RESEARCH REALITIES
IN TRAIL

(WHAT HAVE WE LEARNED AND WHERE DO WE GO FROM HERE?)

A Report to the

TRAIL COMMUNITY LEAD TASK FORCE

August, 1993

S. R. Hilts, P. Geo.,
Environmental Coordinator,
Trail Lead Program Office

EXECUTIVE SUMMARY

The Trail Community Lead Task Force has generally operated under the premise that environmental remediation and interventions should not be conducted without proof that they will be effective in reducing children's blood lead levels. In fact, the mandate of the task force is not to carry out remediation, but to make recommendations to the Ministry of Environment based on assessment of options. However, several valuable programs (e.g., community education, greening of public areas, dust control on alleys) have been implemented without first being evaluated on a trial basis. Such programs have been extremely valuable in garnering community support and involvement. These remediation and intervention programs will be evaluated in terms of their practicability in Trail, rather than in terms of impact on blood lead.

The reality is that proving the effectiveness of interventions or remediations requires carefully designed studies that consume considerable time and money and cannot guarantee conclusive results. This paper explains why it is so difficult to prove an effect on blood lead and shows that no researchers have proved a measurable impact on blood lead due to an individual action. Even studies involving several actions applied in combination have disadvantages. They are costly to conduct properly, they require withholding the actions from a control group and any significant effect cannot be apportioned among the individual actions.

This paper recommends that the Task Force not attempt to prove the effectiveness of each remedial action before undertaking it on a broad scale. Groups of actions that have been successful elsewhere (e.g., assorted dust control measures) should be evaluated for practicability in Trail, then recommended for offering to target groups within the community. The overall package of remediation/intervention should be evaluated in terms of annual declines in Trail blood leads, compared with declines in global background blood leads.

To delay implementing relatively low cost actions for sake of further study would risk jeopardizing community support and would likely not lead to any proven solutions in the long run.

IN THE BEGINNING

When the Trail Community Lead Task Force was struck in 1990, it was faced with the difficult task of developing a strategy for reducing Trail children's lead exposures. Communities with inactive smelters or mine sites have generally 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.

A study conducted in 1989 by Hertzman et. al. (1991) was the primary impetus for formation of the Task Force and also the platform on which further studies and decisions would be based. The study indicated that the primary environmental determinant of children's blood leads was soil lead concentration, followed by house dust lead concentration. Consequently, the authors of the study 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 have been controlled. The study also recommended that a comprehensive awareness and education campaign be implemented.

The Lead Program estimated the cost of residential soil replacement in Trail proper alone at over $55,000,000. In addition to the obvious financial deterrent, soil removal was judged to be quite impracticable and perhaps socially unacceptable in the Trail context. The failure of the new QSL lead smelting technology at Cominco later in 1990 ensured that smelter emissions, and therefore soil contamination, would continue at present 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. Remediation options would be considered in light of new information on exposure pathways and then tested for effectiveness.

COMMUNITY WANTS ACTION

In 1991, the Task Force commissioned a review of its action plan by internationally renowned lead experts from the University of Cincinnati. In their review, Drs. Bornschein and Clark recommended that part of the 1989 study be redone, this time with environmental sampling across the whole range of blood leads. They indicated this exercise should allow a better "model" of exposure pathways to be constructed, which would help identify the remediation options most likely to succeed.

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. It was felt that such a program would garner community support and involvement and would be cost-effective. 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 Technical Committee accepted that the value of such projects would lie in their ability to educate and involve the community and that such projects would be evaluated in terms of their practicability in Trail, rather than in terms of impact on blood lead.

WHY IT'S NOT EASY TO PROVE AN EFFECT ON BLOOD LEAD

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

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

For example, "That cleaning streets every three weeks will result in a reduction in blood lead".

To 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 leads drop following regular 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. To test the example hypotheses, 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 next study design requirement 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 Technical Committee considered that if the study focussed 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 50 treatment homes and 50 control homes, will have the *statistical power* to conclude that any blood lead difference of at least 1.5 µg/dL is 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 for children in Trail (10.8 µg/dL) is now only about 6.8 µg/dL above normal background. That means a change of 1.5 would be a 22% change. 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) it actually seems optimistic to think that any single action could result in a blood lead reduction of 22%.

An alternative to proving that remediation/intervention has an effect on blood lead is to look for an effect on a measure 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 as possible from a carefully designed trial, the HEPA House Cleaning Pilot Project is also looking for an impact on the amount of lead on floors or on children's hands.

