The Use of GIS in Identifying Risk of Lead Poisoning in Australia

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Abstract

Environmental lead poses significant health risks to small children in most Western countries. However, many surveys examining the prevalance of elevated paediatric blood lead levels give insufficient attention to the geography of the major known risk factors. GIS addresses the spatial variation inherent in the distribution of these risk factors, and can identify areas, streets and even individual dwellings with a high probability of environmental lead. Predictions can then be validated with AAS analysis of blood or dust samples. Preliminary results based on GIS analysis of the metropolitan digital cadastral database and its associated housing data and the spatial distribution of relevant entities suggest that the prevalence rate of elevated PbB in one major Australian city may be significantly higher than was reported in the national survey. This analysis forms the basis for a model predicting the presence and risk of environmental lead for any city and offers a means of targeting further investigation of lead exposure, more accurately estimating the number of children at risk using small area Census data and selecting areas for future sample surveys. The need to develop a cost-efficient and accurate method of modelling lead exposure risk childhood is a task to which GIS is clearly well suited.

Keywords and phrases: environmental lead, risk factors, GIS, urban environment, public health

Introduction

Lead is a heavy metal with no health benefit to humans. In 1995 it was ranked number one in the Agency for Toxic Substances and Disease Registry of the US Public Health Service list of 275 toxic substances (http://atsdr1.atsdr.cdc.gov:8080/cxcx3.html). Lead has been shown to cause significant deficits in children's cognitive development and intelligence, and is linked with low birth weights, attention deficit disorder, hearing problems, aggression, chronic lead nephropathy in adults, increased risk of abortion, high blood pressure and fertility problems in adult males and inhibited bone formation (Needleman, 1993; O'Halloran and Spickett, 1992; Price *et al*, 1992; Rosen, 1995; Schwartz, 1994; Tuthill, 1996; Verberk *et al*, 1996). Baker (1995:257) contends that in New Zealand, lead poisoning is probably more common than most of the diseases routinely screened for in childhood. Once lead is released, it remains in the local environment for many years, although its bioavailability varies according to its source, location and type of compound (Edwards-Bert, Calder and Maynard, 1993; Wixson and Dawes, 1994).

Those most vulnerable to the effects of lead are children aged 4 years and below because their bodies are small, and they have higher lead absorption and retention rates than adults. Children absorb up to 50 per cent of ingested lead whereas adults typically absorb only between 5 and 15 per cent (Baker, 1995:251; National Research Council, 1993:146). Because of their normal hand-mouth developmental behaviour, and the fact that they are closer to the ground, small children are also more likely than adults to ingest environmental lead in dust and soil. Mortality and morbidity patterns for adults poisoned by lead in childhood suggest that the effects may persist throughout life (McDonald and Potter, 1996; Price *et al*, 1992). Lead is both a health problem and a social problem, as Newsome, Aranguen and Brinkman (1997:332) also point out. It is a social problem in several ways. First, there is the importance of the lead industry to local economies and the need for lead in the manufacture of many products (eg batteries, solder, crystal, ceramic glazes). Thus there is some political difficulty in addressing possible health risks, especially as lead is so widely dispersed throughout human environments. Second, the failure of significant numbers of individuals to reach their full intellectual potential is a loss of intellectual capital to society, as well as resulting in lower productivity and earnings and increased expenditure on special education. Finally, the health effects of lead impact more amongst certain social groups, due to social processes which result in their disproportionate exposure to lead. Thus identifying, addressing and alleviating contamination and risk of contamination depends on factors outside the realm of purely medical research.

