THE PORT PIRIE
LEAD IMPLEMENTATION PROGRAM

REVIEW OF PROGRESS AND CONSIDERATION OF FUTURE DIRECTIONS

(1984 - 1993)

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The Port Pirie Lead Implementation Program:
Review of Progress and Consideration of
Future Directions (1984 - 1993)

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1.1 Lead contamination of the Port Pirie environment has caused an unacceptable elevation of children's blood lead levels.

1.2 Lead smelting and associated operations over previous decades, along with leaded paint, were considered by the Task Force in 1983 as the major primary sources. The Task Force considered that emissions from current operations were at a satisfactory low level. Historic contamination of soil and dust around the City was seen as the main lead source. Wind re-entrainment of leaded dust producing contamination of children's living areas, along with subsequent ingestion, was seen as the main pathway of lead exposure.

1.3 In 1984, the Port Pirie Lead Implementation Program was established. The Program focussed initially on children with elevated blood lead and then on a systematic decontamination of the most contaminated residential areas of the City. The Program also developed educational and revegetation strategies. Children's blood lead and air lead have been monitored to provide an indication of Program impact.

1.4 Pasminco-BHAS has also implemented a substantial program at the smelter to reduce the transfer of lead to the Port Pirie environment.

1.5 The Port Pirie City Council has undertaken a footpath sealing program, rehabilitation of parks and playgrounds, and recently amended its Supplementary Development Plan to limit the number of new dwellings adjacent to the smelter.

1.6 While overall levels of blood lead and the proportion of children exceeding the blood lead "level of concern" (25μg/dl) have been reduced substantially, the reductions have been smallest for children at the age of peak blood lead (age 2 and 3). Children aged 0-7 years from both high and low risk areas have reduced their average blood lead levels by 6-7μg/dl, although high risk area children remain 4μg/dl higher at 15.3μg/dl. Average blood levels in the high risk age group (1-4 years) in the highest risk areas (northern Port Pirie West and the central business district) are currently around 20 μg/dl.

1.7 Decontamination of home environments reduced blood lead levels, at least for six months. Beyond this initial period, it appears that recontamination from the general environment and/or relapses in beneficial behaviours diminished the impact of the home decontamination.

1.8 In follow-up studies of home-based interventions, permanent relocation from the high risk area (and probably temporary relocation), level of expenditure on house dedusting and refurbishment, improved dust hygiene practices and improved early morning diet were shown as likely to reduce blood lead levels.

1.9 Air monitoring confirms that little change in the concentration of leaded dust being carried by or suspended in air has occurred. Air lead concentrations decline rapidly with increasing distance from the smelter depending on particle size, wind speed and wind direction. Areas within 1.5km of the smelter experience air lead concentrations that exceed the national health guideline (3 month average of $1.5\mu g/m^3$) while on individual days concentrations reach 20 times the guideline value at sites near the smelter.

1.10 The 1983 Task Force, and other investigators until recent years, considered that the predominant source of lead was the widely dispersed lead dust sink derived many decades previously from the smelter, the wharf and the rail corridor. Smaller contributions came from lead based paint and leaded petrol.

More recently, visual and monitoring evidence indicates that fugitive emissions from the smelter and its environs, including concentrate handling activities, are major current sources of airborne lead. Wind action, mechanical disturbances of dust/concentrates and smelter production processes contribute to dispersal.

Following extensive decontamination of the high risk areas and investigations over the last ten years, exposure from leaded paint is now considered unlikely to be a major pathway, except in association with pica behaviour (eating of non-food items).

1.11 Airborne deposition of lead contaminated dust appears to be the primary pathway of contamination of Port Pirie children's living space. Dust is transported mainly through wind action, primarily by re-entrainment, from both environmental sinks (around the smelter and the City) and new smelter emissions. Transport of airborne lead occurs principally on days of high velocity winds in association with dry conditions. Human, vehicle and concentrate handling activities assist in dust raising. Mechanical transport from environmental sinks may also be important.

Exposure of children occurs principally through the ingestion of leaded dust via rainwater, food, hands, mouthing of non-food objects, and other behaviours that increase dust ingestion. Direct inhalation of lead dust makes a lesser contribution to intake.

1.12 The monitoring of blood lead serves to identify individual children at risk, define high risk geographic areas, assess the impact of various interventions and provide a summary assessment of Program impact through community trends. Apart from some modifications to increase the focus on pre-school children, to improve the proportion of such children tested, and to implement a less frequent but more comprehensive trend monitoring component, blood lead testing will continue to serve a central role in any future Program.

1.13 The monitoring of environmental lead assists the definition and ranking of areas of lead contamination, the assessment of progress in reducing environmental lead levels and the investigation of lead sources and pathways. In addition to lead in air, monitoring of lead dust loads in houses and around the City and of lead in locally grown foods should be implemented.

1.14 The National Health and Medical Research Council recently announced an Australian blood lead goal of 10μg/dl and a target of less than 5% of 1-4 year olds above 15μg/dl to replace the previous "level of concern" (25 μg/dl).

1.15 Lead adversely affects several body organs and systems with changes in cell functioning and nervous system development appearing to be the most sensitive to increasing lead exposure. The most substantial evidence relates to the reduction in intelligence quotient (IQ) (as assessed at age 4 and above) of between 0-5 points for each 10μg/dl increase in blood level within the range 10-25μg/dl.

1.16 Disagreement remains between western countries as to the blood lead level needed to avoid adverse effects in children. As at June 1993, Australia and the USA had reduced the blood lead goal to 10μg/dl and in Canada and the EEC the goal was under review.

1.17 Recent surveys in seven western countries (excluding Australia) showed that current average blood lead levels in children were below 10μg/dl. Using available blood lead results, a recent review of urban Australian children estimated that between 300,00 (25%) and 650,000 (54%) were at or above the new Australian blood lead goal of 10μg/dl.

1.18 At the end of 1992, 13% (or 84) of the 1-4 year old children tested in Port Pirie had blood lead levels at or above 25 μg/dl, 28% (178) were at or above 20 μg/dl and 58% (360) were at or above 15 μg/dl. A much smaller proportion of 5-7 year olds also exceed these levels. While children in the high risk areas provide the majority of those who fail to meet the above levels, an increasing proportion of children in the low risk areas also fail as the blood lead target is reduced. These levels correspond with the goal options discussed later in the context of a future program.

1.19 Despite the bulk of Lead Implementation Program resources having been directed to children in high risk areas, little change in the blood lead distribution has occurred. The blood lead level reduction has not occurred predominantly amongst the higher risk children as might have been expected. Rather, children's blood levels across the spectrum of values have declined by roughly similar amounts.

1.20 Estimated changes in lead intakes between 1984 and 1992 suggest that the reduction in food lead intake has made a contribution to lower blood lead levels along with that from the reduction in dust and other intakes. Even if background lead intakes from sources such as food decline somewhat further in the future as petrol lead is reduced, a much greater decline in intakes of local sources of lead than has so far been achieved will be required in the future in Port Pirie to achieve further significant reductions in blood lead levels.

1.21 The Review has identified the following factors that will need to be acknowledged and/or tackled to achieve further reductions in children's blood lead levels:

(1) The long term unsustainability of the degree of behaviour change necessary to reduce blood lead in the high risk areas,
(2) The persistence of environmental lead contamination, especially in the form of lead bearing dusts in an arid often windy residential area,
(3) Recontamination of homes that have been subject to primary home-based decontamination,
(4) Proximity to an operating smelter,
(5) The social characteristics of high risk families affect blood lead and the practicability of intervention,
(6) The difficulty of identifying the relative contribution of lead dust sources to exposure within households,
(7) The 1983 Task Force conclusion that the smelter and its surroundings was not a significant ongoing source of lead contamination,
(8) The inadequate understanding of mechanisms (and their relative contributions) for household lead contamination from the wider Port Pirie environment,
(9) The need for voluntary participation, and limits to the active support of the Port Pirie community,
(10) The lack of precise information on the relative long term impact of the different Program components,
(11) Limitations of the physical environment to greening,
(12) Ongoing contamination of rainwater and its consumption, and
(13) Difficulties associated with permanent relocation and the development of buffer areas surrounding the smelter.

1.22 The following strategies need to be actively considered as options for the future of the Program.

(1) City planning and development that will:

(a) Develop buffer zones between the smelter and residential areas,
(b) Relocate high risk children from highly contaminated areas in the City,
(c) Support measures to control and/or remove City dust sinks, and
(d) Develop physical or vegetative barriers between the smelter and residential areas and at key sites around the City to control dust transport by wind.

(2) Investigations aimed at:

(a) Identifying more accurately the sources of lead contamination and their relative importance, and
(b) Determining the relative importance of sources and pathways of exposure to lead within the home environment.

(3) Further measures to control lead sources on the smelter lease and wharf area.

(4) Household behaviour change focussing on:

(a) Personal and domestic dust control,
(b) Diets that reduce lead absorption, and
(c) Avoidance of rainwater.

(5) Abatement of household lead contamination.

(6) Encouraging active community support and participation.

(7) The involvement of local medical practitioners in the assessment and management of children with the highest blood lead levels.

1.23 To date, the Program has achieved the most readily available reductions in blood lead. Maintaining the current levels of blood lead in the presence of substantial lead contamination will require ongoing efforts. Any further reduction in the blood lead goal to say, 15μg/dl, will require the Program to tackle a much larger group of newly defined high risk children and require strategies beyond those already employed to achieve current blood lead levels. In this context, the need to more effectively address the environmental sources of lead as well as enhance current Program strategies becomes essential.

1.24 The current ten year Government commitment of $3m per annum for the Port Pirie Lead Implementation Program will come to an end in June 1994. Specific options for managing the Port Pirie contamination problem into the future are presented.

1.25 The Program established in 1983/84 was clearly directed toward reducing the blood lead level of high risk children and reducing exposure to what was then considered the main source, historical contamination around the City. The Program was not authorised to extensively investigate the relative importance of alternative sources and pathways nor quantify the impact of individual Program strategies. Thus, limited investigation combined with a changed understanding of the relative importance of sources has contributed to significant uncertainties about the most effective and efficient mix of strategies and the exact quantification of likely outcome of any future Program.

The framework presented represents the best information available from overseas experience, the Program's Steering Committee and the professional judgement of officers involved in the current Program. The proposals to investigate some key issues to reduce uncertainty reflect the relative contribution that the issue is likely to make in achieving particular goals. Key issues include the sources, amounts and mechanisms of recontamination.

1.26 In suggesting appropriate goals for Port Pirie, a locality affected by gross contamination, it is recognised that the national goal of 10μg/dl will be clearly impossible to achieve in a short timeframe without the very substantial resources required to relocate part of the City. As a result, setting out options for realistic goals defined in terms of population percentages, age groups and areas, to be achieved over a ten year timespan, was considered the best approach. Such an approach avoids the considerable parental anxiety that would result from finding a large proportion of children above some action guideline established for the general community affected mainly by motor vehicle emissions. It recognises that the evidence for the small effects of lead on IQ at the low blood lead levels being considered nationally is far from robust and that many other factors have substantially greater effects on IQ and the development of children.

1.27 The options discussed for a ten year Program are as follows.

OPTION	GOAL	AGE (years)	COST (1993$)
1.	Clinical intervention only	1-10	0
2.	All (95%) children in Port Pirie with a blood lead less than 25μg/dl (this is essentially the present goal)	1-7	1.2m/yr
3.	95% of children in the high risk areas with a blood lead less than 25μg/dl	1-4	1.7m/yr
4.	95% of children in the high risk areas with a blood lead less than 20μg/dl	1-4	3m/yr
5.	95% of children in the high risk areas with a blood lead less than 15μg/dl	1-4	200-300m

The current Program has a clearly defined structure, mix of strategies, staffing and resource allocation. The strategies to achieve the goal options 2, 3 and 4 were broadly based on the levels of activity of the current Program adjusted for changes considered necessary to achieve the progressively lower blood lead levels over a ten year period. Option 1 would depend largely on general practitioners funded through Medicare and existing resources within the State public sector. It would mean the total discontinuation of the current Program. Option 5 would require the relocation of at least 2,000 families from the high risk areas along with the establishment of community services and amenities.

2. INTRODUCTION

The Port Pirie Lead Implementation Program was established by the State Government in 1984 in response to a history of environmental lead contamination which had accompanied the 100 years of smelting in Port Pirie. The resultant lead burden exposed a high proportion of children in Port Pirie to an unacceptable level of lead in their environment. The primary objective of the Port Pirie Lead Implementation Program was to protect children from the deleterious effects of lead in their environment. In broad terms, the Program aimed to achieve:

- A reduction in the number of children who had a blood lead concentration greater than the National Health and Medical Research Council (NH&MRC) "level of concern", and
- A reduction in the average blood lead levels of Port Pirie children.

The Lead Implementation Program introduced in 1984 had several principal components:

- Routine, voluntary testing of children up to 7 years to monitor blood lead levels,
- Assessment and decontamination of homes and public places,
- The greening or revegetation of Port Pirie to reduce movement of airborne lead bearing dust, and
- Community education and development.

In parallel with the State Government funded activities, BHAS has made a major contribution which:

- Provided laboratory facilities for analysing children's blood samples and rainwater samples,
- Improved the hygiene practices of workers at the end of work shifts to minimise transfer of lead to the home environment,

- Planned, funded, and implemented a staged program of environmental improvement to reduce current losses of lead to the Port Pirie environment,

- Provided storage and transport for the secure placement of lead contaminated building materials,

- Donated industrial vacuum cleaners for house decontamination, and

- Contributed to the Port Pirie revegetation program.

The Port Pirie City Council has been an active participant in the Program and has undertaken the sealing of footpaths, the rehabilitation of public parks and playgrounds and amendments to its Supplementary Development Plans to restrict new development in the northern part of Port Pirie West.

As a requirement of the State Government's decision to fund the Lead Implementation Program for 10 years, an evaluation of the Program was to be conducted to determine its impact. The Program was to be formally evaluated by June 1989.

To that end, a report was provided for State Cabinet in June 1989 on the results of children's blood lead testing to the end of June, 1988. Results contained within this report showed:

- A reduction in children's average (mean) blood lead levels,

- A reduction in the percentage of children above the NH&MRC level of concern,

- Decontamination of children's home environments contributed to a decrease in blood lead levels,

- The need to augment home treatment with follow-up education and further attention to reduce recontamination from the general environment, and

- It was not possible with the data available to separate the contribution to reductions in blood lead resulting from general environmental modification and from the decontamination of home environments.

A study of the trends in blood lead levels within the group of children where home-based interventions were undertaken to reduce lead contamination was reported on in 1991. In particular, trends in blood lead levels were related to permanent relocation, the types of home-based intervention undertaken and changes in personal behaviour.

This review attempts to integrate the above two reports on blood lead level changes with the results of environmental investigations undertaken by the Department of Environment and Planning and recent world evidence concerning lead toxicity and the relative importance of different sources and pathways to children's lead exposure. From this base it is envisaged that key Program issues can be identified and directions for the future outlined. To this end the review is structured around the following topics:

- Introduction and Background,
- The Port Pirie Lead Implementation Program,
- Progress with Environmental Lead Decontamination,
- Progress with Blood Lead Levels,
- Sources and Pathways of Lead Contamination,
- Biological and Environmental Monitoring,
- Level of Concern and Future Goals,
- Program Issues and Directions for the Future, and
- Options for the Future.

As part of this review process it is to be hoped that gaps in knowledge that were evident to the Task Force (1983) which formulated the Program can be reduced and controversial issues identified and discussed.

3. BACKGROUND

3.1 PORT PIRIE, SOUTH AUSTRALIA

Port Pirie is situated on the eastern side of Spencer Gulf, 230 kilometres north of Adelaide. It is a small provincial city with a population of approximately 15,000 people.

The terrain is flat, the climate arid, and prevailing winds of equal frequency blow in from the north and south. While Port Pirie originally developed as a grain port, the major industry for the last one hundred years has been lead smelting and refining.

3.2 LEAD SMELTING

Concentrated lead ore was first brought by road from Broken Hill to Port Pirie in August 1885. Two years later the ore began arriving by rail in open wooden trucks. Today, the ore arrives in open 55 tonne metal rail wagons.

Until 1914, most of the lead concentrate and almost all the zinc concentrate, together with a great deal of unrefined lead bullion, was sold to overseas buyers and was shipped from Port Pirie to smelters in Europe.

When World War I stopped the export trade the expansion of the Port Pirie smelter became a matter of national urgency.

In May 1915, the smelting operations were purchased by a consortium of companies called Broken Hill Associated Smelters (BHAS). The first objective of the new company was to provide permanent smelter facilities for Broken Hill's mining output.

The Port Pirie smelter still meets that commitment today under the name of Pasminco Metals - BHAS. In addition to lead production, zinc is recovered electrolytically from blast furnace slag and sulphuric acid from the sulphur dioxide produced during the smelting. Other valuable commodities such as antimony, cadmium, copper, gold and silver are extracted leaving the refined market lead with a purity of approximately 99.99% lead.

3.3 HISTORICAL SKETCH OF MAIN EVENTS

Between 1889 and 1983, when lead production was in excess of 12.6 million tonnes, an estimated 160,000 tonnes of lead was lost to the local environment (Ward, 1983). Presumably, additional lead was lost as fugitive emissions over this period.

Prior to the 1940's, slag and coal ash was used as land fill in low lying areas designated for residential purposes, and local residents used the same material for establishing gardens in an effort to overcome high salinity levels in the soil.

Peak production during World War II resulted in 1.4% of the lead produced (2,700 tons per annum) being lost to the environment. Fine particles of lead dust in the smoke rained over the city, settling in soil, rainwater tanks and in the homes surrounding the smelter.

3.3.1 Royal Commission

The high numbers of lead affected workers in Port Pirie early this century resulted in a Royal Commission in 1925 which also saw the beginning of much research into the properties of lead and its effects on the environment in Port Pirie.

3.3.2 Early to Middle 1970's

Extensive investigations of heavy metal pollution in Port Pirie and the surrounding region found the most polluted soils in the central business district and eastern areas of the City, with moderate levels in the northwestern area (Tiller, 1977).

3.3.3 1979

The Port Pirie Cohort Study of the effect of lead on the neurological development of children commenced (McMichael et al, 1985).

3.3.4 1981

A request for blood lead testing of young children was launched by a local school council following notification that drinking water collected in a rainwater tank on the school campus, contained elevated lead levels and was unsuitable for drinking purposes.

3.3.5 1982

In March 1982 testing was made available by the joint endeavours of the Port Pirie City Local Board of Health, Broken Hill Associated Smelters (BHAS) and the South Australian Health Commission (SAHC).

Results of capillary blood testing on 1,239 primary school children aged 5-12 years (approximately 50% of those eligible and living in the City) showed that 7% had a blood lead level at or above 30 micrograms per decilitre (μg/dl), the National Health & Medical Research Council's (NH&MRC) level of concern at that time (SAHC, 1983a).

The survey also indicated that children with the highest blood lead levels tended to reside in particular parts of the City. These areas were later classified as 'high risk areas' and are known locally as Pirie West and Solomontown.

A case control study was carried out later in the year by the SAHC to determine what risk factors were the most predictive of an elevated blood lead level (Wilson et al, 1986).

3.3.6 1983

(1) March 1983

A Task Force was established by Dr. John Cornwall, the then Minister of Health, to look at the results of the case control study, and to better define the nature of the problems of environmental lead pollution in the City (Task Force 1983).

(2) *August 1983*

The Task Force concluded that environmental lead contamination was both a personal and public health problem for the people of Port Pirie. Their report recommended a multi-faceted approach, based on environmental health and individual family considerations, to deal with the immediate sources and root causes of lead contamination, and with lowering blood lead levels in children.

(3) *October 1983*

Dr. Cornwall then engaged the services of Dr. Phillip Landrigan, Director of the Division of Surveillance, Hazard Evaluations and Field Services, National Institute for Occupational Safety and Health, Ohio, USA, to provide a further assessment. Dr. Landrigan, an expert on heavy metal toxicity, concluded that information collected over the preceding year indicated a serious problem of increased lead absorption in young children living in those areas of the City closest to the smelter. His major concern was that some Port Pirie children might suffer subtle but irreversible reduction in intelligence (Landrigan, 1983).

His report highlighted several overseas studies which demonstrated that children with blood lead levels above 40μg/dl had an apparent four to five point decrease in intelligence quotient (IQ). Dr. Landrigan argued that even at blood lead levels below 40μg/dl, lead appeared to cause a subtle but irreversible reduction in children's intellectual functions.

Dr. Landrigan recommended that consideration be given to relocating the total population from the areas of Port Pirie most affected by lead contamination, namely, Ellendale and Port Pirie West (540 houses), the central business district, and Solomontown (1,095 houses).

(4) *November 1983*

Dr. Tony McMichael, a senior research scientist with the CSIRO Division of Human Nutrition, Adelaide, and leader of the Port Pirie Cohort Study team, in a commentary "Environmental Lead and Health", stated "...what seems to be emerging here is a view that the public health question at issue is too serious, too wide-ranging, for social intervention to wait patiently upon further epidemiological research" (McMichael, 1983).

An Implementation Group was formed and asked to review the various findings including the recommendations of the Task Force and the 'second opinion' by Landrigan, and to prepare a draft report. The Implementation Group estimated that more than 200 children in Port Pirie had a blood lead level above 30μg/dl, and recommended a general plan of actions aimed at reducing 'at risk' children's levels and decreasing further lead absorption in all children living in the City (SAHC, 1983).

(5) *December 1983*

Professor Michael Rutter, an eminent British authority on the effects of lead contamination, was contacted by the Chairman of the Health Commission and requested to review the reports of the Task Force and Landrigan together with the draft report of the Implementation Group.

Professor Rutter complimented the general quality of the various reports and agreed in principle with the recommendations made by the Task Force and Implementation Group. He agreed with Landrigan that blood lead levels above 40μg/dl were associated with subtle decreases in children's IQ but he did not support Landrigan's views on relocation. He emphasised that the decision to move was not a neutral one and would have serious social repercussions. He supported the general thrust of the Implementation Group to intervene strenuously without creating panic.

On the 19 December 1983, the public release of all documents and reports was approved by the SA Cabinet. Cabinet also approved the establishment of a local steering committee to implement a program to reduce the risk of children having elevated blood lead levels, and the creation of a centre from which the program could be co-ordinated. The centre was also charged with implementing parts of the program.

3.4 THE LEAD IMPLEMENTATION PROGRAM (1984-94)

The South Australian Health Commission (SAHC) was given responsibility for implementation of the recommended programs, and former Premier Mr. John Bannon requested that all other government departments assist the SAHC in its work (SAHC, 1984).

3.4.1 February 1984: Steering Committee

A local steering committee was formed, and the terms of reference were tabled at the first meeting held in February 1984. The Steering Committee was responsible for overseeing, as necessary, the direction of recommended programs, providing technical advice, co-ordinating various local and government views, and providing advice on the overall operation of the Implementation Program.

3.4.2 March 1984: Environmental Health Centre (EHC)

The Environmental Health Centre (EHC) was officially opened on the 7th March 1984.

A small shop was acquired and refurbished to provide a suitable office from which the co-ordination of the Program was carried out. The shop was designed to provide a place where members of the community would feel at ease to drop in and make enquiries, to arrange appointments and generally to discuss the problems associated with living in a lead contaminated environment.

It was generally accepted that intervention would need to be community based in order to gain local support and acceptance. The Implementation Group recommended that successful implementation would require a multi-disciplinary team, and that where possible, staff should be recruited from and have an acknowledged standing within the community.

There was also a substantial occupational and environmental program implemented at the smelter to complement these activities.

3.4.3 The Port Pirie Lead Implementation Program

The primary objective of the above Program was to protect Port Pirie children from the deleterious effects of lead in the environment. The subsidiary aims were to:

(1) Reduce the number of children with blood lead level equal to or greater than the NH&MRC level of concern (a remediation approach). This was 30μg/dl when the Program commenced but was later reduced to 25μg/dl in June, 1987.

(2) Assist the community in further decreasing lead absorption in all children living in Port Pirie (a public health approach).

Programs to be implemented were broadly divided into four main categories:

- Detection, monitoring and evaluation,
- Decontamination,
- The greening of Port Pirie, and
- Community environmental health.

A detailed discussion of all components of the Program is presented in Chapter 4.

The initial months of operation revealed inadequate resources and organisation effectiveness for the task. It emerged that the number of children with elevated blood lead levels, the distribution of lead, the quality of houses and the treatments needed for houses and yards would require a substantial increase in available resources to effectively address the situation.

Three initial phases of a decontamination program were recommended:

- Homes of children with blood lead levels at or above 40μg/dl,
- Homes of children with levels at or above 30μg/dl, and
- All homes in the high risk areas in which young children lived.

Finally soil and exterior decontamination of all the remaining houses in the high risk areas of Port Pirie West and Solomontown was to be carried out.

3.4.4 Resources

The principal cost of all Program measures was to be met by the State Government. From December 1983 to June 1985, a total of $1.4 million was committed, while the 1985-1986 allocations reached $2.8 million.

Thereafter, the scope of the work required indicated a need for substantial financial resources amounting to approximately $3 million per year over the remainder of the ten year period. Equally, the work force requirements and range of skills were beyond the resources of any single agency.

Support was sought from management of the smelter, and a great deal of money has been spent on upgrading industrial hygiene and housekeeping (see also Chapter 5). In addition, the industry accepted responsibility for disposal of contaminated material and a range of laboratory services. The Port Pirie City Council responded by participation in joint undertakings such as an accelerated street sealing program and rehabilitation of public parks and playgrounds.

In November 1984, Cabinet agreed to provide an additional 200 houses and cottage flats in Port Pirie over the following five years at an estimated cost of $11 million. These were to be part of the South Australian Housing Trust Program for Port Pirie and required a doubling of their activity for that period in Port Pirie.

Approaches to the Commonwealth Government for financial assistance were unsuccessful.

3.4.5 Evaluation of The Program

An interim evaluation was carried out on the first five years of the Program. This report was presented to the South Australian Cabinet at the end of 1989.

This Review report presents the evaluation of the Program to the end of 1992 and discusses options for the future management of lead contamination in Port Pirie beyond the end of the current Program, June 1994.

3.4.6 Consultancy Role

The Port Pirie Lead Implementation Program is recognised in Australia and overseas as having taken the initiative in addressing problems related to environmental lead and elevated blood lead levels in children.

Recent years have seen a flood of enquiries with health professionals from the U.S.A., Canada, Thailand and most Australian States, as well as media teams, visiting the Centre to learn about and view specific strategies that can be implemented to cope with lead contamination.

3.5 PASMINCO-BHAS

The BHAS contributions to the action Program have been as follows.

- Internal ameliorative measures costing more than $1.8 million have involved upgrading the change rooms, showers and laundry facilities for workers and providing full work clothing. These improvements have been directed at reducing the exposure of workers' family members.

- An additional $1.5 million was allocated in 1984 for plant improvements to reduce atmospheric emissions.

- An educational program on personal hygiene and the need for regular house cleaning to reduce household dust levels was initiated.

- Completed slag dumps were faced with rock mulch, covered with soil and revegetated.

- The donation of industrial vacuum cleaners and provision of drivers and trucks to help remove contaminated material from community areas.

- Assistance with the greening of Port Pirie by donating trees and by the experimental planting of different types of plants and trees in soil and slag.

- The provision, free of charge, of all laboratory analyses of lead in blood and rainwater.

3.6 PORT PIRIE CITY COUNCIL

The Port Pirie City Council, with joint funding from the EHC, is also pursuing a footpath sealing program. In general, this follows the grid approach so that footpaths are sealed as the decontamination of homes is completed.

Council has also rehabilitated public parks and playgrounds to reduce lead exposure and augment vegetative barriers.

Recently, Council has included in the General Policies statement of its Supplementary Development Plan a prohibition on new dwellings in the Pirie West area north of Frederick Road, except that existing detached dwellings can still be replaced.

4. THE LEAD IMPLEMENTATION PROGRAM (1984-1994)

To achieve the goals of the Program it was clear that intervention on many fronts would be required. Input from a wide range of government and private agencies was necessary to be effective and has been successfully negotiated throughout the life of the Program. A multi-disiplinary team was required to implement the Program and where possible staff were recruited from within the community.

A general description of the activities involved in the Program are presented in this Chapter. Some of the strategies are considered in detail in later parts of the Review since their understanding is integral to evaluating the Program and considering future options. On the other hand the details of some components of the Program are not necessary for the evaluation but do provide useful background for an understanding of the Program. Finally the recommendations for future possible Programs are based on changes to the present Program and hence need to be outlined to provide a basis for the consideration of future options.

4.1 MONITORING, INVESTIGATION AND EVALUATION

4.1.1. Blood Lead Testing

Blood lead tests are offered to each child up to age seven every six months. The testing is carried out either from a caravan which is taken to schools and preschools or at the Environmental Health Centre (EHC).

Children who have elevated blood lead levels are tested more frequently. Children in houses which are being decontaminated are tested three weeks prior to the decontamination, monthly during decontamination and three weeks after the decontamination has been completed.

Blood lead testing is carried out routinely by a capillary method which has been well validated by the Cohort Study and within the present Program (Australian Standard 2636 - 1983). An extensive quality control program has also been implemented. The samples are analysed by laboratories at the Pasminco-BHAS smelter in Port Pirie with 10% of the samples being split and sent to the Adelaide

Children's Hospital for analysis. Validation with a corresponding venous test for some samples is also carried out. Packed cell volumes (PCV) are assessed on each of the blood samples taken. This is used to assess the possibility of anaemia and may be used to normalise lead results.

4.1.2 Air Monitoring

High volume air monitoring has been carried out routinely at a number of sites in Port Pirie over the period of the Program. About six monitors have been maintained in use continuously. During the period, half have been operated by the Government and half by BHAS. The results are presented routinely to the Steering Committee and are widely available.

There have been some special investigations using high volume samplers which have been located at specific sites to investigate particular problems. The results of the high volume sampling is summarised later in this Review.

In 1992 a mobile high volume sampler with directional wind switching was commissioned by the Program. This monitor is being used initially to investigate contamination associated with the wharf. It will be subsequently used to investigate sources of lead in air moving around the City.

For two or three years moss bags located at many sites around the City were used to assess lead in air. Moss bags have been used at a number of sites around the world to provide an assessment of lead in air which could be collected in the moss. This provides a routine cheap method of assessing air lead levels at a number of sites. The relationship between the data derived from the moss bags and that from the high volume air monitoring has not been established.

Deposit gauges were used in the early years to assess the amount of lead falling to the ground at a number of sites, but have since been replaced by high volume sampling.

4.1.3 Lead in Rainwater

Lead in rainwater was monitored in the early years of the Program as a way of assessing the level of lead at different sites.

The Program provides a service enabling people to get their rainwater tested for lead. The analyses are carried out at the smelter. During 1991 three hundred and thirty three rainwater tanks were sampled with a substantial proportion found to have lead levels above the acceptable level of 0.05mg/litre. While residents are discouraged from using rainwater the analysis service continues to be provided.

4.1.4 Home Assessment

Prior to a house undergoing decontamination an assessment is carried out. Testing is directed towards identifying available lead sources at the time of inspection. Soil samples are collected and analysed using an EDTA extraction method. Paint samples are assessed using a rapid paint test which has been developed for the purpose. In the early years dust samples from the ceiling were collected and analysed. Since these were found to be uniformly high, the analysis of ceiling dust samples has been discontinued. The soil samples are analysed in the Program's laboratory in Port Pirie. A detailed Field Assessment Report (FAR) is prepared and provided to the owner or occupant of the property as well as being used to determine the decontamination process to be carried out.

4.1.5 Investigation of Lead Movement

A number of investigations have examined the way in which lead moves around the City. These were mainly undertaken by the Department of Environment and Planning and have been summarised in a report (Body et al 1988).

Some assessments of the movement of lead into houses has been carried out and in some cases analysis of collected vacuum cleaner dusts performed. Further work on investigating the origin of lead which is currently entering houses and leading to recontamination is being carried out.

4.1.6 Evaluation

The blood lead data which is obtained from routine testing of the children has been used over the course of the Program to evaluate its effectiveness. Unfortunately, this data depends on voluntary participation leading to in considerable difficulties in using it for evaluation purposes. Routine air monitoring data has also been useful in evaluating changes in environmental lead contamination.

A careful evaluation of the Program was carried out after the first five years. This was reported to Cabinet in 1989 and in a thesis by Heyworth (1990). Another detailed study was carried out to identify the reasons why some children were not responding to the decontamination which was carried out on their houses. This data was reported in a thesis by Luke (1991) and has provided another of the bases for considering options for the future.

4.2 DECONTAMINATION

The process of decontaminating houses has been divided into two clearly identified separate stages: Stage I comprises the exterior work and Stage II the interior work. They are summarised as follows.

Stage I

- Fences
- Exterior walls and roofs of houses
- Sheds and other small exterior buildings
- Miscellaneous other objects around the house including TV towers
- Soils

Stage II

- Ceiling dust
- Interior lead based paint
- Ceiling cracks and crevices
- Matchboard
- Soft furnishings, carpets and interior surfaces

A house is identified for decontamination by two processes. The first process identifies children having elevated lead absorption. In this case a complete decontamination is proposed involving both Stage I and Stage II decontamination. When most of the houses identified as having children at risk had been decontaminated it was decided that a broad based public health intervention program involving a systematic decontamination of all houses in the high risk areas which had not been previously decontaminated was necessary. This process was implemented on a grid basis and involved carrying out a Stage I decontamination on each of the houses identified with lead contamination.

Following identification of a house for decontamination, householders are visited by a case worker to clarify the process to be undergone during the decontamination. A number of case worker visits are necessary and include obtaining signed agreements giving approval for various stages of the process if appropriate, and negotiating owner participation in the decontamination work. The case worker visits also include a substantial amount of counselling about reducing lead exposure to children and the environment generally. A house assessment is carried out by staff of the Environmental Health Centre to assess the level of lead contamination in the various parts of the home environment. A building officer then prepares a feasibility estimate by assessing the nature and extent of work required. The proposed work is scrutinised to ensure all the work necessary has been included before finally being approved. The work is carried out by a unit which was established within SACON, the Department of Housing and Construction. The Lead Decontamination Unit as it is known comprises a number of building officers dedicated to the decontamination process. When the work is completed a specific end point is defined and the job closed. This allows ongoing evaluation of the process to be based on a specific end point.

A brief description of each component of the decontamination follows. More detail can be obtained by contacting the South Australian Health Commission.

4.2.2 Decontamination Procedures

When the Program commenced in 1984 specific strategies and procedures for abatement of lead contamination had not been defined anywhere in the world. While some information was available, procedures were developed for Port Pirie based on existing knowledge and scientific judgement of the likely effectiveness of the procedures. The procedures have remained essentially the same throughout the Program and a brief description of each of the major components is provided.

The decontamination of a house commences with treatment of the ceiling dust. This is followed by treatment of the interior of the house and of the paint on the exterior of the house and the surrounding small buildings. Before finally vacuuming carpets and soft furnishings, soil treatment is undertaken where appropriate.

(1) Ceiling dust

Ceiling dust was found to almost invariably have high concentrations of lead. Thus, wherever possible, the ceiling dust is removed from any house undergoing interior decontamination. Access to the ceiling space is generally obtained through a man-hole although occasionally by removal of the roof materials. Ceiling dust is not removed from houses with blown-in insulation. Dust is removed using an industrial vacuum cleaner which remains outside the house. The cleaner was fitted with filters on the outlet to ensure that the losses of small particles of lead do not occur. The dust is transferred to bags and carted to the smelter for disposal.

(2) Gaps

Gaps and spaces in ceilings and walls are fixed to prevent dust entry.

(3) Interior lead based paint

A rapid screening test using a filter paper soaked in an EDTA solution is used to identify paint surfaces with elevated lead levels. The rapid paint test, as it became known, was calibrated to identify painted surfaces which had greater than 2% lead. Treatment of painted surfaces is carried out to prevent exposure of the children to flaking or chalking lead contaminated paint.

Where a lead contaminated paint surface is flaking all the loose flakes are removed and the surface then covered with a non-lead based paint. Chalking paint surfaces are suitably cleaned back and then repainted. Under some circumstances it was found cheaper or more effective to cover the wall with another surface and under some circumstances a new ceiling was installed below the old contaminated ceiling. Covering of the walls and ceilings is generally carried out with materials such as plasterboard.

(4) Matchboard walls and ceilings

Matchboard was a wall or ceiling covering used extensively in Port Pirie homes and comprises four inch boards with tongue and grooves which are fitted together. Generally they have been painted with lead based paint and as they became old and dry shrinkage left gaps between each of the boards. Because of the high probability of being painted with lead based paint and the gaps which were created, matchboard has been replaced or covered with another surface.

(5) Interior cleaning

After the ceiling dust has been removed and all of the interior paint work treated, thorough interior cleaning is carried out. Interior cleaning comprises careful vacuuming of all surfaces where lead contaminated dust might be present. All soft furnishings and fittings including curtains are cleaned using a process known as "Magnadry". The treatment material includes EDTA to facilitate the removal of lead contaminated material.

(6) Roofs

Roofs are frequently of corrugated iron and painted with lead base paint. Under some circumstances it has been possible to seal or stabilise the lead based paint. Often the corrugated iron has deteriorated to the point where it is not feasible to carry out cleaning and repainting. Under these circumstances it is cheaper to replace the roof completely rather than to carry out partial repair and sealing or repainting.

(7) External paint

The rapid paint test is used to determine the lead levels of paint on the exterior of houses, other buildings on the property and the fences. Sealing and repainting of surfaces which have elevated lead levels is carried out wherever feasible. Under many circumstances it was cheaper to remove the surface and replace it with new uncontaminated material.

Particular attention has been paid to areas of fences and walls up to about four feet where children were more likely to have access.

(8) Soil

A strategy of placing an adequate barrier between lead contaminated soil and the children was developed. This did not necessarily involve removal of the lead contaminated soil or reduction of the lead levels to what might be considered background.

CATEGORY A	Less than 500 ppm No action.
CATEGORY B	500 to 2,500 ppm Home owners are advised to maintain a barrier between soil and children and the parents are advised to ensure appropriate behaviour.
CATEGORY C	2,500 to 10,000 ppm As for category B plus assistance to cover contaminated soil with 50 mm of gravel or soil.
CATEGORY D	Greater then 10,000 ppm Excavate contaminated soil and replace with clean fill.

(9) Register

Recently it has been recognised that there are many surfaces which had been originally painted with lead based paint and subsequently with a number of non-leaded paint coats. The rapid paint test often records a weekly positive result in this situation. It is considered that this presents a minimal risk to children where the surface is sound and not flaking. Rather than treat these surfaces a method has been developed of recording where these untreated surfaces exist. Both interior and exterior painted surfaces are being placed on the register where appropriate.

(10) Owner participation

Participation by home owners or tenants is encouraged to increase parental awareness of the problem and to reduce the costs to the Program. Discussions with owners are carried out to identify the skills of the owners and the sort of tasks which they are prepared to undertake. A contract is entered into with the owner about the amount of work to be carried out and the time by when it is to be completed. Generally this work involves painting or garden treatment although occasionally more extensive owner participation work is agreed. Parents of children who undertake owner participation work are required to undergo routine blood tests to monitor their own exposure levels.

(11) Demolitions

When a large amount of work is required to decontaminate a house and it is condemned or structurally unsound a decision not to carry out the decontamination is made. Under these circumstances negotiation with the owners to purchase the house via the Program is carried out. The house is then demolished with all the materials being taken to the smelter for disposal in the slag dump. The soil is assessed and appropriate decontamination carried out. The block may then be made available for purchasing on the open market for redevelopment or by an adjoining property owner for greening purposes.

4.3 GREENING

The objective of greening was to cover open spaces and general bare areas around the City with plants to reduce the amount of lead contaminated dust which was being re-entrained. The first few years of plantings had varying degrees of success. Maintenance proved to be an expensive exercise due to the high salinity levels in soils, the failure of many species to survive, and the destruction of above ground watering systems by vandalism. In well attended areas such as parks and gardens, survival rates have been as high as 70%, but in open, low lying and saline areas, particularly those subjected to disturbances by the public, survival rates have been as low as 5%.

At the beginning of 1990, it was decided that a new approach to greening was required with an emphasis on plantings which had greatest self sufficiency. Salt tolerant species raised in Adelaide metropolitan areas, even when "hardened off" locally in Port Pirie often demonstrated poor survival rates. Also planting time tables, reliant on external source supplies were often inappropriate to local weather conditions.

4.3.1 Nursery Complex

In late 1990 the Program established its own propagating nursery on Pasminco - BHAS property. This has enabled the propagation of local seed sources to be undertaken. Induced mortality in the nursery from simulated field conditions has resulted in about a 50% survival rate of the most salt tolerant species in a more cost effective manner. Groundwater testing showed that in some areas of Port Pirie salinity levels were up to 3 times saltier than sea water.

The nursery is currently operating on a system which consists of local seed being propagated into local soil sources. Later the young seedlings are "hardened off" outside by being placed on a bed of sand. Gradually a saline water solution is introduced and drawn up into the tubes by capillary action, thereby mimicking the natural uptake of the water table.

4.3.2 Recent Developments

In 1992 the Woods and Forests Department became involved in helping to develop a more effective greening program. A soil survey was carried out and groundwater fluctuations are being monitored using test wells.

Three soil situations have been identified which are briefly classified as shallow, intermediate and deep saline soils. Salinity levels at the site are so high that modifications to the site are going to be necessary before vegetation establishment can be expected to be effective. Establishment techniques which are currently being investigated are as follows.

(1) Shallow saline soils

- Excavation of mini evaporation basins
- Planting local vegetation on the excavated soil

(2) Intermediate saline soils

- Local vegetation re-established on mounds

(3) Deep saline soils

- Mound design tested for tree and shrub establishment

4.4 COMMUNITY ENVIRONMENTAL HEALTH

For the Program to be effective it was considered important to fully involve the community in all facets. This has required provision of information and development of an effective support and involvement program.

4.4.1 Community Education and Awareness

The education and awareness activities have two main aims within the Lead Program: firstly to increase community acceptance and involvement in the various activities promoted by the Program and secondly, to specifically educate people about household and personal decontamination activities.

The local print and electronic media are frequently involved in promoting various aspects of the Program. Good working relationships have been established with each of the major media outlets which have provided good support for the Program. Activities such as a weekly local radio talk back segment have been used for promotion.

Activities have included the provision of project material for school children, displays at various locations around Port Pirie, and pamphlets and audio visual aids for teaching purposes in schools. Staff from the Environmental Health Centre frequently speak at workshops and seminars at a variety of venues. A vegetable garden using clean soil has been supported at one of the schools.

A demonstration of the sort of decontamination processes which were possible was established in a domestic dwelling located in a high risk area. The home had undergone a complete decontamination process. A variety of displays was mounted to provide demonstrations of methods available for decontamination. The house was available for inspection by the public.

A wide range of materials promoting the Program has been produced to promote blood testing and other activities. These have included stickers, messages on rulers, coloured pencils, balloons, magnets, posters, personal diet records, pamphlets and soaps.

4.4.2 Community Support

Family contact and support is regarded as an essential element of the overall Program. Extensive support is given to the families of children who have elevated blood lead levels by the case workers. Counselling and advice is aimed at encouraging families to participate in home-based interventions particularly those which involve behavioural changes.

Since many of the people have spent their whole lives in Port Pirie the Program represents a substantial intrusion into these people's lives. In the early days of the Program this was particularly true and considerable effort needed to be made to overcome the resistance.

The community support process was aimed at minimising the extent of disruption to family life resulting from the decontamination process and to ensure that as little stigma as possible was associated with the activities. The case workers also played a role in providing information to families about the Program.

4.4.3 Community Development

The goal of this component of the Program was to involve the residents of high risk areas of Port Pirie more actively in the whole range of programs offered through the Environmental Health Centre and to increase general awareness of the effect of a lead contaminated environment. Rather than just addressing the lead issue, the focus was more broadly on the environment and general quality of life in Port Pirie. The Port Pirie residents were thus encouraged and enabled to take collective action to make changes to their environment and to lobby the appropriate authorities to obtain the resources necessary to carry out these measures.

Community development was aimed at having people act on their own behalf, rather than play a passive role. As a consequence of this program, groups of residents have become actively involved in the maintenance of public areas. Others are forming small local interest groups and the assistance and support given between families has proven to be an effective part of ensuring the implementation of the Program.

4.5 LEAD WORKERS

A number of occupational settings around Port Pirie involve contact with lead and hence incur the possibility of workers contaminating their home environment. While the smelter and the wharf are the major potential sources of lead contamination, other settings need to be kept in mind.

4.5.1. Pasminco-BHAS Smelter

There have been steady improvements in the environmental controls at the smelter since the time of the Royal Commission in 1925. A major environmental program was initiated in the 1970's which has enabled substantial reductions in the lead lost to the environment. At the time of commencement of the Program, substantial changes were made within the smelter to reduce the risk of adults carrying lead contamination home to children. A double locker system, all work clothing, and showering facilities were provided, and a car washing facility established. Shower facilities have also been provided for workers on the wharf who are not smelter employees.

4.5.2 Other Occupations

Apart from the Pasminco-BHAS employees, there are a number of other workers around town who are employed in areas where lead contamination is a possibility. These include the decontamination workers on the Program, Council and other employees working with lead contaminated soil and smelter contractors.

