
Provision of cleaning supplies and advice	Treatment	140	increase of 4.4	No	Lanphear et.al., 1999
	Control	135	increase of 4.9		
House cleaning service (HEPA vacuuming only)	Treatment	55	decline of 0.9	No	Hilts et.al., 1995
	Control	56	decline of 0.6		

8.8 Lead-based Paint Remediation

8.8.1 Expectations Based on Pathways or Risk Models

The pathways modelling exercise for Trail (described in Section 3.2) found that paint generally has relatively little influence on children's blood lead levels in Trail. However, paint could be a factor in individual cases.

The US EPA IEUBK model for lead does include modelling of blood lead levels resulting from paint exposure and there are many published cases of children who have clearly suffered from clinical lead poisoning as a result of ingestion of paint chips. Many studies in U.S. locations have found significant associations between levels of lead in paint, dust and children's blood.

8.8.2 Assessment of Actions Taken in Trail

No trials of lead-based paint abatement have been conducted in Trail.

8.8.3 Assessment of Action Taken Elsewhere

There have been numerous studies to evaluate the effectiveness of lead based paint abatement combined with dust control measures. Some of these studies have shown a reduction in blood lead (Copley, 1983; Staes et.al., 1991), while others have shown a short-term increase (Amitai et.al., 1991) or no significant change (Farfel and Chisholm, 1990). These studies generally found that lead-based paint abatement is most detrimental if accomplished with heat guns, sanding or dry scraping.

Two trials of experimental lead-based paint abatement procedures, developed in response to inadequacies in traditional methods, found that comprehensive lead-based paint abatement was associated with long-term as well as short-term reductions in interior dust lead levels (Farfel and Chisholm, 1991; Farfel et.al., 1994). The experimental abatements used offsite or onsite chemical paint stripping rather than heat guns or sanding, and paint was abated from floor to ceiling, rather than just to 1.5 m above the floor.

9. REMEDIAL OPTIONS: SELECTION

9.1 Public Consultation - Process and Results

Since the inception of the Task Force, public participation has been sought and maintained. The Task Force has always had at least five active community members. However, in developing the recommendations, the Task Force consulted with the community on a broader basis in an effort to incorporate the public's long-term expectations for remedial activities. As well, international experts have been consulted to benefit from their combined experiences and knowledge of remedial efforts.

The Task Force also hoped that its public consultation process would satisfy the Medical Health Officer's requirements for public consultation under the Contaminated Sites Regulation. Hence, the Task Force worked closely with the Medical Health Officer in the development and implementation of the public consultation process.

A separate report on the public consultation process has also been produced (Trail Lead Program 2000).

9.1.1 Methods

The Public Consultation Planning Group, a sub-committee of the Task Force, was established in 1999 to plan and guide the community consultation process.

Beck Circle Consulting was contracted to assist with the planning of the consultation and to facilitate the process.

In January 2000, a press release was issued, explaining the consultation process. Then, the consultants contacted and met with key stakeholders and sub-communities within the community to provide information about the planned process, to generate interest in upcoming meetings and to ask the community how it preferred to participate.

In spring 2000, a newsletter was mailed to every household in Trail and Warfield, explaining the process and advertising meeting locations. In addition to the newsletter, the meetings were advertised in the local print and radio media. Five meetings were held at various community locations. The purpose of these meetings was to present the community with background information and receive preliminary input on the acceptability of health risks and remedial options. A workbook was developed for use at the meetings, which included copies of the presentation overheads as well as input sheets for recording the community members' opinions.

Following the spring meetings, the public consultation planning group and the Task Force reviewed the input sheets. A newsletter was compiled and again mailed to every household in Trail and Warfield. The newsletter summarized results of the meetings and outlined plans for the fall.

In fall 2000, because of low participation at the spring meetings, the forum was changed from a general public meeting to a focus group workshop. The purpose of the workshop was to review draft recommendations. Key community stakeholders were invited to attend, and an open invitation was issued to the general public. A workbook was developed for use at the workshop, which included copies of the presentation overheads. Input sheets for recording small group discussions were also developed.

Following the fall workshop, the Task Force recommendations were modified, based on suggestions that came out of the workshop and further Task Force review. A brochure, giving a brief overview of health risks and outlining proposed recommendations, was compiled and mailed to every household in Trail and Warfield. Included with this brochure was a comment sheet and postage-paid response envelope to enable all interested community members to comment on the proposed recommendations.

9.1.2 Results

Spring Meetings

In February and March 2000, the consultants contacted 35 community members to generate interest in the upcoming meetings. As well, the consultants met with 3 groups - the Children, Youth and Family Committee, Coldwell Banker realtors, and the Rotary Club of Trail – to provide information and generate interest.

In spring 2000, a total of 41 people attended the five meetings. Of these participants, 23 were residents of Trail and Warfield. Input sheets were collected and responses compiled. In general, 90% of the community members who attended the meetings had some concerns about current health risks due to lead. For cadmium and arsenic, 80% of the community members had some concerns about current health risks. In particular, there was concern around cadmium and arsenic in garden soil and locally grown produce.

The responses showed consistent agreement for continuation of these actions:

- Further reductions in Cominco emissions
- Monitoring of blood lead and environmental lead levels, to ensure levels continue to decrease
- Provincial monitoring of disease rates
- Counseling and services for at-risk families

- General public education and early childhood education
- Community dust control such as greening of public spaces, alley spraying and street washing

Some residents commented that it was important to continue having an independent group monitoring and educating.

The responses showed consistent agreement for considering these options in more detail:

- Addressing soil (mixed views for soil removal, most interest in ground cover)
- Addressing lead-based paint
- Improving or expanding the buffer zone surrounding the smelter
- Supporting general health promotion programs
- Helping people who want to quit smoking
- Supporting child development

The meeting participants were evenly divided on these options:

- Re-zoning (e.g. no new residential development in higher risk areas)
- Relocation of at-risk families to lower risk areas

After the series of meetings, the consultants were asked to contact those people they had spoken with prior to the meetings to try to determine the reason for the low participation. The consultants conducted an informal telephone survey of 16 people. In general, the community members contacted were either unclear of the purpose of the meetings or did not feel that the lead issue is a priority. Also, because the Task Force is shutting down, some people perceive that there is no further concern. Of those telephoned, only 1/3 stated that they would participate in the fall.