The prevalence of elevated blood lead levels in Australian children is low by international standards (Donovan, 1996). This does not mean, however, that the issue of environmental lead is unimportant. But the relatively low prevalence rate does mean that mass screening programmes such as those practised in the United States would be an inefficient use of scarce health resources. The 1995 National Survey of Lead in Children found that 7.3 per cent of Australian children aged 1 to 4 (75,000 children) had blood lead levels over the current NHMRC standard of 0.49 μmol/L (10 μg/dL). This compares with 8.9 per cent of children aged 5 and under exceeding the same level in the United States in 1994 (Brody *et al* 1994). The children in the South Australian subset of the national survey had a mean geometric blood lead level of 0.28 μmol/L (n=133), significantly higher statistically than the national mean level of 0.24 μmol/L (n= 1575). The lead smelter town of Port Pirie, which might be expected to bias the results, was excluded from the survey.

Although Australian authorities acted to reduce the lead content in domestic paints much earlier than in the United States and airborne lead has been reduced dramatically with the phasing out of leaded petrol in vehicles, environmental lead is still considered a significant health issue in Australia, particularly in urban areas (Fett *et al* 1992; Gulson, Davis and Bawden-Smith, 1995; Mira *et al* 1996). In general (there are variations between the States) Australian paint contained up to 50 per cent lead until 1950 when it was reduced to about 10 per cent. The concentration was further reduced to about 1 per cent in 1970, to 0.25 per cent in 1992 and was to be reduced to 0.1 per cent in December 1997 (EPA, 1995). Conversely, in the United States, the lead content of paint was not reduced until 1978 (Graef, 1997:vii). Up to 50 per cent of US children in some urban areas have elevated blood lead levels (Kessel and O'Connor 1997) while 16.1 per cent of children in central and southern Sydney have been found to have elevated levels. One quarter of children within a 10 kilometre radius of the Sydney city centre had elevated blood lead levels in 1995 (Mira *et al* 1996) as did Fremantle (Western Australia) children in 1994 (Willis *et al* 1995). The main source of ingested lead in such areas is usually paint in older housing (Alder *et al*, 1993; Gulson, Davis and Bawden-Smith, 1995; Mira *et al* 1996) and more than 3.5 million houses in Australia were built before 1971, when paint typically had high levels of lead (Gulson, Davis and Bawden-Smith, 1995). Many of these houses will still have their original paint. More than 64 million homes in the United States still have the leaded paint they were painted with before 1978 (United States EPA, 1995; cited in Kessel and O'Connor 1997:15). The fact that a relatively low proportion of Adelaide housing is constructed of weatherboard or timber (ie in comparison with Melbourne or Brisbane for example) does not necessarily negate the presence and role of leaded paint - many studies have found stronger relationships between blood lead levels and interior paint than with exterior paint (eg Donovan, 1996).

It is also notable that after Tasmania, South Australia has the highest consumption level of leaded petrol in the country- 44 per cent of vehicles in 1996 ran on leaded petrol, compared with 38 per cent for Australia as a whole (Australian Institute of Petroleum, 1997). South Australia was also the last state to achieve the recommended lead level of 0.2mg per litre for ‘unleaded’ petrol in October 1996 (Australian Institute of Petroleum, personal communication) and its capital city of Adelaide has the highest rate of car usage in the country (1996 Census). Even though the lead content of ambient air has decreased dramatically with the introduction of unleaded petrol (EPA 1996), during the years of higher lead emissions the metal is likely to have accumulated in soil, resulting in high concentration in the soil of yards in close proximity to major roads and/ or traffic lights (Wixson and Dawes, 1994). The phasing out of leaded petrol in Australia began in 1986 but its sale was made illegal in the United States in 1976 (Donovan, 1996:391).