Attempts have been made to identify all lead related workers and to provide counselling on how to avoid carrying lead dust into their homes. Employers are encouraged to provide shower facilities for these workers, while workshops and blood testing at the Environmental Health Centre is provided wherever possible.

5. PROGRESS WITH ENVIRONMENTAL LEAD DECONTAMINATION

The 1983 Task Force concluded that smelter emissions were acceptably low and that the historical lead sink around the City provided the substantial source of lead for the contamination of children's homes.

Furthermore, it recognised that the success of the environmental decontamination strategy depended on the levels of lead emissions from the smelter being sufficiently low that recontamination from that source would not be significant. Likewise, a high compliance rate with decontamination of all areas was seen as necessary to prevent recontamination from the lead sink.

The proposed Program envisaged systematic decontamination of households and the Port Pirie environment (the lead sink), in particular:

(1) Interiors of houses,
(2) Ceilings of houses,
(3) Exteriors of houses, sheds, outhouses and fences,
(4) Gardens surrounding houses,
(5) Roads, streets and footpaths,
(6) Parks, the racecourse and other public areas,
(7) Public access buildings, shops and factories and their surrounding areas,
(8) Schools,
(9) Vacant blocks and undeveloped areas of the City, and
(10) Areas surrounding the City which may be contaminated with lead.

Progess with these measures is summarised in Section 5.2.

With regard the monitoring of progress towards successful control of lead contamination, the Task Force recommended that children's blood lead levels should provide the prime indicator. Progress with reducing blood lead is reviewed in detail in Chapter 6. Beyond blood lead monitoring, the Task Force recommended the monitoring of lead in air, lead in house dust and lead losses from the smelter. Progress using these indicators is summarised in Section 5.3.

Finally, further reductions in lead losses from the smelter were recommended as economic and technical feasibility permitted. Progress in this regard is reviewed next in Section 5.1.

5.1 SMELTER STRATEGIES FOR CONTROLLING LEAD SOURCES

In the past there is little doubt that smelter operations in Port Pirie was unsatisfactory for workers, the environment and the community. Major improvements followed the 1925 Royal Commission into Plumbism, and since that time, conditions have continued to improve.

5.1.1 Emission Control

Standards of smelter operations and occupational health have improved greatly in the past two decades. The measures taken have also resulted in benefits for the City's environment. Some research has suggested that most of the lead sink was the result of pre 1925 emissions. Stack emissions have been reduced from 2-5000 tonnes lead per year before 1925, to levels of the order of 1-2000 tonnes per year during the 1930s and 40s. In 1974, the Department of Environment & Planning estimated stack emissions of 145 tonnes per year after the installation of new filtering equipment. In 1981, it was estimated that stack emissions had been reduced to 50 tonnes per year while estimates of current fugitive emissions have not been possible.

In 1979, the 205 metre stack was commissioned to distribute sulphur dioxide emissions more widely. At the same time, a new baghouse complex served to reduce particulate emissions. Previously emissions were released from several smaller chimneys and tended to deposit lead at only small distances from the smelter. Thus maximum concentrations of contaminant lead occurred in those areas close to, or downwind from the smelter complex.

Dust monitoring in the early 1980s showed substantial reductions in aerial deposition of lead, arsenic and cadmium following introduction of the tall stack and baghouse complex. It is plausible that the reduction in blood lead noted in 1982 and 1983 amongst the early Cohort Study children might be related to these changes in lead emissions.

A number of other improvements have been made at BHAS over the past ten years to reduce airborne lead emissions to the Port Pirie environment, reduce contamination of households by work clothing, and reduce carriage of lead on vehicles leaving the smelter. A summary of the larger projects appears below.

<u>1982</u> Modifications to number 2 blast furnace to provide better containment of fugitive emissions.

<u>1983</u> Installation of number 3 dust recovery system at the slag fuming roasting kilns, and conversion of numbers 1 and 2 scrubbers to long throat venturi scrubbers.

<u>1984</u> Upgrading and extension of main changehouse and extension of laundry for laundering of all workclothes on site. Day shift ceased going home for lunch.

<u>1985</u> Installation of zinc residue pumping system and high pressure Larox filter at lead proportioning plant to overcome residue dryer stack emissions and residue handling hygiene problems.

<u>1986</u> Installation of vehicle washing station.

<u>1987-1992</u> Progressive implementation of a $50 million Environmental and Economic Improvement Plan. A total of 19 projects were carried out, more than half of which were directly environmental. The remainder included significant environmental as well as economic gains.

Projects included:

- Tippler enclosure and draughting (1988),
- Improved sinter plant feed conditioning (1989),
- Improved sinter plant moisture control (1989),
- High temperature electrostatic precipitator at the acid plant to replace existing low temperature unit (1989),
- Partial closure of the concentrate storage and automated blend proportioning (1990),
- New proportioning plant bins, flux stalls, and road boot loading system (1990),
- Blast furnace control room and furnace feeding improvements (1991),

- New hygiene system and associated baghouse at lead refinery (1991),
- Additional chamber at main smelter baghouse to provide improved draughting at sinter plant and blast furnace (1991), and
- Computerised process control equipment and modified draughting arrangements at the top of number 2 blast furnace (1992).

In addition to the foregoing Environmental and Economic Improvement Plan work, other projects in this period included:

- Blast furnace operator guidance system (1990),
- New cooling tower in number 2 slag fuming furnace gas train, which removed stack emissions during slag tapping (1991),
- New high volume water trucks plus additional works road sweeping provided as part of transport contract with Brambles (1991),
- Greening of slag dumps and some fenceline areas and construction of windrows on slag dumps to control wind re-entrainment of dust (1987-92), and
- Construction of an earthen bank between the railway line and the main street (Ellen Street) and its greening with trees and ground cover (1992-93).

5.1.2 Dust Control

Other changes to smelter operations have seen the wetting down of concentrate in railway wagons, the reduction of train speeds through the City and the use of polymer sealants on the wharf zinc concentrate stockpiles. More recently, slag dumps and other operations are being re-arranged to increase the buffer zone between lead operations and residential areas, and this buffer zone is progressively being greened as a windbreak. Finally, a green buffer is being introduced between the wharf and the main street.

5.1.3 Lead Carriage by Workers

Several measures have been introduced over the last decade to reduce the passive carriage of leaded dust from the smelter to workers' homes. Since 1984, day shift workers have no longer gone home for lunch and with the introduction of showering and laundry facilities, workers' clothes now stay on site.

It seems likely that these strategies have contributed to the current position in which, unlike that in 1982, having a parent working at the smelter is no longer predictive of an elevated blood lead level in their young children.

5.2 PROGRAM STRATEGIES TO CONTROL THE LEAD SINK

Although decontamination of various parts of the City environment lead sink was considered to be an effective method of reducing lead contamination and therefore part of the Program, the main focus has been on individual households. It was recognised early on that reserving resources for decontamination of the general City sink would require that many homes where children had been identified with elevated blood lead levels be left untreated for some time. Thus it was decided to start with a house-by-house decontamination approach, beginning with homes of children with the highest blood lead levels.

5.2.1 Home Environments

Since 1984, the Program has given a predominant emphasis to primary household decontamination aiming to reduce bioavailable lead levels, reduce lead bearing dust levels, replace lead based paints and remove lead contaminated soils. The purpose was to modify home environments so that they would not be an important source of lead contamination and would be amenable to maintenance in a good state.

By the end of 1987, virtually all homes of children with elevated blood lead levels had been treated. Since 1987, homes are being decontaminated for newly identified children with elevated blood lead and secondary decontamination is being carried out for children whose blood lead levels have failed to respond adequately to initial or primary decontamination. In early 1988, a grid approach was adopted in which partial treatments or Stage I of the decontamination process (see Section 4.2) were undertaken in smaller defined areas within the high risk areas. These partial decontaminations were limited to the treatment of soil and external structures of the homes. Some 20 grid areas were identified in the two high risk areas of Solomontown and Port Pirie West. Partial decontamination of these grids is due for completion by mid-1994.

5.2.2 General Environment

In accordance with the Task Force's recommendations, certain venues frequented by young children, such as preschools, kindergartens and some primary schools, have received some decontamination effort. To date, other public access buildings such as shops and factories have not been decontaminated.

The City Council has played a significant role in measures to control lead contamination in the general City environment. An augmented program of footpath sealing has been undertaken with joint Government funding and public parks have been treated to place a barrier between children and lead contaminated soil or slag. The parks have also been substantially improved with extensive greening and other refurbishment to prevent dust re-entrainment.

More progress has been made with the complementary strategy of controlling wind re-entrainment of the dust sink by means of greening. The greening component of the Program has been a co-operative undertaking with the object of providing ground cover, shrubs and trees over large areas of otherwise arid land. The smaller plants provide a mechanism for consolidating soil and thus preventing the spread of lead bearing dusts by wind movement. Trees also act as dust traps for windborne dust, and by breaking the laminar flow of wind, limit the movement of dust through the City. This revegetation of Port Pirie not only serves a basic public health objective, but also has obvious aesthetic benefits for the City.

Finally, the previous practice of distributing spent slag for landscape purposes has been actively discouraged unless the lead concentration by measurement is below 300 mg/kg. Under these conditions, the addition of slag to the general environmental sink has all but ceased.

Although much has been accomplished to date, a significant effort to decontaminate the lead sink in many public access areas has yet to be undertaken.

5.3 INDICATORS OF ENVIRONMENTAL CONTAMINATION

During the years prior to the establishment of the Lead Implementation Program and the first years thereafter, extensive measurements of environmental lead were undertaken to:

- Identify the factors which predicted elevated blood lead in children,
- Define the high risk areas, and
- Plan individual household decontamination.

Measurements for this third purpose have continued throughout the years of the Program. Unfortunately, measurements for abatement planning provide little useful information for assessing changes in the level of environmental lead contamination around the City.

While the Task Force recommended monitoring of lead in air, lead in house dust and lead losses from the smelter, data that can be used to indicate progress in levels of environmental contamination over the years is only available for measurements of lead in air.

The lack of systematic effort to monitor changes in environmental lead may well reflect the general opinion that contamination was largely of historical origin and relatively static in magnitude. As recently as 1988, the review report from the Department of Environment and Planning (Body et al, 1988) concluded that there was little evidence of changes to the City lead sink even though evidence was presented to show that substantial recontamination of houses was occurring.

5.3.1 Lead in Air

(1) *Task Force Report (1983)*

(a) Monitoring data

Limited high volume sampling data was available to the Task Force although as the summary below indicates, lead in air concentrations had declined since introduction of the tall stack.

- Orana site: annual monitoring back to 1977, with values reducing to less than 1.5 $\mu g/m^3$ in 1982 with a moderate contribution from petrol.

- Solomontown Beach site: 2-3 $\mu g/m^3$ up until 1979 with a reduction to less than 1 $\mu g/m^3$ in 1982.

- 63 York Road and 58 The Terrace sites: levels in the range 0.3-1.5 $\mu g/m^3$.

Hence by 1983 all monitoring sites had concentrations at or below the NH&MRC guideline.

(b) Conclusions (as at 1983)

Available data led the Task Force to the following conclusions.

- It was considered unlikely that contamination by fugitive emissions represented a major source of lead in air in the northwestern area.

- Limited data suggested that levels of airborne lead in the northwest, central business and eastern areas were currently less than 1.5 $\mu g/m^3$.

- Lead levels in air declined fairly quickly with distance from the smelter.

- Results suggested that current emissions from the smelter were low and could be considered as satisfactory.

(2) *Department of Environment and Planning (Body et al, 1988)*

Although the general levels of total suspended particulate lead (TSPL) in the areas adjoining the lead smelter were slightly above the NH&MRC recommendations, they were considered satisfactory and had been markedly reduced over a ten year period (Sweetapple, 1984).

Later reports by Goh and Hope (1985, 1986) presented similar conclusions to those of Sweetapple but noted that the reduction was not continuing. Some increase in concentrations had been observed.

(3) Comments on trends 1983-1990 by Air Quality Branch, Department of Environment and Planning (DEP)

A major reduction in total suspended particulate lead (TSPL) occurred at the Orana & Solomontown Beach monitoring sites after 1979 with the introduction of the new baghouse and tall stack, bringing the 3 month average values below the 1.5 $\mu g/m^3$ guideline.

Compared with the air lead levels reported in 1983, evidence suggested a subsequent increase rather than a continuing decline despite the many smelter changes during this period (see Section 5.1 above). This evidence can be summarised as follows:

- 3 month mean TSPL at 5 monitoring sites in 1985 higher than July-December 1984,

- The 1.5 $\mu g/m^3$ criterion was exceeded at one site in 1984 (SACON/DHC) and at 2 sites in 1985 (SACON, Port Pirie West Primary),

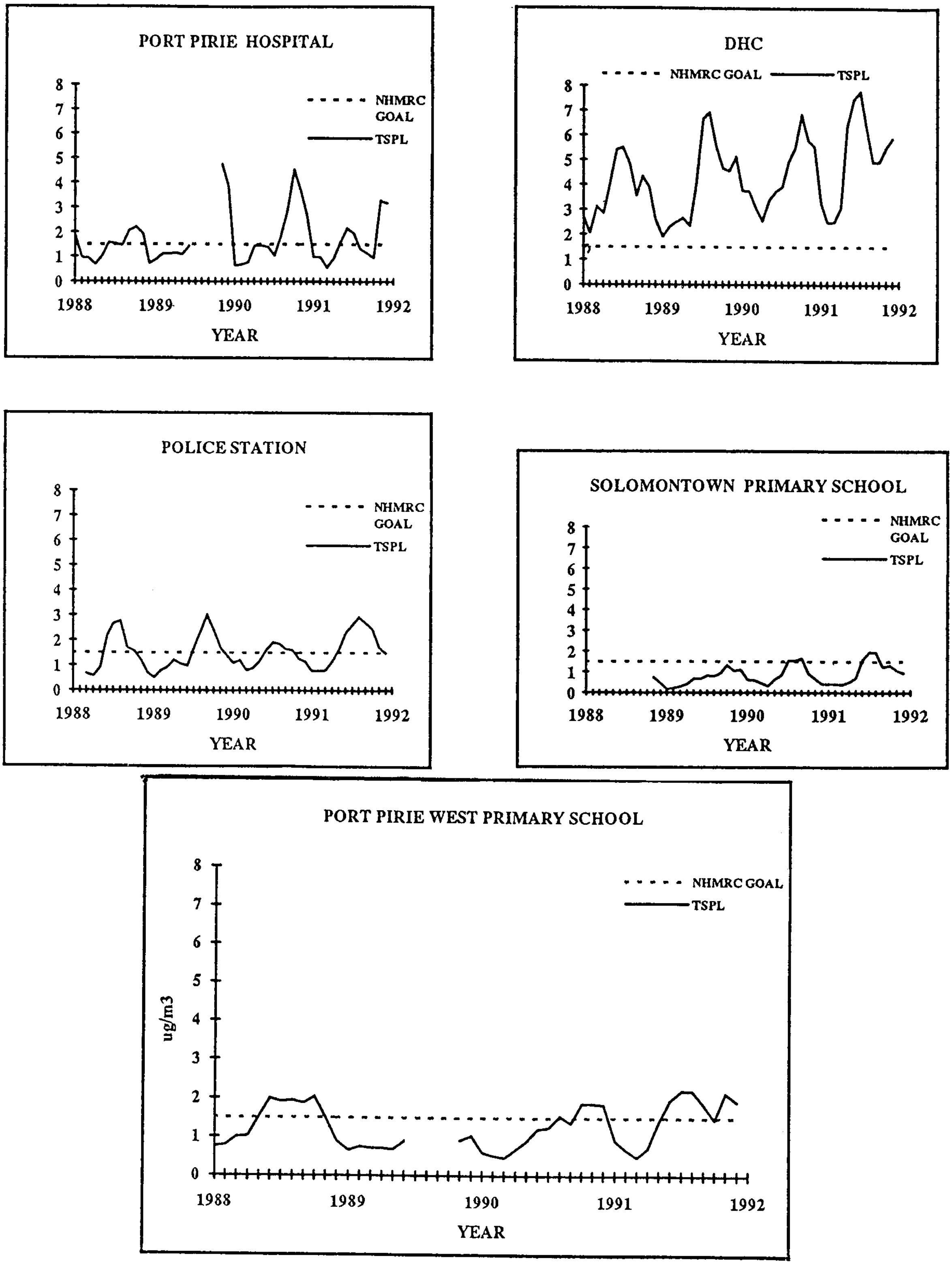
- A 65% increase in TSPL at the Police Station in 3 months to November 1987 compared with the same period in 1986 under the influence of more north to northwest winds,

- No significant reduction in airborne lead levels occurred from 1984 to 1990 at SACON(DHC) and Port Pirie West Primary School, and from 1987 to 1990 at Port Pirie Hospital, and

- 3 month running mean levels of airborne lead for the first half of 1991 at the three sites have increased compared with the same period in previous years.

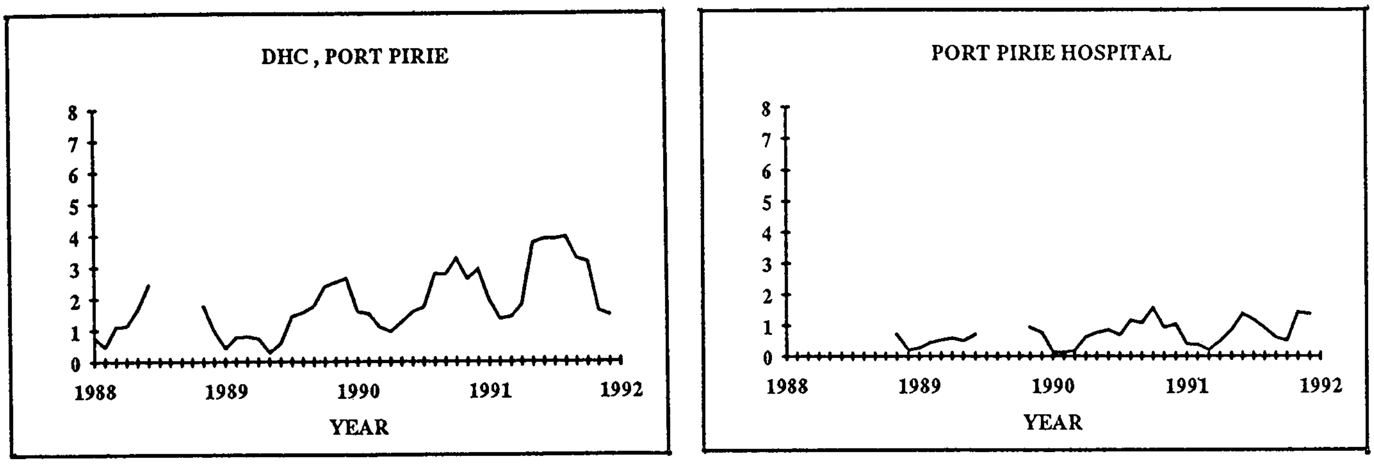
These findings appear to be supported by inspection of the moving 3 month average total suspended particulate lead (TSPL) and thoracic-sized particulate lead (PM10) graphs in Figures 5.1, 5.2 and 5.3.

Figure 5.1 Three Calendar Month Running Mean Concentrations of Total Suspended Particulate Lead (TSPL)



(Source: Air Quality Branch, Department of Environment and Land Management, 1992)

Figure 5.2 Three Calendar Month Running Mean Concentrations of Inhalable (PM10) Particulate Lead



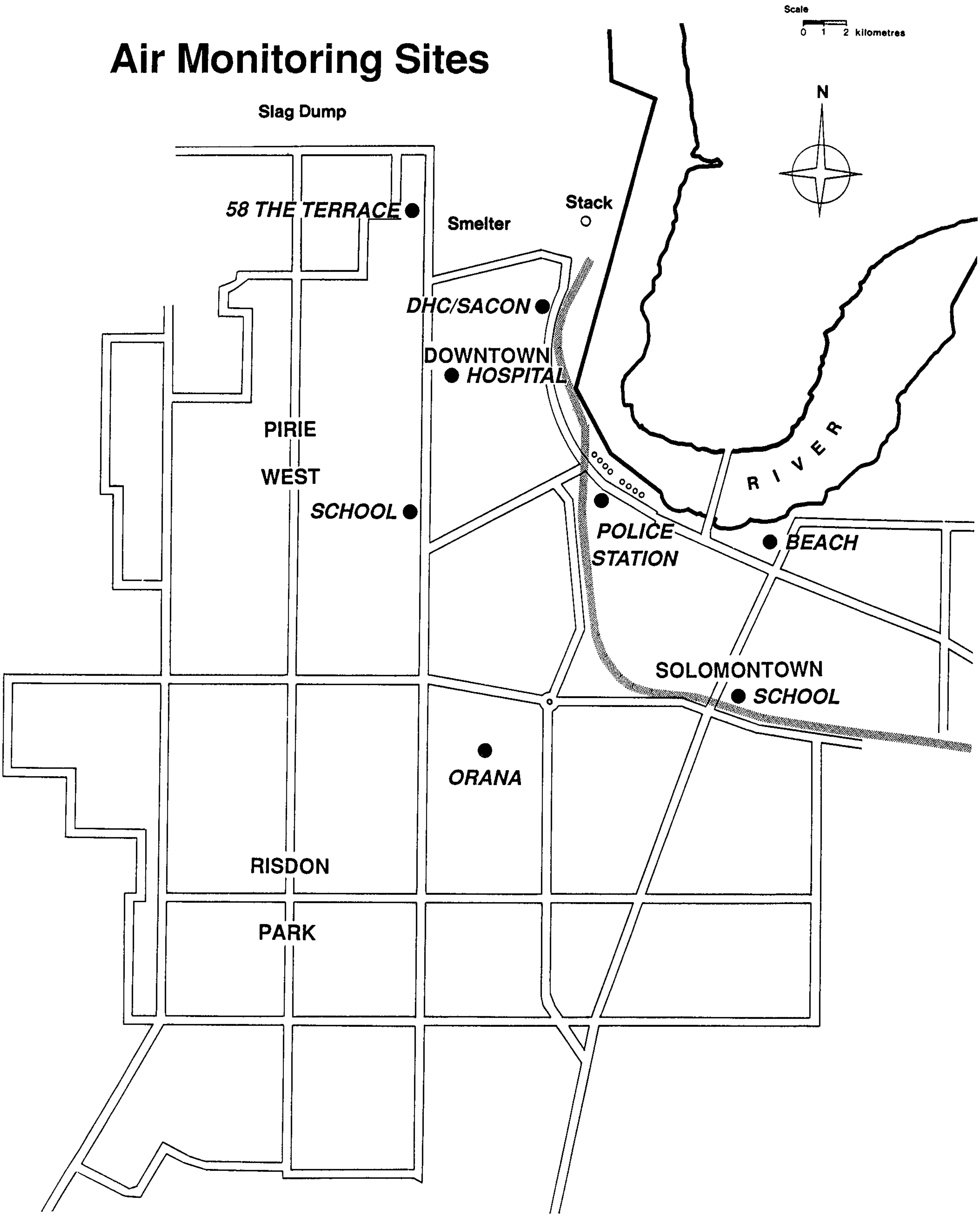
(Source: Air Quality Branch, Department of Environment and Land Management, 1992)

In making any conclusions about trends in air lead, the systematic effects of the following need to be taken into account:

- Higher rainfall in 1986 and 1987,
- A plant shutdown during the winter and spring of 1986,
- Increased north to northwest winds in 1987, and
- Seasonal peaks of TSPL in winter and/or spring.

Lead in air values continue to be highest near the smelter with a fairly rapid decline with distance therefrom.

Figure 5.3 Air Monitoring Sites (High Volume Samplers)



(4) *Comments on 1991 data by Air Quality Branch (DEP)*

Air Quality Branch (1991) reported that:

- At SACON (DHC), three month mean levels of TSP lead exceeded the 1.5$\mu g/m^3$ NH&MRC goal throughout 1991,

- At Port Pirie Hospital the TSP lead levels for the moving three month periods ending May, June, July, November and December exceeded the NH&MRC goal for atmospheric lead, and

- At Port Pirie West Primary School the TSP lead levels for the moving three month periods ending June, July, August, September, November and December exceeded the NH&MRC goal for atmospheric lead.

(5) *Distribution of 24 hour TSPL values*

As a supplement to the three month running average graphs, changes in the distribution of 24 hour lead in air measurements, provide another useful summary indicator of change in air lead concentrations. In Table 5.1, data from 1984 to 1992 are summarised.

In outline, the data suggest that:

- Concentrations of lead in air decline rapidly as distance from the smelter increases,

- Higher values occurred in 1991 compared to previous years at the SACON (DHC) site, and

- Lead in air concentrations have not declined since 1984.

Table 5.1 Daily Lead in Air Concentrations (μg/m³)
Number of 24 hour Recordings (percent) by Lead in Air Concentrations (μg/m³)

Air Lead (μg/m³)	> 6.4	2.6 - 6.4	1.6 - 2.5	1.0 - 1.5	0.4 - 0.9	<0.4	Total
BHAS (Tipper Plant/ Lead Storage Area)							
Mar 87 - Feb 88	25 (41)	23 (38)	10 (16)	1 (2)	1 (2)	1 (2)	61
Mar 88 - Nov 88 (9 months)	18 (41)	18 (41)	5 (11)	3 (7)	- (-)	- (-)	44
SACON							
1984	6 (16)	5 (13)	1 (3)	8 (21)	17 (45)	1 (3)	38
1985	9 (15)	13 (22)	15 (25)	14 (23)	8 (13)	1 (2)	60
1988	7 (12)	15 (26)	15 (26)	7 (12)	13 (22)	1 (2)	58
1990	9 (15)	23 (37)	13 (21)	9 (15)	8 (13)	- (-)	62
1991	14 (24)	16 (28)	14 (24)	11 (19)	3 (5)	- (-)	58
1992	16(26)	19(31)	12(20)	9(15)	5(8)	-(-)	61
HOSPITAL							
1988	2 (3)	6 (10)	5 (8)	6 (10)	24 (40)	17 (28)	60
1990	9 (15)	23 (37)	13 (21)	9 (15)	8 (13)	- (-)	62
1991	3 (5)	5 (8)	6 (10)	10 (17)	18 (31)	17 (29)	59
1992	3(5)	5(9)	6(11)	3(5)	20(35)	20(35)	57
58, THE TERRACE							
1991	2 (3)	5 (8)	9 (15)	6 (10)	12 (20)	26 (43)	60
PORT PIRIE WEST PRIMARY SCHOOL							
1984	- (-)	2 (6)	3 (9)	3 (9)	13 (39)	12 (36)	33
1985	1 (3)	4 (7)	10 (17)	9 (15)	23 (39)	12 (20)	59
1988	3 (5)	7 (11)	5 (8)	10 (16)	31 (49)	7 (11)	63
1990	2 (3)	4 (7)	5 (8)	12 (20)	20 (33)	17 (28)	60
1991	2 (3)	7 (12)	8 (14)	6 (10)	24 (41)	12 (20)	59
1992	1(2)	2(4)	7(13)	4(7)	24(43)	18(32)	56
SOLOMONTOWN BEACH							
1984	- (-)	- (-)	7 (13)	4 (7)	25 (45)	20 (36)	56
1985	- (-)	1 (2)	5 (8)	10 (17)	25 (42)	19 (32)	60
ORANA							
1984	- (-)	- (-)	- (-)	1 (2)	20 (36)	35 (63)	56
1985	- (-)	- (-)	2 (3)	4 (7)	25 (42)	29 (48)	60

5.3.2 Lead in Dust and Soil

Given the preceding evidence of ongoing airborne lead levels, it is not surprising that preliminary evidence from several investigations suggests that households continue to be contaminated and decontaminated households are experiencing recontamination. Apart from new leaded dust entering residential areas from the smelter and its environs, some of this lead contamination is likely to be arising by wind transport from areas of the City lead sink that have not been decontaminated.

This situation suggests limited progress in reducing the level of lead contamination around the general environment of the City. Unfortunately, it cannot be quantified directly due to the lack of longitudinal monitoring data on City lead dust concentrations and mass loadings per unit area.

6. PROGRESS WITH REDUCING BLOOD LEAD

The Port Pirie Lead Implementation Program was established in 1984 with the major purpose of reducing the blood lead level of the child population in Port Pirie. In reviewing the effectiveness of this Program it is therefore necessary to consider the evidence for a decrease in blood lead levels between 1984 and 1992 and for a reduction in the percentage of children over the NH&MRC level of concern. At the time the Program commenced the level of concern was 30 μg/dl. A greater reduction in the mean blood lead level was expected amongst those children whose homes had been decontaminated.

6.1 METHODS

The approach employed to assess the impact of the Program used data on blood lead from three sources. The first source was the biological monitoring component of the Environmental Health Centre (EHC). This is referred to as the EHC data. The second data source was the research results of the Port Pirie Cohort Study, which is referred to as Cohort Study data. The third source was the SA Health Commission survey of 1982.

6.1.1 EHC Blood Lead Data

Blood lead testing has been made available to all Port Pirie children up to seven years of age and the results can be used to assist investigation of community wide trends in lead levels. However, it should be noted that the principal purpose of this testing has been to assess and monitor the blood lead levels of individual children, and the data collection was designed for that purpose. Although the blood testing provides a useful data source for assessing community-wide trends, it was not designed to serve this function. Therefore, inferences need to be drawn with care.

The Environmental Health Centre (EHC) monitors blood levels using cycles of testing and data were available for analysis from the first sixteen cycles. Cycles were of six months duration for cycles 4-16 inclusive, from mid 1986 to the end of 1992, along with:

- Cycle 1 April 84 - March 1985 (12 months)
- Cycle 2 April 85 - Sept 1985 (5 months)
- Cycle 3 Sept 85 - May 1986 (7 months)

Children were included for testing on a voluntary basis and the proportion tested in any one cycle ranged from around 32 per cent to 59 per cent (based upon 1986 census figures to cycle 12 and 1991 census figures to cycle 16). The inclusion of children in repeat cycles of testing was also voluntary, leading to variable numbers of tests per child. The number of children tested by age and cycle is shown in Table 6.1.

Children who lived outside Port Pirie but attended a school within Port Pirie were also tested at the Centre. These children, along with children whose place of residence is unknown, have been excluded from the tables and figures presented in this Chapter.

Total compliance was not achieved. It was not possible to follow-up all children and often parents were unaware of the need to have their children tested more than once. The proportion of Port Pirie children tested at the Environmental Health Centre (EHC) has increased somewhat since cycle 10.

The monitoring program aimed to test each child once in every six months. In addition, more frequent tests were planned during the decontamination process because a child's blood lead level could rise significantly as a result of the activity associated with this process. However, a much smaller proportion received multiple tests than was planned. Children with raised blood lead levels were more likely to have received multiple tests (87%+) compared with those with low blood lead levels (0-9 μg/dl = 63%).

A formal protocol for blood testing was established in February 1986 and became an integral part of the monitoring program. The number of case workers employed on the Program increased and hence, there was greater success in following up children before, during and after decontamination.

Table 6.1
Number of Children Tested by Age and Cycle
(Includes Cohort Study Children)

Age (yrs)	Census Pop'n 1986	Cycle 1	2	3	4	5	6	7	8	9	10	11	12	Pop'n 1991	13	14	15	16
0	181	38	26	44	58	57	33	47	41	45	29	44	49	212	46	47	55	50
1	212	76	52	97	98	95	87	94	84	82	104	121	100	207	95	88	94	110
2	215	77	61	104	102	122	98	99	105	92	87	125	120	211	114	90	100	109
3	211	97	72	96	122	126	113	131	104	67	101	120	120	222	121	106	126	101
4	210	126	110	131	116	154	145	151	137	61	143	121	133	222	159	144	147	154
5	229	111	73	108	122	123	104	139	146	66	132	158	131	195	129	133	147	152
6	188	155	139	100	102	143	122	114	110	63	163	162	147	208	157	132	154	153
7	211	128	135	141	126	90	93	104	96	59	106	123	143	225	127	131	130	131
Total	1657	808	668	821	846	910	795	879	823	535	865	974	943	1705	948	871	953	960
%	100	49	40	50	51	55	48	53	50	32	52	59	57	100	56	51	56	56

Excludes children tested who resided outside of Port Pirie or where place of residence was unknown (approximately 100-150 per cycle for cycles 1-4, 30-60 per cycle since.)

Children attending the EHC have capillary blood samples taken in accordance with Australian Standard 2636-1983 "Sampling of Venous and Capillary Blood for the Determination of Lead Content".

6.1.2 Cohort Study Blood Lead Data

The Port Pirie Cohort Study was undertaken by a group of researchers independently of the South Australian Health Commission to identify the effects of lead exposure on childhood development.

Between May 1979 and May 1982, 831 pregnant women living in or around Port Pirie were enrolled in this study. These women represented approximately 90 per cent of all new pregnancies occurring during that period. Of the 831 women, 646 lived in Port Pirie, whilst the remaining 185 women resided in the surrounding rural area and associated townships.

The cohort of 745 children was born between September 1, 1979 and September 1, 1982 (McMichael et al, 1985). Capillary blood samples were collected at the ages of 6, 15 and 24 months and annually thereafter, up to seven years of age. Children were lost to follow-up primarily as a result of their families leaving Port Pirie, however some parents also chose not to continue their participation (McMichael et al, 1985). At four years of age, there were 548 children remaining in the study (74%), 397 living in Port Pirie and 151 in the surrounding area.

The high proportion of this birth date defined group (cohort) providing serial blood lead measurements represent an important advantage for evaluation purposes over the EHC cycle measurements by virtue of the higher participation rate, the exclusion of new residents, and the control of over-representation of children with elevated blood lead.

Blood lead data from this study have enabled a "before and after" evaluation of the Lead Implementation Program which otherwise would not have been possible. Children were enrolled at birth in the Cohort Study between September, 1979 and September, 1982, and therefore were aged between two and five years at the start of the Program in 1984.

6.1.3 SA Health Commission Survey

In 1982 all Port Pirie primary school children were offered a blood lead test. 50% of this group participated along with some additional preschool children: 1239 in all.

6.1.4 Decontamination Follow-up Studies

(1) *Primary decontamination*

Blood lead trends of children living in a house that had received primary decontamination were considered in detail by Heyworth (1990).

In a separate study records of 175 children could be located who had both their homes treated and received a blood test 12 months following the commencement of these interventions. These represented 24% of the households that had been treated at least 12 months prior to this study. The reduction in blood lead after home treatment was analysed in relation to family and location characteristics, specific features of the intervention and its costs. (Luke, 1991).

(2) *Socio-demographic profile.*

To provide general background, socio-demographic features of the families having home decontamination were compared with those of the Port Pirie community (ABS, 1986).

(3) *Secondary decontamination.*

The study followed-up a small cohort of 59 children whose blood lead concentration remained above the level of concern (25 μg/dl) despite primary decontamination of their homes. These children were studied for at least 12 months to identify which components of the secondary home decontamination or which behavioural changes were most related to favourable changes in blood lead (Luke, 1991). Factors studied included:

- Details of home and other external environments,
- Environmental lead levels including garden soils, house and vacuum cleaner dusts,
- Behaviours including hand-to-mouth activities, eating habits, diet and rainwater consumption, and
- Other family activities relevant to lead exposure.

6.2 ENVIRONMENTAL HEALTH CENTRE (EHC) CYCLE DATA

6.2.1 Mean (Average) Blood Lead

The trend over time shows an appreciable decline in blood lead concentrations. The all age geometric mean has decreased from 19.5 μg/dl in cycle 1 (1984/85) to 12.8 μg/dl in cycle 16 (1992), a reduction of over 30% (Table 6.2). The pattern seen is one of an initial decline between cycles 1 and 4, followed by a levelling out to a mean of around 16.5 μg/dl in cycles 5 to 9 (1987, 1988). Since cycle 10 there has been a further decline in the mean blood lead levels until cycle 12 after which the all age mean has been fairly stable around 13 μg/dl. A pattern of higher mean values, or arrested reduction, during the first half of the year (odd number cycles) can be seen quite regularly in the data. It may relate to higher lead exposures during the preceding spring and summer, the period during which for instance, lead in air values are at their highest.

Although the reduction has been greatest amongst 2 and 3 year olds, it encompasses all ages (Table 6.2). Children aged 1-4 years continue to have higher blood lead levels.

Table 6.2

Geometric Mean Blood Lead Level (μg/dl) by Cycle and Age

EHC, Port Pirie

(Includes Cohort Study Children)

Age (yrs)	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	Cycle 7	Cycle 8	Cycle 9	Cycle 10	Cycle 11	Cycle 12	Cycle 13	Cycle 14	Cycle 15	Cycle 16	Change μg/dl Cycle 1-16 (%)
0	15.2	14.6	14.5	12.2	15.4	14.7	14.9	13.7	12.3	12.5	12.7	9.6	13.0	10.0	11.7	9.6	↓5.6 (37%)
1	21.0	20.5	18.0	17.0	19.0	19.1	19.3	19.1	20.0	16.7	17.7	14.4	16.6	15.9	16.3	13.7	↓7.3 (35%)
2	23.4	22.3	20.4	17.1	17.9	19.3	17.7	18.5	19.9	18.9	16.5	14.8	15.7	16.0	16.4	14.9	↓8.5 (36%)
3	22.8	20.4	19.2	17.3	18.6	16.9	17.3	18.1	17.6	17.2	15.8	14.9	15.3	15.3	16.1	14.2	↓8.6 (38%)
4	22.3	20.0	17.2	17.3	17.5	17.2	15.8	16.5	18.7	15.0	14.4	13.1	13.3	13.1	14.3	14.5	↓7.8 (35%)
5	19.8	16.4	18.2	16.3	16.5	15.3	15.3	15.4	14.8	14.6	14.4	12.0	12.2	12.6	12.4	12.5	↓7.3 (37%)
6	17.5	16.8	16.4	15.1	16.1	16.0	15.4	14.9	14.5	14.4	12.3	11.6	13.1	11.4	11.4	11.4	↓6.1 (35%)
7	16.2	15.0	15.2	14.7	15.7	15.5	14.9	14.5	13.9	13.2	12.2	10.8	11.1	11.1	11.1	11.3	↓4.9 (30%)
0-7	19.5	17.8	17.5	16.0	17.1	16.8	16.3	16.3	16.8	15.3	14.4	12.7	13.6	13.1	13.5	12.8	↓6.7 (34%)

6.2.2 Geographic High and Low Risk Areas

The decline in blood lead has occurred in both high and low risk areas of the City but has been smaller in the highest risk area of northern Port Pirie West the area nearest the smelter (Table 6.3, Figure 6.3). This area, along with northern Solomontown, remains above 16 μg/dl.

Figures 6.1 and 6.2 identify the risk status of residential areas within Port Pirie according to grid co-ordinates used in the blood testing program.

Further, the high risk area experienced a more fluctuating course with an early decline, a plateau between cycles 5 to 9 and then a further decline (Figure 6.3). Port Pirie West continues to experience large fluctuations between cycles. Solomontown along with the low risk areas appears to have reached a plateau in terms of blood lead level decline.

The decline amongst children in the highest risk ages of 1-4 years shows a similar pattern (Table 6.4 and Figure 6.4) with the northern part of Port Pirie West, and to a lesser extent the northern part of Solomontown, diverging from the current blood lead levels in the other areas. Further details of the trends within each area of the City are provided in Chapter 10.

Figure 6.1. Risk Status of Residential Areas in Port Pirie Based on Grid Co-ordinates.

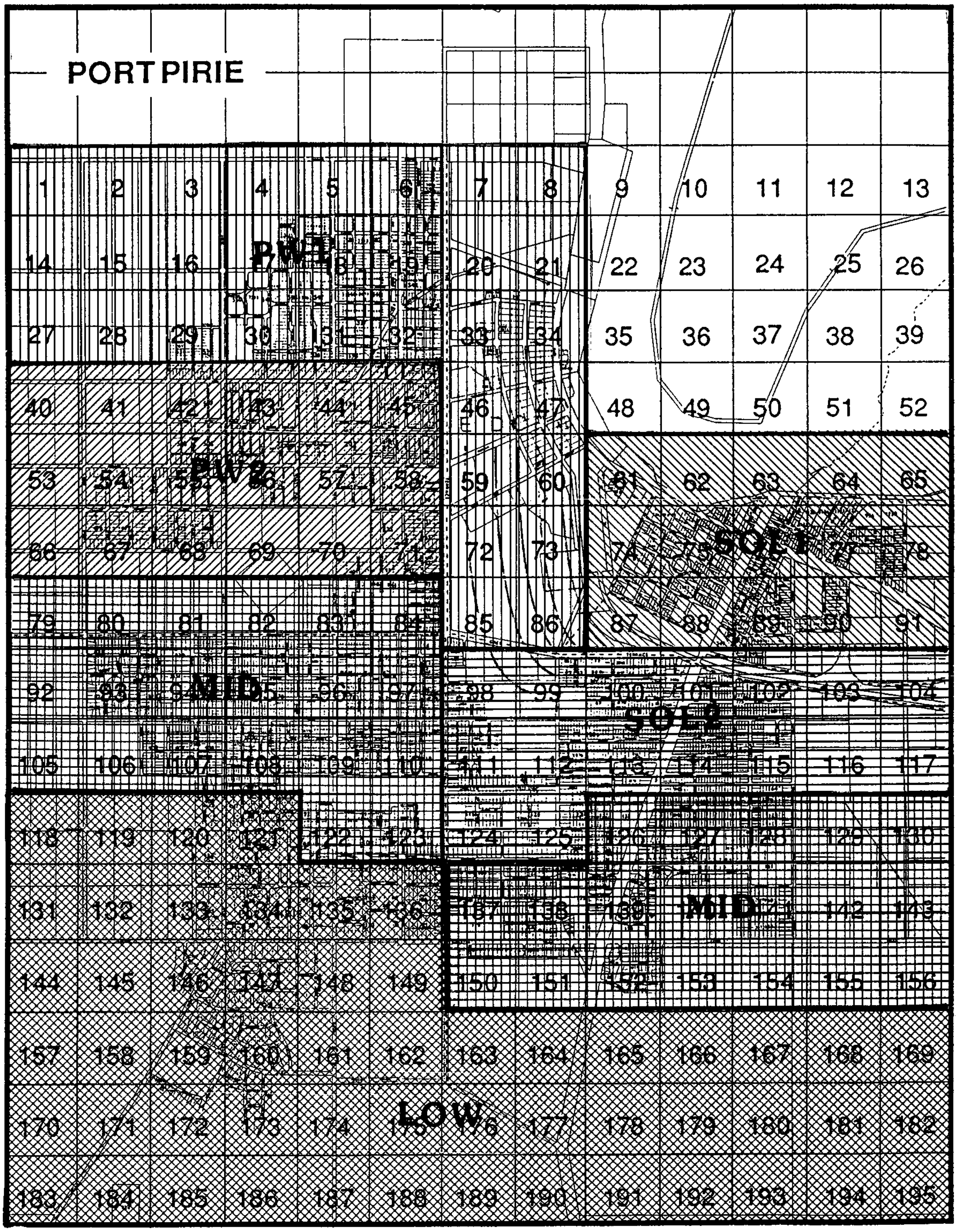


Figure 6.2. High and Low Risk Areas of Port Pirie.