Fall Workshop and Community Services Fair

In fall 2000, 31 people attended the focus group workshop. Of that, 24 people were residents of Trail and Warfield. In general, there was support for the package of recommendations. However, workshop participants made the following suggestions:

- Add age range and dates to the goal statement.
- Request timelines and targets for further emission reduction projects.

- Place a strong emphasis on greening, with soil removal used on a very limited basis for case management purposes.
- Continue education, blood lead testing, and services for at-risk families.
- Clarify the purpose and scope of the Work Project Assistance Program.
- Consider the monitoring committee's coordination (without its own staff) and membership appointment.
- Minimize socio-economic impacts.

The public consultation planning group and the Task Force reviewed the suggestions that came out the fall workshop and modified the recommendations.

Also in fall 2000, the Trail Lead Program staff participated in a "Community Services Fair", where a diverse group of organizations presented information about their services to the attending community members. Many community members stopped at the Lead Program table, and comments were recorded.

December Mail-out

After the recommendations were compiled into a brochure and mailed to every household in Trail and Warfield for comment, the Task Force reviewed the 203 survey responses that were received by the deadline.

Support for the Task Force's recommended goals, actions and delivery scheme were all very high, with 75-82% of respondents indicating their agreement. Support for individual actions was also high, with 80-90% stating that each action was "desirable" or "essential". The strongest support was shown for further emission reductions, environmental monitoring and community dust control.

Among those who did not agree with the Task Force recommendations, there were comments that the whole program had been unnecessary, as well as comments that not enough was being proposed and that the smelter should be shut down.

The final community input mostly served to emphasize the importance of the Trail Health and Environment Committee and the need to ensure that the services are delivered in a co-ordinated manner with continued public communication and involvement.

9.2 Trail Community Lead Task Force Recommendations

9.2.1 Preamble

These recommendations have been prepared by the Trail Community Lead Task Force in accordance with its Terms of Reference (see Appendix A). The Task Force was struck in 1990 to develop recommendations to the Minister of Environment on long-term intervention and remediation options for reducing childhood lead exposure in Trail. In 1996, the Task Force also agreed to oversee a comprehensive human health risk assessment for other smelter contaminants in Trail. The results of that assessment have also been considered in the preparation of these recommendations.

The Task Force has based these recommendations on consideration of the following major factors:

- Estimated health risk levels (based on studies conducted elsewhere that have linked exposure to metals with health effects in humans and animals)
- Community feedback on the estimated health risk levels
- Effectiveness of options for reducing health risks (based on experiences in Trail and at other sites)
- Socioeconomic impact of intervention and remediation options (including both monetary costs and disruption to the community)

The Task Force heard from the community that it would prefer to have local ownership of these recommendations and their implementation, rather than seeing them become part of a provincially-controlled process. However, the Task Force recognizes that the community-based process must ultimately satisfy provincial regulatory requirements.

The Task Force has shown in this report, as much as possible, how its recommendations for action can achieve the goals it has set for children's blood lead levels. The report also discusses how the package of recommendations can satisfy the requirements of the BC Contaminated Sites Regulation (CSR). However, the Task Force feels strongly that its recommendations are intended to fulfil its original mandate. The Task Force recognizes the deep community concern over the potential impact of designating the Trail area as a "Wide Area Site" under the CSR. With this in mind, it wishes to reiterate that these recommendations are strictly aimed at providing sound scientific and community-based advice on appropriate actions to reduce local health risks to acceptable levels.

9.2.2 Goals

Blood Lead

***Recommendations*:**

- At least 90% of children aged 6 to 72 months in area 2 and 3 should have blood lead levels less than 10 µg/dL by 2005.
- At least 99% of children aged 6 to 72 months in area 2 and 3 should have blood lead levels less than 15 µg/dL by 2005.
- Once these goals are achieved, blood lead testing should continue, in order to provide ongoing protection of young children in Trail.
- If these goals are not achieved, the remedial plan should be re-evaluated.

Background:

- 10 µg/dL is the "community concern" level recommended by the US Centers for Disease Control and it is intended to apply to children in the 6-72 months age group. An association between children's blood lead levels and IQ has been observed down to this level in studies involving large numbers of children. These studies have found that, *on average*, groups of children with blood lead levels around 20 µg/dL score about 1-2 points lower on IQ tests than groups of children with blood lead levels around 10 µg/dL, after controlling for other factors that affect IQ.
- A Canadian Federal-Provincial Task Force recommended in 1994 that communities with unusual sources of lead exposure may need special programs where the percentage of children in those communities with blood lead levels above 10 µg/dL is double that seen in the general population. Since the percentage of children above 10 µg/dL in North America is currently about 5%, this would indicate a target of no more than 10% above 10 µg/dL.
- 15 µg/dL is the "individual level of concern" recommended by the US Centers for Disease Control. The Task Force feels that ideally, children should rarely exceed this blood lead level (less than 1%).

Other Smelter Contaminants

***Recommendations*:**

- Potential health risks from other smelter contaminants (i.e. cadmium and arsenic) should be reduced to the levels required by provincial regulations, without shutting down the smelter or conducting widespread soil replacement in the area.

9.2.3 Further Reductions in Cominco Emissions

Why is this action being recommended?

Because the Task Force believes it is still the single most effective way to:

1. further reduce children's blood lead levels
2. further reduce possible health risks from other smelter contaminants

***Recommendations*:**

- Cominco should regularly (at least semi-annually) communicate the following to the public:
  - The process by which opportunities for further emission reductions are being explored
  - Goals, projected timelines and progress on emission control projects (including plans for reducing stack emissions, fugitive plant emissions and materials handling losses).
- Cominco should ultimately include its goals and timelines for emission reductions in the final remedial plan for the area

How is this different from what's done now?