Whether lead poisoning actually occurs depends on the presence of children, while its timing and magnitude depend on a number of less readily measured factors such as the amount of time spent in the location, nutritional status (particularly iron, zinc, calcium and fat intake), hand-mouth behaviour and the frequency and efficacy of household cleaning and vacuuming. The pathways by which lead enters the human body are undeniably complex but it is nevertheless useful to consider the presence of lead indicators and their spatial distribution as one way of estimating risk. In urban populations, the most prominent risk factors are related to housing; namely, housing age, condition (especially as pertaining to paintwork), tenure and renovation, as well as lead in ambient air and soil from the use of leaded petrol. It is also significant that many of the households undertaking renovation of older housing (and who live in such housing either because of the price attraction of older inner city housing or the investment potential of older housing in more upmarket areas) are young couples, including pregnant mothers and couples with young children. Gulson, Davis and Bawden-Smith (1995:233) observe that ‘renovation tends to impact on the most sensitive population’. The link between gentrification and childhood lead poisoning is supported by several studies which have found that the highest levels of blood lead are amongst children from the higher social strata, although the prevalence rate is higher amongst the lower socioeconomic status groups (eg Rosen, 1995). The Australian National Survey found that most children with elevated blood lead levels were socially disadvantaged (Donovan, 1996:391) although an American survey found that 30 per cent of urban infants (aged up to one year) with high socioeconomic status had blood lead levels over 0.49μmol/L (Casey *et al*, 1994).

The literature generally agrees that the age of housing is a good indicator of the presence of old (leaded) paint. Alder *et al* (1993) for example found that Canadian children living in homes built in or before 1945 had an average blood lead level 62.3 per cent higher than that of children living in homes built since 1975. The Australian National Survey also found a relationship between age of housing and blood lead levels, even though the data for house age were based on interviewer and respondents’ estimates rather than official sources (Donovan, 1996). Even where children do not reside in a dwelling likely to have high levels of environmental lead, it is still important to identify such dwellings as Gulson *et al* (1996) found that in some cases children’s elevated blood lead levels were derived not from their own residence but from other residences in their community. Gulson *et al* (1995) also found that some dwellings are contaminated by lead paint in adjoining dwellings via airborne and mechanical transport.

The fact that lead poisoning continues to occur in Australia shows that it is still a problem. The risk factors for lead poisoning are well known but research identifying the precise locations of these factors and their spatial correlation is yet to be undertaken in Australia. In the absence of blood testing - which only measures recent ingestion and not long term exposure - other researchers have attempted to use questionnaires to predict elevated paediatric blood lead levels but results have mostly failed to be much better than chance (eg. Casey *et al*, 1994; France *et al*, 1996; Schaffer, *et al* 1996; and Snyder, *et al* 1995). There is a need to develop an alternative method of identifying children at risk. As an alternative to identifying individual children, we can instead identify precise areas and even dwellings which are likely to have hazardous levels of environmental lead, using official data already collected for a range of other purposes. This approach has the advantage of identifying and quantifying the presence of risk factors in a child's environment of which parents may not be aware. Such research represents a task for which GIS is well suited, given its capacity to integrate and query a variety of different data sets on a precise spatial basis. Several studies (eg Thredfall *et al*, 1993 and Edwards-Bert, Calder and Maynard 1993) which have used coarse spatial units (namely postcodes, Local Government Areas or distance from city centre) to examine the spatial distribution of blood lead levels suggest that geographic location is not of significant predictive value, yet the small body of American research using GIS suggests otherwise (eg Guthe *et al* 1992; Hanchette 1995, 1997; Padgett, 1997; Warburton, 1992).

This paper is concerned not only with developing a model for predicting the spatial distribution of environmental lead but also estimates the number of children potentially at risk from lead derived from these sources. The aim is to show areas and dwellings *most likely* to have high levels of environmental lead, rather than to measure exposure. It is important to understand that the presence of environmental lead contamination in a residential property does not mean that there necessarily will be exposure. However, if there is contamination, then a risk exists. The presence of children under four who exhibit normal hand-to-mouth behaviour, as well as those with pica, are the only other factors required to complete the lead poisoning circuit.

The Adelaide Study

Methodology

Two local government areas in South Australian capital city of Adelaide (population 1 million) were selected as case studies, with the aim of extending the analysis for the entire metropolitan area (see Figure1).