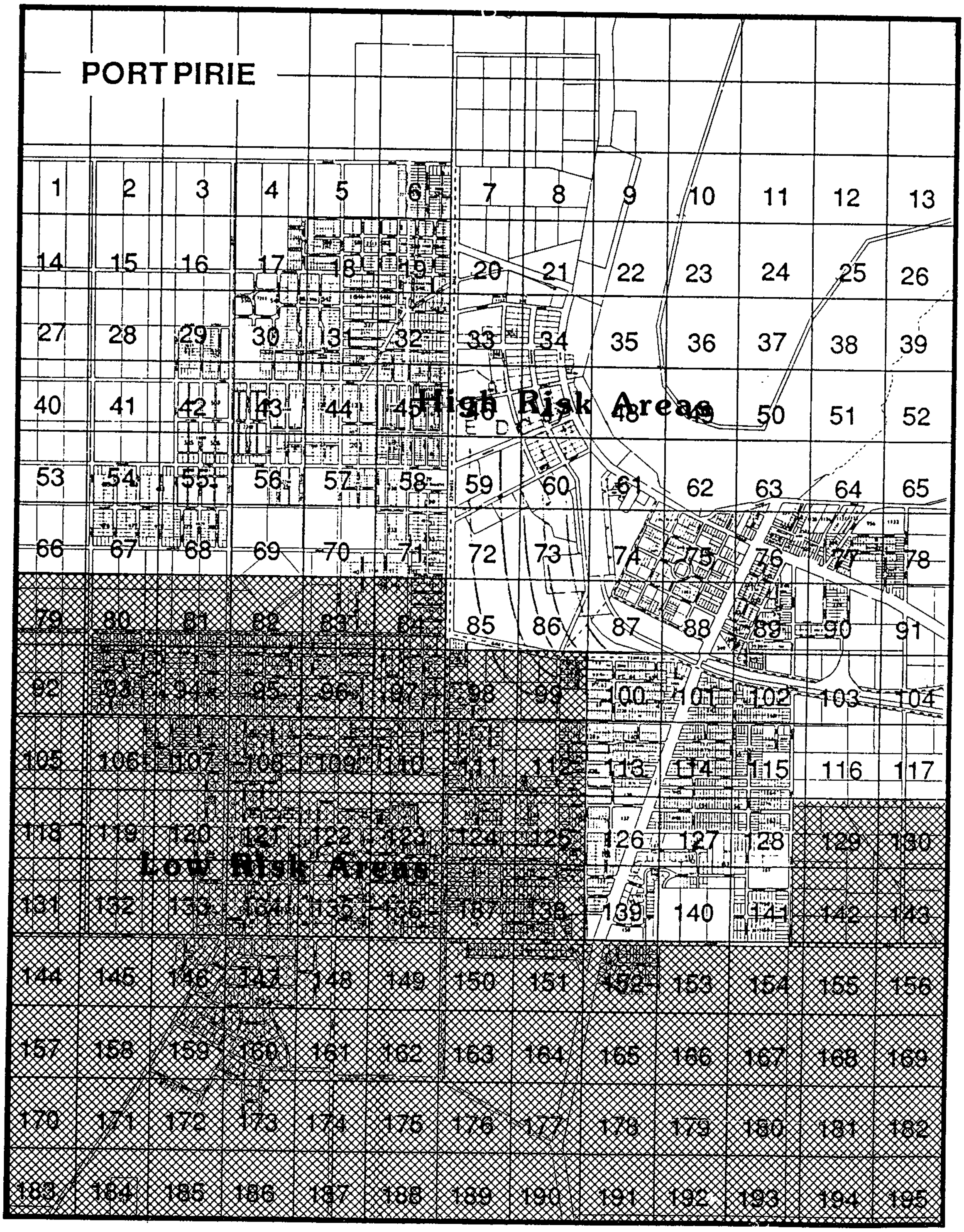


Table 6.3 Blood Lead Levels (μg/dl) of 0-7 year old Children by Risk Status of Residential Area (Includes Cohort Study Children) Geometric Mean (No. of Children)

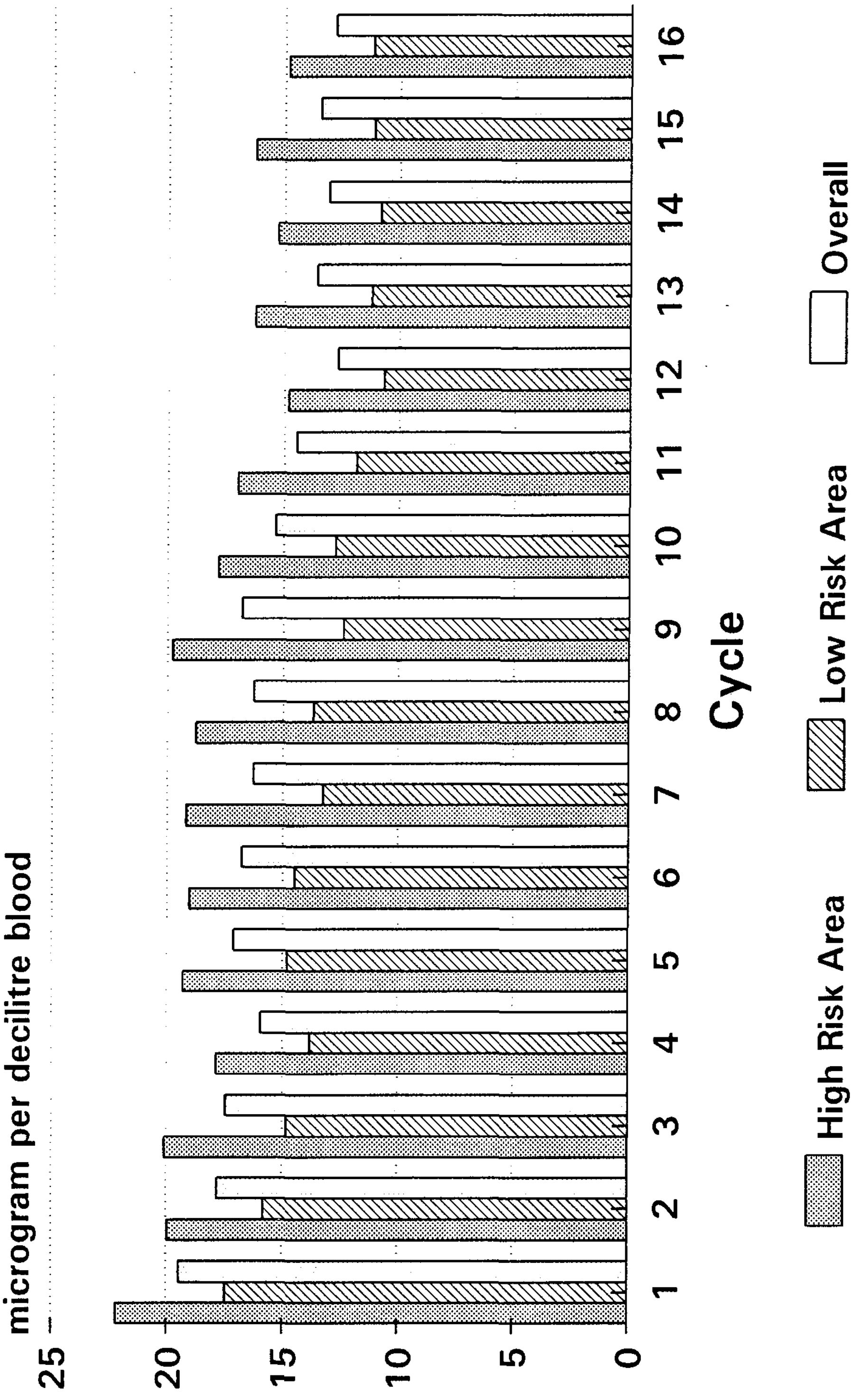
Cycle	PW1	PW2	SOL3	SOL4	MID	Low	Total
1	22.5(87)	23.2(109)	24.7(60)	19.6(152)	17.8(218)	17.2(182)	19.5(808)
2	20.5(79)	20.6(102)	23.3(53)	16.9(119)	16.5(158)	15.7(157)	17.8(668)
3	19.7(96)	20.2(126)	22.6(73)	17.7(144)	15.8(203)	14.5(179)	17.5(821)
4	17.7(101)	18.4(146)	19.6(78)	15.8(160)	14.7(205)	13.4(156)	16.0(846)
5	20.1(109)	19.1(159)	20.4(75)	18.2(155)	15.8(238)	13.8(174)	17.1(910)
6	19.7(91)	18.7(132)	21.5(70)	16.9(146)	15.1(215)	14.2(141)	16.8(795)
7	21.1(104)	18.7(155)	22.5(70)	16.4(139)	14.1(250)	13.0(161)	16.3(879)
8	20.5(92)	18.1(139)	21.5(78)	16.9(141)	14.2(233)	13.5(140)	16.3(823)
9	21.2(78)	19.2(114)	20.3(54)	17.0(89)	14.2(136)	11.3(64)	16.8(535)
10	18.8(97)	17.0(145)	20.3(61)	15.7(156)	13.8(264)	12.3(142)	15.3(865)
11	19.1(101)	17.0(179)	18.1(76)	14.7(167)	12.5(283)	11.5(168)	14.4(974)
12	16.3(96)	14.1(157)	15.9(80)	13.3(156)	11.1(271)	10.6(183)	12.7(943)
13	18.9(92)	16.5(165)	16.7(76)	13.8(166)	11.6(268)	10.9(181)	13.6(948)
14	18.0(84)	14.5(156)	16.2(78)	13.3(151)	11.2(240)	10.9(162)	13.1(871)
15	20.6(85)	15.7(164)	16.5(78)	14.1(159)	11.5(269)	10.9(198)	13.5(953)
16	16.3(80)	14.1(158)	16.0(75)	13.8(175)	11.6(264)	10.8(208)	12.8(960)
Change Cycle 1-16	↓6.2 (28%)	↓9.1 (39%)	↓8.7 (35%)	↓5.8 (30%)	↓6.2 (35%)	↓6.4 (37%)	↓6.7 (34%)

PW1 = Northern Port Pirie West }
PW2 = Southern Port Pirie West }
SOL3 = Northern Solomontown } high risk areas
SOL4 = Southern Solomontown }
MID = Combined intermediate risk areas
LOW = Combined low risk areas

Table 6.4 Blood Lead Levels of 1-4 year old Children by Risk Status of Residential Area (Includes Cohort Study Children) Geometric Mean (No. of Children)

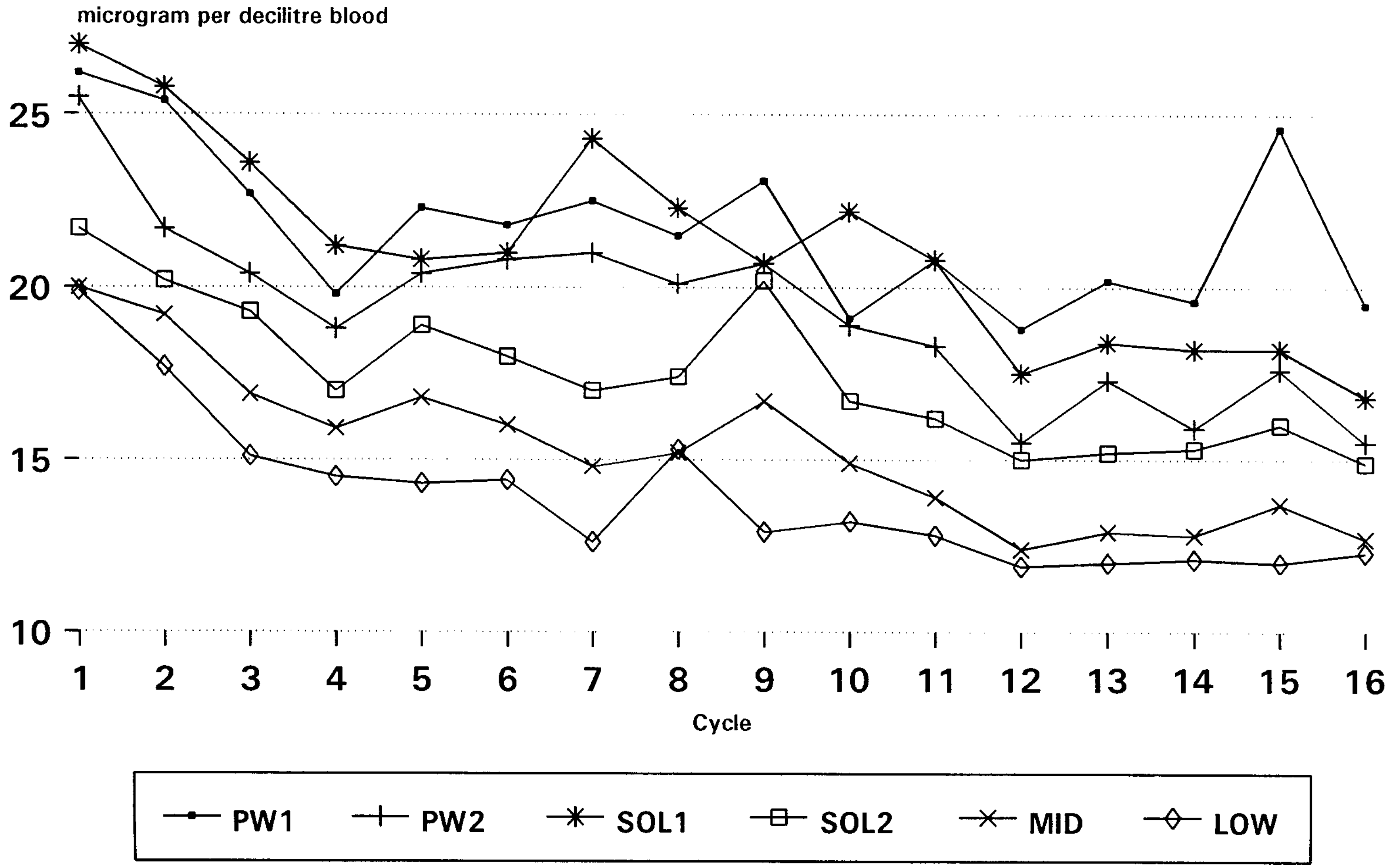
Cycle	PW1	PW2	SOL3	SOL4	MID	Low	Total
1	26.2(42)	25.5(57)	27.0(36)	21.7(77)	20.0(90)	19.9(74)	22.4(376)
2	25.4(35)	21.7(53)	25.8(28)	20.2(46)	19.2(67)	17.7(66)	20.7(295)
3	22.7(44)	20.4(76)	23.6(39)	19.3(74)	16.9(104)	15.1(91)	18.5(428)
4	19.8(46)	18.8(78)	21.2(41)	17.0(83)	15.9(108)	14.5(82)	17.1(438)
5	22.3(58)	20.4(86)	20.8(40)	18.9(93)	16.8(131)	14.3(89)	18.2(497)
6	21.8(57)	20.8(69)	21.0(40)	18.0(85)	16.0(125)	14.4(67)	18.0(443)
7	22.5(67)	21.0(77)	24.3(36)	17.0(82)	14.8(140)	12.6(73)	17.3(475)
8	21.5(59)	20.1(79)	22.3(39)	17.4(78)	15.2(121)	15.3(54)	17.8(430)
9	23.1(52)	20.7(73)	20.7(29)	20.2(47)	16.7(78)	12.9(23)	19.1(302)
10	19.9(52)	18.9(83)	22.2(26)	16.7(82)	14.9(138)	13.2(54)	16.6(435)
11	20.8(55)	18.3(97)	20.8(32)	16.2(93)	13.9(142)	12.8(68)	16.1(487)
12	18.8(45)	15.5(86)	17.5(44)	15.0(84)	12.4(131)	11.9(83)	14.3(473)
13	20.2(50)	17.3(89)	18.4(43)	15.2(87)	12.9(129)	12.0(91)	14.9(489)
14	19.6(51)	15.9(78)	18.2(39)	15.3(75)	12.8(101)	12.1(84)	14.7(428)
15	24.6(41)	17.6(89)	18.2(46)	16.0(89)	13.7(118)	12.0(84)	15.6(467)
16	19.5(36)	15.5(80)	16.8(45)	14.9(101)	12.7(120)	12.3(92)	14.3(474)
Change Cycle 1-16	↓6.7 (26%)	↓10.0 (39%)	↓10.2 (38%)	↓6.8 (31%)	↓7.3 (37%)	↓7.6 (38%)	↓8.1 (36%)

Figure 6.3
Geometric Mean Blood Lead Levels by Cycle and Area of Residence 0-7 years



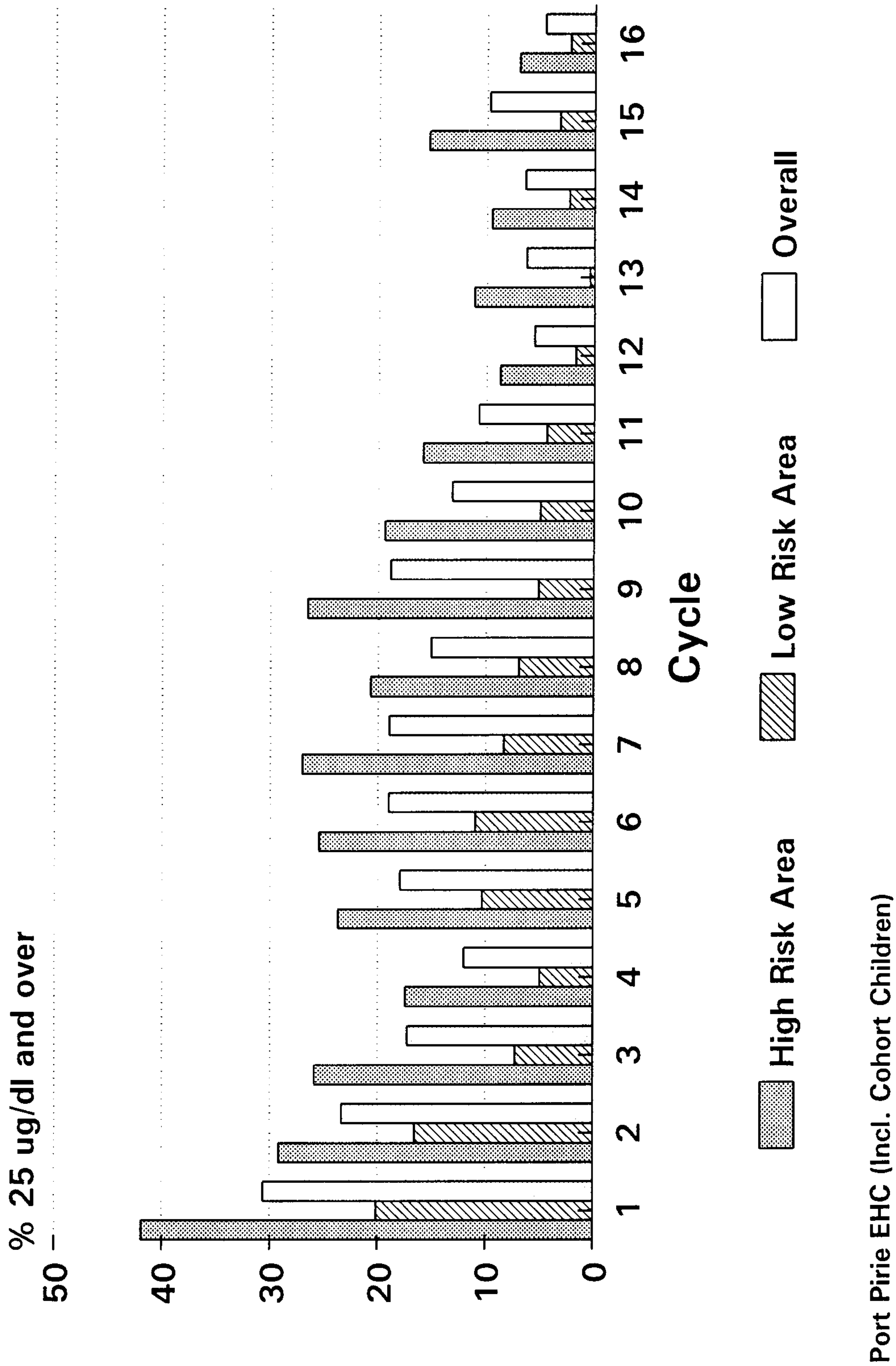
Port Pirie EHC (incl. cohort children)

Figure 6.4
Geometric Mean Blood Lead Levels by Cycle and Area of Residence 1-4 years



Port Pirie EHC (incl. cohort children)

Figure 6.5
Blood Lead Levels 0-7 years
Age Adjusted Percentage by Area



6.2.3 High Risk Children

The percentages of children with blood lead levels of 25 μg/dl or more over the sixteen cycles show the same pattern as that seen for the mean blood levels.

From 29% in cycle 1, this percentage dropped to 11.6% in cycle 4, fluctuated around 15 to 20% in cycles 5 to 9 (1987, 1988), and again decreased substantially in recent cycles (Table 6.5, Figure 6.5).

The proportion over 25 μg/dl has declined particularly within the high risk areas although these have retained a much higher proportion than the low risk areas.

Table 6.5. Proportion of Children (0-7 years) with Elevated Blood Lead (Includes Cohort Study Children)
Percentage At or Above 10, 15, 20 & 25 μg/dl and Number of Children

			⩾10μg/dl		⩾15μg/dl		⩾20μg/dl		⩾25μg/dl	
Cycle	Year	Number	%	Number	%	Number	%	Number	%	Number
1	84-85	808	96%	774	78%	633	53%	430	30%	244
2	85	668	94%	627	70%	465	46%	306	21%	141
3	85-86	821	93%	764	69%	568	43%	352	17%	140
4	86	846	91%	766	63%	534	33%	276	12%	103
5	87	910	93%	845	69%	627	39%	353	18%	163
6	87	795	91%	720	67%	530	40%	316	19%	148
7	88	879	89%	785	63%	558	35%	311	18%	161
8	88	823	89%	731	65%	535	34%	282	16%	128
9	89	535	88%	470	65%	348	39%	207	20%	109
10	89	865	86%	748	56%	488	30%	260	12%	108
11	90	974	83%	804	52%	510	25%	246	11%	103
12	90	943	76%	720	39%	370	16%	155	5%	50
13	91	948	81%	769	47%	442	19%	179	6%	51
14	91	871	77%	674	44%	387	18%	155	6%	51
15	92	953	77%	732	45%	425	21%	201	9%	90
16	92	960	76%	733	41%	393	16%	151	5%	44

The average blood lead level and the percentage of children with blood lead levels of 25 μg/dl or more varies greatly between cycles. This may reflect, at least in part, both the selective volunteer sampling of children in Port Pirie and differences in exposure between seasons. The tendency for surveyed children to include an increasing proportion from high as opposed to low risk areas after cycle 3 may also influence the trends in blood lead levels.

6.2.4 Children from Decontaminated Houses (Heyworth, 1990)

The home environs of children with elevated blood lead concentrations were assessed and steps taken to reduce sources of lead contamination. The decontamination procedures have been described elsewhere in this Review (Chapter 4).

In this section, data on children's blood lead levels before and after the treatment of their homes were examined for any trends that occurred around the time of decontamination (Heyworth, 1990). The readings selected for the present analysis included the last one prior to treatment of the home environs (Baseline Two), the one approximately six months after conclusion of this treatment (Six Months), one approximately 12 months after this treatment (Twelve Months) and one approximately 24 months afterwards (Twenty Four Months).

It should also be noted that, in some cases, households would have been contacted by case workers prior to the Baseline Two blood sample and advice given on means of reducing lead contamination. Because benefits of this health promotion could have preceded the Baseline Two reading, comparisons of Baseline Two with post-treatment readings could have understated the full impact of the intervention.

Furthermore, if, as is frequent in health promotion, there were some loss of the initial gains made through this earlier case worker contact, this could have acted to diminish any further downward trends from home treatment. Because of these problems, another baseline (Baseline One) was selected. This was generally the highest reading obtained prior to home treatment and the one most likely to have preceded case worker contact. In general, Baseline One would be a more relevant measure than Baseline Two for assessing the overall impact of the Program.

A total of 614 children were available by the end of cycle 10 (December, 1989) for analysis. They comprised 259 (42%) with blood lead levels at Baseline One of 25 μg/dl or more, 129 (21%) of them with levels of at least 30 μg/dl, and 355 children with lower levels, many of whom would have been the older siblings of the former. Their ages prior to home treatment were as follows:

0-1 year olds	155 (25%)
2-3 year olds	170 (28%)
4-5 year olds	86 (14%)
6+ year olds	203 (33%)

Children also enrolled in the Cohort Study were excluded from this analysis.

(1) *Baseline to six months*

203 children had all three readings at Baseline One, Baseline Two and at the end of 6 months post-decontamination.

	Geometric Mean (μg/dl) (95% confidence limits)	% ⩾25 μg/dl	% ⩾30 μg/dl
Baseline One	23.8 (22.7, 25.0)	51.7	29.6
Baseline Two	22.2 (21.1, 23.4)	40.4	21.7
Six Months	20.9 (20.0, 21.9)	31.0	11.8

While the reduction in geometric means between Baseline Two and Six Months was not marked, the number of children with high lead levels of 30 μg/dl or more decreased markedly. The downward trend in these numbers occurred for both boys and girls, in most age groups, and in high and low risk areas.

(2) *Baseline to twelve months*

130 children had all four readings at Baseline (One and Two), 6 Months and 12 Months post-decontamination. There was little evidence of further reduction in blood lead over the second 6 month period.

(3) *Baseline to last reading*

325 children had baseline readings plus a last reading made at any time beyond the first 6 months following home treatment. Overall, the patterns were very similar to those of Baseline to Six Months above. Of additional value, however, are the

results for those children that were above 25 or 30 μg/dl prior to decontamination.

Baseline One ≥30 μg/dl: 83 Children

	Geometric Mean (μg/dl) (95% confidence limits)	% ≥25 μg/dl	% ≥30 μg/dl
Baseline One	35.9 (34.8, 37.0)	100%	100%
Baseline Two	32.8 (31.3, 34.3)	89.2%	75.9%
Last Reading	25.0 (23.6, 26.6)	55.4%	30.1%

Baseline One ≥25 μg/dl: 149 Children

	Geometric Mean (μg/dl) (95% confidence limits)	% ≥25 μg/dl	% ≥30 μg/dl
Baseline One	31.5 (30.6, 32.4)	100%	55.7%
Baseline Two	28.5 (27.4, 29.7)	75.8%	42.3%
Last Reading	23.1 (22.1, 24.2)	43.6%	19.5%

Thus it can be seen that substantial reductions in blood lead levels have occurred and the percentages of children with high levels have decreased markedly.

There were several reasons, however, why the full effect of the Program might not have been reflected in these readings. For example, it is normal practice, when levels do not achieve a satisfactory reduction, to provide follow-up education and in some instances further treatment of the home environment. It should be noted, therefore, that these readings were selected only to show trends around the initial intervention attempt.

Voluntary blood testing led to a large difference in the number of children involved in house treatment and the number available for estimating its impact. The loss arose largely due to the 160 children becoming ineligible (too old) for post-treatment blood tests.

A further 66 had no pre-treatment blood test and 90 no post treatment blood tests. Most of these children were older siblings of identified high risk cases.

6.3 COHORT STUDY DATA

The 1979/1980 birth cohort was used to provide a standard curve of blood lead levels by age, with which subsequent curves could be compared since levels are known to be age related with a peak at around 2 years. Figure 6.6 shows the blood lead levels in the 3 cohorts born in 1979/80, 1981 and 1982 respectively (includes only Port Pirie residents).

After a small decline in blood lead levels in 1983, a further major decline is apparent after 1984 for each cohort. Thus, it would appear that a downward trend existed between 1982 and 1984 possibly as a result of the counselling offered as part of the SAHC 1982 survey, the publicity associated with this survey, the improvements in emission controls at the smelter, introduction of the tall stack and new baghouse complex, or a combination of these factors.

The mean blood lead levels of children before development of the Lead Implementation Program were compared with the levels within the first 2 years after this intervention. These comparisons were limited to 3 and 4 year old children for whom numbers were adequate for comparative analysis. Table 6.6 shows the geometric mean blood lead levels before and after December 31, 1984. A statistically significant drop was evident for each age and risk area group except three year olds in the high risk areas of Port Pirie West and Solomontown.

There was also a substantial reduction for all areas combined in the proportion of children with blood lead levels of 25 μg/dl or more, particularly among four year olds. The proportion with blood lead levels of 25 μg/dl or more reduced from 48 per cent in the earlier period to 37 per cent after 1984 for three year olds and from 42 per cent to 17 per cent for four year olds.

Figure 6.6 Port Pirie Cohort Study
Geometric Mean Blood Lead by Age for each Birth Cohort

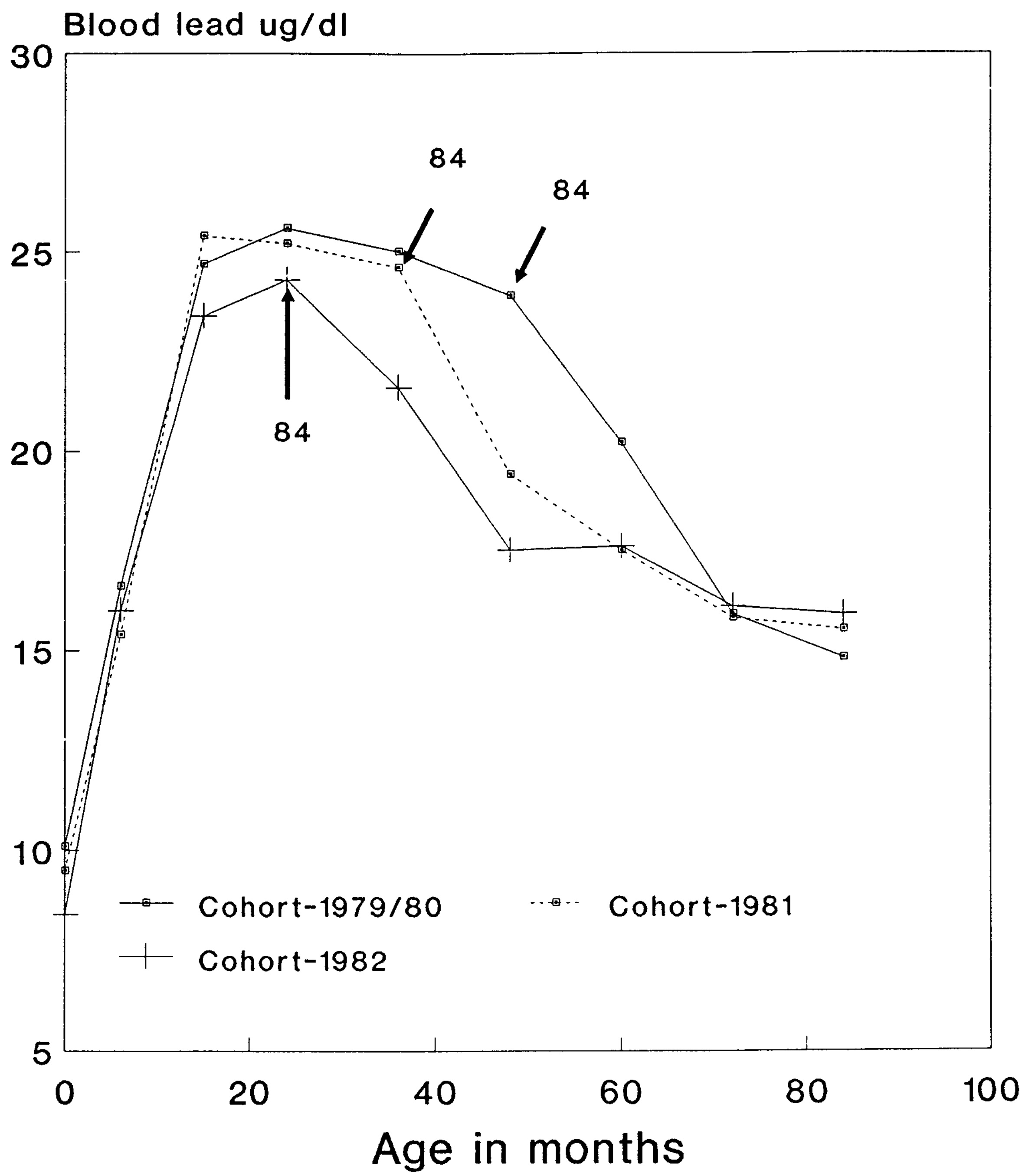


Table 6.6
Mean Blood Lead Levels of Children by Risk Status of Residential Area
Cohort Study

	Mean Blood Lead (μg/dl)	(Number)	Change (μg/dl)	Change (percent)	Significance of Difference
3 year olds					
High Risk:					
pre 1984	27.6	(110)	0.4	1.4%	$p > 0.05$
post 1984	26.0	(34)			
Low Risk:					
pre 1984	23.7	(150)	2.9	12.2%	$p < 0.05$
post 1984	20.8	(69)			
4 year olds					
High Risk:					
pre 1984	26.9	(56)	5.3	19.7%	$p < 0.05$
post 1984	21.6	(85)			
Low Risk:					
pre 1984	22.9	(78)	5.5	24%	$p < 0.05$
post 1984	17.4	(132)			

6.4 COMPARISON WITH 1982 SA HEALTH COMMISSION SURVEY

For children of ages tested in both 1982 and by EHC, four to seven years, blood lead levels in all EHC cycles tended to be lower than those reported in the 1982 survey. While cycle 1 levels were lower, the differences between this cycle and 1982 values were less pronounced than between later cycles and the 1982 values. The average cycle specific means are shown in Table 6.7, together with the corresponding means from the 1982 survey.

Table 6.7
Comparison of EHC Cycle Results with 1982 SAHC Survey Results
Arithmetic Mean Blood Lead Levels by Age

			EHC Cycle Means (μg/dl)			
Age	1982 Survey Means	Number	Cycle 1	Cycle 5	Cycle 9	Cycle 13
4	22.1	69	21.3	17.2	19.9	14.2
5	21.4	111	20.5	16.1	16.3	13.0
6	20.0	142	18.6	15.7	15.1	13.9
7	18.9	147	17.0	16.6	12.5	11.9

6.5 HOME-BASED INTERVENTION

6.5.1 Primary Home-Based Interventions (Luke, 1991)

In this first analysis, it was possible to recover records of blood lead levels and primary home-based environmental intervention data for a total of 175 households where the high risk child had received a blood test 12 months following commencement of these interventions. Within the constraints of the study it was found that:

(1) Favourable trends in blood lead levels accompanied the primary home-based environmental interventions.

(2) The evidence, although weak, suggested that greater reductions in blood lead levels may have occurred where the commitment of resources to the house decontamination was higher.

(3) There was also some evidence, although weak, that within the house decontamination component, the greater the resource investment in dedusting, refurbishing and painting, the greater the reduction in blood lead tended to be. By contrast, the extent of reduction tended to be lower where greater resource investment was directed at carpet cleaning, soil treatment, and materials purchased for the participation of home owners in the home treatment process. Higher expenditure is also related to longer periods of temporary relocation.

(4) When all predictive factors relating to primary home-based interventions were retained in a multivariate model, the most significant predictors of the extent of reduction in blood lead level were the baseline blood level prior to the intervention, and the duration of the intervention. Hence, the higher the initial blood lead level and the longer the house decontamination took (and/or the longer the period of temporary relocation), the greater was the reduction in blood lead level. Unfortunately, the effect of duration of the home treatment process is also obscured by the well documented lowering of blood lead levels as the child ages beyond age 2 or 3 years.

Several constraints should be borne in mind when interpreting this study. It was not an experiment and there was no control group. Moreover, primary home-based interventions were chosen to correspond with the needs of the home environment and individual family rather than to some common treatment which would have allowed a better indication of different home treatment effects. The opportunity to adjust for influential factors such as behaviour was limited by the absence of any measurements of these factors on the primary intervention records.

Thus the tendency for a fall in blood levels to be associated with refurbishing rather than with, say, carpet cleaning, could reflect a propensity for blood lead levels to fall in response to factors quite independent of the refurbishing that was undertaken. This caution is particularly relevant in the absence of measurements of such potentially important factors such as diet, hygiene factors and hand-to-mouth activities.

Furthermore, there was considerable case worker contact both before and after the start of primary home-based environmental interventions. At these times, case worker counselling related to behaviour modification, nutrition, hygiene and other remedial measures. It could well be that much of the improvement in blood lead levels observed was a response to for case worker activity in these areas.

6.5.2 Secondary Home-Based Interventions (Luke, 1991)

In an analysis of children subjected to a secondary environmental home-based intervention, it was possible to collect detailed measurements on both the nature of the environmental treatment component and lifestyle changes associated with case worker intervention. This study was limited to 59 children from 59 families and it was not of an experimental research design. In the absence of external controls not exposed to the environmental home-based intervention, the effects of the intervention could have been obscured. Nonetheless, every effort was made to maintain biostatistical integrity and the results, in large measure, support the findings of the primary intervention analysis (Section 6.5.1) and are biologically plausible.

The effects of specific components of secondary environmental home-based interventions on blood lead were not statistically significant although study numbers were small. Those characteristics most predictive of favourable change in blood lead level were firstly, forms of behaviour change:

(1) Improved dust related hygiene practices,
(2) A more substantial and nutritious early morning diet,
(3) A reduction in a certain easily enforced hand-to-mouth activity,

and secondly:

(4) Permanent relocation away from high risk areas to areas of low risk.

No environmental interventions apart from permanent relocation were found to be statistically significant predictors of lowering blood lead levels. This finding adds further weight to the importance of temporary relocation in the previous study of primary home-based interventions. The evidence for a positive association between environmental modification and extent of reduction in blood lead level appeared to be strongest for repairs and weakest for painting where the coefficient was negative.

In summary, this study suggests that those characteristics most predictive of a favourable effect on children's blood lead levels were forms of behavioural change and permanent relocation from high risk to low risk areas. Home-based environmental interventions were, in aggregate, positively associated with the extent of reduction in blood lead level, although the results did not reach statistical significance. This may be because of the small sample size or because the effects of behavioural change, at least in the short term, tended to be greater and to mask the effects of environmental change. This latter possibility could have been enhanced by imperfections in the measurements of behavioural factors which would have reduced the capacity to make optimum statistical adjustments for behaviour change when assessing environmental intervention effects. Also, in a non-experimental research setting, and without controls not exposed to home-based interventions, the effects of environmental interventions could have been obscured by factors not even considered above.

It should be noted that the opportunity to adjust for confounding factors was limited in the study of primary interventions (Section 6.5.1) by the absence of any measurements of behavioural and related factors. By comparison, in the study of secondary interventions, there was a wide range of measurements available, but the number of cases studied was very small and statistical power was low.

Behavioural modifications are recognised as requiring ongoing reinforcement and it is doubtful whether those discovered to be effective in this study, could be maintained in the longer term. The extent to which personal and domestic dust hygiene was required to be improved was considerable. Given the amount of lead contamination to which these households are exposed, changes in dust hygiene would not seem to be a realistic way to ensure lower exposure to lead by the child. Similarly, hand-to-mouth activity is a normal habit in young children, and certainly not easily curtailed, even if this were desirable. It is of interest that the only hand-to-mouth such activity amenable to reduction, and significant in the analysis, was the mouthing of certain foreign objects such as sticks, stones and toys. Parents were encouraged to not leave such temptations lying about in the dusty environment. In the case of toys, parents were advised to wash them frequently and to keep them in an enclosure when not in use.

A behaviour modification which met with more acceptance and which has been observed to be more enduring, is the consumption of an adequate breakfast. Parents readily understand the likely mechanism for this, and that it is good practice for other reasons. As a result, longer term compliance can be expected.

The only environmental factor found to be a significant predictor of a lowering of blood lead levels in this cohort of children, was permanent relocation from the high to the areas of lower risk of lead contamination.

Should behavioural modifications diminish with time, and tend to return to the pre-intervention state, then the respective contributions of behavioural and environmental modification to longer term effects may vary from those found in this study.

6.5.3 Some Factors Which Were Found To Be Associated With Higher Blood Levels (Luke, 1991)

In the previous two sections only those predictive factors that were found to be statistically significantly associated with a lowering of blood lead levels, after controlling for the effects of other confounding factors, were reported. Before being selected as candidates in the multivariate analysis, all potentially predictive factors were subject to univariate and bivariate analyses. At this stage certain factors were found to be associated with higher blood lead levels. These are listed below as factors, which when considered alone, are related to higher blood lead levels in certain circumstances.

Excluding those previously reported they include:

- Eating food "on the run" rather than at table,
- Having dirty hands or dirty clothes,
- The eating of dirt,
- The habit of dropping of food on the floor and subsequently eating it,
- Chewing on painted surfaces,
- Exposure of the child to household renovations subsequent to lead decontamination, and
- Compared with the general Port Pirie childhood population, a variety of socio-demographic variables such as living in a high risk area, having a larger number of siblings, attending a preschool or kindergarten in the high risk areas, and home ownership by parents.

It is noteworthy that, unlike the situation in 1983 (Task Force Report) a father working at the BHAS smelter was found to be no longer predictive of an elevated blood lead level in a child.

6.6 SUMMARY

(1) Using three sources of blood tests, Port Pirie children up to seven years of age show a reduction in lead levels of at least 30% after the establishment of the Lead Implementation Program. Over the last two years, average blood lead levels have been fairly stable at around 13 μg/dl.

(2) Following establishment of the Program, the proportion of children found to have blood lead levels at or above the level of concern of 25 μg/dl was reduced to one sixth (5%) of those present in 1984 (30%).

(3) Although the reduction in mean blood levels has been greatest amongst children 2 or 3 years of age (35%), current mean blood lead levels remain highest amongst 1-4 year olds at 13.7-14.9 μg/dl.

(4) The northern part of Port Pirie West shows the smallest reduction in mean blood levels while the southern part of Port Pirie West and northern Solomontown show the greatest reduction. These two areas have diverged from the areas nearest the smelter and come closer to values for the low risk areas. The southern part of Solomontown was similar to the low risk areas initially, but has not experienced the same reduction. Distance from the smelter is very clearly reflected in the current mean blood lead concentrations for the different risk areas.

(5) Blood lead concentrations decreased amongst high risk children whose home environments were treated to reduce environmental lead exposure. The lack of evidence of further declines in blood lead beyond the initial 6 months after the decontamination suggests that to be sustained, benefits from home treatment may require augmentation from follow-up education and further attention to reduce recontamination from the general environment. While it is not possible with the data available to quantify the respective effects of each component of environmental modification and home treatment, it is evident that the home environment is subject to broader environmental influences.

(6) In follow-up studies of home-based interventions, permanent relocation from the high risk area (and probably temporary relocation), level of expenditure on house dedusting and refurbishment, improved dust

hygiene practices and improved early morning diet were shown as likely to reduce blood lead levels.

(7) Overall, the reductions have not been as substantial as might have been expected if the contributions from the sources were as postulated (a historical lead sink around the City from which lead contaminated dust was re-entrained along with substantial contributions from lead based paint and contaminated rainwater) and the interventions undertaken were fully effective.

7. PATHWAYS AND SOURCES OF LEAD CONTAMINATION

A carefully considered understanding of the role played by the different sources of lead in Port Pirie and the pathways by which children are exposed, plays a critical part in assessing the progress made by the current Program and planning any future action. Hence in preparing this Review, a comprehensive assessment was made of relevant overseas findings and all investigations that have been conducted in Port Pirie. The complete assessment documents were considered to be too extensive for inclusion in the Review and hence this chapter only presents key summaries and conclusions. The assessment documents are available from the Public and Environmental Health Service.

In addition to summarising current understanding (1993 conclusions), its evolution is highlighted by providing key conclusions from the 1983 Task Force Report, the Department of Environment and Planning Review (Body et al, 1988), and two key Air Quality Branch reports (Department of Environment and Planning, Goh and Hope 1989,1992).

7.1 LEAD CONTAMINATION PATHWAYS: OVERVIEW

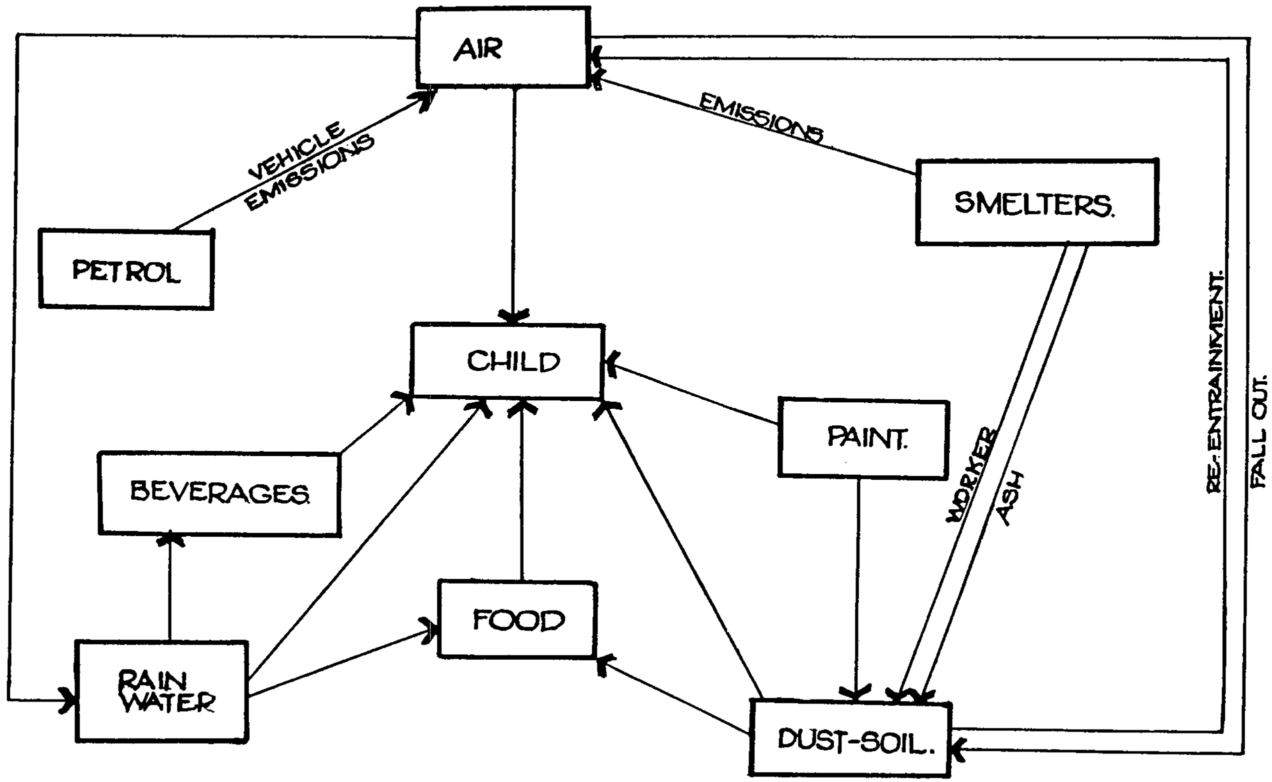
7.1.1 1983 Task Force Conclusions

(1) A child inhales and ingests lead from all sources with which it comes in contact. The behavioural characteristics of the child determine the way in which each child interacts with its environment and hence the amount of lead ultimately ingested.