- No change to Cominco's basic responsibility for continued improvement in emissions control.
- Increased responsibility for communication and direct commitment to community.

9.2.4 Blood Testing

Why is this action being recommended?

1. To identify children with elevated or rising blood lead levels.
2. To assess the community-wide impact of remedial actions.
3. To determine whether the blood lead goal has been reached.

Recommendations:

- Blood lead testing should continue to be offered and promoted.
- Starting in 2001:
  - regular annual blood lead testing should be recommended for children aged 6-36 months (older children will not be denied testing if their parents are concerned)
  - follow-up blood testing should be recommended for children with blood lead levels of 15 µg/dL or higher, and for children under 12 months with blood lead levels over 7 µg/dL
  - a complete blood lead survey of children aged 6-72 months should be conducted in September of 2005, then every 5 years

How is this different from what's done now?

- Currently, annual blood lead testing is recommended for children aged 6-60 months in Area 2/3 and 6-36 months in Area 1.
- Currently, follow-up blood lead testing is recommended for children with blood lead levels of 15 µg/dL or higher and children under 20 months with blood lead levels greater than 10 µg/dL.

9.2.5 Environmental Monitoring

Why is this action being recommended?

To assess the collective, community-wide impact of remedial actions (e.g. emission reductions, street washing, greening, soil barriers, dust suppression)

Recommendations:

- Lead, arsenic and cadmium in outdoor air and dustfall should continue to be monitored by Cominco at locations and frequencies required by the Ministry of Environment. *(As recommended to Cominco by Trail Lead Program staff in a memo dated October 5, 2000, 6 of the 29 special dustfall stations operated by Cominco for the Trail Lead Program from 1992-2000 should be retained and added to Cominco's regular dustfall monitoring network.)*

- Monitoring of lead levels in street dust, currently performed by the Trail Lead Program, should be continued by Cominco. *(The number of stations and frequency of monitoring should be agreed upon by the proposed Trail Health and Environment Committee.)*

How is this different from what's done now?

- The Sentinel Homes monitoring program has been discontinued as of September, 2000

9.2.6 Counseling and Services for At-Risk Families

Why is this action being recommended?

- Because it is an effective way to reduce children's exposure to lead in dust and soil.

Recommendations:

- The following services should be provided for families of children with blood lead levels of 15 µg/dL or higher, and families of children under 12 months age with blood lead levels greater than 7 µg/dL:
  - Home visits to provide advice on reducing lead exposure
  - In-home environmental assessment
  - Assistance with addressing bare soil (see "Addressing Soil",) house dust, or deteriorating lead-based paint

How is this different from what's done now?

- Larger budget (estimate $15-20,000 instead of $6000) for case management services, to allow for more:
  - Materials/Supplies - sod, clean topsoil, flooring
  - Contractors - for a few homes per year where lead-based paint is a problem
- Currently, counseling and services are offered to families of children with blood lead levels of 15 µg/dL or higher and children under 20 months with blood lead levels greater than 10 µg/dL.

9.2.7 Community Education

Why is this action being recommended?

- To tell the public (particularly new residents and new parents) about what they can do to keep children's blood lead levels low and to let people know about available services

Recommendations:

- The following components of the community education program should be continued:
    - Brochures
    - Information to families new to Trail
    - Community Projects (e.g. Handwashing Week)
    - Display Stand
    - Advertising
    - Newsletters
    - Information for pregnant women and new mothers

How is this different from what's done now?

- All of the components of the current community education program are proposed to continue.

9.2.8 Early Childhood Education

Why is this action being recommended?

To encourage pre-schoolers to adopt healthy behaviours in order to:

- keep their blood lead levels low
- keep them in good general health

Recommendations:

- The following components of the early childhood education program should be continued:
  - Visits to Mom & Me, day cares, nursery schools, Building Beautiful Babies program
  - Provision of storybook to new child care providers
  - Provision of materials to go with storybook program (e.g. soaps, stickers)
- This opportunity to reach pre-schoolers should also be used to present other hygiene, nutrition and health messages.

How is this different from what's done now?

- All of the components of the current early childhood education program are proposed to continue.
- General health, nutrition and hygiene messages would be added to make use of an opportunity for health promotion at an impressionable age.

9.2.9 Community Dust Control

Why is this action being recommended?

1. To further reduce children's blood lead levels
2. To further reduce possible health risks from other smelter contaminants

<u>Recommendations:</u>

- Greening of bare areas around the city should be a priority, and Cominco and the City should communicate their plans for this to the public. An inventory of remaining bare areas should be prepared and used to set priorities for action. Areas where action is taken should be monitored to ensure success.
- Dust suppressant should continue to be applied to alleys and other unpaved areas in Trail at least once per year
- Alternatives to magnesium chloride should be evaluated to see if a better dust suppressant for this application is now available.
- Street flushing and sweeping should continue to be performed according to the correct procedure and at the current frequency in the City of Trail and Rivervale (highways maintenance contractor responsibility in Rivervale and on highways through Trail).
- Trucks transporting ore concentrates to Cominco from Waneta reload station should be required to take appropriate measures to reduce concentrate losses along the route.
- Cost-sharing agreements should be developed between the City and Cominco for dust suppression, street washing and greening

How is this different from what's done now?

- Current actions are all proposed to continue

9.2.10 Improving the Buffer Zone Around the Smelter

Why is this action being recommended?

- To reduce the exposure of residents to dusts from Cominco emissions (primarily from the stockpiles)

Recommendations:

- Cominco should develop, communicate and implement a plan to expand/enhance the vegetative buffer within and adjacent to the property boundary (e.g. more trees, earth mounds), commencing in Spring 2001 and continuing as stockpiles are consumed.

- Cominco should endeavour not to remove any additional structures from portions of this zone that are adjacent to residences until the vegetative buffer is well established and has reached a height of at least 20 feet.

How is this different from what's done now?

- Cominco has already been taking steps to improve the buffer zone - the change is an increased responsibility to communicate plans and commit to the public that additional structures will not be removed from this zone until the buffer is well established.

9.2.11 Addressing Soil

Why is this action being recommended?