Both LGAs are located at similar distances from the Adelaide CBD but have quite different socioeco-

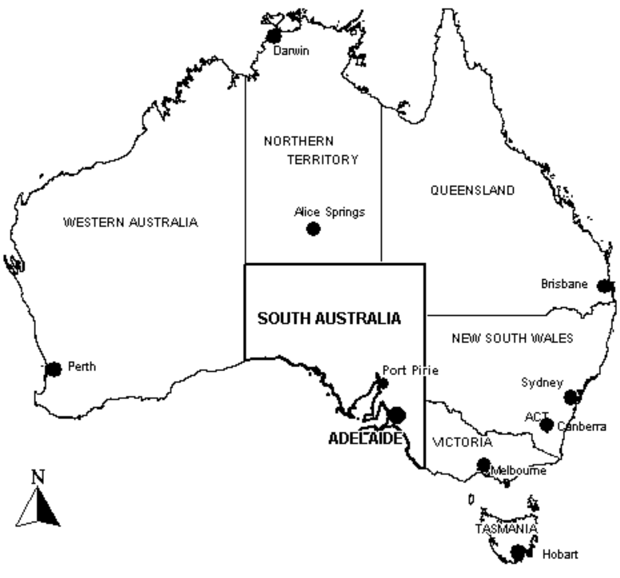

Figure 1a. Location of Adelaide, South Australia

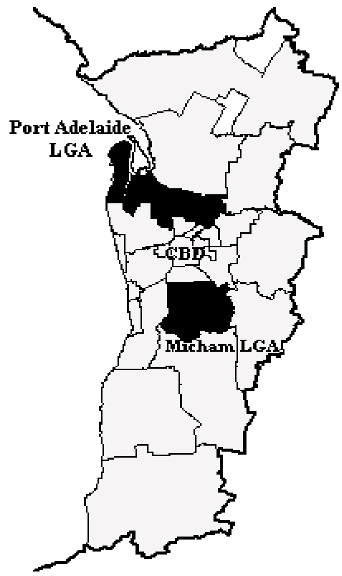

Figure 1b. Location of case study areas in Adelaide

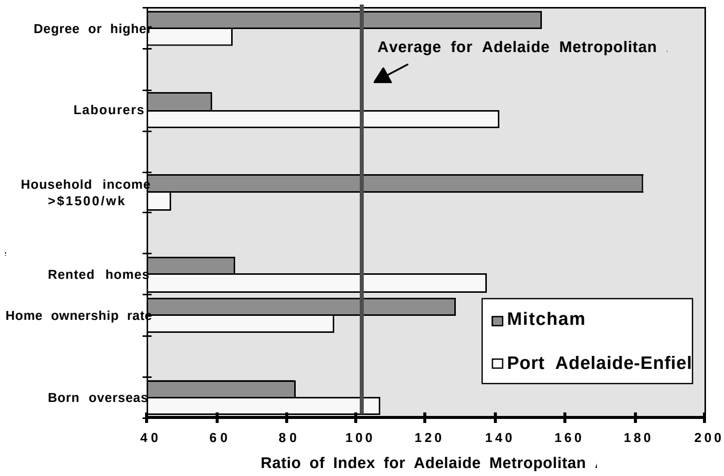

Figure 2. Selected socioeconomic status indicators for Mitcham and Port Adelaide-Enfield, 1996. Source: 1996 Census, Australian Bureau of Statistics

nomic profiles (see Figure 2). The LGA of Mitcham has a population of 59,000, 5 per cent of which is aged 4 years and under at the time of the 1996 Census, while the LGA of Port Adelaide-Enfield has a population of 98,000 with 6.5 per cent consisting of children aged 0-4.

The most important risk factors identified in the literature, namely age of housing, (which is a proxy for leaded paint and condition of dwelling), traffic flows and land use are already represented in existing data sets constructed for various other purposes. These data sets were overlayed to ascertain how many houses (and their resident children) were subject to at least one risk factor. A very simple risk model based on the number of factors present in any location could then be constructed. This model can be further refined by weighting the factors. However, before presenting the results and the estimates of the number of children at risk of lead poisoning, it is necessary to consider the data sets used in some detail. The risk modelling technique we have developed is extremely simple and straightforward but its value depends largely on the availability and quality of data. As was the case in this research, it is often difficult to obtain the range of necessary data sets for the same time periods. This disparity may not matter a great deal in terms of outcomes (for example, traffic flows are unlikely to have altered significantly in the last five years in the case study areas) but it is important to be aware of these issues.