(2) Airborne dust is a major factor in the transport of lead contamination from one part of the environment to another. There is constant movement of lead between the various forms of dust and soil in the environment of the child, although the rate of transfer is undetermined.

(3) The levels of lead in the dust and soil determine the levels in rainwater, food, air and dirt on the hands and under the finger nails of the child and thus the amount of lead ingested and inhaled.

Figure 7.1 Relationships Between Environmental Lead and the Child.



(4) There are significant transfers between the lead in soil and household dust, carpet dust and tank water. Interrupting the transfer between the soil and dust in the air and the dust in the house will be an important step in preventing recontamination of houses in the long term.

(5) The interrelationships between the components of the macro-environment lack definition. There are areas of vacant land as well as unmade footpaths and roads which may be the source of large quantities of lead contaminated dust which will be added to from other sources of lead. Prevention of recontamination of homes will only be effective if this component of the environment can be decontaminated and controlled.

(6) There are no good measures of air lead levels in homes which can be used to assess the contribution of inhaled lead. In Port Pirie where it is felt the smelter emissions are now at a relatively low level, the source of lead in air must be substantially from the soil and other related environmental sources.

These pathways are summarised in Figure 7.1.

7.1.2 1988 Department of Environment and Planning (DEP) Conclusions (Body et al, 1988)

Transportation of lead bearing dust into the child's living environment is shown in Figure 7.2 with contamination pathways for lead bearing paints, soils and rainwater tank waters shown in Figures 7.3 to 7.5 respectively.

It is suggested that Figure 7.6 represents the most probable scenario, based on the observed circumstances at Port Pirie and the understanding obtained during the investigations carried out by the Department of Environment and Planning. The major exposure pathways consist of inhalation of airborne lead, ingestion of rainwater lead and ingestion/inhalation of house dust lead.

**Figure 7.2 Transportation of Lead Bearing Dusts into the Child's Living Environment.
Source: Body Inglis & Mulcahy, 1988**

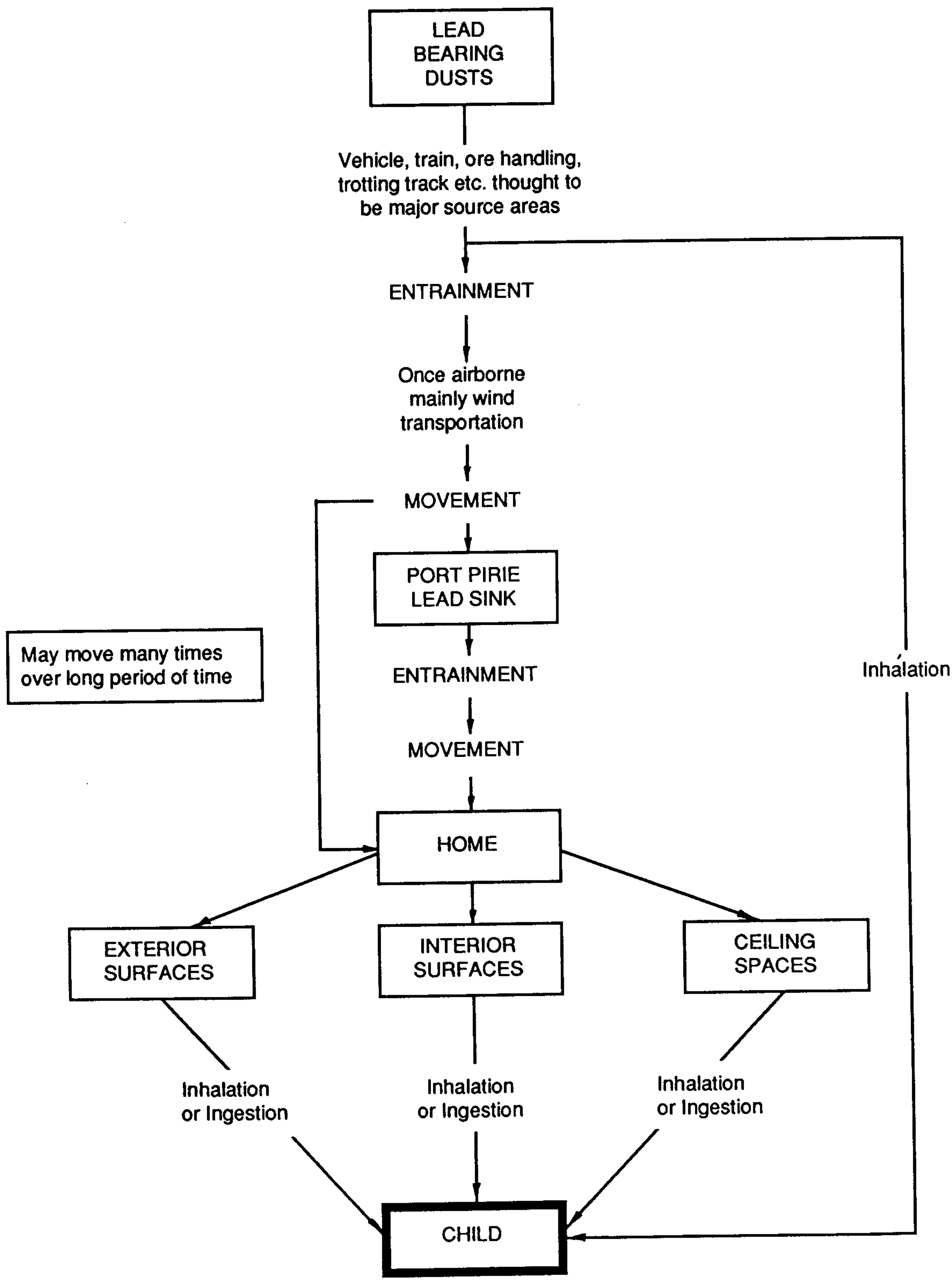


Figure 7.3 Contamination of the Child's Living Environment from Lead Bearing Paints.
Source: Body Inglis & Mulcahy, 1988

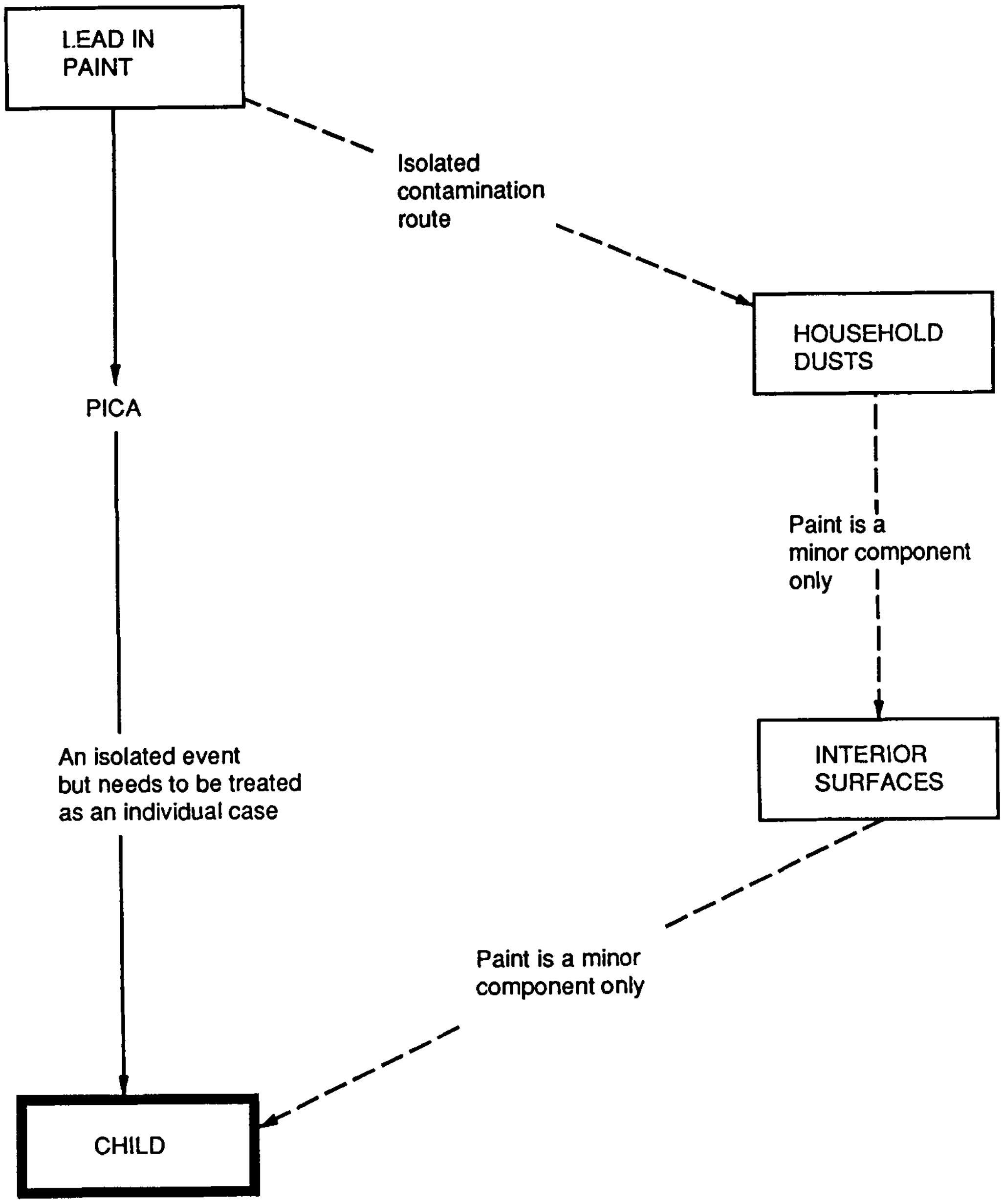


Figure 7.4 Contamination of the Child's Living Environment from Lead Bearing Soils.
Source: Body Inglis & Mulcahy, 1988

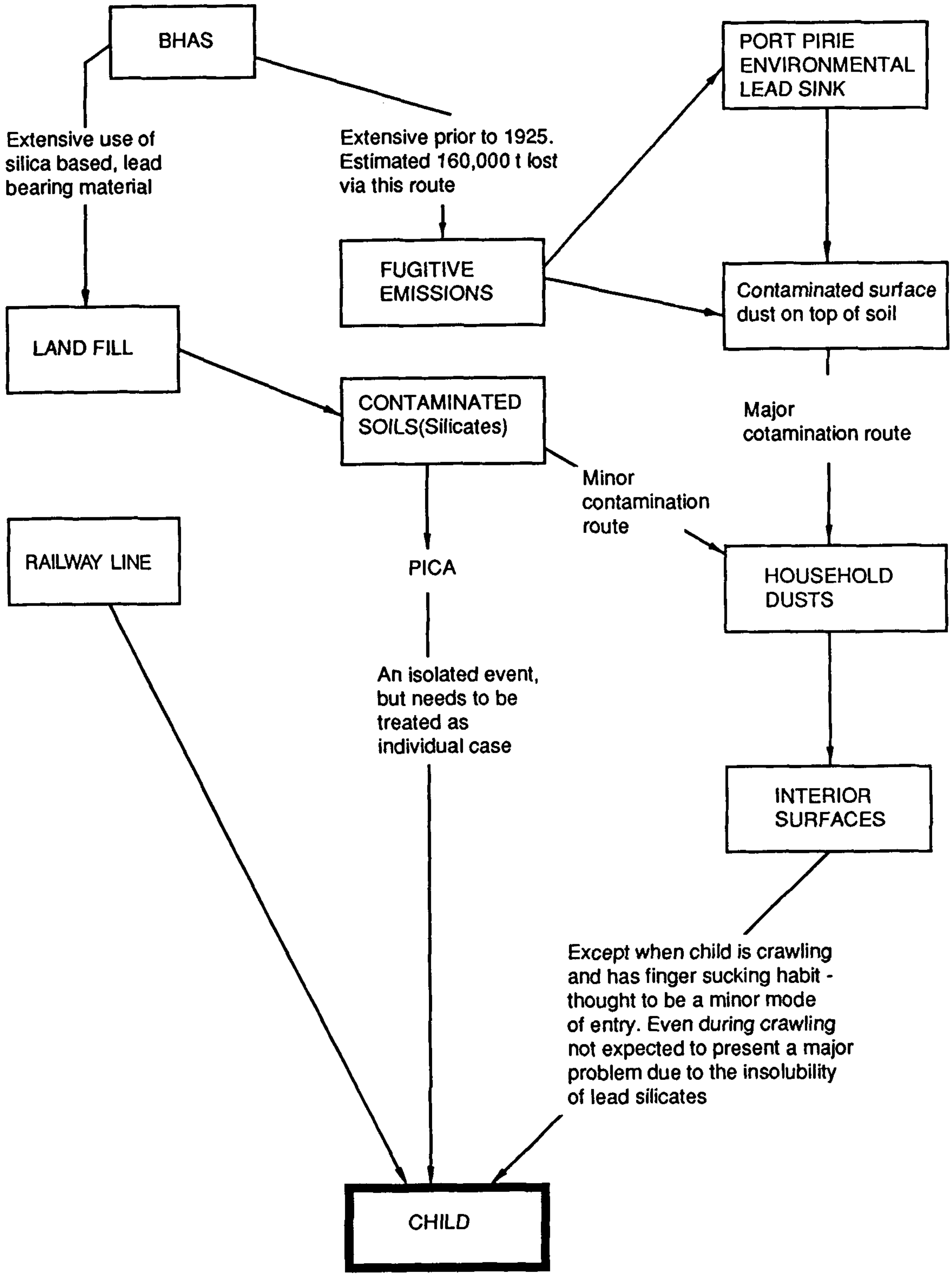


**Figure 7.5 Lead Contamination of Rainwater Tanks at Port Pirie.
Source: Body Inglis & Mulcahy, 1988**

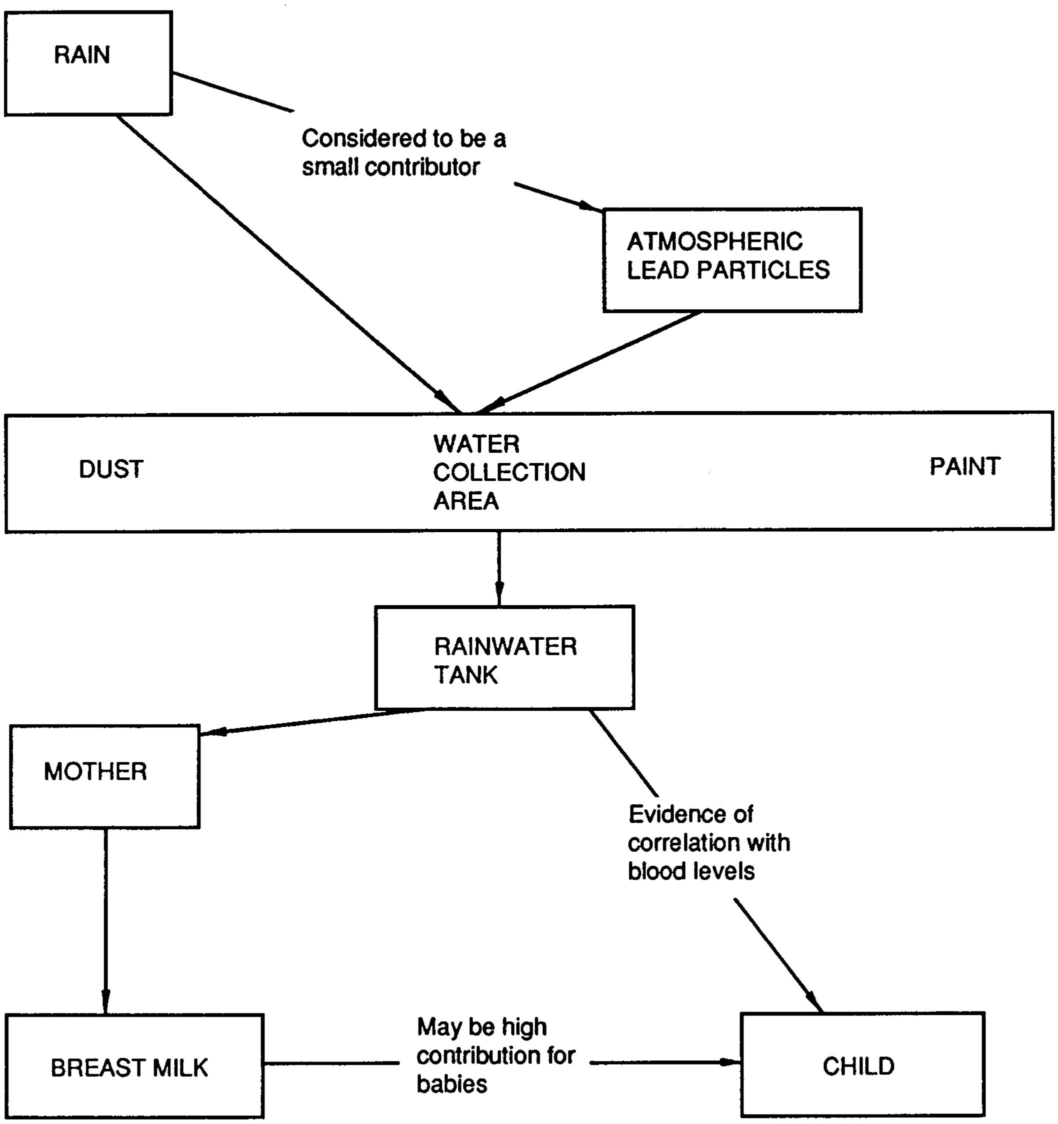
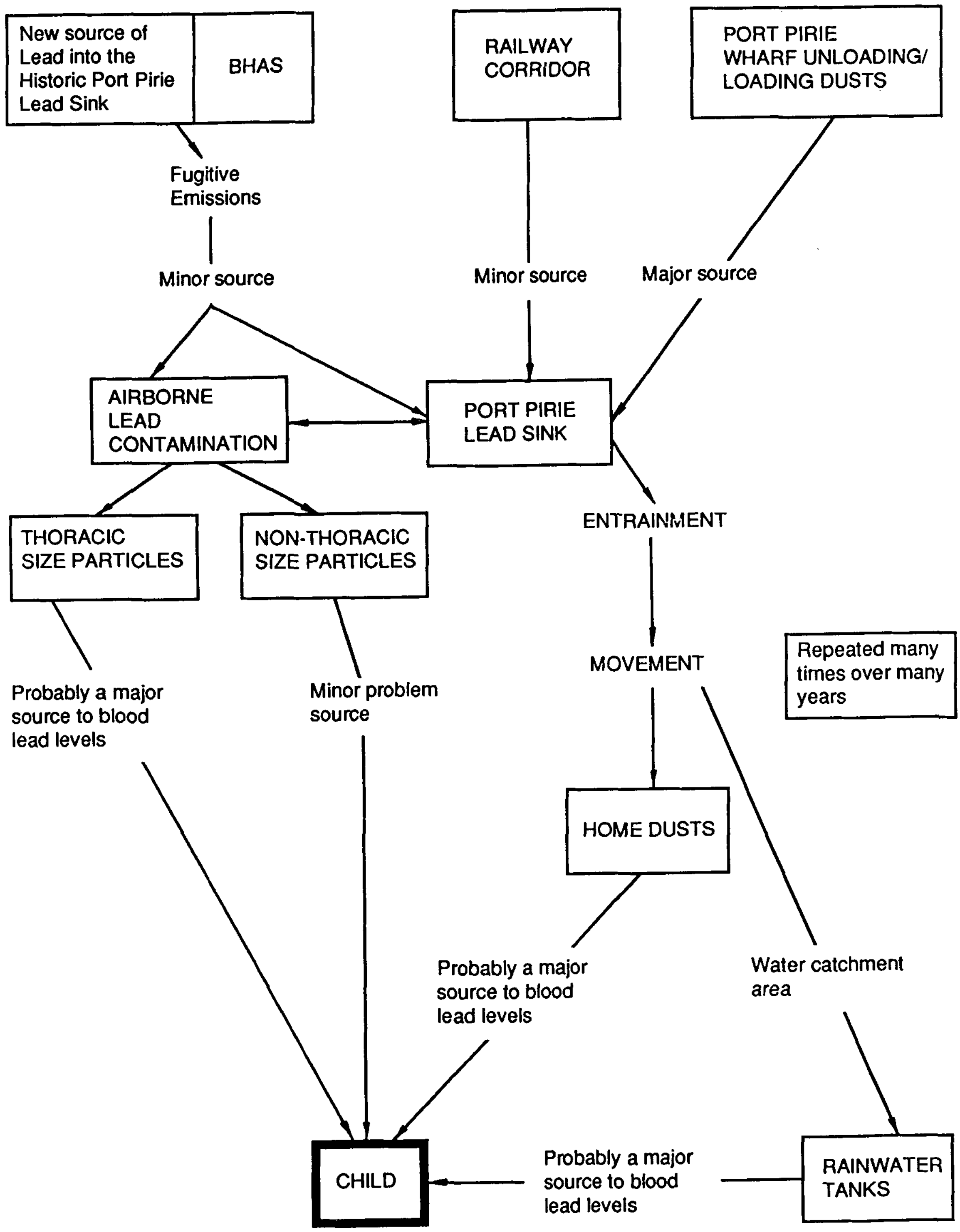


Figure 7.6 Preferred Scenario for the Sources of Lead which may be the Prime Contributors to the Blood Lead Levels of Children Living in Port Pirie.
Source: Body Inglis & Mulcahy, 1988



The evidence from lead speciation and movement studies within Port Pirie indicates that the City now has a large amount of lead widely distributed throughout its surface dusts. The most likely method of dispersion is by the raising of dust, by human initiated events mainly, and wind transportation. Events spanning the past 50-60 years have contributed but it would appear that dispersion has been accelerated over the past ten years by vehicle movement and land clearing.

Once airborne the lead bearing particles have a number of features associated with them.

(1) Particles that are less than ten microns or micrometres (μM) in diameter, about 30% of all airborne dusts, are capable of being retained in the lungs. They are referred to as thoracic size particles (PM_{10}).

(2) Particles of all size ranges can be present in houses where they become available for ingestion via food or hand contamination. There is some evidence that once dust has entered a house the normal cleaning operations, such as vacuum cleaning, can preferentially concentrate the smaller particles. These particles (probably less than five microns) are blown out of vacuum cleaner exhausts. Such dusts have been shown to be higher than average in lead content and are available for inhalation and recontamination of food preparation areas and other surfaces.

(3) Ceiling dusts are a source of large quantities of lead bearing dusts and may contaminate the living area, for example through cracks in the cornices.

(4) Lead bearing dusts also settle on house roofs where they may be washed into rainwater tanks. This is of particular concern when leaf litter is present in the tanks which increases the dissolution rate of ores and concentrates in low pH water.

(5) Lead bearing paints may cause further contamination of household dusts but this has been shown to be localised to particular houses.

(6) Landfill containing slag materials from BHAS has been shown to contain high levels of lead. However, the fill material itself usually shows a slow solubility in dilute acid, and is of large particle size, generally well above ten micron diameter. It has not been identified to any large extent within houses.

It is suggested that the Port Pirie environment was contaminated over fifty years ago by ores, emissions, and fugitive losses from the smelter operations and it is this sink of lead which is gradually dispersing. It is also suggested that towns along the railway corridor from Broken Hill to Port Pirie were also contaminated by lead bearing ores during the same time period.

Movement of the particles from the ground into the atmosphere is caused by human orientated events, with wind further dispersing the particles. Once mobile, particles are inhalable and some settle within houses where they may be ingested via foods or body contamination. Inhalation of dust particles within the house is also significant with house cleaning activities possibly increasing the potential for such inhalation.

7.1.3 1993 Review Conclusions

Lead contaminated dust/surface soil appears to be the primary source of contamination of Port Pirie children's living space.

(1) Lead bearing dusts: inhalation

(a) Since only particles less than 10μm (micron) diameter are capable of being retained in the lung, this pathway is effective only for a component of total dust, and then only while dust is suspended in air.

(b) Outdoor inhalation is reflected by the long term lead in air concentrations of thoracic sized particles (less than 10um or PM_{10}). Although exposure will increase during days of elevated air lead, these periods represent only a relatively minor additional load. A further contribution comes from motor vehicle exhaust.

(c) Indoor inhalation is not well understood as yet, although studies suggest that normal cleaning operations, such as vacuum cleaning, can preferentially concentrate the smaller particles. Thoracic sized particles are resuspended in vacuum cleaner exhaust, during floor sweeping, and dry dusting.

(d) Inhalation is less important than ingestion of leaded dust as an exposure pathway for young children.

(2) Lead bearing dust: ingestion

(a) Airborne deposition of leaded dust provides the principal pathway by which lead contaminates the child's household or micro-environment. The principal house entry pathways are:

- Wind movement through windows and doorways onto indoor surfaces,
- Deposition onto the water collection surfaces of rainwater tanks,
- Deposition on outdoor surfaces including soil and windowsills followed by transport indoors,
- Ceiling dusts falling into the living space, and
- Mechanical carriage by people and pets.

(b) Subsequent ingestion occurs via rainwater, food, hands, mouthing of non-food objects, and other behavioural characteristics that increase dust/soil ingestion.

(c) Activities within the house such as cleaning contribute to recontamination of food, food preparation areas and other surfaces.

(3) Lead bearing dust: environmental transport

(a) Dust is transported mainly through wind movements, primarily by re-entrainment, from both environmental sinks (secondary sources, "old" lead, or indirect pathway) and primary sources (new lead, direct pathway).

(b) Lead dust transport occurs principally on days of high velocity winds in association with dry conditions. Total transport reflects the product of both wind velocity and air lead concentration. Human, vehicle, animal and concentrate handling activities assist in initial dust raising.

(c) High volume sampling studies suggest that dust transfers by re-entrainment within the micro-environment (eg. from yard dust, local streets, neighbouring houses) are not a major pathway. Presumably fences, buildings, vegetation and other obstructions prevent air flow at ground level from reaching re-entrainment velocity. Mechanical agitation also contributes to dust raising.

(d) Mechanical transport on contaminated clothing, skin, equipment, vehicles and salvage materials from the smelter to the micro-environment is considered a minor pathway at the present time. Mechanical transport from environmental sinks may still be important.

(e) Over time, lead in dust sinks is affected by:

- Stormwater action with carriage to the estuary,
- Dilution and coverage by deposition of less contaminated dust,
- Binding to organic matter, clay etc. resulting in a particle size too large for re-entrainment,
- Deposition of re-entrained dust on leaf and other plant surfaces, and
- Chemical changes to the particles which affect their bioavailability.

(f) Rate of dust transport can be estimated by:

- Rate of dust deposition; or
- Air concentration (by high volume sampler) multiplied by wind speed.

(4) Pica (ingestion of non-food items)

In this special circumstance, ingestion of leaded paint, leaded dust, or leaded soil (eg. slag fill) may act as a significant pathway.

(5) *Leaded paint*

Investigations by Body et al (1988) suggest that dust contamination by leaded paint is not a major pathway. This conclusion would be strengthened by confirming that presence of chalking paint can also be excluded by examining dust for planar particles. Likewise, paint lead contamination of rain water was discounted as a major pathway.

7.2 LEAD SOURCES: OVERVIEW

7.2.1 Primary Sources (New Lead)

(1) Car exhaust/petrol	:	1983: Considered minor source (less than five tonnes per annum).
	:	1988: Less than Adelaide (DEP).
	:	1993: No subsequent evidence to change that assessment. Increased use of unleaded petrol. Further consideration deferred.
(2) Mains water	:	1983: Not discussed.
	:	1988: Low levels at Port Pirie (DEP).
	:	1993: 1988 through 1991 values at Morgan offtake = 1-6μg/L. Assuming child intake of 1L/day = 1-6μg/day. Minor source.

(3) External food supply :	1983: General Australian 1-3 year old community (1977). • 50μg/day animal foods including milk, • 97μg/day plant foods including fruit juice, • 9μg/day water and beverages, • Total intake = 156μg/day, • Total absorption (50%) = 70-80μg/day, and • Canned foods contribute little lead to the Australian diet (10-12% of dietary lead in adults).
:	1988: Normal urban background (DEP).
:	1993: General Australian two year old community (Australian Market Basket Survey, 1990). Mean intake = 26μg//day (median = 16). • 11μg/day animal foods including milk, and • 15μg/day plant foods including fruit juice (includes 1.6μg/day from canned foods). Total absorption (50%) = 13μg/day. Normal background intake: intermediate source.
(4) Railway concentrate transport :	1983: Contribution unclear. Further investigation of lead losses required.

	: 1988: Not large since 1970 when wooden wagons replaced (DEP).
	: 1993: Given low train speed, at most 3kg/km/annum, minor source.
(5) Wharf zinc concentrate	: 1983: May become wind-borne dust. Contribution unclear. Needs investigation. Control measures less than adequate.
	: 1988: Largest new source, but relatively minor eg. dust from ship loading and unloading (DEP).
	: 1993: Important source but still under investigation.
(6) Lead paint	: 1983: Chalking and flaking paint considered important.
	: 1988: Minor except in individual cases with pica (DEP).
	: 1993: 1988 conclusion needs to be examined further eg. by speciation studies to confirm chalking paint retains planar features.
(7) BHAS	: 1983: Plant emissions generally satisfactory.
	: 1993: Fugitive losses unquantified but probably a major source.
(a) Stack emissions	: 1983: Considered minor, down to 50.2 tonnes per year (1982 estimate).
	: 1988: Minor (DEP).

	:	1993: Estimated stack fume losses = 15 tonnes per annum. Includes all measurable stack emissions. Minor source.
(b) Fugitive emissions	:	1983: Minor.
	:	1988: Minor (DEP).
	:	1993: Unmeasurable but probably not minor.
(c) Lead concentrate stocks (PbS)	:	1983: Requires further investigation.
	:	1988: Important but not large (DEP).
	:	1993: Possibly major.
(d) General smelter area	:	1983: Not discussed.
	:	1988: Not discussed.
	:	1993: Leaded dust from the smelter and its environs a major source. Further investigation needed to define specific source(s).
(e) Contaminated personnel/clothing	:	1983: Important
	:	1984: Day workers ceased going home for lunch and BHAS provided work clothes with on-site laundering introduced.
	:	1988: Not mentioned (DEP).
	:	1993: Minor source.

(f) Contaminated vehicles/salvage materials	:	1983: Contribution acknowledged.
	:	1988: Not discussed (DEP).
	:	1993: Probably minor source.
(g) Waste slag and ash	:	1983: Prior contribution to environmental contamination.
	:	1993: Refer to secondary sources.

7.2.2 Secondary Sources ("old" lead from reservoirs/sinks, indirect sources derived by prior contamination from a primary source.)

(1) Local foods:	:	1983: Lead in locally produced grains, vegetables and seafood raised but below prescribed limits. No major problem with local foods. Although lead in edible portions of local marine foods raised, they always remained below NH&MRC maximum recommended concentrations.
	:	1988: CSIRO indicates lead levels in local foods satisfactory (DEP).
	:	1993: Generally minor source but depend on consumption of locally grown leafy vegetables and unwashed fruit.
(2) Waste slag	:	1983: Dust losses from slag heaps not observed to be high (nature and size of the material). Bioavailability warrants further investigation.
	:	1988: Re-entrainment minor due to large particle size (DEP).

Minor contamination source for house dust.
Poor bioavailability of lead silicates.
May be relevant in individuals with pica.

: 1993: Under investigation.

(3) Rainwater : 1983: Northwestern, central business and eastern areas often exceed 0.05mg/l. Considered an important source.

: 1988: Dust and paint contamination of water collection surfaces important.
Wet precipitation of airborne lead dust a small contributor (DEP).

: 1993: Considered an important source.

(4) General soil sink : 1983: Northwestern, central business, and eastern areas have generally contaminated soil plus individual house sites elsewhere. Since emission from the smelters has been reduce to low levels in recent years, re-entrainment of lead in soil seems likely to be a major source for dust with high lead levels.

Lead has been deposited into the soil in Port Pirie from many sources:

- Fume emissions from the smelter,
- Dust and fugitive emissions from the smelter,

- Cinders or ashes from the smelter used as fill and fertiliser,
- Spent slag from the smelter used as fill and fertiliser since 1944,
- Dust from ore transport,
- Lead emissions from cars using petrol with lead additives,
- Loss of lead during reclaiming of old batteries,
- Flaking or chalking of lead based paint,
- Dust and dirt swept from houses, and
- Deposition of re-entrained dust.

General paucity of soil lead data. Important contribution.

: 1988: Major source. Mainly old material from over 50 years ago (DEP).

: 1993: Major source, mainly where effective wind access.

(5) Specific soil/dust sinks eg. roads, footpaths, parks and open spaces

: 1983: Potential sources of contaminated dust and dirt.
Major source for air re-entrainment of leaded dust.
Mechanical agitation by vehicles, people, and animals generates a substantial proportion of local dust.
Large tidal flat area to the north-west and within 3km of the smelter.
Further definition of degree and extent of pollution in the park and open space areas desirable.

: 1988: Major source. Mechanical and wind re-entrainment.
Sites include rail corridor, trotting track etc. (DEP).

: 1993: Important source where effective wind access.
Mechanical agitation of limited local importance.

7.2.3 Summary of Lead Sources

(1) 1983 Task Force conclusions

Lead contamination of the total environment in Port Pirie has been substantially derived from the smelter with smaller contributions from lead based paint and lead additives in petrol. This lead has now become an integrated part of the environment being intimately incorporated, often undergoing chemical change in the process of incorporation and subject to transfer to other elements of the environment.

(2) 1988 Department of Environment and Planning conclusions (Body et al, 1988).

Lead bearing dust originated form three main sources: the BHAS smelter, the rail corridor and the wharf. The dust became distributed widely throughout the City. These surface dusts, which constitute a sink for the lead lost into the environment, are the primary source of contamination of children's living space. There is no evidence that the lead sink is increasing in either concentration or gross tonnage to any significant extent (Figure 7.7).

Lead from car exhaust, mains water, food and paint provide additional minor sources (Figure 7.8).

(3) 1993 Review conclusions

The increasing concentrations of lead in air, the short term impact of home decontamination and several lines of evidence from the study of house dust lead, suggest that ongoing contamination and recontamination of children's environments is occurring.

Examination of the distribution of total suspended particulate lead (TSPL) in relation to wind speed and direction at each of the monitoring sites, suggests that the smelter area constitutes by far the major source of TSPL. Simple TSPL concentrations, under particular wind speed and direction conditions, under-estimate the total amount of leaded dust transported by wind streams. Concentration needs to be multiplied by windspeed to more accurately estimate the total transport of lead dust from specific source areas to the City. This correction lends further weight to the importance of the smelter area as an important ongoing source.

Monitoring of thoracic sized leaded particles ($TSPM_{10}L$) suggests that on some days this fine particulate contributes the major fraction of elevated TSPL. At the two monitoring sites near the smelter, the concentration of $TSPM_{10}L$ has increased over the last few years. One likely source appears to be lead products of combustion from within the smelter.

In view of the above, it is suggested that the major sources of airborne lead are:

- BHAS smelter (metallurgical processes and lead concentrate handling),
- Handling of zinc concentrates on the wharf,

and minor sources are:

- The railway corridor,
- Surface dusts containing historic lead throughout the City, and
- Leaded petrol,

as proposed in the review reports of the Air Quality Branch, Department of Environment and Planning (Goh and Hope, 1989 and 1992).

The conclusion that aerial deposition of leaded dust arises largely from the re-entrainment of historically contaminated dust sinks located around the City therefore needs further reconsideration and refinement.

Figure 7.7 Origins of Lead Bearing Dusts at Port Pirie.
Source: Body, Inglis & Mulcahy 1988

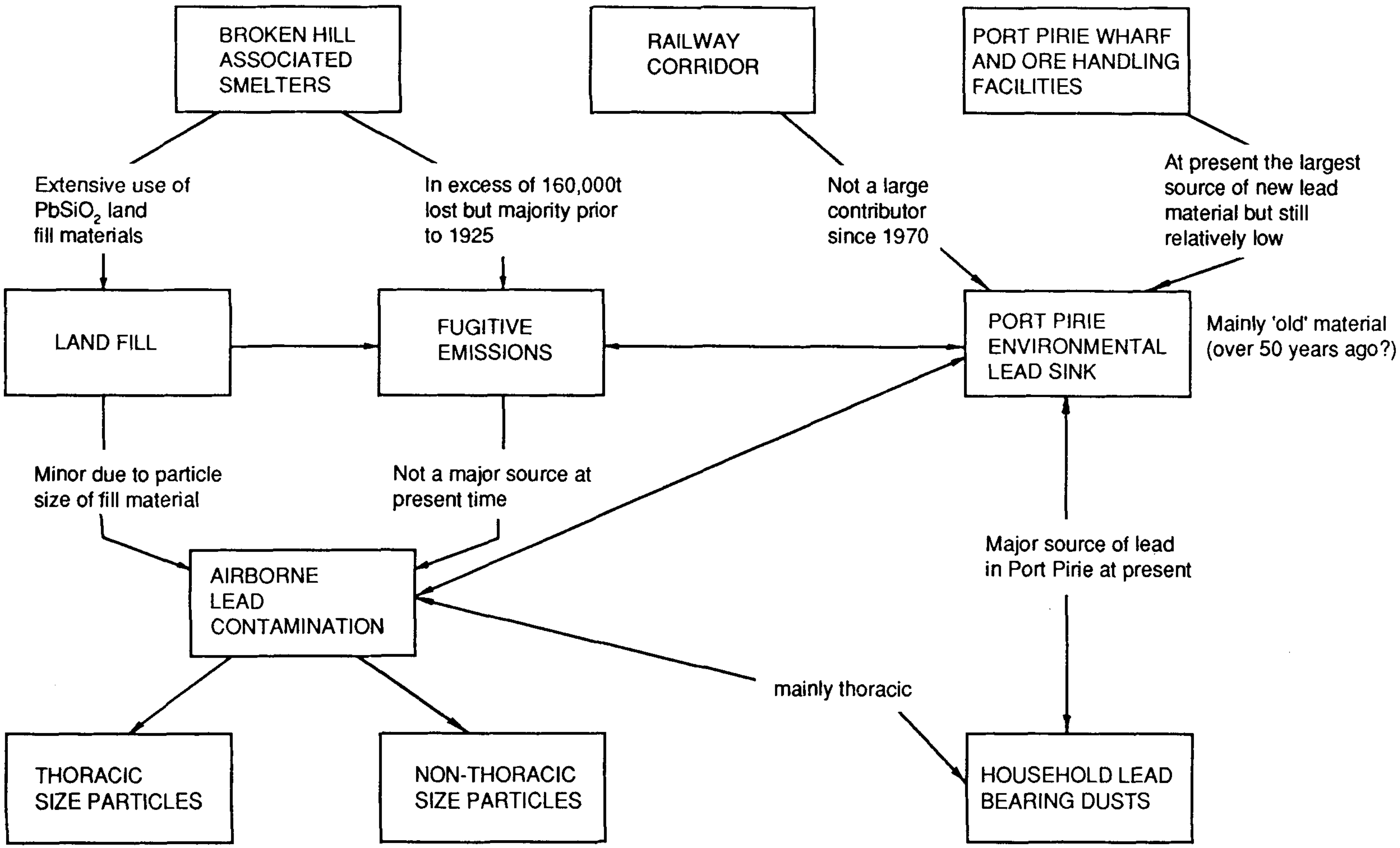
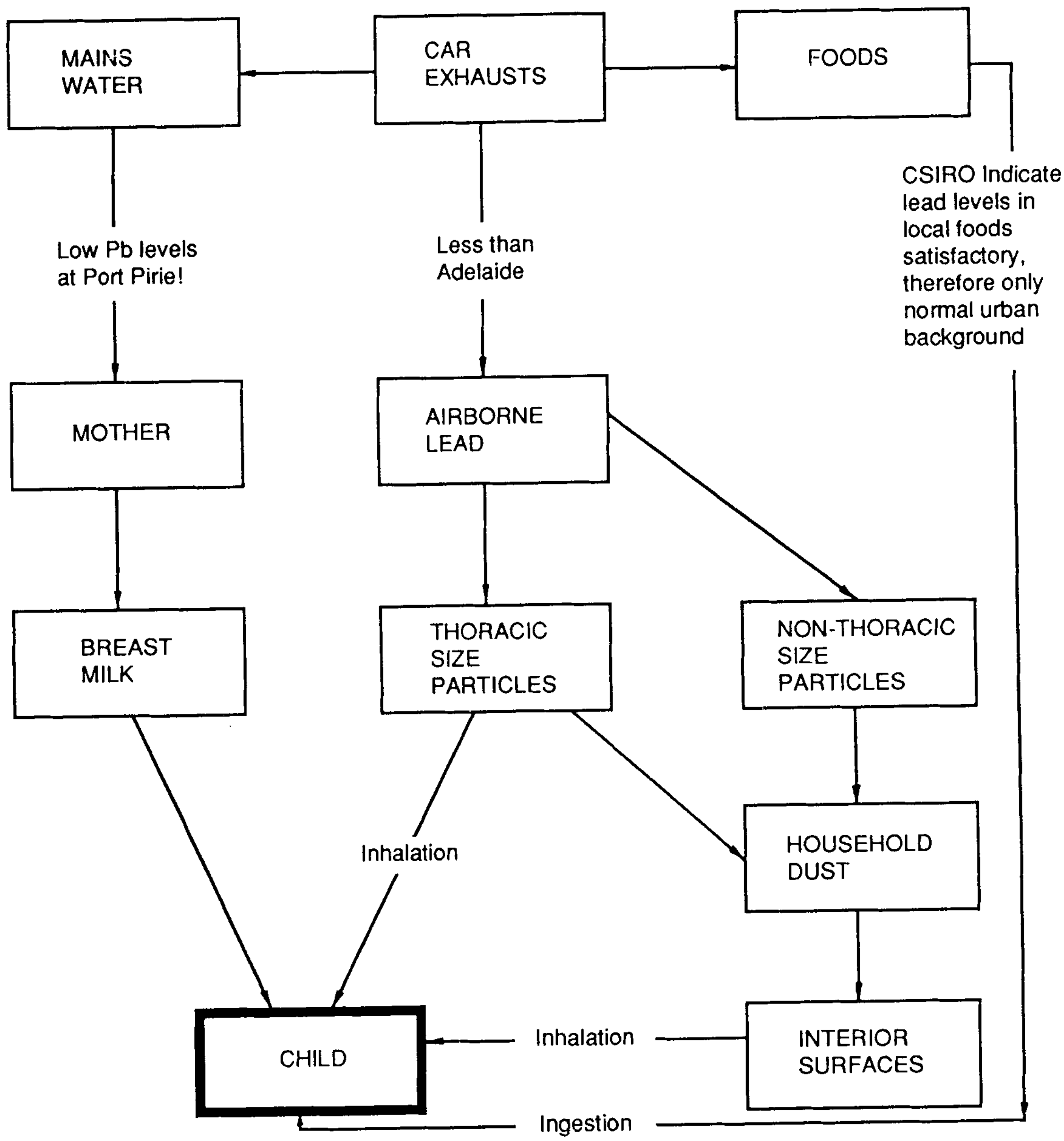


Figure 7.8 Typical Background Lead Sources Found in the Urban Environment in Addition to those Monitored at Port Pirie.
Source: Body, Inglis & Mulcahy 1988



8. MONITORING

This Chapter considers experience obtained in monitoring lead during the Program and suggests monitoring strategies for the future in support of specific purposes.

Greatest monitoring effort has been devoted to the levels of lead in the blood of children (biological monitoring) in the considered belief that this index provides the best single measure of exposure. In turn, exposure reflects the resultant interaction of children with their lead contaminated environment.

8.1 BIOLOGICAL MONITORING

8.1.1 Functions

Biological monitoring serves several purposes:

- Case finding (high risk children),
- Definition of high risk geographic areas,
- Indicate longitudinal trends and provide a summary assessment of program impact, and
- Investigation eg impact of various interventions.

The blood lead monitoring program to date (1984-92) was designed for the main purposes of identifying children with high blood lead concentrations and monitoring their progress during and after household abatement and behaviour change interventions. Beyond these functions, monitoring results have been used to indicate population trends in blood lead and the impact of household abatement as a program strategy. In fulfilling this mix of functions the monitoring program has met with several limitations. These will now be discussed in relation to each function and the desirable features needed to meet future requirements will be highlighted.

8.1.2 Parameter Options

(1) Blood lead

Estimation of blood lead is the most widely used biological marker of lead exposure. With a half-life in blood of 28-36 days, blood lead levels reflect relatively recent exposure.

Lead passes between the blood and bone and hence a single measurement cannot distinguish between low level immediate or chronic exposure and high level acute exposure. Blood lead levels can not serve as exact measures of lead exposure or the total body lead burden. Despite these limitations, blood lead remains the one readily accessible measurement that can demonstrate in a relative way, the relationship of various biological effects to increases in exposure.