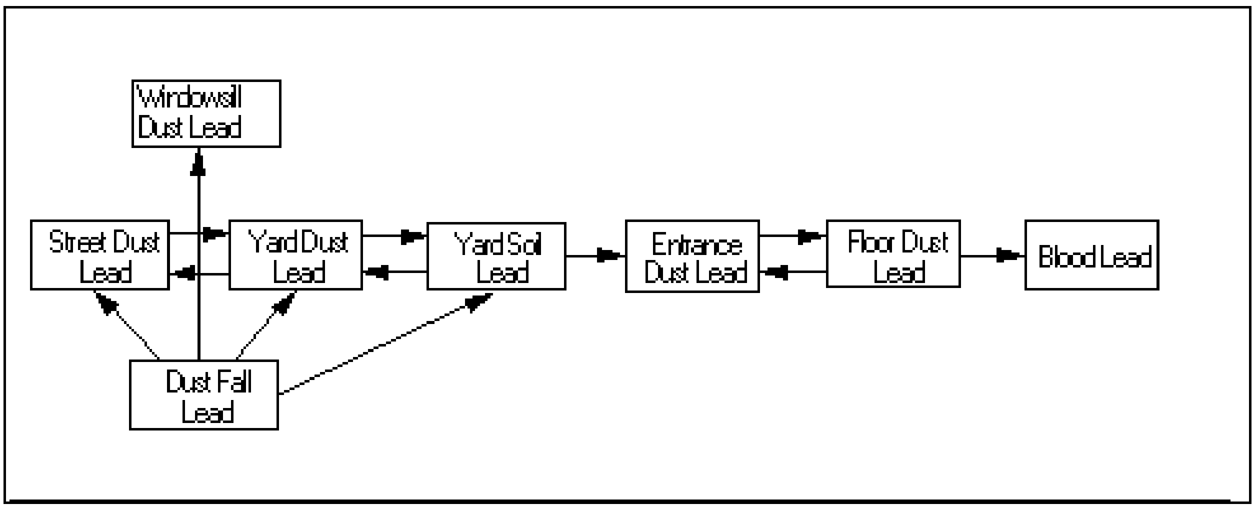
Unfortunately, finding a conclusive effect on an environmental lead measure is at least as difficult as proving an effect on blood lead. There are well accepted protocols for drawing samples from children that are representative of the blood in their entire bodies and that are measures of exposures over their lifetimes. 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.

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.

WHAT WE'VE LEARNED SO FAR

Exposure Pathways

In 1992, the Lead Program collected data on children's blood lead levels, their habits and their living environments in order to better understand how lead gets into children. The University of Cincinnati analyzed the data to determine which factors were most strongly related to blood lead. By combining complex statistical analysis and expert knowledge about lead exposure, the University was able to construct an exposure pathway model which depicts the most likely routes by which children are exposed to lead. The pathway model below suggests that the main direct contributor to blood lead is amount of house dust lead and that environmental lead passes from dust fall through street dust, soil and yard dust into the house dust.
This is not to say that children have no direct exposure to the outdoor lead sources. In fact, the data



analysis also showed that children who spend more time outdoors tend to have higher blood leads.

Despite some concern that education and counselling might have weakened the relationships between blood and environmental lead in Trail, the exposure pathway model is extremely good at explaining the variance in blood leads. In fact, the only reported model with a better "fit" is one developed for Kellogg, Idaho. This means the Task Force can be quite confident in the exposure pathways predicted by the model.

The main purpose for developing the exposure pathway model was to assist in targeting of remediation/intervention efforts. The model suggests that the most effective actions to take would be to reduce the amount of lead settling out of the air and to reduce the amount of dust in homes. The former action is a Cominco responsibility, which the company is addressing through site management and housekeeping, processs control and implementation of new smelting technology (Cominco, 1993). The reduction of house dust is being addressed by the Task Force and by individual families.

The data analysis also confirmed the importance of the Task Force's education messages regarding family hygiene and habits. Children tend to have higher blood leads if they chew their fingernails, put dirt in their mouths, have an indoor dog or cat, live in a house where someone smokes or live in a house that has had recent renovations.

Education and Case Management

Trail's Lead Education Program is widely regarded as one of the most comprehensive and effective of such programs anywhere. The variety of individuals reached and number of contacts made are far greater than in education programs elsewhere. This effort has appeared to pay dividends in terms of reduced blood leads. The average blood lead in Trail fell 13.8 % from the fall of 1991 to fall of 1992, whereas for the previous 16 years, the average annual decline had been about 4%. It is not possible to conclusively attribute all of this decline to the community education and case management programs. However, environmental monitoring data indicate that community lead levels did not change appreciably during the same period. Nor can weather take credit for the decline, as the spring and summer of 1992 were exceptionally dry.