The digital cadastre database (DCDB) and associated valuation data

The DCDB is a computer-based map of all land parcels in the State. It contains approximately 800,000 land parcels, together with their legal identifiers. Associated data includes street addresses and boundaries of administrative regions such as local government areas and suburbs. The DCDB is one of the major core spatial data sets maintained by government and is widely used by government agencies and utility companies as a basic reference for land administration, local government administration, facilities management, planning and asset management. Similar spatial data sets exist in New Zealand and the United States. The spatial accuracy of the DCDB in South Australia is considered to be very good. The 1997 DCDB for Port Adelaide-Enfield was used but only the 1996 DCDB could be obtained for Mitcham.

Each land parcel in the DCDB can be linked to property valuation assessments for rating and taxing purposes using parcel identifications numbers as a common link. This valuation dataset provides a wealth of information to do with lead risk factors, namely the date properties were constructed, the land use code, the material of roofs and walls, and a rating of their condition on a scale of 1 to 9 and it is the DCDB that allows us to put this data into a GIS. The reliability of this information is generally very good, except for properties built in the early parts of the century, when the exact date of construction was often not recorded.

The quality of the condition data is considered fair rather than good, because only the external appearance of the dwellings can form the basis for the professional valuer's condition rating. Hence some dwellings in older areas may appear run-down but may be undergoing (or have completed) substantial internal renovation. Condition is rated on a a scale of 1 to 9 by the Valuation Division of the Department of Human Services. The Department defines dwellings built before 1952 and rated 5 or below, and dwellings built in or after 1952 and rated 7 and below, to be in average to very poor condition. A rating of 5 for a 1951 dwelling means that the dwelling is in its 'original state, ie no major upgrade but average maintenance'. A post 1952 dwelling rated as 7 indicates a dwelling which is 'maintained but in need of paint, would be poor 1970s house to appear here' (Valuation Update User Manual 1991:4). Condition ratings are generally updated once every two or three years, whereas the data on year built is of course static. The valuation data used in this research were for the year 1997 for both case study LGAs.

The National Survey of Lead in Children

The data collected for the National Survey of Lead in Children in 1995 were obtained with the intention of using them to validate the predictions of the GIS - in other words, to ascertain if there was a relationship between the areas predicted by the GIS to have elevated lead levels and the actual blood lead levels of children. However, these data proved to be very limited for a number of reasons. One was that the age of the dwelling was based on either the interviewer's or the householder's estimates rather than on official data. When addresses in the NSLIC were matched with the valuation data and DCDB, it was found that in 78 per cent of cases, the year the householder or interviewer estimated the dwelling was built was incorrect, by an average margin of 5 years. Close to 90 per cent of the households who were renting had incorrect estimates of the year their dwelling was built and the average size of the error there was 6 years, particularly notable as most of the renting households lived in dwellings built before 1970. The degree of error generally increased with the age of the dwelling. The average size of the error was 10 years for dwellings built before 1920, 9 years for dwellings built between 1940 and 1960, 7 years for dwellings built between 1960 and 1970, 4 years between 1970 and 1980 and only 1.5 years for more recently built dwellings.

Other problems were the small number of cases - only 133 cases for the whole State. Only about half of those were located in Adelaide, even though Adelaide contains three quarters of the State's population. In terms of showing any geographical distribution of blood lead levels, the number of cases was too small to draw any valid conclusions. None were located in Mitcham and Enfield LGAs in any case. In addition, some of the questions used in the household questionnaire were badly worded, the data on the condition of paint varied according to whether the householder or the interviewer estimated it and sample collection methods were not always appropriate. Finally, proximity to industrial point sources was not addressed even though previous research (eg Gulson et al 1994) has shown that industry is an important source of lead and that most contaminated sites are the result of industrial activity.