Given its widespread use, standards for analytical practice and systems to ensure quality control are readily available. Deficiencies in analytical rigour increase measurement error especially at low blood lead concentrations. In making an evaluation of the adequacy of the blood lead data, reviewers would as a minimum need to access evidence of the long term stability of accuracy and precision, particularly at low blood lead levels (1-10μg/dl). They would also need to examine the impacts on data of analytical drift over the years, changes in methodology, type of calibration standards used, and degree and effectiveness of contamination control procedures.

The shape of the blood lead curve during the early years of life depends on the primary source of exposure. For example, exposures to lead in dust result in elevations in blood lead beginning about six months of age and peaking between fifteen and thirty months of age. If the source of lead is drinking water, high blood lead levels may be present throughout both the foetal and early newborn periods.

(2) Blood lead at birth

Umbilical cord blood lead data are more likely to be of lower quality given the difficulty of quality sample collection under a rigorous protocol in the delivery room. Most studies do not report their sample collection protocol or have no identified standard sample collection protocols. These deficiencies are of particular concern at low blood lead concentrations. Eighty to ninety percent of cord samples had lead concentrations below 10μg/dl. For these reasons, more weight should be given to studies of antenatal exposure that entail multiple indicators of foetal exposure and/or a sound cord blood sample collection protocol.

(3) *Tooth lead*

The tooth contains several distinct compartments - enamel, primary dentine and secondary or circumpulpal dentine - each of which accumulates lead at different rates and times during development. Each reflects different exposure components arising from saliva, prenatal mineralisation and post natal lead exposure. The last of these compartments requires specific highly specialised techniques for estimation and has not been widely utilised. It is now recognised that lead mobility in teeth is more dynamic than previously thought.

Because of the complex structure and development of teeth, concentrations are particularly dependent on sampling and analytical techniques and tooth age at exfoliation. Data varies between different investigators as a result of varying procedures. Studies have examined peak lead levels, total accumulated dose, or dose related to childhood development. The relationship between lead levels in teeth, and those within the brain and other target organs is not known and clearly warrants further investigation.

(4) *Urinary lead*

Urinary lead levels have also been used to measure current exposure but are of questionable value as a biological marker of exposure because of the relatively low and fluctuating lead levels excreted in the urine.

(5) *Hair lead*

Hair provides a readily available, stable biological medium for lead accumulation. Unfortunately, artificial hair treatments can invalidate the metal analysis of hair and external surface contamination makes it difficult to differentiate between externally and internally deposited lead.

8.1.3 Blood Monitoring by EHC (1984-1992)

Port Pirie children have been tested regularly in order to measure changes in their blood lead levels. Blood tests are also the screening process by which children having levels in excess of the NH&MRC level of concern can be detected and appropriate remedial action undertaken through the Lead Implementation Program. At the commencement of the Program, the level of concern was 30μg/dl, but it was revised downwards to 25μg/dl in 1987.

Blood testing is offered on a voluntary basis to all Port Pirie children up to age seven years. Capillary samples are collected in accordance with the "Australian Standard 2636 (1983) - Sampling of Venous and Capillary Blood for the Determination of Lead Content".

The testing is carried out by technical staff at primary schools, kindergartens, and the Environmental Health Centre (EHC). Test results are also used:

(1) To measure general trends in blood lead levels over the whole population of children sampled, and
(2) To measure changes over time for particular children in order to evaluate the effectiveness of specific interventions intended to reduce their levels to within acceptable levels.

Analyses for blood lead are performed at the BHAS laboratory which is located within the grounds of the smelter and is accredited by the National Association of Testing Authorities (NATA). There have been occasions when sample contamination was suspected as having resulted in falsely high blood lead readings, and some have argued that the laboratory should be remote from the possible effects of lead contamination. This may pose a greater problem if lower levels of concern and action are required.

BHAS analytical quality control is achieved by participation in three major programs: the UK external assessment scheme for clinical chemistry, the Commonwealth of Pennsylvania

Department of Health Program, and the Australian Standards Quality Assurance: Metals in Body Fluid Program.

Quality control procedures at the EHC are as follows:

- A quality control sample of pig's blood with a known lead value is analysed daily by BHAS and twice weekly at the Adelaide Children's Hospital,
- A blank sample of 100 microlitres deionised water with 500 microlitres of tritonphospate with EDTA is prepared daily by EHC staff,
- A split sample is obtained for approximately every tenth client screened, and this sample is sent to both the Adelaide Children's Hospital (ACH) and BHAS for analysis, and
- About once per week, a paired capillary and venous sample from an adult is sent blind to the BHAS laboratory.

The voluntary blood screening program at Port Pirie has run well since the inception of the Program using capillary sampling associated with good quality control. The only concerns have been some erroneously high results from the BHAS laboratory, detected successfully through the quality control program.

8.1.4 Case finding

(1) Progress 1984-1992

The current Program has experienced several limitations in fulfilling this prime function.

(a) Coverage of the eligible population

The Program has attempted to include all children up to seven years of age in voluntary testing every six months. In the absence of a system which identifies the total eligible population by individual registration, census data has been used to provide an estimate of the target population. Against this base, testing has been far from complete with only 47 to 65% of eligible children tested, depending on cycle number and age group.

(b) Coverage of preschool children

Testing has been least complete amongst the preschool age groups, especially during the early years of the Program. The aim to optimise the accuracy of testing has limited blood collection to the high quality conditions available at the EHC and caravan, thereby limiting ability to reach children outside of school and preschool settings. High risk children have to a large extent been identified after the age of peak blood lead thereby limiting the opportunity to initiate home environment assessment and abatement during the first years of life.

(c) Inclusion of all children up to seven years

The testing program has attempted to survey all children in Port Pirie during each cycle without a focus on the high risk areas. This strategy has meant testing resources were used on large numbers of low risk children and left limited capacity to minimise the number of missed children from high risk age groups and geographic areas.

(d) Identifying missed children

The absence of a system which registers eligible individual children has made it difficult to focus testing resources on high risk children, to put in place a reminder system that could minimise the level of non-response within a voluntary participation setting, to readily monitor the proportion of eligible children covered, and to identify new residents.

(2) Future needs

The introduction of a lower blood lead goal will increase the dependence of the Program on its blood monitoring system. While the US CDC guidelines recommend testing of all children so that a demographic definition of high risk children can be developed, presumably to enable a high risk program strategy, much of this background work is already in place in

Port Pirie. Extensions to the risk definition function are considered in the next section on trends.

A lower blood lead goal will also require a much greater focus on preschool children, a well developed system for repeat tests on marginal risk children and measures to maximise the proportion of young children tested.

Desirable features of a future case finding system might include the following.

(a) Focus on high risk children with testing frequency adjusted according to risk with greatest intensity amongst children under four years in high risk grid areas. Case finding amongst school aged children would seem to serve little purpose. Complete coverage could be restricted to testing around the age of peak blood lead levels.

(b) All children under fours years need to be included on an actively updated register along with blood lead results and a summary of household abatement status. The recording of addresses of two or three other residents who are likely to know where each particular child is living provides a mechanism for maintaining contact. This register would provide the main mechanism for identifying and following up missed children.

(c) Blood testing at young children's homes may be required in some situations to maximise coverage and early identification. Such a test may need to be considered a screening only and confirmed if necessary in more optimal testing conditions.

(d) Testing of children before age two may need reference to percentile curves to determine their likely peak blood lead level and intervention undertaken on that basis.

8.1.5 Summary Trends and Risk Area Definition

The second major function of biological monitoring is concerned with longer term trends:

- Population trends in lead exposure to provide a summary evaluation of progress, and
- Surveys of factors that predict high lead exposure to refine the definition of the high risk child population.

(1) Progress 1984-1992

The six monthly census of blood lead levels amongst children up to seven years of age has been used to date to fulfil this function as well as case finding. However, experience has shown that this approach has met with several limitations.

(a) Since only 45-65% of the estimated child population has been included in each cycle, the potential for considerable selection bias has limited ability to provide an accurate estimate of trends in blood lead:

- An unknown number of children with high blood lead has been omitted,
- In the early years, children of highly motivated parents were probably over represented,
- The major function of case finding and monitoring has produced an over representation of children with elevated blood lead amongst those actually tested,
- The school-based organisation of testing has produced an under representation of preschool children,
- Exclusion of Cohort Study children has produced a differential impact across cycles on the representation of different age groups, and
- Lifelong residents have been undistinguished from recent immigrants.

(b) The aim of including all children up to seven years of age (ie. a census approach) has provided a number in excess of that required for making an adequate estimate of trends.

(c) Six monthly cycles are more frequent than necessary for determining trends.

(d) Inclusion of children several years beyond the age of peak blood level has obscured the trends for children at more critical ages.

(e) Limitations (b), (c) and (d) above have involved an excessive commitment of resources thereby diminishing the capacity to pursue non-respondents (missed children) and reducing the impact of selection bias on the blood lead trend estimates.

(2) Potential parameters

While the blood lead remains the most developed parameter for estimating trends, consideration should be given to supplementing blood lead trend data with antenatal blood lead trends. Samples for this purpose could be integrated with those taken during routine antenatal assessment. For the reasons identified earlier in this Chapter, tooth lead, hair lead and cord blood lead are unlikely to provide an acceptable basis for monitoring trends.

(3) Future needs

The key feature of an acceptable method for monitoring trends and defining the high risk group must be representative sampling. Each segment of the childhood population for which a separate estimate of blood lead trends is required (eg specific age groups) needs to validly represent the eligible Port Pirie population of that segment. A sampling approach would reduce the costs of the current census approach, and by freeing resources to pursue non-respondents (missed children), could improve the accuracy of the population blood lead estimates. The capacity to remind and follow up missed children is essential in the context of a voluntary testing program.

A second feature would need to be the collection of information on key factors predicting high risk for each child included in the sampling (trend estimate) program. Again focussing resources on achieving complete information on all children in the sample would allow a better re-definition of the high risk areas than the incomplete information available in the current cycle census approach. Predictor factors would include:

- Age,
- Location of residence,
- Duration of residence,
- House abatement status, and possibly
- Some household environmental lead values.

A third feature involves maintaining consistent methods between trend studies. Hence any change from the current approach will require careful consideration.

Other features could have a substantial impact on the costs of monitoring for trend/risk area definition purposes:

- Sample size should be determined by the number of separate segment estimates required and the desired level of accuracy of the estimate eg $\pm 0.5\text{-}1.0\mu g/dl$,
- Sampling could be planned every third year rather than every six months,
- Only selected age groups need be included eg an estimate at pre-peak, peak, and one post-peak,
- Sampling at specific ages would increase accuracy over the current one year intervals, and
- Sampling should exclude immigrant children and non-Port Pirie residents.

The register of eligible children described above under case finding could also prove beneficial for blood sampling for this purpose as well.

8.1.6 Investigation

Data from the current blood monitoring program has been used in a preliminary investigation of the association between blood lead levels and paint lead, soil lead, ceiling dust lead, vacuum cleaner dust lead, floor dust lead, windowsill dust lead and rainwater lead (Body et al, 1988).

The EHC cycle data was also used to investigate the effects on blood lead of the home abatement program but was limited by the high proportion of non-respondents (missed blood lead tests), selection bias and other problems noted above.

Future investigation options are discussed in Chapter 10.

8.2 MONITORING THE CITY LEAD ENVIRONMENT

8.2.1 Functions

Monitoring activities can be seen to have the following main functions:

- Defining and ranking areas in terms of relative lead contamination,
- Determining trends in lead contamination so as to provide a summary index of progress in controlling sources,
- Providing input parameters for predicting future blood lead levels, and
- Investigating the environmental behaviour of lead.

As noted in Chapter 5, measurements of the concentration of lead in air has been the only monitoring parameter undertaken to date that provides some longitudinal measure of environmental contamination. Lead in air provides a very reasonable monitoring parameter since it is probably the most important pathway of contamination reaching the City reflecting both new and entrained lead from the City sink.

8.2.2 Defining and Ranking Areas of Lead Contamination

(1) Pre 1984

During this period, the CSIRO Division of Soils conducted studies to measure lead concentrations in dusts and soil profiles around the City and constructed contours of relative contamination. BHAS conducted serial rainwater tank lead surveys over several years.

(2) 1984 to 1992

During the early years, the Program assembled concentration data on soils and dusts from various sites around the houses which contained high risk children and were selected for decontamination, along with comparison data from houses in the low risk areas. Similar data was collected from various schools and other public access areas.

(3) Future monitoring

Monitoring activities to serve this function will need to incorporate design features such as large numbers of samples (sufficient to enable construction of contours of relative contamination), although they can be relatively infrequent, and they will need to be standardised to allow control of the systematic effects of variables such as season.

Lead in air measurements using high volume samplers are too expensive to allow sufficient sample sites, and so consideration should be given to cheaper methods such as moss bags and deposit gauges.

Lead in dust will probably provide the core parameter for this purpose but will need in the future to include mass loading of lead in dust as well as lead concentration.

8.2.3 Trends and Summary Impact

(1) Pre 1984

During this period, the Department of Environment and Planning adopted high volume sampling as the main method for lead in air monitoring and discontinued the use of dust fall gauges. The Australian Market Basket Survey provided estimates of total lead intake from food. These have been continued through the life of the Program although they only provide Australian average intakes and not intakes specific to Port Pirie. Prior to the Program, the CSIRO Division of Soils also conducted analyses of lead in local Port Pirie food crops. The E&WS Department has regularly monitored the lead in mains water.

(2) Task Force 1983

Recommendations from the Task Force identified the need for additional lead in air monitoring using high volume samplers and the need to monitor plant emissions of lead.

(3) 1984-1992

(a) Lead in air

Along with lead in blood, measurements of lead in air have provided the key parameters during the course of the Program for monitoring trends. Measurements have included total suspended particulate lead, total suspended particulate lead inhalable sized fraction (PM_{10}) and measurements of the distribution of different sized particles. Lead in air provides a key environmental monitoring parameter reflecting the following:

- The transfer of new lead to the City,
- Transfers of old lead around the City ie redistribution of the lead sink, and

- Vehicle emissions.

Aerial deposition of lead can be considered a key pathway by which lead is transferred to the City and home environments with energy for this transfer coming from wind, mechanical agitation by vehicles and people and dispersion from the smelter stack.

The method of high volume sampling and the sampling sites have been consistent enough over the life of the Program to provide adequate data on the lead in air trends. Unfortunately, this parameter provides concentration data only and does not readily provide information on the total mass of lead transferred through the air, although the product of concentration and wind velocity data provides some index of lead dust flux.

There are some concerns about whether the existing high volume sampling sites fulfil the requirements of the Australian Standard for the design of such sampling sites. Perhaps the most important concern is the presence of physical obstructions within the immediate vicinity of the sampler. Research also indicates that the high volume sampler does not perform equally efficiently for particles over the whole size range up to 50 micrometres diameter and that the direction of the hood also influences the efficiency of collection.

Over several years moss bags have been used at a large number of sites to reflect lead in air concentrations although their sampling efficiency has yet to be confirmed.

(b) Lead in dust

No useful longitudinal data that can be used to monitor trends in lead contamination have been assembled during the Program.

(c) Lead in water

The E&WS Department continued to monitor lead in mains water. Following the discontinuation of the BHAS rainwater surveys, adequate data to allow the monitoring of trends have not been collected from rainwater samples around the City. The only data available was taken from households that have had decontamination procedures or samples requested by residents.

(d) Lead in food

Available Port Pirie data on trends for lead in food are inadequate for monitoring purposes.

(4) Future monitoring

To fulfil the trend function a monitoring program would need to meet several basic design features. While the number of sites do not need to be as large as that required for ranking areas of the City, monitoring does need to reflect each area of the City which has program implementation significance. Consistent methods and equipment used at fixed sites need to be central features. Measurements need to be taken serially and with sufficient frequency to take account of known systematic variations such as seasonal differences. Furthermore, methods need to be selected that are known to provide a valid measurement of environmental lead, both its mass loading and concentration.

The following specific parameters need to be considered for this trend monitoring function.

(a) Lead in air

High volume sampling continues to be an essential tool for monitoring a major pathway of lead transport. Longitudinal measurements of lead in air will also provide a measure of the impact of source control and of measures designed to control the transfer of lead by wind re-entrainment. Given the existing large amounts of monitoring data taken with consistent methods and from consistent sites, a program of high volume sampling should be continued into the future.

In addition to total suspended particulate lead, monitoring of the different size fractions of lead dust including the total inhalable fraction needs to be considered. Monitoring of specific size fractions provide information on likely sources and an indication of the total inhalable lead in air. Some evidence also suggests that it is the small particle lead which most readily finds its way into households and hence may make a more direct contribution to inhalation and ingestion by children.

Attempts at monitoring the mass transport (flux) of lead dust must also be considered.

(b) Food

Now that much of the contamination in the high risk areas has been abated and as the blood lead level of concern declines, it is appropriate that the Australian Market Basket Surveys are supplemented with better measures of lead concentrations in Port Pirie fruit, vegetables, and seafoods. Perhaps using existing dietary records, the range in amounts of local food consumed could be calculated and combined with a survey of lead concentrations in an adequate sample of local foods. A repeat of this process every five or so years would provide an adequate basis for trend estimation.

(c) Lead in water

Monitoring of mains water lead concentration needs to continue. While measurements of rainwater lead are appropriate for estimating the total lead intake of children in specific houses which are being considered for abatement, it would seem that there are too many complicating factors influencing the concentration of lead in the water column of the rainwater tank to make this parameter useful for trend estimation. Given that it is possible to avoid these complicating factors, such as by standardising the collection time to avoid periods of recent rain, it may be useful to collect random samples of rainwater in each of the different risk areas to provide some index of the lead burden settling on roofs in the City.

(d) Lead in surface dust

Along with measures of lead in air, the measurement of concentration and mass of lead per unit area (mass loading) using brushings of surface dust from a variety of surfaces around the City is likely to provide the best index of trends in the Port Pirie lead sink. The amount of lead in dust reflects the amount of lead available for transport around the City.

The sites for surface dust estimation need to be consistently maintained and selected to reflect areas of different levels of lead contamination. The sites would also need to be selected with knowledge of the impact of local factors affecting deposition. One series of samples may need to be taken from road verges to reflect the impact of mechanical agitation. Another series might be taken near obstacles to air flow where the slower boundary layer causes the lead dust particles to settle more rapidly. Another series should be taken from sites where wind action is free of interruption reflecting the experience of open space areas such as roadways, the rail corridor, and open park areas. Consideration would need to be given on the impact of local factors on the relative deposition of particles of different size.

Within households, vacuum cleaner dust and other measures of deposition such as A sticks, or petri dishes containing agar have a place for measuring the deposition of lead dust. This issue is further discussed in Section 8.3.

8.2.3 Environmental Investigation

As discussed in more detail in Section 10.3, measurements of environmental lead concentration and mass loading (mass per unit area) will have a significant role in assisting the definition of sources of airborne lead, assessing the relative contribution of those sources to City contamination, and assessing the impact of source and wind control measures.

8.3 MONITORING HOUSEHOLD CONTAMINATION

Monitoring at the household level can be used for the following purposes:

- Understanding the contribution that lead contamination in various sites within the household makes to blood lead levels in children,
- Household assessment and abatement planning, and
- Determining the level and rate of contamination/recontamination.

8.3.1 Predicting Blood Lead and Identifying Environmental Determinants

(1) Pre 1984

The case control study conducted by Wilson et al (1986) provided useful information for identifying important sources of lead contamination around the household and their influence on blood lead levels.

(2) 1984 to 1992

Monitoring for this purpose has received little attention except for the small series of correlation studies conducted by the Department of Environment and Planning (Body et al, 1988) which examined the relationship between blood lead levels of small numbers of children and household measures of lead in paint, lead in carpet dust, and lead in the dust from several sites inside and outside of houses. A larger correlation study conducted by the SA Health Commission (Calder et al, 1990) found that 5-10% of the variation in children's blood lead could be accounted for by lead levels in the top 5cm of soil.

(3) Future monitoring

In view of the extensive household and grid decontamination of high risk areas, the relative importance of different sources of household lead contamination may well have changed since the beginning of the Program. As identified in Section 10.3, further studies of the relative importance of different household lead sources and their pathways into young children may be required especially in the face of lowered levels of concern.

It may also be useful to repeat the case control study along the lines of Wilson et al (1986) but this time with the study replicated in areas of Port Pirie with different levels of risk.

These investigations should serve to refine household abatement strategies and gain some indication of the importance of recontamination.

8.3.2 Household Assessment and Abatement Planning

(1) Task Force (1983)

The Task Force acknowledged the need for extensive testing of household environments to guide decontamination procedures.

(2) 1984 to 1992

Following the development of a rapid paint test and a simpler method for determining the concentration of lead in soil, monitoring for household assessment has become a role of the Lead Program laboratory. Since the beginning of the Program, every decontamination proposal has been based on an examination of lead concentrations in soil, dust (interior and exterior), paint, rainwater and so on. Measurements of the mass loading of lead contamination have not been a part of this assessment process.

(3) Future monitoring

Monitoring to guide the abatement of households will be an ongoing need as children with high blood lead levels are identified. As discussed in Section 8.2, measurements of homegrown fruit and vegetables may need to be added as part of the assessment of total lead intake of high risk children. Future monitoring may need to develop methods that take greater account of the differences in bioavailability of lead from sources of soil and dust around the home.

8.3.3 Trends and Summary Impact

(1) Task Force, 1983

The Task Force recognised the potential for recontamination of decontaminated houses in its recommendation that longitudinal trends in household lead dust levels should be monitored.

(2) 1984 to 1992

The extensive data collected around households for decontamination planning do not provide information on lead contamination levels over time and are hence of little use for monitoring trends.

(3) Future monitoring

Any monitoring that is introduced to gauge longitudinal trends should incorporate the following features:

- Defined sites that are representative of different risk areas,
- Consistent use of the same sites,

- Standardised and consistent measurement methods, and
- Measurement of lead concentration as well as mass loading of contamination per unit area.

(a) Lead in air

In view of the likely variations in the concentration of lead in indoor air in response to meteorological conditions, levels of household ventilation (eg open windows and doors), effects of vacuum cleaning , and the influence of people movement, it is difficult to see how monitoring of indoor lead in air can be standardised sufficiently to allow the long term monitoring of trends.

(b) Lead in food

Reference has already been made to the need to include better estimates of lead intakes from local and homegrown fruit, vegetables and seafoods.

(c) Lead in surface dust

This parameters would appear to have the greatest potential for monitoring trends in contamination/ recontamination at the household level. Three main approaches can be suggested:

- Serial measurements of vacuum cleaner dust (concentration and mass) using a standardised method,
- Deposit gauges of various sorts including A sticks, petri dishes, or perhaps lead collected in rainwater sedimentation chambers, and
- Serial measurements of lead in surface dust brushings using a standardised method and areas defined by template such that both concentrations and mass of lead in dust can be measured. These brushings should

include a variety of indoor surfaces such as window sills, ceilings, furniture surfaces, and floors.

8.3.4 Investigation of the Household Lead Environment

(1) Lead in air

Future investigations that provided measurements of the range of concentrations of lead in indoor air would serve to provide an estimate of exposure from lead dust inhalation while indoors. The determination of the particle size distribution of indoor leaded dust would provide useful exposure information as well as contributing to the investigations discussed more fully in Section 10.3. These are aimed at a better understanding of the sources and pathways of exposure of children to leaded dust in the home environment.

(2) Lead in paint

Ingestion of leaded paint flakes has been confirmed in many studies overseas as a potential source of large amounts of lead, especially amongst children with pica behaviour. Monitoring the existence of lead in paint around individual households is best undertaken through the monitoring of blood lead. The consequent household assessment would include lead in paint. Beyond this situation two other issues require future investigation.

It has generally been shown in overseas studies that deterioration of indoor lead painted surfaces makes a contribution to the lead levels in indoor dust. Initial investigations by the Department of Environment and Planning (Body et al, 1988) suggested that deteriorating paint retains a flat planar structure and can be readily detected in house dust. These investigations failed to find evidence of substantial lead paint contributions within house dust in the Port Pirie setting. These initial findings need to be confirmed and further work to examine the microscopic structure of chalking paint are required.

The second issue centres on the observation that children not uncommonly run their fingers along painted surfaces thereby providing another source of lead for ingestion. Deteriorating painted surfaces, even those involving non-leaded paint, are thought to be effective traps of airborne lead dust. The significance of this potential source of lead dust needs further investigation.

As action levels for blood lead are lowered and the importance of household recontamination becomes clearer, a substantial commitment to investigating household sources of lead and their pathways into young children will be required. This issue is further discussed in Section 10.3.

9. FUTURE GOALS

The Port Pirie Program was established in 1984 to reduce children's exposure to lead and to minimise the number of children with blood lead levels exceeding the level of concern current at that time.

Since 1984, further research on the adverse effects of lead has caused international opinion about safe blood lead levels to continue evolving. The Port Pirie Cohort Study has made a significant contribution to knowledge on this issue. During recent years, several countries have incorporated this new understanding into public health practice by reducing their blood lead guidelines. Australia and the U.S.A. have replaced a single level of concern criterion with a set of graduated actions in response to a hierarchy of blood lead levels. These considerations form an essential part of any discussion about the future of the Program.

Hence, this Chapter summarises current scientific evidence, reviews recent revisions of international and Australian guidelines and discusses their implications for Port Pirie.

9.1 CHILDREN'S BLOOD LEAD "LEVEL OF CONCERN" : REVIEW OF SCIENTIFIC EVIDENCE 1992/93

International and Australian participants with a diverse range of expertise including childhood behaviour, epidemiology, toxicology and biostatistics met in Melbourne between 5-9 October, 1992, to examine the possible implications of the global community's exposure to lead. The meeting had as its particular focus non-occupational exposures that are usually considered to result in blood lead concentrations of 0 to 30 μg/dl. Included within the group were representatives of the major international cohort studies in Boston, Cincinnati, Port Pirie, Cleveland, Sydney and the United Kingdom.

The meeting was convened as an Australian contribution towards promoting an international consensus on lead issues in support of the Australian Clearing House responsibilities to the Organization for Economic Cooperation and Development (OECD) Risk Reduction Strategy for lead and to assist the International Progamme on Chemical Safety (IPCS) initiatives.

The meeting focused on specific toxicological issues identified as key concerns, including the relationship of lead to nervous system and behaviour development of children during the early period of life. Of particular interest was the apparent effects of lead exposures during the early years of childhood.

A follow-up meeting of the IPCS Task Group on Inorganic Lead was held in Brisbane in February, 1993. The draft conclusions of these meetings, in relation to the effects of lead on children, can be summarised as follows.

Lead adversely affects several body organs and systems with changes to cell functioning and nervous system development appearing to be the most sensitive. An association between blood lead and elevated blood pressure has been reported. Lead produces a cascade of effects on the oxygen carrying material in blood (haemoglobin) and affects its synthesis. However, some of these effects are not considered to be adverse. Calcium balance is affected thus interfering with other cellular processes.

(1) The most substantial evidence from cross-sectional and longitudinal studies of populations with blood lead levels generally below 25 μg/dl relates to detriments in intelligence quotient (IQ). It is important to note that such observational studies cannot provide definitive evidence of a causal relationship with lead exposure. However, the size of the apparent IQ effect as assessed at 4 years and above is a deficit of between 0 and 5 points (on a scale with a standard deviation of 15) for each 10 μg/dl increment in blood lead level, with a likely apparent effect size of between 1 and 3 points. At blood lead levels above 25 μg/dl, the blood lead - IQ relationship may differ. Estimates of effect size are group averages, and only apply to the individual child in a probabilistic manner.

    Existing epidemiological studies do not provide definitive evidence of a threshold. Below the range 10-15 μg/dl, the effect of confounding variables and limits in the precision of analytical and mental functioning measurements increases the uncertainty attached to any estimate of effect. However, there is some evidence of an association below this range.

(2) Animal studies 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. These can persist well beyond the termination of lead exposure.

(3) Reduction in peripheral nerve conduction velocity may occur with blood lead levels as low as 30 μg/dl. Also, sensory and motor function may be impaired with blood lead levels as low as about 40 μg/dl and autonomic nervous system function may be affected at an average blood lead level of approximately 35 μg/dl.

(4) Risk of lead induced kidney disease is increased in workers with blood lead levels greater than 60 μg/dl. Newer studies using more sensitive indicators of kidney function suggest kidney effects at lower levels of lead exposure.

(5) Lead exposure is associated with a small increase in blood pressure. The likely order of magnitude is that for any two fold increase in blood lead (eg. from 15 to 30 μg/dl), there is a mean 1 mmHg increase in systolic blood pressure. The association with diastolic pressure is of a similar but smaller magnitude. However, there is doubt as to whether these statistical associations are really due to an effect of lead exposure or are an artifact due to confounding factors.

(6) Some, but not all epidemiologic studies, show a dose-dependent association with premature delivery and some indices of growth and maturation during pregnancy at blood lead levels of 15 μg/dl and above.

(7) The evidence for cancer generation by lead and several inorganic lead compounds in humans is inadequate.

(8) Effects of lead are demonstrable on a number of enzyme systems and biochemical parameters. The blood lead level above which effects are demonstrable with current techniques for the parameters which may have disease significance, are all greater than 20 μg/dl. Some effects on enzymes are demonstrable at lower levels of blood lead, but their significance is uncertain.

9.2 CHILDREN'S BLOOD LEAD AND "LEVEL OF CONCERN": OVERSEAS SITUATION

The following summary has been taken from the draft OECD report "Risk Reduction Monograph No. 1" released in February, 1993 (OECD, 1993).

Because of scientific uncertainty and different perceptions of what constitutes a tolerable risk or adverse health effect, there is disagreement among OECD countries as to the blood lead level that should be used as a limit to avoid adverse effects in children. Organizations within various OECD countries have suggested levels of concern ranging between 10-15 and 25 micrograms per decilitre (μg/dl). Recent surveys in seven OECD countries indicate that children's mean blood lead levels are well below even the lower end of this range.

9.2.1 Canada

The average levels of lead in air have steadily declined over the last few decades. The decline has been largely attributed to reductions in the use of lead in gasoline, as lead emissions from other sources (for example, mineral and processing facilities) have remained relatively constant.

The average blood lead levels for the population at greatest risk from exposure (ie. children) also declined from about 19 μg/dl in 1972 to 12 μg/dl in 1984 and to about 6 μg/dl in 1988, well below the 25 μg/dl level of concern which is currently under review. Although there is a strong correlation between blood lead levels in children and air lead levels, it has been suggested that the decline may also be related to other factors such as a voluntary industry phase-out of lead soldered food cans and a decline in the use of lead in indoor paints.

9.2.2 United Kingdom

Concentrations of lead in air at rural and urban sites have declined. One of the greatest declines correlates with a 1985-1986 reduction in the maximum permissible level of lead in gasoline from 0.40 to 0.15 g/l.

The average blood lead levels for children have declined steadily during the mid-1980's with average levels being well below the 25 μg/dl level of concern. Figures from the last national survey of blood lead levels in 1987 gave a geometric mean in the region of 7.1-7.5 μg/dl for children. Recent small scale local investigations indicate that the trend of declining average blood lead is continuing.

According to the UK Department of the Environment, the reduction in the permissible level of lead in gasoline during 1985 had a minimal impact on the already downward trend in blood lead levels in adults, but did appear to contribute slightly to the decrease of lead in the body burden of children. It was also suggested that the decline reflected a long-term trend that related to several personal, social and environmental factors such as reductions in lead intake from food or water.

9.2.3 United States

During the 1980s, the average annual concentrations of lead in air declined at urban and point source sites and are well below the National Ambient Air Quality Standard of 1.5 $\mu g/m^3$. The downward trend has, in part, been related to reductions in emissions from transportation, stationary fuel combustion, industrial, solid waste and other miscellaneous sources. Transportation emissions have dropped by more than 98 per cent since 1970. The decline has been attributed to a decrease in the lead content of leaded gasoline from approximately 2 g/gallon (0.528 g/l) in the early 1970s to 0.1 g/gallon (0.026 g/l) in 1986. Reductions in emissions at point sources are believed to be related to changes in productivity, process technology and emission control devices.

Lead intake from food for various segments of the population, including children, declined during the 1980s to about 5 μg/day in 1988. Reasons for the decline range from improved food preparation, canning and hygiene practices, to reductions in the level of lead in food crops which is linked through soil to crustal weathering, lead deposition from air, and/or lead concentrations in irrigation and ground waters. It has been suggested that the steady decline in the use of lead soldered food cans during the 1980s was a major contributing factor to the decline of lead intake from food.

According to a national blood survey, NHANES II, the average annual blood lead level for children declined during the latter half of the 1970s and continued well below the level of concern, at the time, of 25 μg/dl for children. More recent average levels of around 5-7 μg/dl have been reported.

Although overall blood lead levels in children declined, black children have higher blood lead levels. It was noted that urbanization and income were directly associated with lead exposures and that children in high risk categories (for example, inner-city black children in families with low socio-economic standing) have more complex exposures, such as from the weathering and chalking of leaded paint, than US children as a whole.

9.2.4 Overseas Summary (OECD, 1993)

Children's Blood Lead	
Country	**Actions**
Australia	Goal of 10 μg/dl and action level of 15 μg/dl (1993)
Austria	NR
Belgium	NR
Canada	Action level set at 25 μg/dl, under review as of 1989
Denmark	NR
France	The Ministries of Health, Environment and Housing are financing a series of studies aimed at identifying risk factors in domestic housing in the Paris urban area, and determining the magnitude and extent of the lead poisoning problem in the country.

Germany	Mean blood levels have been found to be decreasing for a group of 6-12 year old school children in Berlin over the period from 1976 to 1985.
Greece	NR
Iceland	No data available
Ireland	NR
Italy	NR
Japan	NR
Luxembourg	NR
Netherlands	NR
New Zealand	NR
Norway	No data available
Portugal	NR
Spain	NR
Sweden	NR
Switzerland	NR
Turkey	No data available
United Kingdom	1982 government advice suggests that actions should be taken if blood lead exceeds 25 μg/dl. Re-affirmed 1988.
United States	10-14 μg/dl, community-wide educational, nutritional and environmental intervention; 15-19 μg/dl, individual child educational and nutritional interventions; 20-44 μg/dl, medical evaluation, environmental investigation and remediation; 45 μg/dl and higher requires medical intervention.
European Community	Considering lowering the action level to 10 or 15 μg/dl
Mexico	NR

NR = No response by the national government of the country to OECD requests for information on this topic during 1991 and 1992.

9.3 ENVIRONMENTAL AND BLOOD LEAD LEVELS IN OTHER AUSTRALIAN COMMUNITIES

9.3.1 Environmental Lead

Between 1985 and 1988 estimated lead emissions declined in all States and Territories resulting in an average reduction of 18 per cent for Australia (Figure 9.1). More than 90 per cent of these estimated emissions derive from leaded petrol. The decline has been attributed first to a reduction in the concentration of lead in petrol in 1983 and, second, to the introduction of unleaded petrol containing 0.013 g/l or less. Since 1 January 1986 all vehicles, whether manufactured locally or imported, have been required to operate on unleaded petrol. Although overall emissions have declined, there are concerns relating to specific point source releases that regularly exceed recommended guidelines.

Since 1977, dietary intakes of lead for all segments of the population have declined dramatically and are well below the Provisional Tolerable Weekly Intake recommended by the World Health Organisation (Figure 9.2). For example, the estimated intake for infants has been reduced by 90 per cent. Improvements are believed to be the result of changes to food canning technology and the discontinued use of pesticide sprays based on lead arsenate.

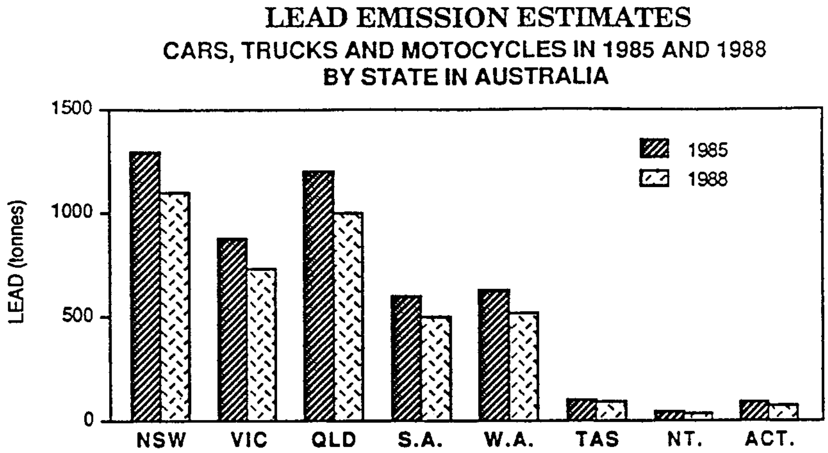
9.3.2 Blood Lead

There have been various blood lead level surveys identified in Australia over approximately the last ten years. The following summary focuses on children aged 0-4 years, the group at greatest risk from intake of environmental lead (Edwards-Bert et al, 1993).

The majority of studies were conducted in areas adjacent to major industrial sources of lead in the environment. These included studies based at Port Kembla, Broken Hill, Hobart, Mount Isa and Boolaroo (Newcastle). Another small investigation was conducted in an area of concern around a lead contaminated site (Windang). Urban studies have been conducted in Sydney and Mort Bay, Adelaide, Melbourne and Perth. The Bellambi survey served as a low risk area reference for the Port Kembla study.

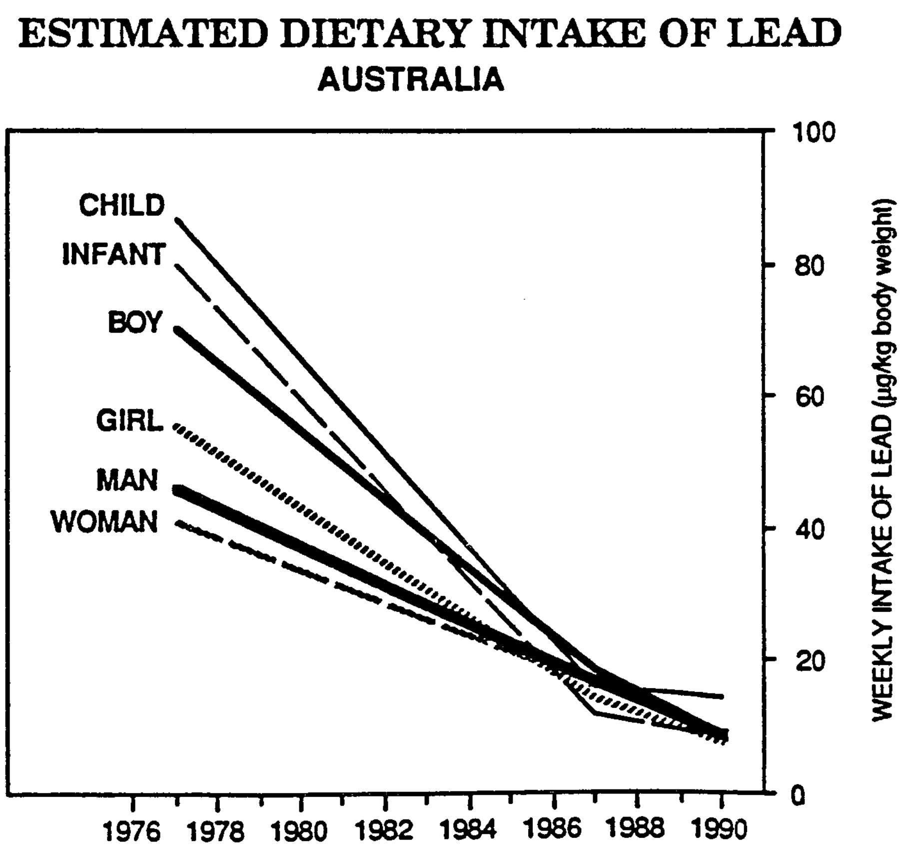
The following Table (9.3) provides an overview of the blood lead surveys identified above. As they vary somewhat in recruitment methods, age distribution and methods of testing, caution is needed when comparing them with the Port Pirie data (Chapters 6 and 10).

Figure 9.1



Source: Autralian Bureau of Statistics,1992.

Figure 9.2



Source: Autralian Academy of Science 1981 and National Health and Medical Research.

Table 9.3: Distribution of Blood Lead Levels (PbB) According to Selected Values: Comparison of Australian Studies (Children ages 0-4)

Study Details				PbB as % of Total ($\mu g/dl$)			
Area	**No.**	**Year**	**Area**	**⩾10**	**⩾15**	**⩾20**	**⩾25**
Windang	15	1992	other	27%	7%	nil	nil
Broken Hill	899	1991	mine	85%	60%	nil	20%
Port Kembla	83	1989	smelter	93%	64%	26%	8%
Boolaroo	124	1991	smelter	84%	49%	20%	6%
Mount Isa	57	1990	smelter	68%	48%	nil	4%
Hobart	35	1991	smelter	59%	18%	3%	nil
Mort Bay	158	1991	urban	51%	17%	8%	3%
Sydney	400	1975-7	urban	73%	34%	9%	2%
Adelaide	513	1985	urban	96%	64%	27%	10%
Melbourne	15	1981	urban	93%	40%	13%	nil
Bellambi	30	1989	urban	81%	47%	13%	6%
Perth	123	1991	urban	17%	0.2%	nil	nil

(Source: Edwards-Bert et al, 1993)

9.4 RECENT GUIDELINE REVISIONS

9.4.1 United States Centers for Disease Control and Prevention (CDC)

This section summarises key features of the October 1991 U.S.CDC report, "A Statement by the Centers for Disease Control: Preventing Lead Poisoning in Young Children" (US Department of Health and Human Services, 1991). It classified blood lead concentrations into 5 ranges (with one being further subdivided) and indicated recommended action in relation to children with blood lead levels in these ranges.

A succinct summary of the recommendations in this Statement are provided in the table below.

Class	Blood Lead Concentration (μg/dl)	Comment
I	$\leqslant$9	A child in Class I is not considered to be lead poisoned.
IIA	10-14	Many children (or a large proportion of children) with blood lead levels in this range should trigger community-wide childhood lead poisoning prevention activities. Children in this range may need to be rescreened more frequently.
IIB	15-19	A child in Class IIB should receive nutritional and educational interventions and more frequent screening. If the blood lead level persists in this range, environmental investigation and intervention should be done.
III	20-44	A child in Class III should receive environmental evaluation and remediation and a medical evaluation. Such a child may need pharmacologic treatment of lead poisoning.
IV	45-69	A child in Class IV will need both medical and environmental interventions, including chelation therapy.
V	$\geqslant$ 70	A child with Class V lead poisoning is a medical emergency. Medical and environmental management must begin immediately.

In addition to the table, key points are as follows:

- The single action value for blood lead of 25 μg/dl to be replaced by a multitiered approach oriented to several blood lead level steps,
- A combination of community-wide, primary prevention and high risk approaches is advocated, and
- Resources should be directed according to risk based priorities.

All these features are consistent with the existing Port Pirie Lead Program strategies with the main change being a revision of the blood lead levels that relate to particular actions.

9.4.2 National Health and Medical Research Council (1993)

At its 115th session in June 1993, the Council issued a statement entitled "Lead in Australians: Revisions of the 1987 (103rd Session) Guidelines". A summary of the blood lead guidelines is provided below along with the table of recommended public health and individual responses for various blood lead levels.

ACTION GUIDELINES TABLE

Managing the Health Risks of Environmental Lead: Recommended Public Health and Individual Management Responses at Various Blood Lead Levels.

Note: Representative surveys for lead are only called for in communities at higher risk as below.

Recommended responses in relation to communities where representative surveys of blood lead concentrations in children aged 1-4 years show:	Recommended responses in relation to individual children (all ages) with a blood lead concentration of:
>95% below 25μg/dl (1.2 μ mol/L) **>5% above 15μg/dl (0.72 μ mol/L**	**15-24 μg/dl** **(0.72 - 1.16 μ mol/L)**
Investigate lead sources in the affected community.	Personal exposure evaluation and source remediation/abatement.
Develop environmental management plans with effective strategies for community involvement in design and implementation.	Personal education and counselling on exposure control for guardian(s) and child, as indicated.

Plan to particularly target sub-sections in the community showing blood lead levels above 15μg/dl (0.72 μ mol/L).	Repeat test as appropriate in individual circumstances to assess effectiveness of actions taken.
Plan to include specifically prepared community education programs and a time-frame for on-going re-assessment of community blood levels.	
>5% above 25 μg/dl (1.2 μ mol/L)	**≥25 μg/dl (1.20 μ mol/L)**
As above but on a more intensive and broader community basis.	Detailed medical history and examination with particular focus on possible adverse effects based on exposure history and blood lead level.
Consideration of earlier re-assessment of community blood lead levels.	Personal exposure evaluation, including environmental sampling as indicated.
	Remediation/abatement of exposure source. Personal education and counselling on exposure control for guardian(s) and child, as indicated. If exposure control not possible, consider relocation.
	Re-test in about 3 months to assess the effectiveness of actions taken.
	≥55 μg/dl (2.65 μ mol/L) As above for >25 μg/dl.
	Urgent clinical assessment regarding immediate medical management.

Footnotes:

(1) The need for and extent (eg age range, geographic area) of community surveys should be assessed by health authorities on the basis of known risk factors for lead exposure.

(2) In community based surveys, protocols for the follow-up of children identified as requiring individual management should be established.