These recommendations are included so that the approach to addressing soil is clear. The actions highlighted here are actually part of the Counseling and Services recommendations and the Work Project Assistance Program recommendations.

Recommendations:

- For at-risk families (as defined under Counseling and Services - section 9.2.6), soil should be addressed by providing:
  - ground cover materials and services for families in cases where there is a reasonable chance that the cover will be maintained by present residents
  - soil removal/replacement in cases where successful ongoing maintenance of ground cover is not likely
  - Soil should also be addressed through the Work Project Assistance Program (see section 9.2.12):
- Anyone doing excavation in Trail should be encouraged to apply for assistance. Assistance would include advice on how to reduce exposure during and after the project, free transport and disposal of contaminated soils, and free replacement soil, if needed, from an approved source.

How is this different from what's done now?

- Currently, very little soil replacement has been offered for at-risk families
- Currently, anyone who decides to excavate and replace soil, such as someone wanting to change to the soil in their garden, must pay the costs of disposing of the old soil and obtaining new clean soil.

9.2.12 Work Project Assistance Program (WPAP)

Why is this action being recommended?

- To encourage homeowners and contractors to follow precautions when undertaking excavation, construction, demolition or renovation projects, in order to minimize dust exposure to workers and residents.
- To assist people who need to dispose of contaminated soil or dust.
- This program is not meant to encourage people to undertake projects such as soil replacement. Instead, it is intended to make it safer and easier for people who, on their own, have decided to do some work on their properties.

<u>Recommendations:</u>

- A program should be set up to provide assistance with excavation, construction, demolition or renovation projects.
- The assistance for such projects should address dust control, worker exposure, resident exposure, neighbours' exposure, and disposal of contaminated materials (e.g. soil, dust, paint chips, painted materials).
- Assistance offered through the program should include:
    - Advice on how to minimize exposure to contaminated soil and dust
    - Free disposal of contaminated soil or dust
    - Free clean soil to replace the volume of excavated contaminated soil, if necessary.
- Bunker Hill Superfund Site has set up a comprehensive program that should be studied as a possible model for some elements of Trail's program.
- An education program should be set up so that the community (including contractors) is aware of the WPAP and how it works.
- A training program should be set up for contractors and public works employees so that they competent in the control of dust and disposal of contaminated materials.

How is this different from what's done now?

- Currently, there is no program aimed specifically at excavation, construction, demolition or renovation projects.

9.2.13 Delivery

Why is this being recommended?

- To ensure that the recommended actions are assigned to parties that have agreed to implement them.

Recommendations:

- The following actions should be delivered from the Kootenay Boundary Community Health Services Society offices (public health unit):
    - Blood lead testing
    - Counseling and services for at-risk families
    - Community education
    - Early childhood education
- Cominco should be responsible for environmental monitoring, emission control and physical remediation work (e.g. case-by-case soil actions, greening, and the Work Project Assistance Program).
- Cominco should coordinate its residential remediation work with the counseling/services being delivered from the public health offices.
- The City of Trail should continue delivery of street cleaning and should apply dust suppressant to alleys and other unpaved areas.

How is this different from what's done now?

- The Trail Lead Program would be replaced by programs/actions delivered by KBCHSS, Cominco and the City.

9.2.14 Oversight/Coordination

Why is this being recommended?

- To ensure that the goals are attained in a timely manner
- To ensure effective monitoring, coordination and evaluation of progress toward the goals
- To ensure effective oversight by, and communication with, the community

Recommendations:

- A committee should be established to ensure that the program does not suffer from fragmentation or loss of credibility and to facilitate public communication and oversight.
- The committee will ensure that there is no discontinuity of service between dissolution of the Trail Community Lead Task Force and implementation of the final remedial plan for the area.
- The committee should include representatives from the City of Trail, Kootenay Boundary Community Health Services Society, BC Environment, Cominco, United Steelworkers of America, the Greater Trail Community Health Council and the community (similar to the current Task Force).
- The committee should be appointed by the City of Trail.
- At its first meeting the committee should review the Draft Terms of Reference that has been prepared and attached to these recommendations by the Trail Community Lead Task Force.
- The initial mandate of the committee should be to monitor, coordinate and advise on the implementation of the Task Force's recommendations and to participate directly in development of the final remedial plan. Once the remedial plan has been approved, the role and reporting responsibility of the committee should be re-evaluated. (see Appendix B)

How is this different from what's done now?

- The proposed committee is very similar to the current Task Force in makeup, but it's reporting responsibility may be different.
- The proposed committee would not have its own staff, staff from each of the delivering agencies would report to, and participate in meetings of, the committee.

9.3 Projections for Achievement of Remedial Goals

This final section of the report looks at what level of remediation would be required to achieve "acceptable" health risk levels from smelter contaminants in Trail. For lead, it is assumed that the proposed Contaminated Sites Regulation amendment to allow use of blood leads (or other "biometrics") in assessing health risks will be passed. It is also assumed that the local Medical Health Officer will support the Task Force's recommended blood lead goals for the community.

For arsenic and cadmium, it is assumed that we are interested in estimating what would be required to ultimately reach the BC default acceptable risk levels of 1 in 100,000 for incremental lifetime cancer risk and 1 for non-cancer hazard index.

9.3.1 Blood Lead

Air

Decreases in air lead levels tend to have an impact on all children in the community, resulting in a downward shift in the average blood lead level, by reducing both inhalation and ingestion exposures. While reduced air lead levels also help reduce the number of children with higher blood lead levels (> 15 µg/dL), some children who live on properties with bare soil or deteriorating lead-based paint may not benefit as much as the typical child.

Based on studies of the correlation between air lead levels and blood lead levels, we know that a 1.0 $\mu g/m^3$ change in air lead should lead to a 4-6 µg/dL change in average blood lead level (Angle et.al., 1984 and US EPA, 1994b).