Traffic counts

The State Department of Roads and Transport supplied the roads coverage of the whole State. Traffic counts for all main roads were readily available from the same department while counts for suburban streets within the two case study LGAs were available from the respective local government engineering departments. The counts attributes were then added manually using ArcEdit module of ArcInfo. The most recent traffic count data held by the Department of Roads and Transport is for 1993, while the counts for suburban roads and streets were dated 1997 for both Port Adelaide-Enfield and early 1998 for Mitcham.

The benchmark used to define main roads was a minimum of 20,000 vehicles per day. This contrasts with the definition used by the NSLIC, which was 5000 or more vehicles per day. The NSLIC found no correlation between blood lead levels and proximity to roads using this benchmark. However, when the data were reanalysed by the health department of in the State of Victoria, using the 20,000 vehicles per day benchmark, there was indeed a strong relationship. An attempt was made to reanalyse the South Australian data using the 20,000 vehicles per day benchmark but only 11 of the 133 cases had data on traffic counts and only seven of these were next to roads with more than 20,000 vehicles per day. The high traffic count cases had a geometric mean blood lead level of 0.35 µmol/L and the others had 0.27 µmol/L, but clearly the small number of cases means that this finding is not statistically significant.

Census counts

The 1996 Census counts of 0-4 year olds were allocated to residential areas within the DCDB. The usual problem of relating small area data and point data (in this case, individual dwellings) arises - this poses a methodological obstacle in many social applications of GIS. While the situation with Australian small area census data is somewhat better than in the US, it is surpassed by New Zealand's small area data units. The smallest Australian areal unit, the 'collector's district', (CD) contains 220 households on average. The smallest American spatial unit, the 'block group', contains about 400 households. However, New Zealand's smallest unit is the 'mesh block' of approximately 50 households, which offers substantially more spatial accuracy.

The usual method of dealing with population data for areas is to convert the counts to a density for each spatial unit, so that any selected point or area within the smallest Census areal unit will have a density which can be summed to form a count. This method does not account for non-residential areas within that areal unit which do not have a population and consequently underestimates densities. However, use of the DCDB overcomes this problem to some extent. The DCDB was overlayed with the boundaries of the CDs and then the number of children aged 0-4 for each CD was divided by the number of residential dwellings in that CD (as identified by their land use code in the valuation data). The resulting average number of children per dwelling was then allocated to every residential dwelling within each CD.

Results

Age of housing

Both case study areas had similar proportions of housing built before 1970. Port Adelaide-Enfield had 81 per cent, Mitcham 78 per cent. This compares with 50 per cent for Australia as whole (Berry 1993) and 53 per cent for Adelaide (DENR and ABS). However, Mitcham has somewhat more housing built before 1952 (34 per cent) than Port Adelaide-Enfield (28 per cent). Table 1 gives a breakdown of housing age for the two case study LGAs.

Year Built	Mitcham	Port Adelaide-Enfield
<1925	7.3	11.1
1925-1934	13.7	5.0
1935-1945	6.2	2.8
1946-1951	6.6	9.4
1952-1960	23.0	33.1
1961-1971	21.0	19.4
1972-1980	11.7	6.3
>1981	10.5	13.0
N	**20447**	**34988**

Table 1. Date of Construction of Residential Dwellings in Mitcham and Port Adelaide-Enfield. Source: South Australian Department of Environment, Heritage and Aboriginal Affairs

Clearly, we may expect most children in these LGAs to live in older housing and indeed it was found that 30 per cent (approximately) of Mitcham children (n = 1200) and 27 per cent of Port Adelaide-Enfield children (n = 1150) live in houses built before 1952. A further 30 per cent of Mitcham children lived in houses built between 1952 and 1971. But around half of Port Adelaide-Enfield children lived in such housing. This is a reflection of the socioeconomic differences between the two LGAs - a large proportion of Port Adelaide-Enfield housing is public housing built in the post war period, while there is also a significant amount of cheap private rental housing. Families with children have priority for public housing, while households privately renting are typically quite young and in the childbearing stage of their lifecycles. Such households are often attracted (or constrained) to the relatively affordable private rental housing in the Port Adelaide-Enfield area. In common with many other middle ring suburbs, the building boom of the 1960s is clearly evident in Port Adelaide-Enfield.