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(1) A goal of less than 10μg/dl was recommended for all Australians with particular urgency for children aged 1-4 years.

(2) The setting of a target date was deferred until the 116th Session (November, 1993).

(3) The setting of a 'level of concern' was no longer considered an appropriate way of dealing with this complex issue and should be replaced with a range of graduated responses.

(4) Public health action should be taken as detailed in the table where representative community surveys showed more than 5% of children aged 1-4 years with a blood lead level above 15μg/dl.

(5) Depending on blood lead concentrations and commencing at 15μg/dl, a range of graduated responses in relation to individual children should be taken as detailed in the table.

9.5 IMPLICATIONS FOR THE PORT PIRIE LEAD IMPLEMENTATION PROGRAM

Both of the new NH&MRC and U.S.CDC sets of guidelines herald an increased concern for blood lead levels below the old level of concern (25μg/dl) which has formed the basis of the current Program. The action responses suggested need to be considered and incorporated into any future Program.

9.5.1 Lower Risk Children (Less than 15μg/dl)

The following discussion relates to children with blood lead levels below 15 μg/dl.

(1) *Screening*

The US CDC guidelines recommend:

- Universal screening of pre-school age children at both 12 and 24 months of age, except where adequate screening shows that the area is at low risk,

- Re-testing of all those between 10 and 14 μg/dl after a further 3 months have elapsed,

- The use of demographic information combined with blood lead results and environmental lead results to predict the highest risk areas, and

- The use of a door-to-door blood testing method combined with a rapid inspection of household lead sources and a parent questionnaire concerning sources of lead and children's behaviours.

The main implications for Port Pirie would seem to be the increasing focus on preschool aged children and the recruitment/organisation changes required to make that possible, the possible introduction of a parent questionnaire, the need to re-test a much larger group (all those between 10 and 14 μg/dl) within a fixed time interval, whether voluntary testing can be retained, and the resources required for an increased screening effort. It should be possible to refine the screening effort to exclude geographic areas at low risk based on the extensive data available on blood leads that already exist.

The NH&MRC guidelines recommend screening of only those communities shown to be at higher lead exposure on the basis of representative surveys or the presence of known exposure risk factors. There are no new implications for Port Pirie.

(2) *Hazard abatement*

The CDC guidelines strongly advocate greater emphasis on community-wide hazard abatement (primary prevention) as the level of acceptable blood lead is lowered. It advocates that public health agencies should proceed on the basis of a community based risk assessment including steps such as :

- An environmental survey to assess community sources,
- Assess exposure patterns,
- Assess high risk populations in combination with blood lead results,
- Combine blood, environmental, housing, and demographic data to define high risk geographic areas,
- Prepare a primary prevention plan which targets resources to the most pervasive sources and the highest risk populations, and
- Co-ordinate and enlist other public agencies in the abatement effort. CDC note that at these blood lead levels it is unlikely that a single predominant source of exposure exists and hence a prioritised, multi-source approach which targets high risk neighbourhoods and high risk homes and systematically eliminates the lead hazard will be required.

Most of these issues are already included within the Port Pirie Program although it is likely that an augmented community-wide lead abatement effort will be required that focuses on all sources and pathways but gives priority to the major contributors to elevated blood lead amongst young children. Unlike the CDC guidelines which focus on leaded paint, the focus of additional effort in Port Pirie is likely to be on circulating leaded dust.

There are no new implications for Port Pirie from the NH&MRC guidelines except the benefits of the national accelerated reduction of lead in petrol.

(3) *Community-wide education*

The CDC guidelines put major emphasis on the community-wide education process to control blood lead levels in this range. Key features include the following:

- Nutrition education programs, and

- Education programs for parents to assist them in abating lead contamination in their household and assisting children to avoid contact with lead sources. This education effort is at a community level but uses a variety of strategies including face to face contact, mass media, brochures, and other forms of interaction. The strategy advocates the involvement of a large range of agents particularly health care workers, schools, day care providers, small and large businesses, sporting and recreational institutions, contractors and others engaged in a lead abatement program.

Much of this already exists within the Port Pirie Program although the main implications are probably for an enhanced nutrition education program and perhaps the enrolment of additional agents and strategies in the community education program.

The NH&MRC recommended Australia-wide education program for the general community and health professionals may benefit Port Pirie.

(4) *Identifying high risk areas*

Given the need for the CDC guidelines to address the whole of the United States, it is not surprising that they see great need to effectively combine data on different factors in an attempt to define priority target areas. This issue has already been discussed within the screening section.

The main implication for Port Pirie might be whether maximum advantage is being taken from combining the data bases that we have on blood lead levels, demographic factors, and environmental lead levels to pin point the most important target areas and give them some relevant priority. To date our geographic definitions have been fairly broad.

There are no new implications for Port Pirie from the NH&MRC guidelines regarding this strategy.

9.4.2 Higher Risk Children (above 15μg/dl)

(1) *Trigger for individual child approach*

The CDC guidelines advocate a change in the blood lead level requiring an individual case approach (high risk) from the current 25 μg/dl to a new threshold of 15 μg/dl after 2 consecutive tests 3 to 4 months apart.

The main implication for Port Pirie will be the significantly enlarged number of children that will fall within the high risk case approach and the consequent need for increased resources. It is probable that under this new criterion, children from a significant area of the City could not be expected to achieve blood lead levels below 15 μg/dl using current Program strategies.

The NH&MRC guidelines do not recommend confirmatory blood tests of all children found to exceed 15μg/dl on a screening test.

(2) *Screening and blood lead measurement*

In addition to the strategies outlined under the low risk section, the CDC guidelines proposed the following:

- Repeat capillary blood leads in 3 months for all those between 15 and 19 μg/dl,

- Confirm with venous blood lead all those at or above 20 μg/dl and a repeat test every 3-4 months,

- Combine the blood screening with detailed environmental and behavioural history from parents by way of a questionnaire, and

- Evaluate interventions using blood lead measurements.

The main implications for Port Pirie would be a greater load of repeat testing, increased venous testing and a greater number of cases for individual follow-up.

The NH&MRC guidelines recommend repeat tests as appropriate in individual circumstances and a retest after about 3 months to assess the effectiveness of actions taken in the case of children above 25μg/dl. There are no other new implications for the Port Pirie Program.

(3) *Home inspection and abatement*

The CDC guidelines emphasis the need for greater emphasis on hazard abatement as the level of concern is lowered. The strategy proposes the following measures.

- Individual home inspection and abatement for those cases with confirmed blood lead of between 15-19 μg/dl, if resources permit.
- For those at or greater than 20 μg/dl, individuals require emergency measures to reduce exposure, long term hazard abatement, and inspection and testing post-abatement before children return home.
- Communicating the inspection findings with householders.
- The need to broaden the inspection and abatement action to the wider environment of the child including for example preschool, school yards, non residential buildings and so on.
- That individual homes/children be prioritised according to the highest risk, and with those addressed first. Urgent abatement measures are required for those at least above 20 μg/dl.
- The CDC guidelines recognise the predominance of leaded paint as the ongoing source of lead hazard in the USA. Both complete lead paint abatement and incomplete abatements (which eliminates the worst hazards and uses preventive maintenance to prevent near term exposures) are suggested within the framework of the new US Department of Housing and Urban Development Guidelines.

- The US Department of Housing and Urban Development Guidelines also specify post-abatement dust standards as a guide for allowing high risk children to return to their homes. Maximum levels of lead in dust have been set for floors (200 μg/square ft), window seals (500 μg/square ft), and window wells (800 μg/square ft).
- Interim guidance by the US EPA for residential soil recommends that clean-up should attain soil concentrations of between 500 to 1000 mg/kg.
- The CDC guidelines recommend time frame limits for environmental investigation and intervention for children of different levels of blood lead. For those between 20 and 44μg/dl a limit of 10 working days is suggested. Those between 15 and 19μg/dl should receive attention depending upon program resources and the ability of program staff to respond.
- Attention is directed to those issues related to the management of the abatement process: testing materials and methods, proper training of all workers, protection of all workers in the abatement area, containment of all lead bearing dust and debris, final clean up of the abatement area including vacuuming, disposal of abatement debris so as not to contaminate another environment, final inspection and retesting to make sure the property is fit for rehabilitation, and the need for regulations and standards to guide abatement strategies and assessment.

The reduction in threshold for individual case management has significant implications for the Port Pirie Program:

- Increased numbers of at risk children will put pressure on resources,
- The introduction of time frames in which abatement must be commenced will mean more children come within this time limited intervention requirement,
- The extent of abatement on individual environments may need to be increased. For example, complete abatement of leaded paint in those dwellings previously dealt with by preventive maintenance, and internal decontamination of those houses in the Stage I grids,

- The possible introduction of post-abatement dust standards,
- An adequate training and supply of environmental investigators/assessors,
- Adequate skills and supply of abatement planning and trades personnel,
- Assessment methods,
- Adequate containment of abatement dust and other debris,
- Adequacy of final clean up and inspection/retesting, and
- Development of more stringent standards and codes of practice to guide decontamination.

The NH&MRC guidelines also recommend personal exposure evaluation, source abatement and counselling on exposure control for all children about 15μg/dl. In addition, NH&MRC recommends consideration of relocation in the case of children above 25μg/dl where exposure control is not possible. Unlike the CDC guidelines, the NH&MRC does not specify time limits for exposure control based on blood lead levels or recommend that children with the highest blood lead levels be given priority regarding public resources and urgency of intervention.

As discussed above, the main implication for Port Pirie will be the greatly increased number of children requiring individual intervention and the inadequacy of current resources and strategies for achieving the new target given the current level of lead contamination and source control.

(4) *Individual case education*

The Port Pirie Program has given considerable attention to individual case support and education, including advice on nutrition strategies, to limit lead uptake. The main implication for the future will probably be the greatly increased numbers that come with the individual case approach and perhaps the need to give nutrition strategies greater prominence in the future.

(5) *Medical evaluation*

The CDC guidelines require automatic clinical diagnostic evaluation and medical management of all children with a venous blood confirmed level of 20 or more μg/dl. The evaluation should include a detailed environmental and behavioural history of the child and its family, careful clinical assessment, laboratory assessment of iron deficiency and iron status, x-ray examination of the abdomen and some of the long bones, and regular surveillance with venous blood lead estimations. Intervention may include provocative lead mobilisation tests and maintenance of an adequate calcium intake. As a first priority, medical attendants are directed to take an active involvement in ensuring that urgent environmental assessment and abatement takes place to rapidly diminish exposure of the child.

The increased emphasis on medical involvement is clearly a major departure from existing practices in Port Pirie. Major questions need to be considered and resolved.

- Who does the medical evaluations and where?
- Who does the medical interventions and at what level does hospitalisation and other measures occur?
- The costs of clinical work up.
- The value and organisation of the laboratory and x-ray examinations.
- The level of interest amongst local general practitioners and strategies for defining appropriate guidelines and equipping them for their more active role in the Program.

The NH&MRC guidelines also recommend medical evaluation for children above 25μg/dl without specifying a confirmatory venous blood sample or the laboratory and x-ray examinations required. It is generally agreed that 40μg/dl represents the level where there might be some benefit from medical evaluation.

(6) *Infrastructure development*

The bulk of CDC recommendations in this area are already part of or at least considered by the Port Pirie Program. Other issues such as codes of practice for abatement, disposal of abatement debris, have already been mentioned. An adequate training and supply of inspectorial and trades people has also been mentioned. Perhaps an outstanding issue, given the need to achieve much more substantial reductions in blood lead amongst some of the high risk individual children, is the need for decontaminated safe houses available to the Program and other approaches for relocation to a lead free environment during abatement.

9.4.3 Children With Blood Lead at or above 45 μg/dl (US CDC), at or above 55 μg/dl (NH&MRC)

The CDC guidelines provide extensive direction on the management of this group of children. Those who are asymptomatic require urgent reduction in lead exposure, possible oral chelation with Succimer, and urgent relocation to a lead free environment including, at times, hospital. Those with symptomatic lead poisoning in this group require urgent admission to a paediatric centre and chelation therapy.

Similarly, the NH&MRC recommends urgent clinical assessment regarding immediate medical management for children with a blood lead at or above 55μg/dl.

There may be a requirement to discuss management options with Adelaide Children's Hospital consultants and other health care providers to make the Program guidelines more explicit in the management of these categories of children.

10. PROGRAM ISSUES AND FUTURE DIRECTIONS

As noted in Section 7.2, the 1983 Task Force was of the opinion that smelter emissions were acceptably low and that the historical lead sink around the City provided the substantial source of lead for the contamination of children's homes.

The Program proposed a combination of changing the environment and changing behaviour. The environment component envisaged systematic decontamination of:

- The interior of houses,
- The ceilings of houses,
- The exterior of the houses, sheds, outhouses and fences,
- The gardens surrounding the house,
- The roads, streets and footpaths,
- The parks, racecourse and other public areas,
- Public access buildings, shops and factories and their surrounding area,
- The schools,
- Vacant blocks and undeveloped areas of the City, and
- Areas surrounding the City which may be contaminated by lead.

The relocation of all affected households was not deemed to be an acceptable option.

The Task Force recognised that the success of the environmental decontamination strategy depended on the levels of lead emissions from the smelter being such that recontamination would not be significant. Likewise, a high compliance rate with decontamination of all areas was seen as necessary to prevent recontamination.

A Program, as suggested by the Task Force, has been successfully implemented and substantial reductions in children's blood lead achieved. Nevertheless, investigations supported by the Program suggest that some of the Task Force's conclusions need to be reconsidered as the future of the Program is contemplated, namely:

- That recontamination of houses can be controlled by the strategies advocated, and

- The lead emissions from the smelter (or its vicinity) are acceptably low.

It also appears that vacant and undeveloped areas of the City to the northwest, north and northeast, subject to uninterrupted wind currents and thereby re-entrainment of historical lead, may also be acting as uncontrolled sources of re-contamination.

The pattern that emerges from overseas smelter studies, is that while initial reductions can be achieved through decontamination programs, their success is limited by the ongoing pollution from the smelters. Relocation of families away from the source of pollution is indicated as being the most successful measure to reduce blood lead levels, apart from closure of the smelter. It should be acknowledged, however, that most of the overseas communities studied lived closer to the smelter and were subject to higher air lead concentrations than pertain in Port Pirie. Likewise in a review of the United States paint abatement programs, Farfel (1985) concluded that partial abatement was inadequate to reduce or sustain blood lead levels within the acceptable range ($<25\mu g/dl$). Relocation to a house free of lead paint was the most successful measure.

10.1 FUTURE REDUCTIONS REQUIRED

10.1.1 Future Reductions of Blood Lead Required

In attempting to quantify the extent of future reductions in blood lead required, this Section will consider both the proportion of children above target blood lead levels as well as average or mean levels.

(1) *Proportion of children above future target options*

(a) Current target: 95% of children 0-7 years less than 25 $\mu g/dl$.

Based on children presented for testing, results in Table 6.5 indicate that the current target has been reached in some recent cycles.

(b) Target 3: 95% of children aged 1-4 years in the high risk areas less than 25 μg/dl.

A deficiency with the current target allows it to be met only by combining all Port Pirie children across all ages up to 7 years. At the same time it allows a much higher proportion of children at the higher risk ages and living in higher risk areas to exceed the 25 μg/dl target.

Across the City about 13% (1992) of children aged 1-4 years exceed the target (Table 10.1) compared with 4 % (1992) of children aged 5-7 years (Table 10.2). In different risk areas (Table 10.1, Figure 10.1), up to 60% of 1-4 year olds continue to exceed the target.

Hence the target should more appropriately be specified in terms of age specific and area specific criteria.

(c) Target 4: 95% of children aged 1-4 years in the high risk areas less than 20 μg/dl.

Currently (1992), 28% of children aged 1-4 years across the City exceed this target (Table 10.1) compared with 12% of 5-7 year olds (Table 10.2).

Within the high risk areas this proportion exceeds 70% (1992). Even within the low risk areas, few parts of the City would approach this target except perhaps Risdon Park.

(d) Target 5: 95% of children aged 1-4 years in the high risk areas less than 15 μg/dl.

Currently(1992), 58% of children aged 1-4 years across the City exceeded this target with a further 33% of 5-7 year olds (Table 10.2).

Within the high risk areas, the vast majority of 1-4 year old children were at or above 15 μg/dl. Even the lowest risk area (Risdon Park) had 30% of children exceeding the target.

Amongst the 5-7 year olds, at least 40% in the high risk areas and at least 10% in the lowest risk areas exceeded the target.

(2) *Number of children above future target options.*

Based on the use of targets which specify proportions of children, it is perhaps tempting to focus on the actual numbers of children exceeding targets as a way of quantifying the future workload and budget of the Program.

By this approach, without correcting for actual numbers of children resident as against numbers tested, one might conclude that the uncorrected numbers of children involved might be around 100 for the 25 μg/dl target, 250 for the 20 μg/dl target and 550 for the 15 μg/dl target.

Indeed, during the current Program resources have been directed at children with the highest blood levels as a priority. This high risk approach has seen the systematic decontamination of all houses in the high risk areas, and along with other strategies, has contributed to substantial reductions in blood lead levels.

Figure 10.1 Grid Regions of Port Pirie according to Residential Risk Area and Grid Co-ordinates

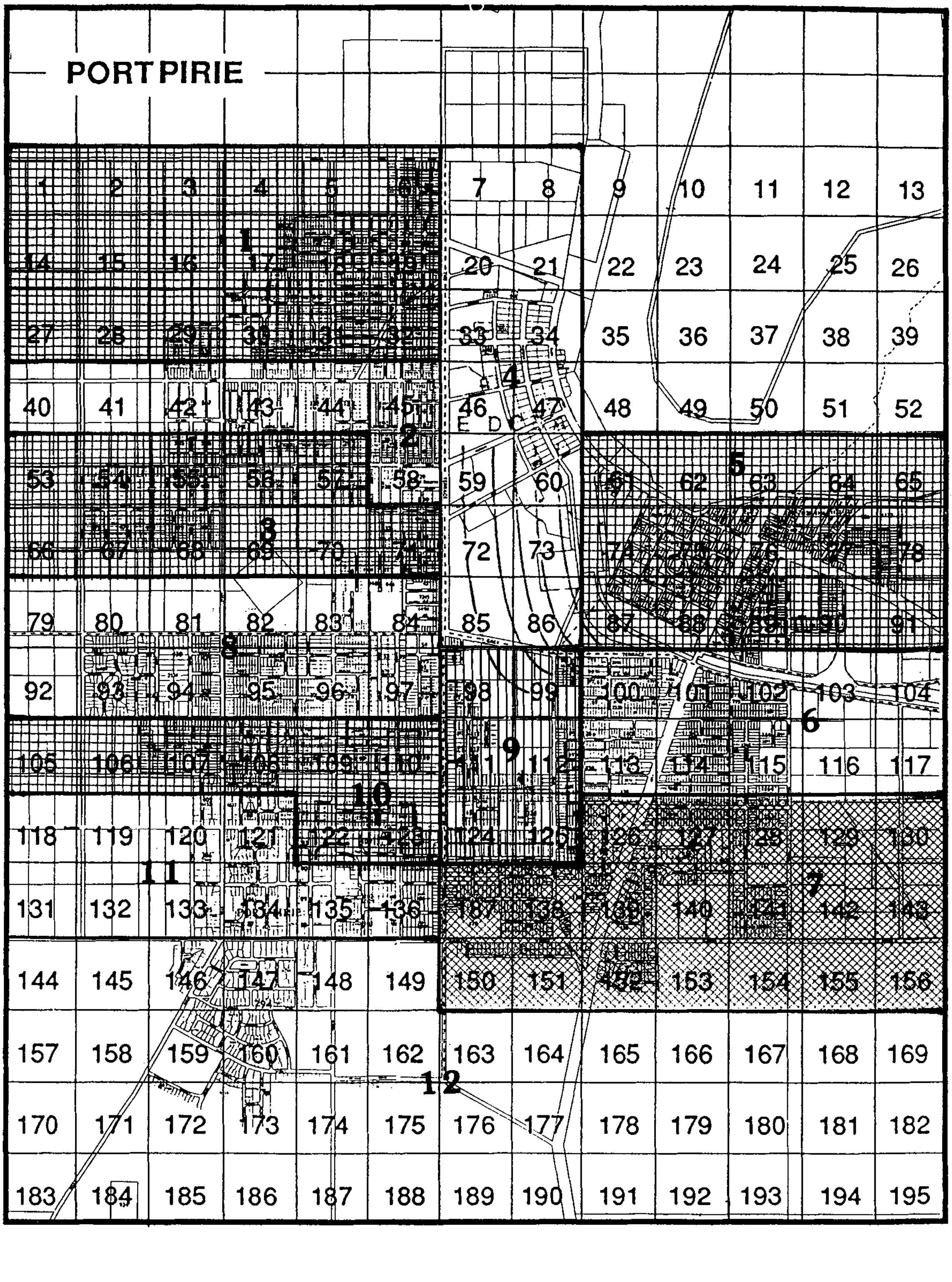


Table 10.1 Number and Proportion (%) of Children 1-4 years Above Target Blood Lead (µg/dl) for Each Region at 1992. (Cycles 15 & 16 combined and includes Cohort Study children)

Region	Number	⩾10µg/dl		⩾15µg/dl		⩾20µg/dl		⩾25µg/dl	
		Percent	Number	Percent	Number	Percent	Number	Percent	Number
1	41	98%	40	95%	39	76%	31	41%	17
2	55	96%	53	76%	42	36%	20	16%	9
3	58	91%	53	64%	37	31%	18	14%	8
4	10	100%	10	90%	9	70%	7	60%	6
5	57	96%	55	79%	45	46%	26	18%	10
6	73	96%	70	79%	58	38%	28	21%	15
7	50	88%	44	54%	27	22%	11	10%	5
8	55	82%	45	45%	25	25%	14	7%	4
9	46	80%	37	41%	19	11%	5	4%	2
10	54	70%	38	35%	19	9%	5	6%	3
11	47	72%	34	34%	16	15%	7	6%	3
12	80	75%	60	30%	24	8%	6	3%	2
Total	626	86%	539	58%	360	28%	178	13%	84

Table 10.2 Number and Proportion (%) of Children 5-7 years Above Target Blood Lead (µg/dl) for Each Region at 1992 (Cycles 15 & 16 combined and includes Cohort children).

Region	Number	≥10µg/dl		≥15µg/dl		≥20µg/dl		≥25µg/dl	
		Percent	Number	Percent	Number	Percent	Number	Percent	Number
1	37	92%	34	65%	24	38%	14	11%	4
2	48	92%	44	56%	27	25%	12	8%	4
3	33	82%	27	42%	14	9%	3	3%	1
4	11	100%	11	45%	5	18%	2	18%	2
5	27	96%	26	59%	16	22%	6	4%	1
6	47	87%	41	49%	23	15%	7	2%	1
7	52	67%	35	19%	10	6%	3	0%	0
8	47	70%	33	34%	16	15%	7	4%	2
9	25	52%	13	20%	5	0%	0	0%	0
10	64	50%	32	13%	8	3%	2	0%	0
11	57	70%	40	19%	11	4%	2	4%	2
12	80	50%	40	16%	13	4%	3	3%	2
Total	528	71%	376	33%	172	12%	61	4%	19

Despite the focus on high risk areas, the community awareness and lead education strategies, along with efforts by parents, has contributed to substantial reductions in the blood lead levels of children in the low risk areas. It is clear from Table 10.3 and Figure 10.2 that blood lead levels across the spectrum have systematically declined, more or less in parallel. There is little evidence from these figures that the children with higher blood lead levels have declined more than those with lower blood lead levels despite the bulk of resources being directed at a high risk approach. Rather, it would appear that the same distribution of values has been retained, presumably reflecting the range of exposures that exists across the child population, at each successive reduction in blood lead levels.

Table 10. 3. Geometric Mean and Percentile Distribution of Blood Lead Levels (μg/dl) in 1984, 1988, and 1992.

Age 0-7 years

Year	Number	Geo. Mean	Percentile										
			5	10	20	30	40	50	60	70	80	90	95
1984-85	808	19.5	10	12	14	16	18	20	22	25	27	32	36
1988	1111	16.1	8	9	11	13	15	16	18	20	23	27	32
1992	1250	13.1	6	7	9	10	12	13	15	17	19	23	27

Age 1-4 years

Year	Number	Geo. Mean	Percentile										
			5	10	20	30	40	50	60	70	80	90	95
1984-85	376	22.4	11	14	17	19	21	23	26	28	31	34	38
1988	570	17.3	8	10	12	14	16	18	20	23	25	30	34
1992	626	15.0	7	8	10	12	14	15	17	19	22	25	30

10.1.2 Further Reductions in Mean Blood Lead Levels Required

Table 10.4 presents the reductions in mean (average) blood lead levels achieved to date amongst 1-4 year olds for each of the regions of Port Pirie. Both the absolute and percentage reductions have been substantial in all regions although the high risk areas commenced with higher level and continue to retain that margin over low risk areas, particularly northern Port Pirie West and the central business district.

These relative blood lead levels across regions have persisted despite the deployment of the bulk of Program effort in the high risk areas.

As noted in Chapter 6, there are clear variations between cycles, particularly in areas nearest the smelter, with higher values in the odd number cycles which correspond to the January to June half of the year.

It is also apparent, after taking into account the variations between cycles, that reductions over the last 2½ years (5 cycles) have been rather modest.

Similar general results are also evident amongst 5-7 year old children although blood lead levels are generally several μg/dl lower (Table 10.5) than amongst 1-4 year olds.

Using the distribution of blood lead levels amongst Port Pirie children (Figure 10.2 and Table 10.3), the mean blood lead values that would correspond with the different target options was calculated.

5% at or above 25 μg/dl $\equiv$ mean 10.6 μg/dl
5% at or above 20 μg/dl $\equiv$ mean 8.4 μg/dl
5% at or above 15 μg/dl $\equiv$ mean 6.3 μg/dl

Table 10.6 presents the reduction in mean blood lead, the percentage reduction achieved to date, and the percentage reduction required for each of the target options for the 12 different risk regions in the City. Clearly, substantial reductions are still required in the high risk areas even for the modified current target (goal option 3). For even lower blood lead targets, the area of the City involved increases dramatically making a Program that focuses on the high risk areas quite inappropriate unless accompanied with equally dramatic control of environmental and household lead sources.

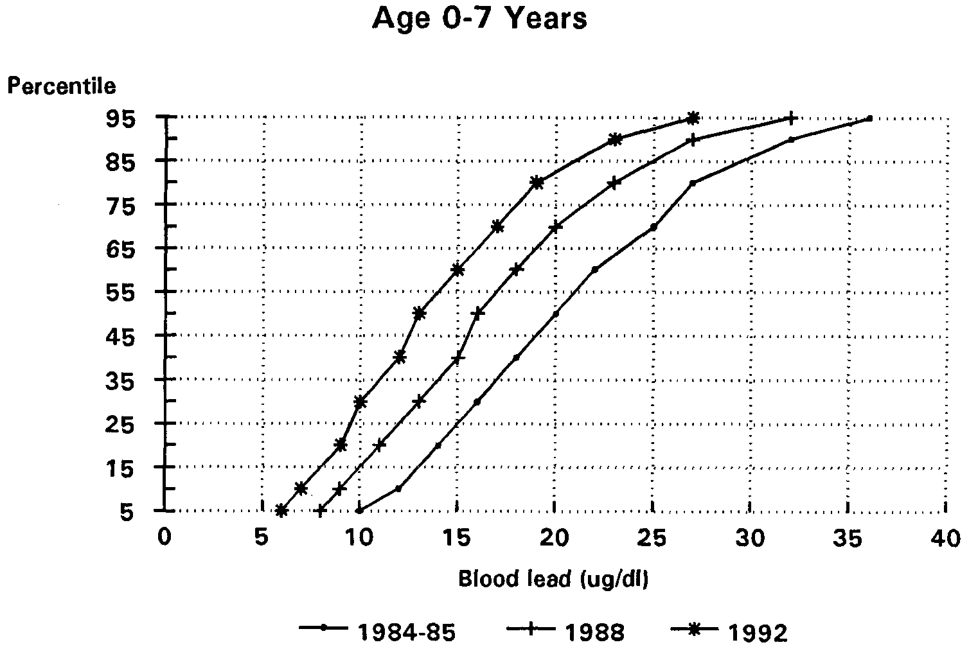
Table 10.4 Blood Lead Levels (μg/dl) of Children 1-4 years by Residential Regions (Includes Cohort Study Children). Geometric Mean (Number of Children).

	Region												
Cycle	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1	25.6(35)	26.6(41)	22.9(16)	29.3(7)	27.0(36)	22.5(43)	18.7(32)	20.2(19)	20.8(34)	21.1(39)	20.2(23)	19.8(51)	22.4(376)
2	24.9(29)	22.2(38)	20.7(15)	27.5(6)	25.8(28)	22.1(30)	19.1(28)	19.7(9)	17.1(16)	19.0(30)	16.8(25)	18.3(41)	20.7(295)
3	22.4(36)	21.0(57)	18.7(19)	24.5(8)	23.6(39)	21.9(46)	16.4(41)	16.9(27)	15.7(28)	17.6(36)	15.1(33)	15.2(58)	18.5(428)
4	19.9(38)	19.1(49)	18.4(29)	19.0(8)	21.2(41)	18.8(59)	15.5(38)	16.5(34)	13.4(24)	15.9(36)	14.6(31)	14.5(51)	17.1(438)
5	22.1(45)	20.6(60)	19.7(26)	23.0(13)	20.8(40)	19.8(67)	17.8(53)	16.6(37)	17.0(26)	15.8(41)	13.6(35)	14.8(54)	18.2(497)
6	21.8(42)	23.0(48)	16.6(21)	21.6(15)	21.0(40)	18.9(58)	15.9(53)	17.3(36)	16.3(27)	15.0(36)	14.8(24)	14.2(43)	18.0(443)
7	23.3(50)	23.2(50)	17.3(27)	20.2(17)	24.3(36)	18.5(53)	14.7(59)	15.4(43)	14.6(29)	14.4(38)	13.3(26)	12.2(47)	17.3(475)
8	22.6(45)	22.0(49)	17.3(30)	18.5(14)	22.3(39)	18.3(55)	14.9(50)	16.1(36)	15.5(23)	14.9(35)	17.3(18)	14.4(36)	17.8(430)
9	23.9(42)	22.3(43)	18.6(30)	19.9(10)	20.7(29)	21.0(35)	18.3(34)	15.5(29)	17.8(12)	15.4(15)	14.3(9)	12.0(14)	19.1(302)
10	20.1(41)	20.4(57)	16.2(26)	19.1(11)	22.2(26)	19.3(54)	15.3(50)	16.4(50)	12.6(28)	12.5(38)	13.4(25)	13.1(29)	16.6(435)
11	21.8(43)	20.0(56)	16.2(41)	17.3(12)	20.8(32)	19.1(61)	13.2(51)	14.8(49)	11.9(32)	13.6(42)	12.9(24)	12.7(44)	16.1(487)
12	20.3(33)	15.7(53)	15.3(33)	15.3(12)	17.5(44)	17.2(56)	11.5(46)	14.0(42)	11.3(28)	12.0(43)	12.5(29)	11.6(54)	14.3(473)
13	20.1(38)	18.0(57)	16.2(32)	20.5(12)	18.4(43)	17.2(54)	12.2(44)	13.6(41)	12.3(33)	13.0(44)	12.2(34)	11.9(57)	14.9(489)
14	19.2(43)	15.7(45)	16.2(33)	22.1(8)	18.2(39)	17.6(45)	13.6(40)	12.2(28)	12.3(30)	12.4(33)	14.2(32)	11.0(52)	14.7(428)
15	24.5(34)	18.1(45)	17.0(44)	25.1(7)	18.2(46)	18.3(54)	14.5(42)	13.6(39)	13.0(35)	12.8(37)	12.2(32)	11.9(52)	15.6(467)
16	19.0(27)	16.3(39)	14.8(41)	20.8(9)	16.8(45)	16.2(64)	13.2(30)	13.5(45)	12.8(37)	11.7(45)	12.2(33)	12.4(59)	14.3(474)
Change (%)	↓6.6 (26%)	↓10.3 (39%)	↓8.1 (35%)	↓8.5 (29%)	↓10.2 (38%)	↓6.3 (28%)	↓5.5 (29%)	↓6.7 (33%)	↓8 (39%)	↓9.4 (45%)	↓8 (40%)	↓7.4 (37%)	↓8.1 (36%)

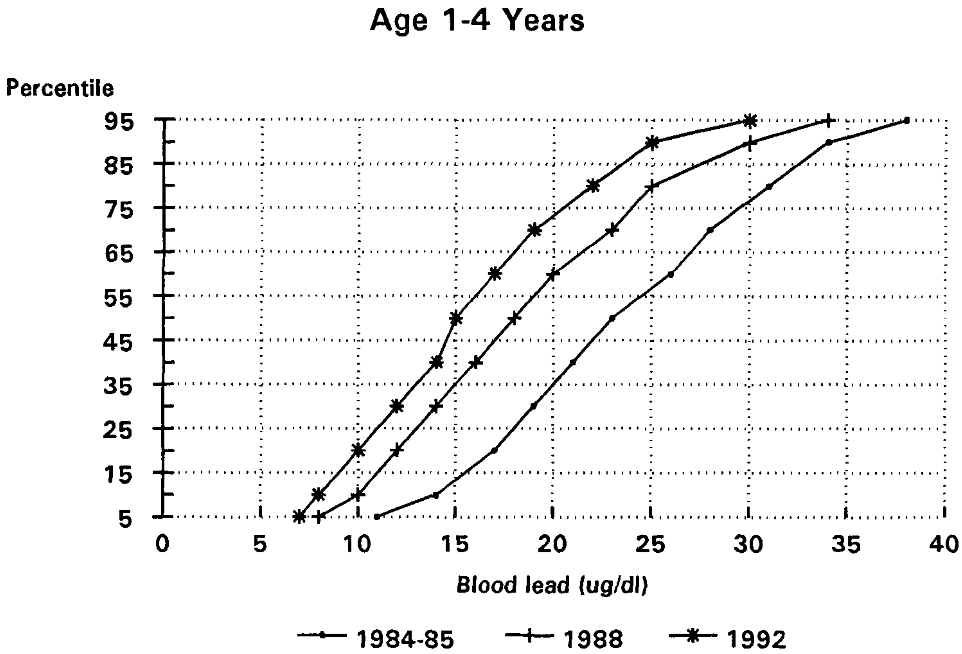
Table 10.5 Blood Lead Levels (µg/dl) of Children 5-7 years by Residential Regions (Includes Cohort Study Children). Geometric Mean (Number of Children).

	Region												
Cycle	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1	20.1(29)	21.5(29)	21.0(15)	22.2(10)	22.3(22)	20.8(36)	16.0(41)	16.6(46)	15.7(34)	17.0(30)	15.4(41)	15.6(61)	17.6(394)
2	17.1(30)	20.9(31)	16.9(14)	21.1(8)	20.7(25)	16.6(42)	13.5(29)	15.8(38)	13.7(26)	14.7(19)	15.2(29)	13.7(56)	16.0(347)
3	17.4(33)	21.6(30)	18.1(13)	22.6(8)	22.2(33)	17.9(37)	14.5(29)	15.7(32)	14.3(27)	13.9(28)	14.3(25)	13.7(54)	16.4(349)
4	17.3(34)	19.8(41)	15.6(18)	17.9(7)	18.8(35)	15.6(39)	13.1(27)	15.4(27)	14.5(25)	13.5(27)	12.4(27)	12.3(43)	15.3(350)
5	18.6(33)	19.0(40)	17.3(23)	17.2(9)	20.3(31)	17.0(31)	13.8(25)	14.5(25)	17.0(23)	14.4(36)	13.0(27)	14.0(53)	16.1(356)
6	17.0(25)	17.8(36)	16.4(22)	11.0(1)	23.3(26)	17.7(22)	14.4(31)	14.7(21)	14.3(33)	13.0(35)	13.6(27)	14.3(40)	15.6(319)
7	17.4(24)	17.3(40)	16.5(29)	28.3(4)	21.5(31)	17.0(29)	13.5(36)	14.9(19)	12.9(24)	12.5(38)	12.9(30)	13.7(53)	15.2(357)
8	18.4(23)	16.5(28)	16.2(20)	21.0(7)	21.9(34)	19.3(32)	13.9(43)	12.9(22)	13.3(26)	12.5(35)	11.9(30)	12.7(52)	15.0(352)
9	18.4(16)	18.7(22)	16.8(12)	22.6(3)	20.8(22)	16.8(15)	15.4(11)	11.1(16)	11.5(11)	11.3(21)	10.5(14)	10.7(25)	14.4(188)
10	17.8(31)	15.0(34)	15.4(21)	18.9(11)	19.4(33)	16.9(39)	13.3(49)	13.6(36)	11.6(28)	11.5(37)	11.6(27)	12.0(55)	14.2(401)
11	16.6(33)	16.4(45)	15.1(27)	18.7(10)	16.3(40)	14.7(43)	10.5(49)	12.4(47)	10.4(24)	11.0(35)	10.5(30)	10.8(60)	12.9(443)
12	15.5(32)	13.3(39)	12.0(25)	12.7(10)	14.6(33)	13.8(43)	10.3(46)	10.9(36)	8.8(24)	9.7(41)	10.3(33)	9.6(59)	11.5(421)
13	17.1(24)	16.7(39)	14.5(29)	16.3(11)	14.5(26)	14.1(44)	10.6(46)	10.7(32)	10.5(30)	10.3(46)	10.3(24)	9.9(62)	12.2(413)
14	15.5(20)	15.7(34)	12.2(30)	14.9(9)	15.3(32)	14.4(42)	10.4(41)	10.9(38)	8.4(22)	9.9(51)	11.6(20)	9.3(57)	11.7(396)
15	17.9(27)	15.2(37)	12.7(26)	15.8(10)	15.8(23)	13.6(38)	9.9(46)	10.9(40)	9.8(20)	9.4(54)	10.5(46)	9.9(64)	11.6(431)
16	14.5(33)	14.0(36)	12.9(31)	13.9(8)	14.9(23)	14.6(42)	11.1(50)	11.2(33)	10.0(25)	10.4(51)	11.0(38)	9.5(66)	11.8(436)
Change (%)	↓5.6 (28%)	↓7.5 (35%)	↓8.1 (39%)	↓8.3 (37%)	↓7.4 (33%)	↓6.2 (30%)	↓4.9 (31%)	↓5.4 (33%)	↓5.7 (36%)	↓6.6 (39%)	↓4.4 (29%)	↓6.1 (39%)	↓5.8 (33%)

Figure 10.2 Percentile Distribution of Children's Blood Lead Levels (μg/dl) in 1984-85, 1988 and 1992.



Cycles combined using first test
for each year



Cycles combined using first test
for each year

Table 10.6 Reductions in Mean Blood Lead Levels (µg/dl and percent) Achieved to Date (Cycle 16) and Further Reductions in Mean Levels Required to Meet Target Options, by Areas in Port Pirie (1 4 year olds)

Region	1	2	3	4	5	6	7	8	9	10	11	12	Total
Cycle 1	25.6	26.6	22.9	29.3	27.0	22.5	18.7	20.2	20.8	21.1	20.2	19.8	22.4
Cycle 16	19.0	16.3	14.8	20.8	16.8	16.2	13.2	13.5	12.8	11.7	12.2	12.4	14.3
Reduction (µg/dl)	6.6	10.3	8.1	8.5	10.2	6.3	5.5	6.7	8.0	9.4	8.0	7.4	8.1
%	26	39	35	29	38	28	29	33	39	45	40	37	36
Target 3: 95% less than 25 µg/dl. Equivalent mean = 10.6 µg/dl													
Further Reduction (µg/dl)	8.4	5.7	4.2	10.2	6.2	5.6	2.6	2.9	2.2	1.1	1.6	1.8	3.7
%	44	35	28	49	37	35	20	21	17	9	13	15	26
Target 4: 95% less than 20 µg/dl. Equivalent mean = 8.4 µg/dl													
Further Reduction (µg/dl)	10.6	7.9	6.4	12.4	8.4	7.8	4.8	5.1	4.4	3.3	3.8	4.0	5.9
%	56	48	43	60	50	48	36	38	34	28	31	32	41
Target 5: 95% less than 15 µg/dl. Equivalent mean = 6.3 µg/dl													
Further Reduction (µg/dl)	12.7	10.0	8.5	14.5	10.5	9.9	6.9	7.2	6.5	5.4	5.9	6.1	8.0
%	67	61	57	70	63	61	52	53	51	46	48	49	56

10.1.3 Future Reductions in Lead Intake

Over recent years the US Environmental Protection Agency has been developing a model for relating long term exposures to lead from various sources and pathways to blood lead levels in children at various ages (US EPA, 1989). The model has two principal components: the exposure - biological uptake relationships and the uptake - blood lead relationships. The model assumes long term exposure thus giving blood lead levels time to find an equilibrium with body lead burden. It includes a lead contribution from the child's mother prior to birth.

The Agency has attempted to validate the model using actual data from smelter communities with encouraging results although differences of opinion as to its accuracy remain amongst lead experts. Nevertheless, it is the best model available for long term lead exposure and will be explored in this section in attempting to provide a basis for estimating the future reductions in intake required in Port Pirie.

(1) Exposure - uptake relationships

Using data and assumptions for 2 year olds, the following estimates of intakes and biological uptakes (absorption) illustrate the model and will be explored using data from the Port Pirie situation.

(a) Air lead and inhalation

Using two different 3 month average air lead concentrations, the estimates are as follows. In Port Pirie, these air lead levels roughly correspond with the values for high and low risk areas.

		0.5 μ/m³	1.5 μ/m³
(i)	Outdoor air lead (μg/m³)	0.5	1.5
(ii)	Indoor air lead (μg/m³)	0.15	0.45
(iii)	Time spent outdoors (hours/day)	2-4	2-4
(iv)	Time weighted average (μg/m³)	0.18-0.21	0.54-0.63
(v)	Volume of inspired air (m³/day)	4-5	4-5
(vi)	Lead intake from air (μg/m³)	0.7-1.1	2.2-3.2
(vii)	% deposition/absorption in lungs	42	42
(viii)	Total lead uptake from lungs (μg/day)	0.3-0.5	0.9-1.3

(b) Dietary lead (OECD, 1993)

		1984	1990
(i)	Dietary lead consumption(μg/day)	65	26
(ii)	% absorption in gut	42-53	42-53
(iii)	Dietary lead uptake (μg/day)	27-34	11-14

(c) Mains water (Morgan offtake)

		1984	1992
(i)	Water lead (μg/litre)	1-6	1-6
(ii)	Water intake (litres/day)	1	1
(iii)	Water lead intake (μg/day)	1-6	1-6
(iv)	% Absorption in gut	50	50
(v)	Mains water uptake (μg/day)	0.5-3	0.5-3.0

(d) All other sources

Dust provides the predominant source in this group, but intake is difficult to quantify. Research suggests that at age 2 years, children ingest between 80-135 mg of dust/soil each day, absorbing about 25% of the lead contained therein. Given that outside and inside dusts around Port Pirie commonly contain several thousand parts per million of lead, the potential uptake of lead from this source is very substantial.

Likewise, paint chips and chalking paint can provide large lead intakes with their often high concentrations of lead.

Rainwater is the third potentially major source that is difficult to quantify. Lead concentrations can vary widely from around 10μg/L to values twenty or more times that. Even assuming daily intakes of less than 0.5 litres, an intake of 5-30 μg/day (uptake 3-15 μg/day) from this source would not be uncommon amongst children using locally collected rain water.

(2) Uptake - blood lead relationships

Predicted equilibrium blood lead levels from long term uptakes used in the US EPA model appear below in Table 10.7. These estimates include lead transferred from the child's mother (with a blood lead of 4 μg/dl) during pregnancy.

Table 10.7 Predicted Equilibrated Blood Lead Levels (μg/dl) Over Time Among Children with Constant Lead Uptakes.

	Lead Uptake (μg/day)							
Age	10	20	30	40	50	60	70	80
1	3.0	5.9	8.9	11.9	14.8	17.8	20.8	23.8
2	4.9	9.0	13.0	17.1	21.1	24.2	28.3	32.3
3	4.6	8.2	11.9	15.5	19.2	22.0	25.6	29.3
4	4.5	8.2	11.8	15.4	19.0	21.8	25.4	29.0
5	4.4	7.9	11.4	14.9	18.4	21.0	24.5	28.0
6	4.4	7.8	11.3	14.7	18.2	20.7	24.2	27.6
7	4.2	7.4	10.7	13.9	17.2	19.5	22.8	26.0
8	3.4	5.9	8.3	10.8	13.3	14.9	17.4	19.9
9	2.3	4.6	6.9	9.3	11.6	13.9	16.2	18.5
10	2.6	5.2	7.8	10.4	13.0	15.6	18.2	20.8

From this table the different target and mean blood lead options correspond with the following uptakes.

95% less than 25 μg/dl (70 μg/day) ≡ Mean 10.6 μg/dl (20-30 μg/day)
95% less than 20 μg/dl (50-60 μg/day) ≡ Mean 8.4 μg/dl (20 μg/day)
95% less than 15 μg/dl (40 μg/day) ≡ Mean 6.3 μg/dl (10-20 μg/day)

Uptakes are in brackets (μg/day).