In Trail, we've seen average blood lead levels go from about 11 µg/dL to about 6 µg/dL as air lead dropped from 1.0 $\mu g/m^3$ to 0.3 $\mu g/m^3$. (Decline of about 6 µg/dL per $\mu g/m^3$.) So, if air lead levels were further reduced to 0.2 $\mu g/m^3$, average blood lead levels could be expected to drop by a further 0.6 µg/dL (10%).

Assuming that air lead levels stay about the same over the next few years, we can expect average blood lead levels to drop somewhat further. The group of children 6-60 months old tested in 2000 still included children born before the new smelter began operation. Several participants at the Expert Review meeting in Trail in May 2000 suggested that as these children age and leave the testing group over the next few years, we can expect the average blood lead level to decline to about 5 µg/dL or slightly less.

Soil

Is it wise to try to determine a "safe" level of lead in soil and remediate above this level? In the United States, the EPA's Integrated Exposure-Uptake-Biokinetic (IEUBK) Model for Lead has been used to set "clean-up" levels for lead-contaminated sites such as smelting and mining towns. The IEUBK model has generally been found to over-predict blood lead levels at sites without active lead smelters. It has also been found to over-predict the improvements in blood lead levels that can be achieved by removing contaminated soil (e.g. US EPA Three Cities Soil Abatement Studies).

In Trail, we've seen that this model was able to predict average blood lead levels based on local environmental levels *before* the new smelter was constructed. However, the model now predicts considerably higher blood lead levels than what we measured in the fall of 1999 or 2000. The model appears to place too much emphasis on soil concentrations, and not enough on the indirect contribution of air lead via deposited dust. Such freshly-deposited dust is very fine and contains high concentrations of bioavailable lead. As noted above, the observed decline in blood lead levels in Trail does concur with the air lead - blood lead relationship observed at other sites.

A few other active lead smelter communities have done some residential yard soil removals (E. Helena, Port Pirie, Herculaneum). These sites either have limited blood lead data that doesn't allow any reliable assessment of the effect of soil removal, or the soil removal actions have not been very extensive.

As discussed in Section 8, the US EPA Three Cities Soil Abatement Study was the most comprehensive study of the effect of soil removal on children's blood lead levels. It found an effect in only one of the three study cities (Boston), and even there, the effect was considerably less than predicted by modelling.

In Silver Valley, Idaho, soil removal/replacement has been done on over 1600 residential yards and the smelter has been closed for 18 years. There is evidence that the soil removals have reduced blood lead levels in recent years, but by far the biggest declines in blood lead levels occurred in years prior to the soil removal activities. Currently, the percentage of children aged 6-60 months with blood lead levels over 10 µg/dL in Silver Valley is about 20% - similar to Trail.

Rather than recommending soil removal/replacement on a community-wide basis, the Trail Community Lead Task Force is recommending a case-by-case approach be taken to address bare soil where children live, as part of the case management program. Ground cover materials and labour, vegetable garden soil replacement, and lead-based paint abatement will be made available to families in the case management program. The Work Project Assistance Program will make some of these services available to the whole community once the program has been developed. Children's blood lead levels will be monitored to ensure that these actions are sufficient.

Expectations

Figure 29 shows the trends in percentages of Trail children with blood lead levels <10 µg/dL from 1991 to 2000. The graph shows that the percentage <10 increased at a rate of about 4% per year from 1991 to 1996, then increased more rapidly from 1996 to 1999, following the start-up of the new lead smelter. The projected curve from 2000 to 2005 shows that it is reasonable to expect that the percentage of children with blood lead levels under 10 µg/dL will reach 90% by 2005, especially since this graph is for children aged 6 to 60 months, while the goal for 2005 is based on the standard 6 to 72 months age group.