Community Greening

The Trail Rotary Club has completed an impressive amount of seeding and planting in public areas that were identified by the Lead Program as having high lead levels. This work has been funded by the Task Force, the Federal Environmental Partners Fund and West Kootenay Power and Light. The Rotary members involved with these projects consulted with horticulturalists and other specialists to ensure that species planted and methods used would be conducive to survival in the dry, nutrient poor sites. The greening has so far been very successful and work is continuing on additional sites. Of course, there is no way to evaluate the impact of these greening efforts on blood lead levels or environmental lead levels.

Dust Control on Alleys

Magnesium chloride dust suppressant was sprayed on the unpaved alleys in East Trail, Shavers Bench and Sunningdale in June, 1993. This odourless, colourless salt brine is widely used to reduce dust on dirt roads. It physically binds the top layer of the road surface and attracts a film of moisture that keeps the surface wetted.

There were several people who called the Lead Program Office to express concern about the magnesium chloride before it was applied. Their concerns were generally alleviated when they learned that it does not have any harmful health effects and that is is only mildly corrosive to metal. There have been no phone calls since the alleys were sprayed.

A small survey will be conducted in the fall of 1993 to measure residents' satisfaction with the alley spraying. It will not be possible to evaluate the effect of this project on blood lead levels or environmental lead levels.

Ground Cover Subsidy Program

The exposure pathway analysis described above also showed that children tend to have higher blood lead levels if they live in homes with higher percentages of bare soil. This information suggests that ground cover such as grass, concrete, or ground shrubs can provide an effective barrier between contaminated soil and children. This principle has been accepted, but not proven, at other sites as well. (Farrell and Calder, 1988; Lamb and Kiernan, 1988; Mielke, 1992)

The lead program in Port Pirie, Australia has found that home-based lead abatement is more successful when householders participate actively than when all the work is done for them. To test whether householders in Trail would respond similarly, a residential ground cover pilot project was commenced in 1993. The project provides a fifty percent rebate on material costs to householders who cover bare soil in their yards. The aim of the project is to see whether a significant percentage of eligible families will participate and whether their ground cover projects will be well maintained.

Only 28% of eligible families applied for ground cover projects. It remains to be seen how many of these will complete their projects and how well they are maintained.

HEPA House Cleaning Pilot Project

An investigation of the potential benefit of providing repeated house vacuuming using HEPA vacuum cleaners commenced in Trail in November, 1992. This project is set up as a *randomized controlled trial* which meets the requirements of intervention trials discussed above. Treatment homes receive vacuuming once every six weeks, while control homes do not. The study design will allow an evaluation of impact on blood lead and house dust lead levels. More details of the project can be found in "*HEPA House Cleaning Pilot Project - Draft Interim Report*," available from the Lead Program Office.

The results of the study thus far indicate that HEPA vacuuming has resulted in significant reductions in floor dust lead levels. From the first project cycle (November/December, 1992) to the fifth cycle (May/June, 1993), the amount of lead picked up by vacuuming has declined by 48%. From the first cycle to the fourth cycle (March/April, 1993), the amount of lead in carpet surface samples declined by 38% in treatment group homes, while the control homes remained unchanged.

Data from this study are also confirming the strong association between amount of floor dust lead and blood lead. A rather surprising result is that the amount of lead on floors is very strongly correlated with the amount of dust on floors. In other words, homes within the limited study area that have high amounts of dust on their floors also have high amounts of lead, regardless of such factors as proximity to the smelter site. It appears that lead dust concentrations are constant enough throughout the study area that dust loading becomes the dominant factor in determining lead loading.

Bioavailability

The health risk posed by contaminated soil is not determined by lead concentration alone. Factors such as the chemical form (species) of lead, soil pH, texture and organic content all influence the bioavailability of lead in soil. For example, soil contaminated by lead mining waste has been claimed to pose a lower health risk than does soil contaminated by lead based paint. The risk from smelter emissions lead in soil appears to fall in between.

The Task Force felt that investigating the bioavailability of lead in Trail soils might assist in determining health risk at various soil lead levels and might provide additional options for remediation. Dr. Andy Davis of PTI Environmental Services was retained to discuss this issue and to report on electron microprobe analysis of three soil samples from Trail.

Dr. Davis reported that lead in the sample from Tadanac near the Cominco materials stockpiles was composed primarily of sulphide mine concentrate and its oxidation product, while lead in samples from East and West Trail was mainly iron-lead oxide and manganese-lead oxide, probably originating from stack emissions.