Likewise, paint chips and chalking paint can provide large lead intakes with their often high concentrations of lead.

Rainwater is the third potentially major source that is difficult to quantify. Lead concentrations can vary widely from around 10μg/L to values twenty or more times that. Even assuming daily intakes of less than 0.5 litres, an intake of 5-30 μg/day (uptake 3-15 μg/day) from this source would not be uncommon amongst children using locally collected rain water.

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	Lead Uptake (μg/day)							
Age	10	20	30	40	50	60	70	80
1	3.0	5.9	8.9	11.9	14.8	17.8	20.8	23.8
2	4.9	9.0	13.0	17.1	21.1	24.2	28.3	32.3
3	4.6	8.2	11.9	15.5	19.2	22.0	25.6	29.3
4	4.5	8.2	11.8	15.4	19.0	21.8	25.4	29.0
5	4.4	7.9	11.4	14.9	18.4	21.0	24.5	28.0
6	4.4	7.8	11.3	14.7	18.2	20.7	24.2	27.6
7	4.2	7.4	10.7	13.9	17.2	19.5	22.8	26.0
8	3.4	5.9	8.3	10.8	13.3	14.9	17.4	19.9
9	2.3	4.6	6.9	9.3	11.6	13.9	16.2	18.5
10	2.6	5.2	7.8	10.4	13.0	15.6	18.2	20.8

From this table the different target and mean blood lead options correspond with the following uptakes.

95% less than 25 μg/dl (70 μg/day) ≡ Mean 10.6 μg/dl (20-30 μg/day)
95% less than 20 μg/dl (50-60 μg/day) ≡ Mean 8.4 μg/dl (20 μg/day)
95% less than 15 μg/dl (40 μg/day) ≡ Mean 6.3 μg/dl (10-20 μg/day)

Uptakes are in brackets (μg/day).

(3) Future reductions in lead uptakes

Using the blood lead/uptake relationships in Table 10.7 above along with the estimates of background intakes from air, food and water and the percentage absorption estimates to convert intakes into biological uptakes, Table 10.8 provides an estimate of the reduction in uptake achieved over the course of the Program and future reductions required to meet various target options.

Hence, in the high risk areas a total uptake of 70 μg/day in 1984 has declined to 50 μg/day in 1992, with reductions in food lead apparently making a major contribution. Uptakes from the dust/paint/rain water group (all other) appear to have been reduced much less. However, it is within the dust/paint/rainwater category that substantial reductions will be needed if lower targets are to be achieved. While lead in food will potentially decline further with removal of lead from petrol, some uptake from these background sources will remain. Table 10.8 illustrates the profound reductions in environmental lead uptakes that will be required to reach lower blood lead targets.

Table 10.8 can only be used as a rough guide. All components of intake, uptake and predicted blood lead levels are based on crude data and estimates of variable quality. The table does serve, however, to give an approximate quantitative context to the target options under consideration.

Table 10.8 Changes in Lead Uptakes 1984-92 and Future Reductions Required to Meet Mean Blood Lead Targets.

	High Risk Area		Low Risk Area	
1984				
Mean blood lead (μg/dl)		25.8		19.7
Total uptake (μg/day)		70		50
• Food	27-34		27-34	
• Mains water	0.5-3.0		0.5-3.0	
• Air	0.9-1.3		0.3-0.5	
		28.4-38.3		27.8-37.5
• All other uptakes (rainwater, dust, local food) (μg/day)		31.7-41.6		12.5-22.2
1992				
Mean blood lead		19.1		12.0
Total uptake (μg/day)		50		30
• Food	11-14		11-14	
• Mains water	0.5-3.0		0.5-3.0	
• Air	0.9-1.3		0.3-0.5	

	12.4-18.3	11.8-17.5
• All other uptakes	32.7-37.6	12.5-18.2
Uptake reduction: 1984-92 (μg/day)	20	20
% Food contribution	65-100%	65-100%
%Dust and other source contribution	0-35%	0-35%
Target 3 (Mean 10.6 μg/dl ≡ 95% less than 25 μg/dl)		
Total uptake (μg/day)	20-30	20-30
• Background sources (μg/day) (1992)	12.4-18.3	11.8-17.5
• All other sources (μg/day)	1.7-17.6	2.5-18.2
Reduction all other uptakes required (μg/day)	15.1-35.9	0-15.7
Target 4 (Mean 8.4 μg/dl ≡ 95% less than 20 μg/dl)		
Total uptake (μg/day)	20	20
• Background source (μg/day) (1992)	12.4-18.3	11.8-17.5
• All other uptakes (μg/day)	1.7-7.6	2.5-8.2
Reduction all other uptakes required (μg/day)	25.1-35.9	4.3-15.7
Target 5 (Mean 6.3 μg/dl ≡ 95% less than 15 μg/dl)		
Total uptake (μg/day)	10-20	10-20
• Background source(μg/day) (1992)	12.4-18.3	11.8-17.5
• All other uptakes (μg/day)	-8.3 to 7.6	-7.5 to 8.2
Reduction all other uptakes required (μg/day)	25.1-45.9	4.3-25.7

12.2 FACTORS LIMITING FUTURE REDUCTION IN BLOOD LEAD

10.2.1 Characteristics of Children at High Risk

The socio-demographic profile of Port Pirie residents appears to be typical of a small city which is home to a large industrial complex. Residents tend to work in blue collar occupations, they have income levels that tend to be lower than in other areas of South Australia. Unemployment tends to be higher than elsewhere in the State (ABS, 1986).

These characteristics tend to be more pronounced in those areas where exposure to lead is high. This may reflect the lower cost of housing in these ares. It may also be of historical origin in that high risk areas of Pirie West and Solomontown are older areas, both are close to the smelter, and therefore convenient locations for smelter workers to live. There are more immigrants, especially of Southern European extraction, in these high risk areas.

The children most likely to require lead abatement of their homes live in close proximity to the smelter and attend schools and preschools in the high risk area. These families tend to live in older deteriorating houses with features that favour the ingress of lead bearing dusts. Many of these homes were built in the early part of the Century and prior to decontamination, used matchboard linings, and were often covered with lead based paints. Many had "leantos" and were commonly surrounded by bare soil, including vacant blocks, pathways and roads, and were relatively devoid of vegetation. Such conditions favour the re-entrainment and contamination of the interior of the home with lead bearing dusts.

Compared to children living in low risk areas, their families tend to have lower incomes and, by inference, less able to maintain their environments in an optimal state with respect to lead contamination. Similarly, these families are less able to afford measures that could mitigate against lead exposure

It has been said that such families consider the issue of lead contamination of relatively low priority given their pre-occupation with "day-to-day" concerns.

10.2.2 Limitations of the Environmental Modification Component of Household Lead Abatement

There is no argument that the most effective way to lower blood lead levels in children is to either remove the lead or physically separate those exposed from the contaminant by engineering strategies. The U.S. CDC guidelines, reviewed in Section 9.4 repeatedly state that this should be primary objective in any lead abatement program.

The extent to which the current components of primary home-based decontamination for index children (ie those with blood lead levels in excess of 25 μg/dl) can further lower the blood lead levels of Port Pirie children depends on many factors which have become more evident during the life of the Program.

Since the Program began there have been about 130 children under the age of 5 years requiring reinvestigation due to a failure of blood lead to decline below 20 μg/dl by 12 months following household lead abatement. This changing cohort, with some leaving because of age or departure from the City and new additions from the very young, those shifting into another contaminated house, and those exposed from housing renovations, will surely be larger if, as is almost certain, the levels of concern and action are reduced.

Some of the limiting factors operating within the current household abatement regime have been suggested from recent research. As outlined in Chapter 6, the studies of primary and secondary abatement (Luke 1991) concluded that greater resource allocation to abatement or longer periods of temporary relocation were related to a tendency to reduce blood lead levels, and that the component largely responsible for this was moneys devoted to repairs (or renovations) which includes much of the effort to seal off a home from the external environmental lead. However, as described in this document, the associations did not approach the 5% level of statistical significance, and the results should be viewed with caution as the study was non-experimental in design and the numbers small. These tentative findings suggest that unless further studies demonstrate otherwise, additional long term reductions in blood lead will be difficult to achieve by abatement of individual households given the existing wider environment of the high risk areas.

Specific limitations of the current abatement procedures with regard certain individual households will now be briefly presented.

(1) Dedusting of ceilings and wall cavities.

Contractors usually take one to two days to vacuum the frequently observed large build up of rich lead bearing dusts from a ceiling space.

Factors limiting success include the extent to which all dust can be removed (sometimes it is located in areas which are inaccessible, eg very low roofs), the skills employed in not allowing these dusts to enter the interior of the house during dedusting, and the success of work done to prevent recontamination of the ceiling space and any areas of the home that could be recontaminated from this space. The latter are dependent on successful sealing of the home after decontamination.

Wall cavities are generally not dedusted and may provide a source for ongoing recontamination. This may become more important if the goal is reduced.

(2) *Repairs including the final sealing of the home.*

All of the above activities have the potential to challenge the structural integrity of the home. For example, dedusting frequently results in a previously impervious ceiling developing gaps between the matchboards. Other sources of future potential dust ingress include cracked cornices and poorly fitting windows and doors. Thus repairs are designed to further seal the inside of the house against the ingress of lead bearing dusts from outside.

This component of decontamination is therefore an important limiting factor in the long term success of the intervention. It is noteworthy that in the study by Luke (1991), resources allocated to this component of primary and secondary home-based environmental interventions showed a positive association with extent of fall in blood lead level, although did not reach statistical significance.

Thus, adequate sealing of a home is a plausible limiting factor in successful environmental intervention. Inadequate repairs could result in longer term reversal of blood lead reductions.

On the other hand if the lead contaminated dust is airborne, then open doors and windows provide the greatest opportunity for entry. While sealing of cracks is important to prevent dust deposited in the ceiling and wall space from entering the living areas, reduction of levels of airborne lead may be more important.

(3) *Garden area decontamination, including soil treatment.*

The removal of lead contaminated surface soil and replacement with clean fill, removes an immediately available source to the child and a potential cause of recontamination of the home through re-entrainment into dusts by wind or by being carried into the house on shoes, clothing or pets.

The success of this operation is dependent upon accurate identification of contaminated soils accessed by the child or likely to contribute to lead bearing dusts. A common limitation to the success of this component of environmental intervention is the tendency of home owners and children to disturb the new soil in the course of playing, digging, gardening and other activities, thus again exposing lead contaminated material. There have been instances where insufficient contaminated soil was removed and/or the fresh soil cover was inadequate.

Another probable limitation is the use of crusher dust to seal outside surfaces, especially driveways and play areas. This material is relatively cheap and a good cover in the shorter term. However, the quality varies and there is a general tendency for crusher dust to break down with traffic. Crusher dust may also be acting to hold leaded dust at the surface compared with gravel which allows the leaded dust to wash through into the subsurface.

Over time, a sparsely and intermittently covered surface composed of much finer material which tends to become airborne may be the end result. Thus, not only is the surface breached exposing lead contaminated soil, but lead bearing dusts again threaten the interior of the home.

In considering limitations of present strategies, a more resilient alternative to crusher dust should be investigated. The use of undergrowth, shrubs, bushes and trees, and the maintenance of lawns or any grass cover around the house provides an effective and attractive means of containing lead bearing dusts and soils. Other options include grades of road gravel or BHP iron slag, more resistant to human and mechanical activity, and onto which dusts may become fixed.

Finally, it needs to be considered whether the current action levels for soil treatment are too high, particularly in association with large areas of bare soil, pronounced hand-to-mouth activity or pica.

(4) The removal of lead based paint and restoration.

During decontamination, any surfaces identified as being sites of flaking, chalking or peeling lead based paint are scraped down to a stable surface and repainted with non-lead based paint. Use of high heat levels must be avoided during removal to prevent lead fume being produced.

The limits to success of this component are, in part, dependent upon:

- Accurate identification of leaded paint,
- Complete removal of lead based paint so that any future deterioration of the top coat does not result in re-exposure of any old lead based paint,
- The care taken not to distribute particles of the old paint throughout the house and garden, and
- Exclusion of susceptible children from the zone of scrape down, to avoid any inhalation or ingestion of leaded paint particles.

Experience has shown that vertical corrugated iron and fibrous cement board with smooth surfaces collect less dust than horizontally placed corrugated iron and wood grained cement board. Given that children often run their fingers along these cladding surfaces, dust adherence may be providing an important further source of leaded dust intake.

There are instances where children's blood lead levels have risen after parents have undertaken home renovations themselves without following established decontamination protocols.

(5) *Carpet cleaning.*

When all of the above lead abatement procedures have been completed, the services of a carpet cleaning contractor are employed to perform deep cleaning of the carpets. This component is to remove not only deeply embedded lead bearing dusts but also any contamination which may have resulted from the decontamination process.

The limitations of carpet cleaning are related to the professionalism of the contractor, the nature of the carpet (thick pile, or carpet laid on dirt does not respond as favourably), but mostly to the temporary nature of the outcome. It is now well known that carpets concentrate dusts, even more so than the remainder of the home interior, and that this occurs through the ingress of airborne lead bearing dusts and by human activity. The very act of domestic carpet vacuum cleaning has been shown to re-entrain the smaller particles, which are readily inhaled by children and which may then settle on other surfaces.

There is a strong positive association between carpet dust lead levels and blood lead levels of resident children indicating the fundamental role of environmental contamination.

(6) *Owner participation in home decontamination.*

It has been EHC policy to involve suitable parents in some of the less demanding components of decontamination. This can save money and have desirable social influences. Opinions as to whether this policy limits the effectiveness of the work vary. Most parents do a good job, others require more supervision.

This policy could be limiting in it's effect. Owner participation has been known to result in delays to the whole process, with or without a good result, and potentially exposing the at risk children to lead secondary to abatement. Most of the jobs so allocated involve that important component, the sealing against external dusts (eg mending gaps and cracks, final coats of paint, soil cover).

Owner participation may need to be reviewed, especially if levels of concern are lower. If continued, it must be associated with strict guidelines and supervision. It has the potential to be a severe limiting factor.

(7) Temporary relocation during home decontamination

During home-based environmental interventions, it is imperative that children are not exposed through the decontamination activity. Therefore all families are offered an option of temporary relocation. This may be to the home of a friend or relative, to one of the "safe houses" maintained by the EHC for this purpose, or into a caravan preferably, but not always, located away from the temptations of the more comfortable house undergoing treatment.

There have been instances where this strategy has not operated well, making it a potential limiting factor to a fall in blood lead level. Those problem cases that have been observed, have involved the family (including the at risk child) returning to the home undergoing decontamination and risking high exposure to lead. This is most common in the case of temporary relocation into a caravan during extremes of climate.

There is a need to prevent exposure of the at risk child to lead during decontamination becoming a limiting factor by:

- Ensuring that the at risk child is removed from the home during lead decontamination, and by
- Developing strategies for temporary relocation that will be effective and meet with compliance.

(8) Home owner renovations after decontamination.

It is policy for those charged with the supervision of families whose homes have been subjected to primary environmental home-based interventions, to encourage occupants to seek advice from the EHC and SACON before proceeding with alterations post decontamination. Many do not, thus exposing previously contained lead contaminated material and reintroducing it into the environment of the child.

Similarly, otherwise successful soil treatment may be disturbed. In this discussion, it is worth remembering that a child's association with the preparation of any older painted surface may be a potential hazard. The homes of older relatives and friends in Port Pirie may not qualify for decontamination, and children are advised not to visit them during any refurbishing.

(9) Permanent relocation

Where a house has been shown to be unsuitable for decontamination, the house has been purchased and demolished. This results in relocation to a much less contaminated house and very effective decontamination. In some cases the owners are reluctant to move for various reasons such as the older age of the people, the length of time they have lived in the house or the inability of the Program to pay sufficient for the house for the move to be attractive for the owners. Under circumstances such as these only soil and fence decontamination is carried out leaving the house to be dealt with at a later time.

Residents and the Council have also been reluctant to zone large areas within the present City boundaries as "no further housing development" or "non residential" because of the problems this may cause and the value of services provided within the areas. This has severely restricted the opportunity during the recent development of a Supplementary Development Plan to include a substantial buffer zone in Pirie West.

(10) Additional exposure associated with abatement procedures

The decontamination or deleading of homes may be, in itself, a cause of additional exposure, especially when families fail to take up the voluntary option of temporary rehousing while abatement is carried out.

At Port Pirie, the Lead Decontamination Unit operates under strict guidelines to safeguard both occupational and environmental health. These are monitored by the staff of the Environmental Health Centre who also advise families on how best to protect their young children from lead exposure under such conditions. Despite these precautions, lead bearing dusts may be disturbed during the process with an increase in environmental lead within the home or children may gain access to lead paint scrapings.

10.2.3 Behaviour Modification

The 1983 Task Force Report described a number of behaviour modification measures that were seen as appropriate post-decontamination strategies to limit lead intake. Amongst the large number of potential measures described in the literature, the following are seen as appropriate in Port Pirie: reducing the entry of airborne dusts into the home by the application of ventilation practices that took account of weather conditions and wind direction; the more frequent damp dusting of surfaces; vacuuming with suitable intact disposable bags; using separate clothes for outdoor and indoor living; the frequent washing of hands, hair, bed linen and clothes; taking great care not to allow lead contaminants access to food preparation; several modifications to diet and avoidance of rainwater consumption.

However, caution is needed before placing too much importance on behavioural factors, as any such strategies are relevant only in an environment already contaminated by lead. This in turn is related to the location of residence. The Kellog, Idaho, Study (Yankel et al., 1977) concluded that children living in dirty homes had higher blood lead levels than did children living in clean homes, but that residence in a dirty home was of much less importance than exposure to polluted soil and air from past and present smelter activities.

The experience at El Paso, Texas, where meteorological and geographic conditions are similar to those at Port Pirie (a dry arid plain with mountains behind a primary lead smelter), have been much the same (Morse et al., 1979). Environmental lead levels, mainly in dusts and soils, have provided the most important long term predictors of blood lead levels in young children.

In Port Pirie, most of the impact of behaviour modification was observed in the early years of the Program, with families visibly resuming previous habits after a few months or years of counselling by a limited number of staff. Many residents have ceased wet mopping and active interior dust control believing that it was no longer necessary after decontamination. Generally, younger siblings have followed similar blood lead profiles to those of their older brothers and sisters.

The study of secondary decontamination (Luke, 1991), however, showed that hygiene promotion could be successful at the 12 month follow-up. Along with better early morning dietary habits, improved household dust hygiene appeared to be the clearest predictors of reduced blood lead levels amongst this small group of children. Reduction in hand-to-mouth activity appeared to be less easily achieved. In particular, only that hand-to-mouth behaviour taking the form of mouthing of foreign objects that could be removed from the child's environment was predictive of a reduction in blood lead level in this study. Hand-to-mouth activity and the sucking of foreign objects are normal toddler behaviours and would be difficult, and probably unwise, to restrain. While many foreign objects can be kept relatively clean and access to those not suitable for frequent cleansing may be removed from the child's environment to some extent, there clearly are limitations in controlling this activity. Nonetheless, a reduction in the habit of sucking foreign objects was observed and found to correlate with a reduction in blood lead level.

The favourable response observed with this cohort of children is probably related to the policy of maintaining close contact between case workers and the families and the intense level of case worker activity. While this modified behaviour could have been re-inforced into the future with adequate support, the level of personnel resources needed to cover all at risk children would appear quite impracticable.

Secondly, while such behaviour would seem to be amenable to improvement in the short term, the potential to maintain a level of hygiene that is adequate for such a contaminated environment would appear to be questionable. It is well recognised that such behaviours are difficult to sustain over time, especially amongst those in poorer circumstances. This may well prove to be a major limiting factor to further reductions in blood lead in these children by behaviour modification.

In summary then, behaviour modification has had a potent initial impact on the blood lead levels of many Port Pirie children. However, this desirable effect usually diminishes in the face of continuing high levels of environmental lead contamination.

If the levels of concern and action are lowered further, this poor long term outcome is likely to become more accentuated. It is doubtful whether the allocation of additional resources to this component of primary intervention would be useful or cost effective mainly because of the recontamination of homes by lead bearing dusts. This diminishing benefit is most apparent in those residential areas of highest risk from accumulated lead contamination and fugitive smelter emissions (Pirie West and Solomontown).

10.2.4 Ongoing Contamination/Recontamination By Leaded Dust

It is recognised that the lead pollution problem of Port Pirie is the legacy of over 100 years of smelter operation.

It is also apparent that the major source of this contamination is from the smelter complex, the strongest evidence being the clustering of children with elevated blood lead levels in areas adjacent to, or living in areas adversely affected by its emissions.

In 1983, the Task Force identified the lead dust sink as the major source of lead for children. This sink contains the stack and fugitive emissions of over 100 years of smelter activity which has been deposited around the City. Losses include the 160,000 tonnes of lead estimated from materials balance studies and stack emissions in previous decades as well as an unknown quantity of fugitive emissions. This lead, mostly in the form of surface dusts, is prone to dispersal by a combination of passive mechanical carriage and re-entrainment by human activity or wind.

There is a tendency for this lead bearing dust to become concentrated within homes for reasons that are not fully understood but are related to repeated vacuum cleaning, entrainment of surface soils (dusts) by winds and entry through doors and windows, inadequate sealing of dwellings and deposition on surfaces such as tables, carpets and water collection areas. The dusts also largely contribute to the high lead levels found in topsoils, on concrete footpaths and play areas.

While the smelter has made substantial efforts to reduce it's emissions over the past decade, there is local and observed evidence of ongoing contamination from the wharf area, lead concentrate handling and the smelter and its environs (Chapter 7).

In the face of an extensive leaded dust sink, one component of recontamination is considered to be the transfer of lead bearing dusts. This may arise from an adjacent home, not occupied by a high risk child and therefore not eligible for formal primary environmental home-based intervention. The area decontamination or grid approach will have been completed by the middle of 1994 for all grids in the areas of higher risk. This strategy has the potential to remove more local contamination and perhaps reduce the problem of recontamination of deleaded homes. Although largely concentrated in the areas of high risk, the removal of all this matter would be nothing short of an engineering miracle. Means of containment and reducing it's mobility will be considered later.

The fundamental role played by the lead contaminated environment is suggested by the strong association between carpet dust lead levels and the association between residential relocation to a less hazardous environment and reduced blood lead level. (Luke, 1991).

Recontamination of decontaminated households was also examined in the study by Luke (1991). Although two measures of dust exposure, exposed dirt adjacent to the household block and dust level within the house, showed some reduction following 12 months of Program support, exposure to lead bearing dust and soil remained considerable in and around these houses.

In the presence of evidence suggesting ongoing levels of lead in carpet dust and substantial dust levels inside and immediately outside the home, most forms of hand-to-mouth activity may be expected to continue to result in elevated blood lead levels in some children. Indeed, blood lead levels have shown least reduction in north Port Pirie West where initial contamination and subsequent recontamination are considered to be greatest (Chapter 6).

Given the current rate of recontamination of deleaded homes, as indicated by biological and environmental sampling, and if current strategies of home-based intervention of index children are to be continued, it would seem apparent that greater emphasis should be given to reducing the impact of all lead sources on the population. It is unlikely that greater resource allocation to existing methods of lead decontamination will have the potential to further reduce blood lead levels in Port Pirie children, given the level of mobile lead contamination.

The current situation requires more monitoring and investigation, and there are now more modern techniques, which if used together, should enable concentrations and the actual sources of lead to be identified. These include qualitative chemical analysis, energy dispersive x-ray analysis, scanning electron microscopy and the use of lead isotope finger printing.

This need to better define and control current sources will be discussed further in Section 10.3.2.

10.2.5 Greening

Substantial efforts have been made to increase vegetation around the City along roadways, in residential areas, in park areas, and in bare allotments in the form of trees, shrubs and groundcover. To date several hundred thousand seedlings have been planted. Unfortunately, the success of the greening program has been severely hampered by the twin local conditions of:

- Relative drought, especially during the summer months, and
- The high salt water table.

Insufficient emphasis on rapid growth groundcover instead of slower growing trees has delayed the effective development of the green barrier.

The cost of water has rendered it impractical to maintain plantings using irrigation as a means of combating these problems, despite the selection of drought and salt resistant species.

Recently, the greening program has begun its own nursery, raising seed from locally successful individual specimens in increasing saline and water restricted conditions. The approach will increase the availability of appropriate seedling stock for increased greening activity.

10.2.6 Lead in Rainwater

Like many people in South Australia, the inhabitants of Port Pirie prefer to drink rainwater than the City's mains supply, which is harder, chloraminated water. Rainwater has been used extensively in the past for both drinking and food preparation.

The Environmental Health Centre provides a rainwater testing facility to all residents. The NH&MRC recommended lead level in rainwater is 0.05 milligrams per litre. Unfortunately, experience has shown that one isolated rainwater sample is quite unreliable as a measure of ongoing lead levels and should not be used to designate rainwater as safe. Serial measurements of individual tanks have shown that the lead level may fluctuate from below 0.05 milligrams per litre to well above 0.10 milligrams per litre. More recently, sampling of several rainwater tanks over time has shown that the range for a single tank over a given year may vary from 0.04 to 2.80 milligrams per litre. This variation in lead level is undoubtedly due to the variable dust fallout on the collection surface and resuspension of leaded tank sludge following rainfall. During a dry season, much lead bearing dust collects on the roofs of houses in Port Pirie and, with a shower of rain, is washed into rainwater tanks. Should this water be acidic, such as may occur due to the accumulation of leaves and other organic material in the gutters, the lead can become more bioavailable.

Although the Environmental Health Centre actively discourages all children and pregnant women from drinking rainwater, children still present with persistently elevated blood lead levels that are considered, after investigation, to result from rainwater consumption.

10.2.7 Voluntary Participation

The impact of the Port Pirie Program depends heavily on the voluntary participation of the local community. Involvement of any party in any of the Program components can be, and sometimes is, declined. Thus in an effort to maximise local participation, an active and resource consuming part of the Program has been devoted to general public education, case worker support of individual families and conflict resolution. Nevertheless, the need for voluntary participation in most Program components remains an important limitation to the successful reduction of blood lead.

10.2.8 Active Community Support and Participation

The crucial role of voluntary participation underlines the importance of active community support for the Program's strategies.

While this support has become less mixed over the life of the Program to date, many community reactions have limited success. Amongst them can be included:

- Fear that actions to reduce lead sources and contamination would threaten the future of the City's major source of employment,
- Mixed loyalties amongst parents of high risk children who were employed at the smelter,
- Adverse publicity that stigmatized the City and threatened commercial development (job opportunities) and its ability to attract services and residents with skills needed within the City,
- Many parents felt threatened and defensive about the possibility of placing their children at risk by residing in the City and chose to ignore the problem,
- Parents who participated during the early years often faced hostile reactions from other residents or were challenged by their own parents,
- Parents resented the inference that they lacked skills in caring for their children or that hygiene in the home was lacking, and reacted negatively to the need to address these issues,
- Parents reacted to the stigma of having a child with elevated blood lead, the intrusiveness of the decontamination process and the disruption to family life brought about by Program activities,
- Local general practitioners gave limited support since few children experienced clinical lead poisoning, and

- Many residents considered the Program a waste of time and public money.

It is to be expected that many of these reactions will again surface should the level of concern be reduced and more intense community support be needed in the years ahead.

10.2.9 Pasminco-BHAS

Recent evidence suggests that a major source of recontamination is located in the vicinity of the smelter lease. It is unclear whether current fugitive emission is the main contributor or whether leaded dust of variable age from several possible sources around the smelter and environs is the main contributor.

There is an obvious need to further define the relative importance of current sources from the smelter area, and to take action to contain them. This option is addressed in Section 10.3.2(1). Measures already being undertaken, or subject to feasibility studies at present, are presented in Section 10.3.3.

10.2.10 Summary

In summary, the factors mostly limiting further reductions in blood lead levels in Port Pirie are:

1) The long term unsustainability of the degree of behaviour change necessary to reduce blood lead in the high risk areas,
2) The persistence of environmental lead contaminants, especially in the form of lead bearing dusts, in an arid often windy residential area,
3) Recontamination of homes that have been subject to primary home-based decontamination,
4) Proximity to an operating smelter,
5) The social characteristics of high risk families affects blood lead and the practicability of intervention,
6) The difficulty of identifying the relative contribution of lead dust sources at the household exposure level,

7) The 1983 Task Force conclusion that the smelter and its surroundings was not a significant ongoing source of lead contamination.
8) The inadequate understanding of mechanisms (and their relative contributions) for household lead contamination from the wider Port Pirie environment,
9) The need for voluntary participation and limits to the active support of the Port Pirie community,
10) The lack of precise information on the relative long term impact of the different Program components,
11) Limitations of the physical environment to greening,
12) Ongoing contamination of rainwater and its consumption, and
13) Difficulties associated with permanent relocation and development of buffer areas surrounding the smelter.

10.3 OPTIONS FOR THE FUTURE

10.3.1 City Planning and Development

(1) Buffer zone

Evidence presented previously has suggested that the most important ongoing sources have been crudely identified as the wharf, smelter areas and adjacent land. It is indeed advantageous that these source areas are adjacent to each other at one end of the City although the precise location and relative contribution of each has not yet been defined. This situation would at least allow consideration and development of a separation or buffer zone.

Leaded dust emanating from this source area consists predominantly of large particles (ie >5 micrometres) which are therefore subject to settling by gravitational forces, with the largest particles settling nearest the source area. A buffer zone around the source area would allow substantial amounts of airborne dust to be deposited before reaching residential areas, although in the absence of wind control measures, could be subject to subsequent re-entrainment The greening of the buffer zone would provide additional dust control.

Given the close proximity of the smelter and residential areas, the availability of land for buffer purposes is limited. Such a development will require additional future commitment by the Port Pirie City Council to zoning strategies as part of City development as well as continued commitment by Pasminco to re-arranging activities on their lease to provide land for buffer needs. A belt of vegetation or greening, forming an arc around the smelter, could not only achieve the above desirable effects but could be safely visited by the community for short term recreational purposes. The potential lead absorption would be low given that most contaminant would be contained and that the exposure times would be limited.

Although the creation of the desirable 1-2km buffer is clearly impractical, an equivalent impact on the target population could equally be achieved by removing young children (see relocation section) and restricting the housing of prospective young residents within 2km of the smelter.

(2) Relocation of high risk children

The option of permanently relocating children out of the high risk areas, the recommended long term solution by Dr P.J. Landrigan (Second Opinion Report, 1983), was rejected by the Lead Implementation Group in favour of a household based decontamination strategy. The relocation option was seen as socially disruptive and prohibitively expensive at $70-100 million for the 1600 or more households involved.

This decision on program strategy needs to be seen in the context of 1983 at which time lead contamination was seen as largely historical and not continuing, and the action level for lead in blood was set at 30μg/dl.

Previous sections of this Review have noted the significant contribution of household abatement but its limited benefit amongst the 1-3 year olds, particularly in northern parts of Port Pirie West and Solomontown. Evidence that contamination is continuing, in large measure through the ingress of lead bearing dusts, when combined with the lowered action levels currently being contemplated, suggests that the relocation strategy may need to be seriously considered again.

In those localities in Port Pirie most subject to lead pollution, it may not prove possible to achieve adequate reductions in blood lead levels in the long term. To live in such environments and maintain low blood lead levels may require unrealistically high levels of personal and domestic dust hygiene and a severe curtailment of the normal mouthing habits of young children. It was notable that the most significant predictor of reduced blood amongst children in the secondary decontamination study (Luke, 1991), was permanent relocation out of the high risk areas. This observation shows that in the absence of an environment heavily contaminated with lead, the lead burden of even these children, as defined by their blood lead levels, can be readily reduced. This form of environmental intervention would obviously be more beneficial for selected families in the longer term, without requiring the ongoing case worker contact such as would be required for the maintenance of behavioural change.

Many will reject the notion on the grounds that it will cause socio-economic chaos, incur great expense and dislocate the population. These undesirable outcomes however, are by no means certain. The numbers requiring relocation will depend on the blood lead targets set. For a target of 20μg/dl, the main emphasis will need to be on those already recognised as being sensitive to and overwhelmed by historic and current lead pollution. The process can and should be carefully planned with highest priority being given to families with pregnant women and young children. New families of this type could be dissuaded from taking up residence in such areas thus saving the cost of future relocation. This is already taking place to some extent. Older residents are safe from the effects of low level lead exposure, and provided they recognise the hazard their homes could present to any developing children who might spend long periods with them, could be allowed to remain. Over time, permanent relocation from these high risk areas could enable the establishment of attractive and lead entrapping parks of grasses, bushes, shrubs and trees. These areas could then be visited rather than lived in with resultant dramatic falls in exposures.

Special financial provision may be needed to assist those high risk families who cannot afford to accept current valuations of their homes to relocate to lower risk, more expensive housing.

(3) Dust and wind control

In previous sections, this Review has sought to demonstrate that the main approach to controlling the lead contamination of residential areas rests on the control of leaded dust and its transport by wind.

The main strategies to this end would seem to be:

- Removing re-entrainable dust from around the City,
- Creating physical barriers of vegetation or artificial materials to control dust transport from the smelter environs,
- Creating barriers to windborne migration of leaded dust around the high risk areas,
- Reducing the re-entrainment of dust by interruption of air flow over dusty surfaces, especially around the smelter and the northern end of the City, and
- Removing the dust source from the northern end of the City.

(a) Removing re-entrainable dust from City (dust sink)

(i) To date, the main activities have involved:

- Street sweeping,
- Natural street washing with rainfall,
- Capping of historical dust with road and pathway sealing,
- Household decontamination, and
- Residential grid decontamination.

(ii) Many other areas around the City still retain their historical leaded dust load:

- Parks - Phoenix Park,
  - surrounds of ovals,
  - other bare areas,
- Solomontown Beach area,
- Island,
- Rail corridor,
- Streets and pathways, street verges,
- Industrial bare areas eg. silos, petrol stores,
- Urban vacant areas, and
- Bare areas to the north and northwest of the City.

(iii) Future action

It is not practical to remove the leaded dust sink within the first 1-2km from the smelter where surface dust lead levels exceed 2500ppm unless research can identify particular areas that deserve special attention. It is even more difficult to remove leaded dust from the remainder of the City wherein surface dust lead levels approach 2500ppm in many large areas. Thus other dust/wind control measures are to be preferred.

(iv) Streets, verges

Evidence for the U.S.A shows that even quite small amounts of rainfall (5-10mm) removes about 90% of the road surface leaded dust.

Other evidence also shows that street sweeping only removes large dust particles, thus giving it a limited role. Road verges accumulate leaded dust providing a source for re-entrainment by wind and vehicle movement (U.S. EPA, 1986).

(v) Pathway sealing

The Task Force (1983) recommended a program of footpath sealing based on the proposition that exposure to this source of historical dust would be prevented by capping.

Given the importance of ongoing deposition, the value of simply capping the historical dust must now be questioned. Sealing may well aid re-entrainment of deposited dust by providing a smoother surface and less interruption to air movement Alternatively, sealing may reduce re-entrainment by removing the pebbles and larger particles, which are the first to move under the influence of wind flow and which kick up the smaller particles (saltation).

In any case, the existence of ongoing contamination of pathway surfaces necessitates further consideration of the value of sealing as a lead dust control strategy.

(b) Barriers between the smelter and residential areas

The development of a green buffer zone between the smelter and its environs and the residential areas serves as another key strategy in separating children from sources of leaded dust. Such a zone could be expected to act in several beneficial ways:

- Reduce the re-entrainment of leaded dust from the contaminated zone itself,

- Reduce wind velocity and create turbulence thereby enhancing the deposition of the larger airborne particles,
- Provide a large leaf surface area to act as a reservoir for leaded dust particles, and
- Cover leaded dust with leaf litter and provide organic matter for lead binding.

Clearly the green buffer would provide greatest benefit when located between ongoing lead dust sources and residential areas.

While vegetation barriers have advantages in appearance and providing additional park area, artificial barriers, such as purpose built fences, may provide the same functional benefits.

(c) Barriers within the high risk areas

Some wind (dust) control functions would be served by greened areas located within the town, particularly in the high risk areas. If located to moderate northwest to northeastern winds, these barriers would reduce the airborne transport of leaded dust around the residential areas.

Successful establishment of trees, shrubs and groundcover in the relevant areas of Port Pirie must cope with a high salt water table and relative drought conditions. In this context, the propagation by the EHC of seed from locally successful plants under increasing saline conditions, deserves support into the future. Further trials involving the elevation of planting beds above the salt water table need to be undertaken. The success of the slag dump regeneration program by Pasminco suggests that the large volumes of low lead slag, with appropriate top soil cover, should be investigated as a feasible method of preparing such elevated planting areas. The additional elevation and physical barrier may also serve to further interrupt wind transport of leaded dust.

As with the barrier between the smelter and residential areas, barriers within the City could also be of artificial materials such as castellated fencing.

(d) Dust re-entrainment and migration

Areas of historical and recently deposited leaded dust can become secondary sources wherever vehicles or other activities cause mechanical disturbance or wherever the wind, uninterrupted by physical barriers like house, fences or vegetation, is able to reach sufficient velocity to re-entrain surface dust particles. Hence areas of open space like the beach areas, road verges and rail corridors, Phoenix Park, the Island, bare areas in parks and undeveloped areas to the north and northwest would seem more likely to act as significant secondary sources than built up residential areas complete with frequent fences, buildings and vegetation.

To date the Lead Program has not addressed itself to these non-residential area, secondary sources (sinks). These sinks include lead dust deposited over past and recent times and will include dust that has been re-entrained and deposited any number of times as well as lead dust recently deposited from a current primary source.

A variety of strategies are available to interrupt wind flow at the ground surface. A major effort will be required to trial and adapt the various strategies, listed below, to each particular site.

- Windrows - earthen or intermittent fencing
- Groundcover vegetation
- Covering the ground with mulch, coarse sand or gravel

- Rolling the surface to increase compaction
- Watercarts and sprinklers
- Use of paved surfaces with regular sweeping in key areas
- Disc pitting or contour ploughing

(e) Future use of slag

The 1983 Task Force noted the suggestions that spent slag could be regarded as an insignificant source of lead for children given that the lead was bound up in a vitreous material and unavailable even after the action of stomach acid. Nevertheless, it saw the need for further investigation.

In subsequent research, Body et al (Department of Environment and Planning, 1988) showed that spent slag was relatively resistant to acid leaching. Research elsewhere has also reported similar findings.

To date the Program has avoided the use of slag above 300 mg/kg lead around the City despite its potential value as a plentiful and inert filling material for elevating garden beds above the salt water table. Even if required to be capped with less contaminated soil, its low and unavailable lead content suggests that further consideration needs to be given to allowing slag with lead concentrations up to 500 mg/kg to be used beneficially.

Further investigation of the impact of long term weathering on the availability of lead from slag eg following fracturing into smaller particles, and consideration of an appropriate test of leachability may assist the future development of suitable guidelines.

10.3.2 Future Investigations

(1) Sources of lead

Unfortunately, current evidence does not enable sufficient definition of current sources and their relative contribution to allow specific environmental interventions to be effectively targeted. Once identified, such primary sources of pollution can be modified or suppressed, mechanisms of transfer to susceptible children may be blocked and suspected ongoing contributions to the Port Pirie lead sink reduced or stopped.

Possible sources include the variably aged leaded dust deposited in and around the smelter, old slag dumps, the wharf stockpiles, current fugitive emissions and lead concentrate handling and storage operations.

In the absence of specific measures to control these ongoing sources, it must be considered doubtful whether current Program strategies will be able to achieve further reductions in blood lead or indeed maintain the achievements made to date.

The investigations envisaged would have two main components:

- The nature and contribution of current fugitive emissions from various sources within the smelter, and

- The relative contributions of the various sources to total airborne leaded dust reaching the City.

Initial work to develop a library of the species of particles present in the many sources of lead dust from around the smelter lease is being undertaken by Pasminco - BHAS.

(a) Fugitive emissions

Further monitoring and analyses need to be undertaken to gain a better understanding of the nature of various fugitive emissions, especially in terms of particle size, chemical structure and origins. Together, these studies could also provide an estimate of current lead loss to the environment.

Speciation technologies such as scanning electron microscopy, x-ray diffraction crystallography and the measurement of lead isotope ratios, have the potential to trace localised environmental lead contaminants to their origins.

To this end, Pasminco-BHAS has already initiated studies to document the variation in chemical composition of lead particles from several process sources around the smelter.

(b) Source contributions

As well as current fugitive emissions, other sources from the general smelter area need to be investigated to determine their relative contribution to airborne dust. Several of these potential sources are listed above.

Further work using a combination of source direction analyses and the speciation techniques mentioned above should be considered. For example, the lead isotope "finger printing" technique has been used successfully in Port Pirie and other Australian cities to accurately identify the geological source of both environmental and biological lead. The fact that much of BHAS lead concentrate now has it's origin from overseas mining operations, means that the lead isotope ratios of any given import may be unique, and certainly different from Broken Hill lead.

(2) Household contamination

In view of the primacy of the notion that household contamination around Port Pirie was the result of historical emission, only preliminary investigation of the relative contribution of sources at the household level and of pathways of exposure to children has been undertaken.

Harris et al (1986) demonstrated that small lead particles passed through the vacuum cleaner bag and were emitted back into the air. Body et al (1988) observed the recontamination of a group of previously decontaminated houses by measuring the lead concentration of dust deposited in collection dishes. In other investigations, this group examined interior house dust for the presence of planar (chip) shaped particles as an indication of the amount of lead paint present and found very few such particles. Using a rotating spore collector, Body's group also made an initial attempt to collect particles suspended in indoor air and determine the species of lead particles present.

Other preliminary work was carried out be Luke (1991) and has been summarised in Chapter 6. Of particular relevance to this section were the observations of recontamination of outside areas during a follow-up study of children and homes and the finding that having a parent working in the smelter was no longer predictive of elevated blood lead amongst their children.

Recent findings such as the recontamination of houses and the central contribution of the smelter to air lead levels, have highlighted the need to improve understanding of the mechanisms of exposure at the household level. Without an improvement in the efficiency and effectiveness of intervention, it will be futile trying get the blood lead levels of Port Pirie children below 20 - 25 μg/dl. Issues that need answers include:

- The relative contribution to household lead of airborne and mechanically transported lead ie airborne vs outside dust carried inside,
- The rates of recontamination inside and outside of homes,
- Differences in the mass loadings of lead dust in the different rooms and areas within rooms in relation to young child activities,
- The nature (species) of recontamination particles,
- The effects of deposition of lead particles in household yards on future bioavailability for children,
- The significance to indoor lead dust of deteriorating paint surfaces,
- The conditions under which airborne lead most readily enters the living space of homes,
- The significance of wind re-entrainment of the urban lead dust sink to household contamination, and
- The significance of lead dust in airconditioner filters and the presence of a persistent gap in the wall to lead dust entry.

(3) Effects of household abatement strategies

In an ideal experimental program, the relative benefits of the different intervention components can be gauged by consistently applying standardised components (eg. dedusting, removing lead paint) to groups of households, and all other factors being equal, comparing the impact on the blood lead levels.

Clearly, the Port Pirie Program cannot be placed in that scientific mould. The characteristics of each house and relevant behaviour and other factors with a potential impact on lead exposure were assessed for each household and a custom designed intervention undertaken. While this approach was considered the only practicable and economic proposition, it does severely limit the information available to assist the design of the most effective and efficient program in future years. Moreover, it presents a limitation on planning decisions about the future of the Program.

Throughout this Review, available overseas and Program findings (eg Heyworth, 1990, and Luke, 1991) along with Program experience have been used to make the most accurate conclusions possible about the specific effects of Program strategies. Nevertheless, the limitations of such conclusions must be kept in mind.

In summary, the short term reductions in blood lead levels in Port Pirie children appear to have been were mostly due to house decontamination, behavioural changes or relocation. It is suspected, however, that there may be effects of environmental modification that are more durable than the powerful but short term behavioural effects and thus behavioural change may make a smaller relative contribution in the longer term. Furthermore, the effects of Program activity are limited by ongoing recontamination from the wider environment. A need to validate this preliminary study now exists in view of its important implications for decisions about the efficiency of the different abatement strategies used to date and the effectiveness of these strategies in achieving further blood lead reductions.

One approach would be to implement a case control study where children exposed to home-based interventions in past years are compared with controls. With adjustment for behavioural differences, it should be possible to investigate associations of blood lead levels with specific environmental modifications. Such a study could be used to test the hypothesis that, while behavioural modification may be largely responsible for initial improvements in blood lead levels, home-based environmental interventions have a more sustained long term effect. The Port Pirie community is now more aware of the potential for detrimental effects from low level lead exposure in children and may be more receptive to a study of household abatement than was the case in the early years of the Program.

10.3.3 Source Control by Pasminco-BHAS

Recent evidence suggests that major sources are located in the vicinity of the smelter lease although it is unclear whether current fugitive emission is the main contributor or whether leaded dust of variable age from several possible sources around the smelter and environs is the main contributor.

There is an obvious and urgent need to further define the relative importance of current sources from the smelter area and to take action to contain them. This option is addressed in Section 10.3.2(1). However, while this necessary investigation work proceeds, action to contain sources already identified or general measures to place as substantial a barrier as possible between the smelter complex and residential areas is essential.