Figure 29 - Trends in Percentage of Children with Blood Lead < 10 µg/dL

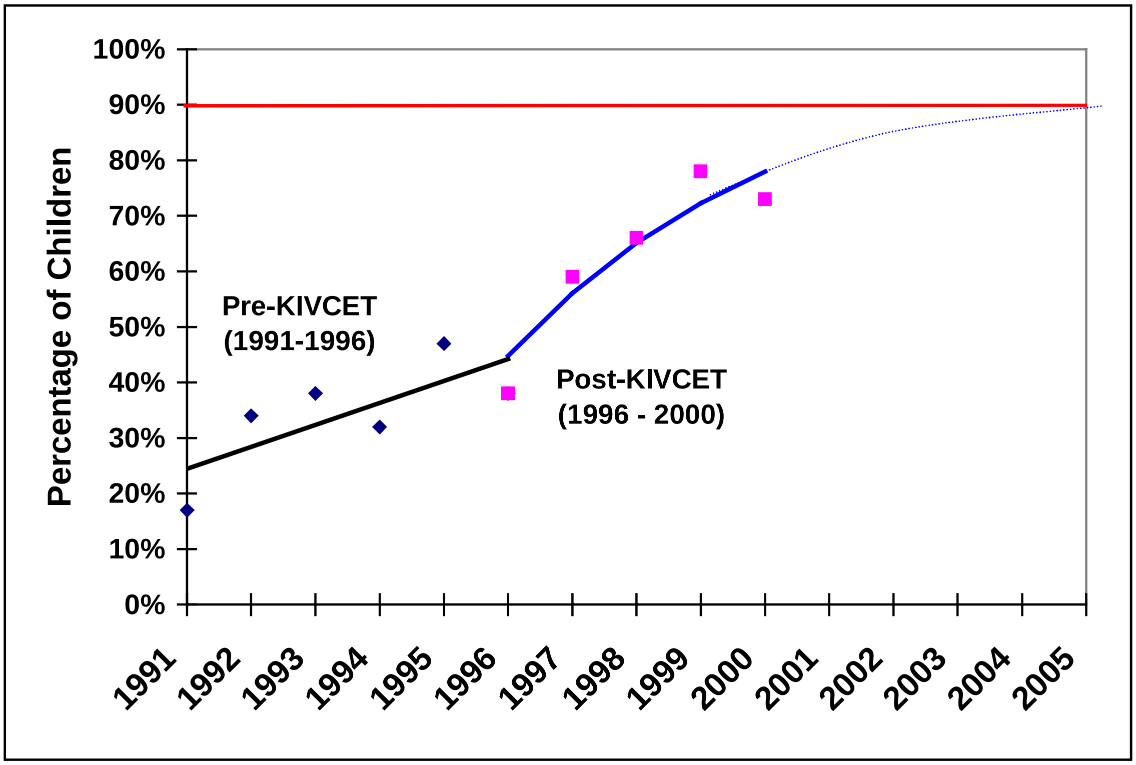
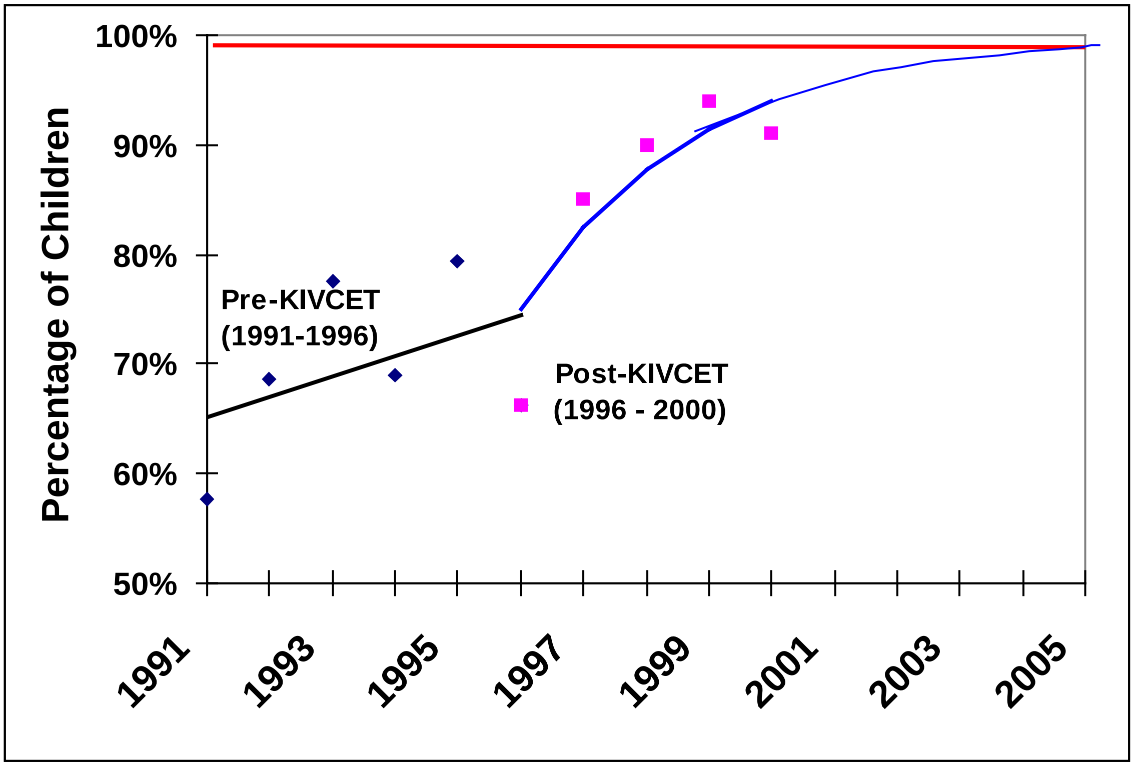


Figure 30 shows the trends in percentages of Trail children with blood lead levels <15 µg/dL from 1991 to 2000. The projected curve from 2000 to 2005 shows that it is also reasonable to expect that the percentage of children with blood lead levels under 15 µg/dL will reach 99% by 2005.

Figure 30 - Trends in Percentage of Children with Blood Lead < 15 µg/dL



9.3.2 Arsenic

Air

The current air arsenic concentration in Trail is about 0.02 µg/m^3 - about 10 times higher than the estimated 1 in 100,000 incremental lifetime lung cancer risk level for air arsenic (0.002 µg/m^3), but about 1/10 of what it was in 1990 (0.2 µg/m^3).

The relationship between air arsenic level and cancer risk is assumed by risk assessors to be linear (i.e. if the air arsenic concentration were reduced by 50% to 0.01 µg/m^3, the estimated incremental lifetime lung cancer risk would also drop by 50%, to 5 in 100,000).

Soil

The soil arsenic level corresponding to an incremental lifetime skin cancer risk level of 1 in 100,000 is 29 ppm (excluding exposure from consumption of homegrown produce). Widespread soil replacement in neighbourhoods near the smelter would be required to achieve an average soil arsenic level of 29 ppm.

Replacing soil only in vegetable gardens could reduce estimated incremental skin cancer risks by about 50% in neighbourhoods close to the smelter and by about 75% in neighbourhoods further from the smelter. It's important not to lose perspective, though -

eliminating arsenic exposure due to consumption of local produce only reduces overall dietary arsenic exposure by about 12%.

9.3.3 Cadmium

Air

The current air cadmium concentration is about 0.009 µg/m^3 - very slightly above the estimated 1 in 100,000 incremental lifetime lung cancer risk level of 0.006 µg/m^3.

Soil

The risk assessment showed that cadmium in soil is only a potential health concern for people who are heavy smokers. Making clean soil available for vegetable gardening would reduce the cadmium exposure of two pack/day smokers to an acceptable level (hazard index of 1).

9.3.4 Conclusions

Blood Lead Levels

Average blood lead levels are already fine and are expected to decline further over the next few years as the effects of the new lead smelter continue to be realized. Future improvement in air lead levels would lead to further substantial reductions in the average blood lead level.

Based on assessment of the main available risk model for lead (IEUBK) and experiences elsewhere with soil removal, it does not appear that removing soil on a community-wide basis would be an effective way to deal with children's lead exposure.

Stepping up the case-by-case approach to dealing with bare soil, house dust and deteriorating lead-based paint can further reduce the proportion of children with elevated blood lead levels. It's very difficult to predict the amount of impact this will have. It's seems, though, that it will be realistic to achieve the goals of 90% of children with blood lead levels under 10 µg/dL and 99% under 15 µg/dL by 2005.