Condition

One quarter of Mitcham dwellings are in bad condition. Approximately 800 children aged 0-4 live in these dwellings. However, only a quarter of bad condition dwellings in Mitcham were built before 1952. This may be a reflection of the level of gentrification that has occurred in Mitcham - the older houses are very popular and tend to be quite valuable. In Port Adelaide-Enfield, 40 per cent of housing was in bad condition, even though Mitcham and Port Adelaide-Enfield have similar proportions of housing built after 1952. Many of these dwellings were built after 1960 and house an estimated 2,500 children.

Land use

All land uses identified in the literature as possible lead risks were selected and used as a point for the centre of a buffer zone. (An obvious land use involving lead which is not included here is lead smelting, as the only lead smelter in South Australia is located in the regional town of Port Pirie.) The buffer size of 50 metres radius was arbitrarily selected but was deemed conservative, given that lead can be transported hundreds of metres depending on the presence of physical barriers such as trees or buildings around point sources, and on wind strength and size of particles. At this stage, the shape of the buffer is a simple circle with the land use as a point in the centre. The aim is to keep the analysis as simple as possible for the initial model, which can then be refined with more sophisticated techniques. For example, the use of a rose diagram to form an ellipse-shaped buffer, taking account of wind strength and direction, would refine the buffering technique or even more sophisticated procedures such as those described by Collins, Smallbone and Briggs (1995) may be employed.

Land use	**Mitcham**	**Port Adelaide-Enfield**
Wholesale trade - petroleum products	4	47
Service station	23	88
Printing, publishing and allied industries	0	23
Paints, varnishes, lacquers	0	5
Petroleum and coal products	0	8
Pottery, china and earthenware	0	2
Iron and steel basic industries	1	72
Non-ferrous metal basic industries	0	2
Industrial waste disposal	0	4
Car parking	0	2
Base metals	0	2
Total N	**28**	**255**

Table 2. Land Uses Associated with Lead, Mitcham and Port Adelaide-Enfield LGAs

It was found that Port Adelaide-Enfield has 255 possible lead risk land uses (see Table 2), although 5 of these were multiple land uses, which meant that there were actually 247 land parcels. These covered virtually the entire range of land uses identified in the literature but the most important were service stations, printing industries, wholesale trade of petroleum products and iron and steel basic industries.

Mitcham had only 28 lead risk land uses, 23 of which were service stations. Approximately 20 children in Mitcham live within 50 metres of these land uses but 135 children live in close proximity to the risk land uses in Port Adelaide-Enfield.

This pattern is consistent with the limited information on lead-contaminated sites obtained from the South Australian EPA which merely tells us that there are 22 such sites in Enfield and none in Mitcham. The EPA will not disclose the locations of these sites for research purposes, holding that the public may be needlessly alarmed (most, but not all, of these sites have been cleaned up) and also because the EPA does not want to create expectations of the availability and accuracy of EPA information for other purposes amongst the public (EPA, personal communication).

Proximity to main roads

Approximately 120 Mitcham children live within 25 metres of roads with average daily vehicle flow of 20,000 or more (4 per cent of all children in the LGA). The 25 metre buffer is measured from the centre of the road and note that road widths vary. Since, the Department of Transport's roads coverage does contain information on road widths, it will be easy to increase the size of the buffer according to the width of the road. However, for the sake of simplicity, a 25 metre buffer has been allocated to all roads regardless of width. Note that the NSLIC did not adjust distances from roads according to road widths (which of course reflect traffic flows). This means that the number of children in close proximity to major roads as calculated here is a conservative figure.