To this end, a 55 point Environmental Action Plan is being incorporated in the overall Environmental Management Plan for 1993/94 to 1995/96. The main aims of the Plan are to minimise fugitive process emissions and minimise dust generated by materials handling.

The aims are being tackled by:

- Implementing process and management practice changes,
- Improving enclosure and containment of processes and materials,
- Relocating point sources of dusts and emissions, and
- Enlarging the effective buffer zone around the smelter perimeter.

Specific components of the Plan already being undertaken, or subject to feasibility studies at present, include the following:

- Enclosure of the zinc concentrate storage and handling operations on the wharf,

- Construction of a physical and green barrier between the central business district and concentrate handling operations,

- Re-organisation of operations on the Pasminco lease to create more effective buffer zones, including construction of physical barriers,

- Controls on recognised fugitive emissions, and

- Further controls on dust emissions from the lead concentrate storage and handling areas.

Earthen banks, similar to those on the western side of the wharf, are being constructed on the southern side of the BHAS car park and contractors marshalling area near the ETSA sub-station on Leahy Road. These will be planted with trees and groundcover during the winter of 1993. The green belt near the old arsenic dam on the western side of the smelter will also be extended inwards when back-filling of the area with spent slag is completed.

As an extension of the 55 point Environmental Action Plan highlighted above, a detailed Lead Material Stabilisation and Vegetation Plan has been established and is being implemented.

This Plan focuses upon all areas of the smelter perimeter, slag dumps and material storage areas with the following main strategies:

- Covering of all bare areas of spent slag with clay/silt and vegetating with trees/shrubs/grasses,

- Planting of windbreaks and buffer zones at regular intervals to break northerly wind flows,

- Removal of all lead bearing materials to a central enclosed pit area,

- Closure of several smelter roads, and the rerouting of traffic onto two major sealed roads,

- A vegetation program using purchased plants and trees,

- Irrigation of all plantings as a major component of the vegetation program enabling faster establishment and quicker growth of plants,

- Acceleration of the rate of greening with more than 20,000 plants to be planted over 3 years, and

- Much greater emphasis on the greening of slag dumps and smelter boundaries.

Action by Pasminco-BHAS in pursuit of these strategies should be acknowledged and supported.

10.3.4 Household Behaviour Change

Evidence in several sections of this Review has suggested the importance of household behaviour in reducing the intake of lead by young children. The limitations of these strategies have also been highlighted:

- The difficulty of maintaining the appreciable changes in behaviour that are required for effective reductions in lead intake by the families of high risk children and hence the likely limited duration of the effects, and

- The need for intensive case worker support of behaviour change with its resource implications.

Nevertheless, changing behaviours which influence lead intake offer an important method that needs to be incorporated in any comprehensive lead abatement program, particularly in the face of significant environmental lead pollution and the need to further reduce blood lead goals.

(1) Personal and domestic dust hygiene

Dust hygiene practices need to be strongly encouraged in all families, particularly those at high risk. Some behaviours considered to be of particular value in a dusty environment include:

- The removal of contaminated 'foreign' objects from the young child's environment that are likely to be put in the mouth,
- The washing of hands, utensils, surfaces and foods such as fruit, immediately before eating,
- The wearing of clean clothes, especially indoors,
- Eating at table, not on the floor,
- Not leaving doors and windows open on windy dusty days, especially those facing the approaching wind,
- Not wearing outdoor or work shoes indoors,
- Not lying face down on a bare carpet for daytime naps,
- The use of damp dusting to prevent the spread of dusts instead of feather dusting, and
- The maintenance of clean fingernails.

More novel measures may also need to be considered as potential program strategies:

- Assistance with vacuuming and/or regular dedusting of high risk houses,
- Changes to vacuum cleaners or their use such that resuspension of fine dust is avoided, and
- Removal of carpets in high risk houses.

(2) Diet

Evidence suggests that the eating of a breakfast containing substantial amounts of whole grain products or fruit assists with reducing blood lead levels. Parents appear to be particularly receptive to dietary advice which they regard as of general benefit to their growing children. The use of a diary of food intake, maintained by the families and monitored by EHC staff, is also considered to have been of great benefit in encouraged improved diets. Many dietary constituents influence lead absorption including the reduction due to the interaction of lead with high fibre foods. Conversely, those children, who do not "break the fast" are generally more prone to a greater uptake of ingested lead into their blood.

(3) Avoidance of rainwater

Roof surfaces provide an extensive area for the deposition of airborne leaded dust as shown by the lead concentration of sediments in gutters and rainwater tanks. The concentration of lead in the water column varies considerably with time in response to recently added dust contaminated water and the resuspension of tank sediment. Tank water samples continue to show elevated lead concentrations around the high risk areas of the City, at least for some of the time. Faced with a need to further reduce lead intake, any contribution from rain water offers the potential for practicable intervention. The main limitation faced is its dependence on voluntary participation.

Investigation of systems that collect contaminated sediment before it enters the tank should be pursued vigorously provided an acceptable impact on resulting rainwater lead can be demonstrated.

Beyond this approach, education of families to avoid rainwater, provision of rain water substitutes and the removal of rainwater tanks need to be considered.

10.3.5 Abatement of Household Contamination

Section 10.2 considered the limitations of the current household abatement program. Hence only a summary of the changes that may need to be considered in the future development of the Program will be recapitulated here.

(1) Secondary decontamination

These strategies relate mainly to high risk households in which children have not responded adequately to primary abatement procedures or which contain children with particularly elevated blood lead levels.

(a) Dedusting

- The need to include wall spaces
- The need for additional procedures to dedust difficult ceilings eg. with very low roof spaces
- The need to replace horizontal corrugated iron with vertically placed sheets or smooth fibrous cement board

(b) Soil treatment

- The need to adopt a lower soil lead criterion
- The need for a more resilient capping material than crusher dust
- The need for barriers to dust re-entrainment

(c) Paint

- The need to treat previously stable surfaces
- The need to treat surfaces that were previously placed on a register rather than abated
- The need to lower the 2% paint criterion
- The need for improved collection of removed paint residues

(d) Internal repairs

- The need for greater efforts to seal houses against the ingress of leaded dust

(e) Acceptability of owner participation

(f) Exposure during abatement

- The need for improved collection of contaminated materials during abatement and final clean-up
- The need for improved arrangements for temporary relocation during abatement

(2) Primary decontamination

From the middle of 1994, all houses with children above 25μg/dl and most children under 4 years of age in the high risk areas above 20μg/dl, will have received a primary abatement procedure, both internal and external. In addition, all houses in the high risk areas will have received an external abatement procedure, particularly for contaminated paint and soil. Hence future requirements for primary abatement should be substantially reduced with the main requirements directed at:

- Internal decontamination and repairs of houses taken up by young children subsequent to the grid (external) decontamination,
- Assessment and abatement of contaminated soils and paintwork that was placed on a register rather than abated during the grid decontamination, should young children begin residence in these houses,
- The potentially large group of children requiring household decontamination should the level of concern be reduced,
- Abatement of recontamination by leaded dust,
- More energetic measures to control dust/wind movement in and around houses with:
  - greater emphasis on house sealing, and
  - greater use of vegetation or artificial barriers to reduce dust carriage around houses or entering allotments from local sinks,
- Measures to control mechanical carriage of leaded dust, and
- Industrial hygiene in lead related activities other than Pasminco-BHAS.

10.3.6 Active Community Support and Participation

That the residents of Port Pirie have the central role in most of the future options discussed above, hardly needs re-emphasising. Even if a bigger role is given to the control of lead sources and movement of leaded dust around the City, any reduction in the action levels for various Program activities will throw an even greater weight on residents in the future.

It therefore seems desirable that after the Government, the Port Pirie City Council and Pasminco publicly commit themselves to agreed future options, a process involving an active discussion with residents be entered into. An early component might involve an evaluation by residents of the Program to date. Another component will involve communicating the reasons for any change in the level of concern. A third component might explore public perception of the future risks from lead, strategies for the future and relative costs and benefits of those strategies. Finally, City Council strategies will need public endorsement and other strategies, such as community projects to control dust, will need to attract active participants.

Employment prospects remain of central concern to residents. Hence planning of the Program's future will also require public discussion of the future of the lead industry and ongoing commitment to the Port Pirie development process already underway.

Local media have played an important education role in recent years in partnership with proactive contributions from the Environmental Health Centre. Implementation of the future developments described above will demand that the media partnership be maintained and extended.

10.3.7 Evaluation by Medical Practitioners

Recent guidelines (Section 9.3) suggest medical involvement in the evaluation of each child's behaviour and environment; clinical, laboratory and x-ray assessment; and supervision of the child's diet. This increased emphasis on medical involvement is clearly a major departure from existing practices in Port Pirie and will need to be considered should the Program's action levels and response guidelines be revised.

10.4 RESOURCE CONSIDERATIONS

10.4.1 Focus on High Risk Children

Resource limitations have required that individual household abatement activities focus on children with blood lead levels above the level of concern. As this group has been brought under control, resources have been directed at children with blood lead in the 20-25μg/dl range. For several reasons discussed in the section on limitations, high risk children have proven to be generally more resistant to blood lead reduction requiring a more intense investment in resources. It can be expected in the future, that any need to bring the blood lead of these children down further will be increasingly difficult.

Conversely, a modest program investment in community education has been associated with a substantial reduction in blood lead amongst children in the low risk areas of the City. In this setting, the Program effort is assisted by parents who are better educated and have greater capacity to contribute, better housing and an environment less contaminated with lead.

In strictly quantitative terms, gains in overall blood lead reduction have been achieved more effectively and efficiency by intervention with lower risk children. Other over-riding considerations have dictated the high risk approach.

Thus to date, the Program has seen the most readily achievable gains in blood lead reduction: moderating the highest individuals and reducing the most readily influenced low risk groups.

Any further reduction in the blood target, to say 15μg/dl, will require the Program to tackle a much larger group of newly defined high risk children requiring strategies beyond those already employed to achieve current blood lead levels. In this context, the need to more effectively address the environmental sources of lead as well as refocus Program strategies becomes all too evident.

10.4.2 Program Costs

(1) SA Government

The SA Government has provided nearly all the funds for the direct Program functions. A summary of these functions is provided below along with a summary of State Government expenditures over the last eight financial years (Table 10.9). Functions performed by other partners in support of the Program are also listed to complete the picture of Program costs.

(a) Environmental Health Centre

- Staff and functions

  Management
  Administration and data processing
  Case workers
  Blood testing
  Scientific and laboratory
  Health education

- Grants

  - Dept. Environment & Land Management (air quality monitoring and investigations)
  - Dept. Woods & Forests (greening project)
  - City Council (footpath paving)

- House acquisition

(b) Soil stabilisation (greening, nursery)

(c) SACON (house decontamination)

Table 10.9: Annual Expenditure by the SA Government under the Lead Implementation Program

		1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93
(a)	Environmental Health Centre								
	Staff and Functions	$655,841	$465,293	$493,886	$529,618	$409,453	$577,056	$659,369	$606,378
	Grants	$425,356	$458,453	$310,617	$178,931	$169,000	$93,000	$130,260	$218,017
	• Dept. Environment and Land Management (Air Quality Monitoring)	$398,356	$369,453	$125,617	$11,431	$12,000	$13,000	$12,960	$32,224
	• Dept. Woods & Forests (Greening Project)							$37,300	$20,793
	• City Council (Footpath Paving)		$50,000	$58,000	$54,000	$57,000	$80,000	$80,000	$150,000
	• Port Pirie West Primary School								$15,000
	• Cohort Study	$27,000	$27,000	$27,000	$13,500				
	• Greening Australia		$12,000						
	• Port Pirie Development Committee			$100,000	$100,000	$100,000			
	House Acquisition		$12,000	$128,745	$141,560	$188,978	$291,138	$129,219	$155,220
(b)	Soil Stabilisation (Greening, Nursery)				$142,900	$140,500	$42,280	$57,293	$50,000
(c)	SACON (House decontamination)	$1,058,847	$1,835,463	$1,736,752	$1,695,689	$2,366,841	$2,260,360	$2,184,301	$2,027,385
(d)	TOTAL	$2,140,044	$2,771,209	$2,670,00	$2,688,698	$3,274,772	$3,263,834	$3,160,442	$3,057,000

(d) Support from Environmental Health Branch (SAHC)

- Chairman, Steering Committee (1/10)
- Senior medical consultant (Review report, Program support) (6/10)
- Research and evaluation projects
- Blood data analyses, typing etc

(2) Pasminco-BHAS

(a) Blood lead analyses
(b) Rainwater lead analyses
(c) Cartage and disposal of contaminated materials
(d) Smelter and site modifications to reduce emissions

(3) Port Pirie City Council

(a) Footpath sealing
(b) Greening

(4) Adelaide Children's Hospital

Blood lead analyses

10.4.3 Analysis of House Decontamination Costs

As part of the follow-up study of 175 children whose homes had undergone primary decontamination that was referred to in Section 6.5 (Luke, 1991), an analysis of decontamination components and their costs was provided.

The components consisted of:

- Painting/removal of leaded paint,
- Repairs/refurbishing,
- Carpet cleaning,
- Dedusting,
- Soil treatment, and
- Materials purchased for home-owner participation.

Each house was decontaminated using various combinations of these components. The most common combinations being:

- Dedusting/refurbishing/painting/carpet cleaning/soil treatment = 28 (16%),
- Dedusting/refurbishing/painting/carpet cleaning/materials = 25 (14%),
- Dedusting/refurbishing/painting/carpet cleaning/soil treatment/materials = 21 (12%), and
- Dedusting/refurbishing/carpet cleaning/materials = 12 (7%).

All of the other 37 combinations used involved less than 10 houses each.

The distribution of costs between the components was:

- Dedusting 4%,
- Refurbishing 57%,
- Painting and removal of leaded paint 21%,
- Carpet cleaning 3%,
- Soil treatment 6%, and
- Materials 9%.

The above proportion attributed to painting /removal of paint does not include that part of refurbishing undertaken to replace materials that were deemed impracticable or uneconomic to simply prepare and paint.

The external only decontaminations (grid approach) have involved mainly external painting/repairs and soil treatment, particularly the former. Hence the cost distribution for recent grid decontaminations will have had an even heavier emphasis on the costs of painting/removal of paint.

10.4.4 Future Resource Needs

By the middle of 1994, the Program's mandate to decontaminate the houses of high risk children and remove exterior sources of lead from the high risk residential areas will have been essentially completed. Ongoing primary household intervention will be required for newly identified high risk children along with re-investigation and secondary household intervention for the children that fail to respond adequately to the primary intervention. The resource needs required for these strategies became more apparent when the most recent trends in blood lead level, area by area, were considered in Section 10.1.

Clearly, the major determinant of future resource needs will be the blood lead goal adopted for the future. Nevertheless some general conclusions can be made that will be modified to varying extents depending on the action level values.

Components that will need to be maintained and/or extended include:

- Greening and general environmental dust control,
- Community education and support,
- Family education and support,
- Household dedusting,
- City development including zoning and buffers,
- Primary source investigation and control,
- Investigation of home environment dust movement (including recontamination) and control,
- Monitoring, and
- Family relocation, both temporary and permanent.

Resource needs for these components is likely to exceed the current $1 million per annum by an amount depending on action level decisions.

Components that can be reduced include:

- Grid decontamination of home environments, and
- Primary decontamination of home environments and its associated laboratory support.

The extent to which these components will be required in the future depends heavily on any changes to action levels. Nevertheless, the funding required is likely to be substantially less than the current $2 million per annum.

An integrated overview of future resource options is considered more fully in Chapter 11: Options for Goals and Strategies.

11. OPTIONS FOR GOALS AND STRATEGIES

In this Chapter, specific options for managing the Port Pirie contamination problem beyond the end of the current 10 year Government commitment are presented and considered in detail. The current Program will come to an end at the end of June 1994. It is important for the people in Port Pirie to know what action the State Government proposes to take beyond the end of the current Program. Also to ensure satisfactory arrangements can be made for present staff whose contracts terminate at the end of June 1994, it is desirable to have as much notice as possible of the future options for these people.

The options presented for both goals and strategies have been developed on the basis of all the information presented in the preceding chapters together with discussions within the Program's Steering Committee and an element of professional judgement on the part of those involved in developing the options. While there are uncertainties related to the details of the strategies and the exact quantification of the likely outcomes, these strategies are considered to be reasonable for the achievement of the goals as set out. Incorporated in the proposals are recommendations to investigate some of the areas where there is uncertainty. The amount of investigation is dependent upon the contribution that the various factors requiring investigation are likely to make to achieving the particular goal.

It was clearly established in 1983/84 that the Program would be primarily directed towards achieving a reduction in the blood lead levels of the children and reducing their exposure to lead contamination. The goal did not include extensive investigation nor require comprehensive protocols to be put in place to quantify the effects of various parts of the Program in achieving the goals. While a considerable amount of investigation and evaluation has been carried out there remains many uncertainties about the effects of specific components of the decontamination Program and the amount and mechanisms of recontamination. This has resulted in some uncertainty regarding the likely effects of the strategies proposed to achieve the new goals and the need for some investigations as a component of the proposed strategies.

11.1 NATIONAL GOALS AND STRATEGIES

The National Health and Medical Research Council (NH&MRC) is currently revising its guidelines for lead in blood and air, which involves a consideration of the blood lead level of concern. The process is a complex one which has resulted in setting a goal and action levels related to lead levels in children rather than establishing a new level of concern. At the June 1993 meeting of the NH&MRC, a new goal for all Australians was set at 10μg/dl, as well as a target of 15μg/dl, but the setting of a target date was deferred until its November 1993 meeting. The meeting also established public health responses to be taken in communities where representative surveys showed more than 5% of children aged 1-4 years to have blood lead levels above 15μg/dl. This National policy will clearly have significant implications for making decisions about the future Program in Port Pirie.

The NH&MRC process consisted of three main components: a National review of the distribution of blood lead levels in children around the country, a review of lead toxicity (essentially carried out under the auspices of the International Program on Chemical Safety, IPCS) and a social, economic and environmental impact assessment of the effects of establishing a new policy for blood lead in children.

The blood lead survey suggests that in Australia there may currently be as many as 447,000 children aged up to four years with blood lead levels above 10μg/dl and up to 20,000 with blood lead levels above 25μg/dl. Most of these children reside in the major cities along with some from localities where there is a significant source of contamination such as Broken Hill and Port Pirie. The survey provides a basis for an estimate of the amount of work which might be needed around the country to achieve particular goals (Edwards-Bert et al, 1993).

The IPCS toxicity evaluation suggests that there are clearly definable effects of lead on IQ below 25μg/dl and that the most likely magnitude of this effect is the loss of one to three IQ points for each 10μg/dl of lead in blood between 10-25μg/dl. The uncertainties involved in the estimate of the effects suggests that below about 10-15μg/dl it is not possible to draw any conclusions.

The social, economic and environmental impact assessment is being carried out on the basis of establishing goals to be achieved in a particular time frame. This has been set out as achieving 99% of the children below a particular blood lead level by 1996 or 1998. The blood lead levels which are being considered are 25, 20, 15 and 10μg/dl. It is considered that the goal should apply to all children in the 1-10 year old age group and that the goal should apply to groups which are essentially equally exposed to lead. That is, the goal should apply to areas that are uniformly contaminated rather than having areas of low contamination added to areas where there is high contamination to meet the requirement of having 95% of the children below the criteria.

The IPCS toxicological evaluation was completed in February 1993. The survey of children's blood lead levels was presented as a draft in October 1992 and the final version was completed in March 1993. The social, economic and environmental impact assessment provided an interim report to the NH&MRC in June 1993.

In considering the options and timing for goals in the National policy it was recognised that a substantial proportion of the children with elevated blood lead levels was the result of emissions from motor vehicles using gasoline with lead additives. The reduction or removal of the lead additives is likely to result in reductions in the blood lead levels in the majority of children. In the United States of America there has been a reduction in mean blood levels of the general population from about 15 μg/dl to about 5μg/dl, much of which has been attributed to the removal of lead from gasoline (OECD, 1993). There are two other significant causes of elevated lead levels in children: contamination of the child's environment from deteriorating paint or during renovation of old houses which have substantial amounts of lead based paint and children living in areas where there has been substantial contamination associated with point sources such as lead mines and smelters.

11.2 SELECTION OF GOALS FOR THE FUTURE PROGRAM IN PORT PIRIE

The selection of National goals where the majority of the problem is perceived to arise from motor vehicle emissions is different to the situation in Port Pirie where the removal of lead additives from gasoline is not expected to make much difference. It was recognised in considering options for the goals for the National Strategy that places such as Port Pirie and Broken Hill would have uniquely different and much greater problems in achieving the goals. To achieve a goal where all of the children have blood lead levels below 10 or 15μg/dl in Port Pirie in a short timeframe was considered to be clearly impossible. As a result, options were considered for achieving goals over a ten year timeframe, that is for a program running from July 1994 to June 2004. It may be possible to achieve the goals in a shorter timeframe but would require a very substantial increase in the resources necessary. Thus options for achieving the goals in a shorter timeframe have not been considered.

Two broad approaches to setting goals were considered. The first option is to establish a blood lead level of concern as a goal where all of the children in the City should be below the level of concern. The definition of a level of concern has clear toxicological implications and when children are found with blood lead levels above the level of concern considerable anxiety may result in the parents. This would be particularly true in Port Pirie if a relatively low level like 10 or 15μg/dl was set. The evidence for the adverse affects of lead at the lower levels is relatively weak and it is recognised that there are many other factors which have substantially greater effects on the IQ and development of children, thus it was considered that establishing a level of concern as a goal was inappropriate.

The best approach was considered to be to present options which defined goals in terms of achieving a given proportion of the children in a defined age group and area below a designated blood lead level. This presents goals in a realistic manner in that there are always small numbers of children in a particular group who for some reason or another will continue to have elevated blood lead levels. This may be for reasons beyond the control of the Program and so provision needs to be made for them in evaluating the goal.

The options discussed for a ten year Program are set out in the table.

OPTION	GOAL	AGE (years)
1.	Clinical intervention only.	1-10
2.	All (95%) children in Port Pirie with a blood lead less than 25μg/dl (this is essentially the present goal).	1-7
3.	95% of children in the high risk areas with a blood lead less than 25μg/dl.	1-4
4.	95% of children in the high risk areas with a blood lead less than 20μg/dl.	1-4
5.	95% of children in the high risk areas with a blood lead less than 15μg/dl.	1-4

11.3 STRATEGIES TO ACHIEVE GOALS

The strategies to achieve the goals as set out under the various options are presented on the basis of the considerations in this Review and a subjective evaluation of the likely effectiveness of each. The recommendations are what are considered the appropriate mix of strategies which would best achieve the particular goal, although it is recognised that an alternative mix of strategies might be considered.

In any continuation of a Lead Program in Port Pirie, the function and location of the Environmental Health Centre and the associated offices will need to be reviewed. The Environmental Health Centre may need to be relocated to another site depending on the functions required.

For convenience, this discussion of the options is based on a comparison with the present Program rather than attempting to define each component and the resources required for each. For many options an increase in the current activities is suggested. Unless otherwise specified, this would be an increase in the activities of the Program delivered by the Environmental Health Centre.

The discussion of the options also focuses on the high risk areas where there is a greater likelihood of children having elevated lead levels.

The high risk areas will need to be redefined for all options except Option 1 and still include these parts of the central business district requiring action. The high risk areas for each option will be dependent on the goal set and will be defined to include a substantial proportion of the children with blood lead levels above the particular goal.

11.3.1 Option 1: Clinical Intervention Only

This Option allows for the general practitioners and other paramedical people within the City to provide all the advice and management of the children with elevated lead levels. It would be expected that concerned parents would take their children to the local doctor to arrange for blood lead testing. The costs of this would then be met by the National Medicare Scheme together with contributions from the parents. Advice about sources of lead for absorption would need to be provided by the medical practitioner or the Child, Adolescent and Family Health Service (CAFHS) nurse and with such other advice as the parents could obtain. The Port Pirie City Council would have to accept considerable responsibility for providing advice to concerned parents. This would also need considerable support by the Public and Environmental Health Council and the Public and Environmental Health Service. This Option would be a reversion to the situation of ten years ago and while it is difficult to predict the outcome it is considered probable that blood levels would increase.

This Option is likely to make it difficult for people to get appropriate blood testing, advice and help with managing their lead problem. This option would be seen by most parties currently involved in Port Pirie as being unsatisfactory.

This Option would have only minor cost implications for the State Government other than any normal ongoing contributions that the Public and Environment Health Service or CAFHS might provide for out of their current budgets.

11.3.2 Option 2: All (95%) Children in Port Pirie Less Than 25μg/dl: The Present Goal

This Option presents a continuation of the present Program in Port Pirie. It would continue the current goals of reducing the children's lead exposure and ensuring that all children had blood lead levels of less than 25μg/dl. Since there are always some children who have blood lead levels which continue to be high, the goal of this Option is effectively to have 95% of all children in Port Pirie with a blood lead of less than 25μg/dl. Given that almost no children in the low risk areas exceed 25 μg/dl, significantly over 5% could exceed 25 μg/dl in the high risk areas under this goal. There would be some savings compared with the current Program because the major household decontamination work will have been completed by the end of the present Program. The strategies are outlined below.

(1) City planning

(a) Buffer zone

The area north of Frederick Road and the central business district should be zoned "no further development" with no new houses being built in the area. Houses should not be allowed to be demolished and rebuilt.

(b) Relocation of children

Where children are identified in heavily contaminated houses which can not be readily decontaminated, relocation should be the preferred option.

(c) Dust control

An active program of dust control needs to be maintained. This would include continuing the general greening program including more use of groundcover to provide dust suppression in the short term. The development of a barrier around the plant and wharf area should continue as the opportunity occurs. Developments by the City Council which will aid in dust control should be encouraged, particularly ensuring the maintenance of areas already greened and the dumping of street sweepings in a secure location.

Consideration will need to be given to intervening where sources of recontamination are identified by future investigations.

(2) Pasminco-BHAS actions

(a) Slag dump

Current management practices on the slag dump need to be continued. In particular the dust suppression and greening activities on the dump must continue.

(b) Plant and lease area

The broad range of initiatives to reduce the amount of contamination emanating from the plant needs to be continued. Actions need to be taken to ensure that emissions do not increase as a result of the decreased workforce and economies which are forced on Pasminco-BHAS by the recession.

(c) Wharf

Control of dust from the stockpiles on the wharf needs to continue. Particular attention needs to be paid to ensuring that recommended controls to prevent dust loss are implemented. The development of a barrier between the wharf area and the City in the form of mounding and trees should continue.

(3) Abatement of household contamination

A house decontamination program needs to be continued which is primarily directed at dealing with houses where children are identified as having blood lead levels greater than 25μg/dl or where there are very young children and the blood lead level is rising sufficiently rapidly for it to be considered it will rise above 25μg/dl.

(a) Primary decontamination

There should be only a limited need for primary (principal) decontamination as most houses likely to be identified with children at risk will have had a complete decontamination or the exterior and soils treated by the end of the current Program.

(b) Secondary decontamination

There will be a need for an ongoing program directed at the decontamination of houses which are identified with children who are at risk of having blood lead levels greater than 25μg/dl. This will involve some work on houses which have been previously decontaminated and the need to decontaminate the interior of houses which have not been previously treated where the children's blood lead levels are becoming elevated.

(c) Grid decontamination

When the high risk area has been redefined, there may be a small area requiring a general grid decontamination which has not been completed under the current Program.

(4) Household behaviour change

To ensure the gains of the current Program, it will be necessary to maintain an ongoing education program for parents and children to ensure that the behavioural contribution to the reduced blood lead levels continues to be effective.

(a) Personal and domestic hygiene

The current level of activity should continue.

(b) Diet

Additional activities directed to improving nutrition as a way of reducing lead absorption should occur.

(c) Avoidance of rainwater

The current level of activity involving free rainwater tests and advice should continue.

(5) Active community support and participation

It would be anticipated that the current levels of activity directed towards encouraging community support for the Program by State and Local Governments, Pasminco, community groups and the Environmental Health Centre should continue.

(6) Blood testing and medical evaluation

(a) Blood testing of children

Blood tests should be offered annually to children between one and four years of age. Attempts should be made to get as high a compliance rate as possible. Where children have blood lead levels above $25\mu g/dl$, more frequent monitoring will be necessary to ensure that actions have been effective in reducing the blood lead levels.

Blood lead tests should be offered to all pregnant mothers to help increase awareness of problems and to help identify children at risk.

(b) Survey related to goals

A survey of all children 1-7 years old should be carried out every three years to provide data for the evaluation of the overall situation in the City.

(c) Medical evaluation

Information should be provided to medical practitioners on request. No other changes are envisaged in this area.

(7) Environmental monitoring and investigation

(a) Air monitoring

Routine air monitoring at the current sites by Pasminco and the Government should continue at the present level.

(b) Sources of lead

Investigation to identify the sources of lead resulting in elevated air lead levels needs to be carried out. The current levels of activity in this area by Pasminco and the Environmental Health Centre need to be co-ordinated and the activity enhanced. The objective should be to identify the major sources of lead contributing to high air lead levels, over the next few years.

(c) Household contamination

Work needs to be undertaken to define the rate of household recontamination in the high risk areas. Some work needs to be carried out to identify the major sources of lead causing this contamination and the relative importance of pathways for entry into houses.

(d) Household abatement strategies

The effective components of the Program which are leading to a reduction in blood lead levels need to be identified. In particular the most cost effective components should be used to modify any future Program depending on the resources available.

11.3.3 Option 3: 95% of 1-4 Year Old Children in the High Risk Areas with Blood Lead Levels of Less Than 25μg/dl

This Option presents a more realistic goal than Option 2 for the present Program by ensuring that the children in the high risk areas with elevated lead exposure are adequately considered. With this Option it would be expected that considerably more than 95% of the children in the low risk areas would have blood lead levels less than 25 μg/dl. Option 3 is similar to Option 2 but requires additional efforts in the high risk areas and presents the goal in a more realistic way by focusing on the children at greatest risk. The strategies are outlined below.

(1) City planning

(a) Buffer zone

The area north of Frederick Road and the central business district should be zoned "no further development". No new houses should be built in the area and the present houses should be progressively purchased and demolished. Restrictions on families with young children living in the area north of York Road and east of Senate Road should be considered.

(b) Relocation of children

Where children are identified in heavily contaminated houses which cannot be readily decontaminated, relocation should be the preferred option. Efforts should be made to relocate families with children less than 4 years old from the area north of York Road and from the central business district.

(c) Dust control

An active program of dust control needs to be maintained. This would include continuing the general greening program including the additional use of groundcover to provide dust suppression in the short term. The development of a physical or vegetation barrier around the plant and wharf area should be actively pursued as the opportunity occurs. Developments by the City Council which will aid in dust control should be encouraged, particularly ensuring the maintenance of areas already greened and the dumping of street sweepings in a secure location.

Consideration will need to be given to intervening where sources of recontamination are identified by future investigations.

(2) Pasminco-BHAS actions

(a) Slag dump

Current management practices on the slag dump need to be continued. In particular the dust suppression and greening activities must continue.

(b) Plant and lease area

The broad range of initiatives to reduce the amount of contamination emanating from the plant need to be continued with further attention being given to any currently uncontrolled dust sources around the plant and lease area. Actions need to be taken to ensure that emissions do not increase as a result of the decreased workforce and economies which are forced on Pasminco-BHAS by the recession.

(c) Wharf

Control of dust from the stockpiles on the wharf needs to continue. Particular attention needs to be paid to ensuring that recommended controls to prevent dust loss are implemented. The development of a barrier between the wharf area and the City in the form of mounding and trees should continue.

(3) Abatement of household contamination

A house decontamination program needs to be continued but primarily directed at dealing with houses where children are identified as having blood lead levels greater than 25μg/dl or where they are very young and the blood lead level is rising sufficiently rapidly for it to be considered they will rise above 25μg/dl.

(a) Primary decontamination

There should be only a limited need for primary (principal) decontamination as most houses will have had either a complete decontamination or the exterior and soils treated by the end of the current Program.

(b) Secondary decontamination

There will be a need for an ongoing program directed at decontamination of houses which are identified with children who are at risk of having blood lead levels greater than 25μg/dl. This will involve work on houses which have been previously decontaminated and the need to decontaminate the interior of houses which have not been previously treated where the child's blood lead levels are becoming elevated. This may require abatement of paint which is currently on the register and treatment of deteriorating paint.

(c) Grid decontamination

When the high risk area has been redefined there may be a small area requiring a general grid decontamination which has not been completed under the current Program.

(4) Household behaviour change

To ensure the gains of the current Program, it will be necessary to maintain an ongoing education program for parents and children to ensure that the behavioural contribution to the reduced blood lead levels continues to be effective.

(a) Personal and domestic dust hygiene

The current level of activity should continue with an increased focus on the high risk areas. This will particularly involve additional focus on dust.

(b) Diet

Additional activities directed to improving nutrition as a way of reducing lead absorption should occur.

(c) Avoidance of rainwater

The current level of activity involving free rainwater tests and advice should continue. Additional efforts to reduce consumption of rainwater will be required.

(5) Active community support and participation

It would be anticipated that the current levels of activity by State and Local Governments, Pasminco, community groups and the Environmental Health Centre should continue. Particular attention to high risk areas will be required.

(6) Blood testing and medical evaluation

(a) Blood testing of children

Blood tests should be offered to 1-4 year old children annually. Attempts should be made to get as high a compliance rate as possible especially amongst those under 3 years. Where children have or are predicted to reach blood lead levels above 25μg/dl, more frequent monitoring will be necessary to ensure that actions have been effective in reducing the blood lead levels. An "at risk" register and more follow-up of children at risk will be required.

Blood lead tests should be offered to all pregnant women to help increase awareness of problems and to help identify children at risk.

(b) Survey related to goals

A survey of all children 1-4 years old should be carried out every three years to provide data for the evaluation of the overall situation in the City.

(c) Medical evaluation

Information should be provided to medical practitioners on request. No other changes are envisaged regarding this strategy.

(7) Environmental monitoring and investigation

(a) Air monitoring

Routine air monitoring at the current sites by Pasminco and the Government should continue at the present level. Monitors should be sited to ensure they are not protected by fences or vegetation which will influence the results obtained.

(b) Sources of lead

Investigations to identify the sources of lead resulting in elevated air lead levels needs to be carried out. The current levels of activity in this area by Pasminco and the Environmental Health Centre need to be co-ordinated and the activity enhanced. The objective should be to identify the major sources of lead contributing to the high air lead levels, over the next few years.

(c) Household contamination

Work needs to be undertaken to define the rate of household recontamination in the high risk areas. Some work needs to be carried out to identify the major sources of lead causing this contamination and the relative importance of pathways of entry into houses.

(d) Household abatement strategies

The effective components of the Program which are leading to a reduction in blood lead levels need to be identified. In particular the most cost effective components should be used to modify any future Program depending on the resources available it.

11.3.4 Option 4: 95% of the 1-4 Year Old Children in the High Risk Areas Less Than 20μg/dl.

This Option represents a significant lowering of the goal which will require an increase in the resources and activities in many areas. The rate at which this goal can be approached will be dependent on the resources allocated and will require considerable changes from the current Program. The strategies are outlined below.

(1) City planning

(a) Buffer zone

The central business district and the area north of York Road and east of Anzac Road should be zoned "no further development" with no new houses being built in the area and residence by young children actively discouraged. Houses in the central business district and north of Fredrick Road should be progressively purchased and demolished. Consideration will need to be given to whether parts of Solomontown should also be zoned.

(b) Relocation of children

All children in the central business district and the area north of Revell Street should be relocated. Children with elevated blood lead identified in contaminated houses which cannot be readily decontaminated in the remainder of the high risk should be actively relocated. Blood lead data will need to be reviewed to determine relocation requirements.

(c) Dust control

An active program of dust control needs to be maintained with an increase in the activity above that of the current Program.

The new Program would include augmentation of the general greening program and the development of a physical barrier around the plant and the wharf area as rapidly as possible. Dust control by the City Council would need to be enhanced with a footpath and a road sealing program. A street cleaning program involving sweeping and washing of the roads and collection of the dust should be implemented with street sweepings dumped in a secure location.

Abatement of the lead contaminated dust sink in open areas of the City will be required. Actions to interrupt dust re-entrainment, for example fences in open areas such as the Island and around the rail corridor should be considered.

Intervention will be necessary where recontamination by sources of lead dust are identified by future investigations.

(2) Pasminco-BHAS actions

(a) Slag dump

Current management practices on the slag dump need to be continued. In particular the dust suppression and greening must continue.

(b) Plant and lease area

As well as the initiatives currently underway, there will need to be a substantial increase in the activities relating to the suppression of contamination from the plant. Further gains will need to be made in reducing the amount of lead contamination reaching residential areas. These actions will, in part, be dependant upon the investigation component of the Program being enhanced to identify potential sources.

(c) Wharf

Control of dust from the stockpiles on the wharf would need to be effective and the wharf activities should be enclosed to prevent dust loss.

(3) Abatement of household contamination

A house decontamination program needs to be continued which would involve both primary and secondary decontamination of houses. The actions would be in part dependent upon the outcome of the investigations which will need to be carried out on sources of lead within houses. Consideration will have to be given to more stringent criteria for decontamination activities.

(a) Primary decontamination

There will be a need for primary (principal) decontamination based on identifying houses where children have or are predicted to reach blood lead levels greater than 20μg/dl and should be considered where there are pregnant women living in a high risk area.

(b) Secondary decontamination

There will be a need for secondary decontamination of houses where children are found to have or predicted to reach blood lead levels greater than 20μg/dl. This will involve work on houses which have been previously decontaminated and the work may need to be directed to leaving the houses with lower levels of contamination than previously. The work will require abatement of paint which is currently on the register and treatment of deteriorating paint.

(c) Grid decontamination

The high risk area will need to be redefined and there will be a need for some general grid decontamination. There may be a need for general grid work directed towards addressing recontamination.

(4) Household behaviour change

A program of education for parents and children will need to ensure that behavioural contributions to the reduction of blood lead levels are enhanced.

(a) Personal and domestic dust hygiene

An active program of reducing the dust levels in houses should be carried out. This program will require a moderately high profile and will need to continue indefinitely.

(b) Diet

An active program directed at improving nutrition as a way of reducing lead absorption should occur. Some research and development in the understanding of the effects of nutrition on lead absorption will be required.

(c) Avoidance of rainwater

The level of lead in rainwater which is acceptable for drinking will be lower than the current level. An active program to stop the use of rainwater where there are young children or pregnant women will have to be carried out.

(5) Active community support and participation

An enhanced program involving activity by State and Local Governments, Pasminco, community groups and the Environmental Health Centre must occur. This program must be directed towards increasing the level of support by all people in the City for the Lead Program and the goals that have been defined.

(6) Blood testing and medical evaluation

(a) Blood testing of children

Blood tests should be offered to 1-4 year old children annually with every effort made to ensure two measurements on all children prior to age 3 years. A very active program to identify all children below 5 years old will be essential along with a high compliance rate in testing. Where children have or are predicted to reach blood lead levels above 20μg/dl more frequent monitoring will be necessary to ensure that actions have been effective in reducing the blood lead levels. An "at risk" register and intensive follow-up of children at risk will be required.

Blood lead testing should be offered to all pregnant women to help increase awareness of problems and to help identify children at risk.

(b) Survey related to goals

A survey of all children 1-4 years old should be carried out every three years to provide data for the evaluation of the overall situation in the City.

(c) Medical evaluation

There will need to be a general practitioner education program. Practitioners will need to actively support the Program and to participate by evaluation of children and recommending actions to reduce blood lead levels.

(7) Environmental monitoring and investigation

A program to identify sources of lead that are contaminating the environment and recontaminating households will need to be actively pursued. A goal of understanding the major sources within three years should be set and actions taken to continue investigations to identify minor sources and contributions to children's lead absorption should continue.

(a) Air monitoring

Routine air monitoring at the current sites by Pasminco and the Government should continue. There should be an increase in the air monitoring at fixed sites to better define the air lead situation in the City. The extra air monitoring sites should include one or more located on the perimeter of the smelter.

(b) Sources of lead

An investigation program directed at identifying the sources of lead resulting in elevated air lead levels needs to be carried out. This would require a commitment by both Pasminco and the Government to a co-operative program directed at identifying the major sources in the next three years. As opportunity and resources permit, this program of investigation should be further directed towards understanding the contribution of other sources and pathways leading to children's absorption of lead.

(c) Household contamination

Investigation effort will need to be directed towards defining the mechanisms and rate of household contamination and recontamination in the high risk areas. The sources of lead causing this contamination need to be identified within three years.

(d) Household abatement strategies

The most effective components of the present Program which are leading to a reduction in blood lead levels need to be identified and incorporated into the future Program strategy along with other potential household abatement strategies.

11.3.5 Option 5: 95% of 1 to 4 Year Old Children in High Risk Areas Less Than 15μg/dl.

It is considered that achievement of a goal where almost all of the children in the whole of Port Pirie have blood lead levels less than 15μg/dl is not possible by simply increasing the stringency and expanding the present Program. In particular, without relocating a substantial proportion of the City where there is significant lead contamination and ongoing recontamination, achievement of this goal is not considered possible. It is likely that all children in the current high risk areas, central business district, Port Pirie West and Solomontown, would need to be relocated. This would have to be coupled with an almost total prevention of losses of lead from the slag dump, smelter and the wharf areas. It would appear that this is not achievable with the current technology in the smelter and the activities associated with it. To achieve this goal in a relatively short time-frame with the smelter continuing to operate in its present mode, the main strategy would appear to be massive relocation of the children.

11.4 RESOURCES AND COST ESTIMATES

The present Program in Port Pirie has a clearly defined structure, staffing and resource allocation. The strategies to achieve the various goals as set out in Section 11.3, were broadly discussed in terms of changes to the present Program rather than attempting to define in detail every component of each strategy. It is considered that a similar approach can be broadly taken to the consideration of the resources and cost estimates for Options 2, 3 and 4. Options 1 and 5 present extreme situations which cannot be easily related to the present Program and have been estimated separately. These cost estimates assume that current Pasminco-BHAS and City Council commitments will be maintained.

The cost of Option 1 is effectively nil to the South Australian Government since it would mean the total discontinuation of the present Program. General practitioner involvement would be funded through Medicare.

Option 5 requires the relocation of large numbers of children and their families from Port Pirie West and Solomontown to areas of low lead contamination. It is estimated that there are at least 2,000 houses in the areas which would require relocation. To provide housing with services and community amenities including shopping centres, churches and other community facilities it is estimated that the cost would be at least $100,000 per house. This translates into a cost for a program of the order of $200 to $300 million.

Estimates for the implementation of Options 2, 3 and 4 have been based on the costs of the present Program, and at current rates, are set out in Table 11.1 and 11.2. These are rough estimates which are based on the levels of activity and achievements it would appear necessary to achieve the goals set. If the goals are to be achieved more rapidly then the provision of more resources in the early years of the Program would be necessary. A summary of the direct annual costs for Options 2, 3 and 4 for a ten year program are set out below.

Table 11.1 Resources Required for Options 2, 3 & 4 (x $1,000)
(Compared with the Current Program)

	Present	Option 2	Option 3	Option 4
Management	56	56	56	56
Administration	175	120	150	175
Case Workers	155	77	120	260
Blood Testing	100	94	130	180
Promotion & Education	40	40	80	80
Laboratory & Testing	115	50	130	130
House Decontamination	1,825	300	400	700
Relocation & Demolition	275	150	300	700
Greening & Dust Control	170	200	250	500
Air Monitoring	13	13	14	29
Investigation & Evaluation	60	100	100	190
TOTAL	2,984	1,200	1,730	3,000

Table 11.2 Salaries, Goods and Services Required for Options 2, 3 & 4 (x $1,000)
(Compared with the Current Program)

	Present		Option 2		Option 3		Option 4	
	Salaries	Goods & Services	Salaries	Goods & Services	Salaries	Goods & Services	Salaries	Goods & Services
Management	48	8	48	8	48	8	48	8
Administration	102	73	80	40	80	70	102	73
Case Workers	115	40	58	19	87	33	173	87
Blood Testing	70	30	70	24	100	30	115	65
Promotion & Education	30	10	30	10	60	20	60	20
Laboratory & Testing	100	15	35	15	100	30	100	30
House Decontamination		1825		300		400		700
Relocation & Demolition		275		150		300		700
Greening & Dust Control	30	140	30	170	70	180	150	350
Air Monitoring		13		13		14		29
Investigation & Evaluation		60		100		100		190
Sub Total	495	2489	351	849	545	1185	748	2252
TOTAL EXPENDITURE	2984		1200		1730		3000	

In summary, the options offered for consideration are as follows.

OPTION	GOAL	COST (1993$)
1	Clinical intervention only.	0
2	All children in Port Pirie with a blood lead less than 25μg/dl (this is the present goal).	1.2m/yr
3	95% of children in the high risk areas with a blood lead less than 25μg/dl.	1.7m/yr
4	95% children in the high risk areas with a blood lead less than 20μg/dl.	3m/yr*
5	95% children in the high risk areas with a blood lead less than 15μg/dl.	200-300m

* An amount greater than $3 million per year will be required if goal is to be achieved in a shorter timeframe.

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