Lung Cancer Risk

Reducing the estimated incremental lifetime lung cancer risk from inhaled arsenic and cadmium will require further reductions in smelter emissions. Current arsenic emissions would have to be reduced by 10 times in order to reach the 1 in 100,000 risk level.

If the incremental lifetime lung cancer risk from smelter contaminants in Trail air were reduced to 1 in 100,000 there would be no more than one extra case of lung cancer expected every 960 years, rather than the current estimate of 1 every 60 years.

Skin Cancer Risk

Community dust control actions that have been recommended to reduce lead exposure will also contribute to reduced potential health risks from arsenic dust ingestion. However, it is not possible to quantify the expected impact that these actions will have on calculated risks.

Estimated incremental lifetime skin cancer risks can be reduced to near the default acceptable level (maximum of 4 in 100,000 in neighbourhoods close to smelter) by providing clean soil for vegetable gardening. Reducing the estimated skin cancer risk to the 1 in 100,000 level would require widespread soil.

If the incremental lifetime skin cancer risk from arsenic in Trail were reduced to 1 in 100,000 there would be no more than one extra case of skin cancer expected every 960 years, rather than the current estimate of 1 every 200 years.

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APPENDIX A

Original Task Force Terms of Reference

(Accepted by the Task Force June 11, 1990)

TRAIL COMMUNITY LEAD TASK FORCE TERMS OF REFERENCE

Revised: November 7, 1995

GOALS

Long-term goal: An acceptable level of (blood) lead exposure risk for the sensitive populations in Trail and vicinity.

Short-term goal: That no more than 10 percent of children have blood lead levels at or above 15 μg/dL in 1998.

MEMBERSHIP

Chair: A. Sandy Santori	Mayor, City of Trail
Ames, Dr. Nelson	Ministry of Health
Clausen, Hank	Community Member
Dimock, Dr. Barss	Community Member
Fischer, Marion	Community Member
Hardie, Rick	Regional District of Kootenay Boundary
Jensen, Sue	Community Member
Joseph, Ron	City of Trail
Kenyon, Graham	Cominco Ltd.
Moll, Peter	School District #11
Moon, Bev	Community Member
Regnier, Sherry	Community Member
Wood, Barry	Ministry of Environment
Wynn, Tom	Trail and District Environmental Network; Local 480 U.S.W.A.

CONDUCT OF MEETINGS

Business meetings shall be held quarterly and shall be open to all members of the public and media. The chairman may arrange in-camera meetings at such times as necessary to discuss Task Force matters that deal with confidential or sensitive issues.

FUNCTION

The Task Force, in collaboration with the community, Cominco, recognized experts, and participating provincial agencies will:

- identify and assess potential health risk situations associated with lead exposure, and will establish key health and environmental indicators to monitor longer term trends.

· serve as a community forum for the discussion of lead issues, concerns, policies, proposals, and remediation plans.

· initiate and develop communication programs to maintain an appropriate level of awareness of the progress, results, and conclusions of the Task Force amongst community residents and other interested parties.

· carry out a program of investigation, monitoring, assessment, pilot testing, and consultation leading to recommendations to provincial and local government agencies on longer term intervention and remediation options.

· recommend financing formulas in terms of assigning costs for various types of remediation measures between Cominco, home owners, local government and the province.

DECISION MAKING

On all Task Force matter requiring a decision, the Task Force shall attempt to reach said decision by process of consensus. If the Task Force is unable to achieve a consensus, the decision shall be decided by majority vote. A minimum of five Task Force members is required to comprise a quorum.

Minutes of the Task Force will be available for public review.

TECHNICAL COMMITTEE TO THE TASK FORCE

The Technical Committee shall develop a scientifically based program to provide the Task Force with the environmental and health information it requires to make informed, cost-effective decisions. The Technical Committee shall consist of staff from Cominco, the Ministries of Health and Environment and the Lead Program Office, who will take a lead role in assembling information on exposure pathways, undertaking literature reviews, identifying additional research requirements, developing pilot remedial programs, and recommending remedial measures for consideration by the Task Force.

EDUCATION COMMITTEE TO THE TASK FORCE

The Education Committee will develop communication initiatives, establish specific educational programs and events, define audiences and priorities, and outline the utilization of local media. The Education Committee shall consist of staff from Cominco, the Ministry of Environment, and the Lead Program Office, and interested community members.

FINANCE COMMITTEE TO THE TASK FORCE

The Finance Committee will ensure financial accountability to the agencies funding the Task Force programs, and will oversee the financial management of those programs. The Finance Committee shall consist of up to five persons, four of whom shall be the representatives of the funding agencies and the fifth shall be a Task Force member.

TRAIL LEAD PROGRAM OFFICE

The Trail Lead Program Office is located at 300 - 843 Rossland Avenue, Trail, in the Regional District of Kootenay Boundary building. (Telephone 368-5323, Fax 368-6515)

MINISTRY OF ENVIRONMENT'S ROLE AND RESPONSIBILITIES

The Waste Management Branch of the Ministry of Environment is responsible for ensuring the remediation of sites which pose a health or environmental risk and for regulating the discharge of air, water, and soil contaminants in order to prevent future contamination of remediated sites.

Reducing the air discharge of lead and other heavy metals from Cominco's operation has been a priority for many years. Permits authorizing stack emissions have been made progressively more restrictive as improved smelting technology became available. The installation of a new lead smelting plant will significantly reduce the emission of lead and hence the likelihood of future contamination of any soil requiring remediation. Ensuring compliance with permit lead emission limits and ambient air sampling obligations is a prime responsibility of the Ministry. An assessment of the ambient levels of heavy metals in soils within the community will be undertaken as a further check on the success of emission control measures.

The Special Waste Regulation under the Waste Management Act has the effect of requiring much improved materials handling facilities for the numerous lead bearing intermediate products within the smelter to prevent the release of contaminants into the groundwater or into the air as fugitive dust. Schedules for materials handling improvements and the recycling of existing stock piles will be established. Progress will be monitored as part of the Ministry's regulatory responsibilities.