Dr. Davis was unable to draw any conclusions regarding bioavailability from these results. Further analyses of more soil samples would be required to fully characterize the soil lead species found in Trail and to assess their relative bioavailabilities. Dr. Davis recommended that the Task Force examine the possibility of adding phosphate fertilizers to soil. This might induce some lead in soil to alter to lead phosphate, which has a very low bioavailability.

Participants in the April, 1993 Program Planning Exercise cautioned that soil lead bioavailability and speciation work is extremely costly and may not lead to conclusive answers. It was recommended that efforts in Trail focus instead on reducing exposures to mobile dusts, rather than soil, at least until smelter emissions are reduced.

IS IT REALISTIC TO PROVE EACH REMEDIATION/INTERVENTION OPTION?

Given the foregoing discussions, one has to wonder if it is reasonable to require that each remediation/intervention option be evaluated for its impact on blood lead. Clearly, if the Task Force had followed this rule strictly, several of the valuable programs described above (e.g. community education, greening of public areas) would not be underway today.

If this rule were to be followed strictly from this point, it would take many years and a good deal of funding to test the options. Each trial would take a minimum of one year and cost $50,000 or more. Based on studies done elsewhere, the chances of proving that individual remediations are effective are rather slim.

A review of the scientific literature reveals not one case of a single action having a measurable effect on blood lead. In fact, the HEPA project in Trail appears to be the only study that has even tried to measure the impact of a single action.

Charney et. al. (1983) published perhaps the best example to date of a highly successful intervention trial. 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.

An example of a study that was inconclusive due to deficiencies in study design is Roberts et. al. (1991). That study 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 is flawed in that the sample size was very small, no control group was monitored, and the final dust samples were collected in winter. Therefore, it is impossible to conclude that the reductions in floor dust lead were due to the removal of shoes at the door.

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 interior painted surface cleanup, house cleanup with a HEPA vacuum followed by mopping with high phosphate detergent, some carpet removal, covering of bare soil with sod or bark, provision of clean sand boxes, provision of household cleaning supplies and provision of dust control information. The study seems somewhat flawed in that 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 drop in treatment group blood leads in comparison with the control group. The drop is again due to some unknown combination of the abatements conducted.

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 and Staes et. al., 1991), while other have shown a short-term increase (Amitai et. al., 1991) or no significant change (Farfel and Chisolm, 1990).

The U.S. Environmental Protection Agency has conducted lead abatement studies in Boston, Baltimore and Cincinnati at a total cost of US$17 million. The studies were aimed at assessing the effectiveness of soil lead abatement 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 already received lead based paint abatement. The three studies tested the various abatements separately and in combinations. The final results of these studies have not yet been published. However, the investigators' presentations at a 1992 conference indicated that none of the three studies found the benefit anticipated from the abatements. In fact, only Boston found any benefit at all.

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. In recent years, workers at the Bunker Hill site have gathered subjective evidence that subsequent soil replacement efforts have been successful in further lowering blood leads, now that emissions have ceased (Cobb, 1993). These results have not been published.

The Occupational Health Centre at Queen's University (1991) could not find an effect on blood lead due to soil replacement in 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. A new unpublished analysis based on 1992 blood lead screening data suggests that blood leads in the remediated neighbourhood have now declined relative to a control group (Njoo, 1993).

A report on the effectiveness of education in the former lead smelter community of Granite City, Illinois will soon be released by the Agency for Toxic Substances and Disease Registry (Kimbrough, 1992). This study found evidence that family counselling at homes of children with blood leads greater than 10 μg/dL resulted in a decline in mean from 15 to 7.8 μg/dL over four months. However, the study did not involve comparison with a control group and the potentially strong confounding factor of seasonality has not been assessed. The final report will provide data on a one year follow-up of blood leads.

In summary, it is not realistic to try to scientifically prove the effectiveness of each individual remediation/intervention option. In fact, based on published research, it is questionable whether one can reasonably expect to prove the effect of even several actions applied in combination.

WHERE DO WE GO FROM HERE - SOME PERSONAL RECOMMENDATIONS

The exposure pathways modelling exercise has given us a good indication of the remediations/interventions that are most likely to be effective in the current situation of high smelter emissions. That is, the Task Force should focus on education, case management and environmental interventions that will reduce children's exposure to mobile dusts. Education messages aimed at hygiene and habits can be effective. Actions such as dust control through street washing, house cleaning and greening have been shown to be effective when used in combination.