Even though the number of children in Port Adelaide Enfield is double that of Mitcham, only 151 children live within 25 metres of roads carrying more than 20,000 vehicles per day in Port Adelaide-Enfield (2 per cent of children in the LGA). The proportion of the population of 0-4 year olds who live within 25 metres of main roads in Port Adelaide is half that for Mitcham, simply because there are more industrial and commercial premises rather than residential properties along the main roads in Port Adelaide-Enfield. That is, fewer residential properties line the heavy traffic roads in Pt Adelaide- Enfield than in Mitcham. Of course, the lesser role of heavy traffic in Port Adelaide-Enfield may be counteracted by the greater number sites with lead risk land uses and vice versa. However, if traffic is given a heavier weighting than land uses, then traffic is a more significant problem for Mitcham than for Enfield. Six per cent of all road segments in both LGAs carry more than 20,000 vehicles per day.

Conclusion

In sum, we found that the dwellings at risk and their resident children can easily be identified using the GIS. Table 3 shows the frequency of each risk factor while Table 4 shows that there is more than 4000 hildren (approximately 40 per cent of the population of 0-4 year olds) in the two case study areas possibly exposed to lead risk factors. The two most common risk factors found together are old housing and poor condition, which represented over 90 per cent of dwellings in the two risk factor category. The relative importance of each of the risk factors is similar in both case study LGAs, although traffic is more

	Dwellings		Children	
Risk Factor	*N*	*Per cent of all dwellings*	*N*	*Per cent of 0-4 population*
Old housing[1]	14699	27	2550	27
Poor condition[2]	19096	35	3300	35
Close to major road[3]	1596	3	260	3
Close to industry using or producing lead[4]	777	1	150	2

Table 3. Total Dwellings and Children at Possible Risk of Environmental Lead, Mitcham and Port Adelaide-Enfield

No. Risk Factors Present	N dwellings	N children	% Total dwellings	% Total pop'n aged 0-4
1	15264	3284	27.7	35.3
2	9745	902	17.7	9.7
3	275	45	0.5	0.5
4	16	1	0.0	0.0
Total 1 or more	**25300**	**4231**	**45.8**	**45.5**

Table 4. Number of Environmental Lead Risk Factors Present, Mitcham and Port Adelaide-Enfield

important for Mitcham, while risk land uses are more common in Port Adelaide-Enfield.

Maps of selected portions in each case study area can be viewed or downloaded from: http://sisl.ssn.flinders.edu.au/html/images/lead/index.html.

The model produced here can easily be refined by weighting the factors and incorporating other parameters such as wind direction and direction, presence of traffic lights (the presence of stationary traffic is an important factor in airborne lead [Gulson et al 1996:179]), historical land use data, material of roof and walls and accounting for different width roads. However, it is a good model with which to introduce GIS to public health bureaucrats and researchers unfamiliar with the technology.

The next step is to verify the predictions of the GIS by analysing samples of dust, soil, paint and ideally blood in the selected areas and comparing them with samples from areas identified by the GIS as low risk. This fieldwork is in progress and the results will be finalised by early 1999. Assuming the predictions are accurate, a mail out campaign would greatly improve the efficiency of public health expenditure on lead, or even justify such expenditure. We could of course target only those households with young children, by identifying them through such means as immunisation registers - but we would have little idea of the *scale* of the risk, given that it is the housing related risk factors that pose the most risk. Obviously the role of risk factors beyond the domains of GIS, such as the cleanliness of homes and the occupations and hobbies of parents, cannot be ignored. But the use of GIS in lead prevention programmes offers a great deal in terms of geographic targeting and thus saving of public awareness campaign expenditure and that is an unfortunate reality of most Western public health systems. More broadly, it is clear that GIS is useful in any kind of public health problem that requires targeting of certain groups at a small area level or has some kind of environmental dimension.

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