The Ministry, in cooperation with Cominco, will keep the Task Force appraised of progress in reducing both stack emissions and fugitive dust.

Legislation specific to contaminated sites is still in the development stage. However, the Minister has broad powers under existing legislation which can be applied to situations where concentrations of lead or other heavy metals in soil pose a threat to public health or the environment. In this circumstance, the Ministry will cooperate with the Task Force in seeking community consensus on the remedial measures necessary to reduce the risk of lead exposure to acceptable levels.

COMINCO'S ROLE AND RESPONSIBILITIES

Cominco initiated the investigation that developed into the Trail Lead Study. They did so as a cooperative venture to determine if any significant health risk exists in the Trail area in light of current scientific knowledge on lead, and, if so, to identify key routes of intake and practicable risk reduction measures. Cominco will continue working towards these objectives in concert with the community and the government agencies involved.

Cominco's primary responsibility is to complete the implementation of the projects and plans that will minimize the emissions of lead into the environment. These include full operation of the new smelter so that old plants can be shut down, and containment of fugitive emissions from plant operations and storage areas.

In collaboration with the Ministry of Environment, Cominco will monitor the ambient air concentration and deposition rates of lead and other significant heavy metals, and communicate results and trends to the Task Force.

Cominco will work within the Task Force to develop and implement programs and practicable remedial measures necessary to reduce exposure risk to an acceptable level as determined by ongoing monitoring of blood leads relative to current health protection standards. Cominco will share with the community and government agencies the collective responsibility for the costs of establishing, administering, and implementing such programs and measures.

MINISTRY OF HEALTH'S ROLE AND RESPONSIBILITIES

The Ministry of Health will offer periodic advice, through the use of study results and existing public information, to assist in developing comprehensive educational programs for all families with young children, using opportunities afforded through existing services, e.g., prenatal classes, post-natal visits, well baby clinics, etc.

The Ministry shall maintain ongoing observation of scientific literature and other jurisdictions regarding future direction of children's blood lead intervention levels.

The original "Terms of Reference" were drafted by the B.C. Ministry of Environment, then accepted by the Task Force on June 11, 1990. The Terms of Reference as revised November 7, 1995 are accepted as shown by the following signatures of the representatives of the Task Force funding agencies:

City of Trail
Mayor A. Sandy Santori: ______________________________

Cominco Ltd.
Graham Kenyon: ______________________________

Ministry of Environment
Barry Wood: ______________________________

Ministry of Health
Dr. Nelson Ames: ______________________________

APPENDIX B

Draft Terms of Reference for

Proposed Monitoring Committee

TRAIL HEALTH & ENVIRONMENT COMMITTEE DRAFT TERMS OF REFERENCE

GOALS

Blood lead: At least 90% of children aged 6 to 72 months in areas 2 and 3 should have blood lead levels less than 10 µg/dL and at least 99% should have blood lead levels less than 15 µg/dL by 2005.

Other contaminants: Potential health risks should be reduced as much as possible, without shutting down the smelter or removing all the soil from the valley.

ROLE

- To monitor, co-ordinate and advise on the implementation of the Trail Community Lead Task Force's recommendations.
- To facilitate public communication and oversight with respect to the delivery of services and progress toward goals.
- To provide for public financial accountability, especially in terms of public input on priority setting.
- To participate directly in the development of the final remedial plan for the area once Cominco completes the ecological risk assessment.

MEMBERSHIP

The City of Trail shall appoint the Committee initially. Volunteer representatives from the following groups will be sought:

City of Trail
Village of Warfield
Kootenay Boundary Community Health Services Society
Cominco Ltd.
Ministry of Environment, Lands & Parks
United Steelworkers of America
Greater Trail Community Health Council
"At-large" community representatives (up to 6)

When a member leaves the Committee, the vacancy will be advertised and filled according the City of Trail policy on Committee appointments.

CONDUCT OF MEETINGS

Business meetings shall be held at least quarterly and shall be open to all members of the public and media. Minutes of the Committee meetings will be available for public review.

DECISION MAKING

On all matters requiring a decision, the Committee shall attempt to reach said decision by process of consensus. If the Committee is unable to achieve a consensus, the decision shall be decided by majority vote. A minimum of five members is required to comprise a quorum.

REPORTING RESPONSIBILTY

The Committee will report to the City of Trail and will be chaired by the mayor of Trail.

TERM OF COMMITTEE

The Committee will sit at least until the final remedial plan for the area has been approved. Once the remedial plan has been approved, the role of the Committee should be re-evaluated.

There will be no maximum term for individual Committee members.

The Trail Community Lead Task Force drafted the initial "Terms of Reference" for the Committee. The final Terms of Reference, as revised by the Trail Health and Environment Committee, were accepted on ___(date)___ as shown by the following signatures:

City of Trail
Mayor A. Sandy Santori: ____

Cominco Ltd.
Randy Sentis: ____

KBCHSS ____
Dr. Nelson Ames, or
CEO

Ministry of Environment, ____
Lands and Parks
Rick Crozier

Appendix to Terms of Reference for Trail Health & Environment Committee

CITY OF TRAIL'S RESPONSIBILITIES TO THE COMMITTEE

City of Trail staff will report to the Committee on compliance with the Trail Community Lead Task Force's recommendations with respect to street washing and dust suppression on alleys. City staff will also report to the Committee on community greening initiatives undertaken by the City.

COMINCO'S RESPONSIBILITIES TO THE COMMITTEE

Cominco will provide funding, facilities and/or equipment needed by the Committee to conduct meetings (e.g. refreshments, presentation equipment, photocopying, minute-taking).

Cominco's community remediation manager will report to the Committee on the results of environmental monitoring and remedial activities (including the Work Project Assistance Program, case management services, greening and emission reductions). The remediation manager will also be resourced to support the Committee in its role of coordinating the implementation of services/actions.

KBCHSS RESPONSIBILITIES TO THE COMMITTEE

The Kootenay Boundary Community Health Services Society staff responsible for the blood lead testing, case management and education programs will report to the Committee