I feel that the Task Force should not attempt to prove the impact of each remedial action before undertaking it on a broad scale. We could conduct costly studies for a decade without taking action if we insist on irrefutable evidence that our efforts will be successful. It might still be worthwhile to conduct trials of several actions "ganged up" together (e.g. HEPA vacuuming, provision of ground cover, provision of cleaning materials). However, we've seen that even these studies can be inconclusive and conducting them properly would mean withholding these services from a control group for yet another year.

The success of education efforts should be measured in terms of changes in awareness and/or behaviour in specific segments of the population, rather than in terms of impact on blood lead.

Successes by others with dust control and cleanup measures should be accepted as evidence that these actions are effective in reducing childhood lead exposures. If the HEPA House Cleaning Pilot Project fails to show an impact on blood lead or house dust lead, we should revise the protocol according to the floor dust data gathered and recommend it for offering to some families in 1994, perhaps in conjunction with other interventions. The cleaning according to a revised protocol could then be monitored to assess whether a reduction in house dust is being sustained. The entire package of education, case management and interventions could be evaluated in terms of annual declines in Trail blood leads, relative to global background declines.

The annual costs associated with providing such interventions are really quite low. For example, it would cost approximately $68,000 to provide ground cover materials and monthly HEPA vacuuming to all families with children at 15 µg/dL or higher, plus all families with children under 24 months of age in the higher risk area. When compared with costs of soil replacement or even the costs of scientific intervention trials, these costs are reasonable.

The Task Force should not reconsider soil replacement until such time as smelter emissions are substantially reduced. By that time, there will be more information available on the effectiveness of soil replacement and we will know how well we are doing with education and interventions.

REFERENCES

Amitai,Y; Brown,MJ; Graef,JW; Cosgrove,E (1991): Residential deleading: effects on the blood lead levels of lead-poisoned children. Pediatrics 88(5), 893-897.

Charney,E; Kessler,B; Farfel,M; Jackson,D (1983): A controlled trial of the effect of dust-control measures on blood lead levels. N Engl J Med 309(18), 1089-1093.

Cobb, J (1993): Personal Communication. Panhandle Health District I, Silverton, Idaho.

Cominco Metals Ltd. (1993): Emissions management report. Trail Operations, 25 pages.

Copley, G (1983): The effect of lead hazard source abatement and clinic appointment compliance on the mean decrease of blood lead and zinc protoporphyrin levels. Mimeo. City of St. Louis, Department of Health and Hospitals, Division of Health, Office of the Health Commissioner, St. Louis, MO.

Farfel,MR; Chisolm,JJ (1990): Health and environmental outcomes of traditional and modified practices for abatement of residential lead-based paint. Am J Public Health 80, 1240-1245.

Farrell,TP; Calder,IC (1988): Management of soil lead contamination in Port Pirie, South Australia. In: Lead in Soil. (Ed: Davies,BE; Wixson,BG), Supplement to Volume 9 of Environmental Geochemistry and Health, University of Missouri, 213-233.

Hertzman,C; Ward,H; Ames,N; Kelly,S; Yates,C (1991): Childhood lead exposure in Trail revisited. Can J Public Health 82, 385-391.

Kimbrough,RD (1992) Statement to the Subcommittee on Investigations and Oversight, Committee on Public Works and Transportation, U.S. House of Representatives, June 9, 1992.

Lamb,GL and Kiernan,B (1988): Bunker Hill Study - Kellogg, Idaho. In: Lead in Soil. (Ed: Davies,BE; Wixson,BG), Supplement to Volume 9 of Environmental Geochemistry and Health. (Ed: Beck,BD), 121-128.

Mielke,HW; Adams,JE; Huff,B; Pepersack,J; Reagan,PL; Stoppel,D; Mielke,PW (1992): Dust control as a means of reducing inner-city childhood Pb exposure. In: Trace Substances in Environmental Health - XXV. Supplement to Volume 14, Environmental Geochemistry and Health. (Ed: Beck,BD), 121-128.

Njoo,H (1993): Personal Communication. Department of Public Health, City of Toronto.

Occupational Health Centre at Queen's University, Abramsky Hall (Ed.) (1991): The lead abatement evaluation project: analysis of data to 1988. (Draft), 70 pages.

Roberts,JW; Camann,DE; Spittler,TM (1991): Reducing lead exposure from remodelling and soil track-in in older homes. In: Proceedings of the Annual Meeting of the Air and Waste Management Association, Vancouver, B.C., June 1991.

Staes,CJ; Matte,T; Copley,G; Binder,S (1991): Impact of lead-based paint abatement on children's blood lead levels, St. Louis. Abstract.