Lead in petrol: where does it go?

More than 7000 tonnes of fine lead particles are consigned to the air over Australia each year. Most of it, 5600 tonnes, comes from the exhausts of petrol-engined vehicles.

Lead smelters and coal-burning power stations account for about another 1200–1500 tonnes and the remaining 250–600 tonnes come from the burning of sump oil and the melting of steel scrap. And where does the lead go? Eventually, most of it settles out or is washed out by rain, coming to rest in either soil or watercourses. In cities, house dust can contain appreciable quantities of lead.

A study by the CSIRO Division of Soils of an area adjacent to Adelaide is providing valuable insight into lead dispersal.

For instance, it has revealed that 50 km from the city the topsoil is contaminated by petrol-derived lead. Indeed, petrol has been shown to be the main source of the lead contamination found in most of the surface soil in the 3000-sq-km study area.

Lead is a poison, and half a gram of the metal can cause weakness, headaches, and anaemia, the classic symptoms of lead poisoning in adults. A much smaller amount will do the same in children. Larger quantities will severely damage health, or even cause death. In contrast to the effect on adults, lead poisoning in children is not always reversible.

Lead can be excreted at low rates and so, if intake rates are low, levels in the blood will not build up appreciably. However, unlike metals such as selenium and zinc, lead is a substance for which the body appears to have no need whatever.

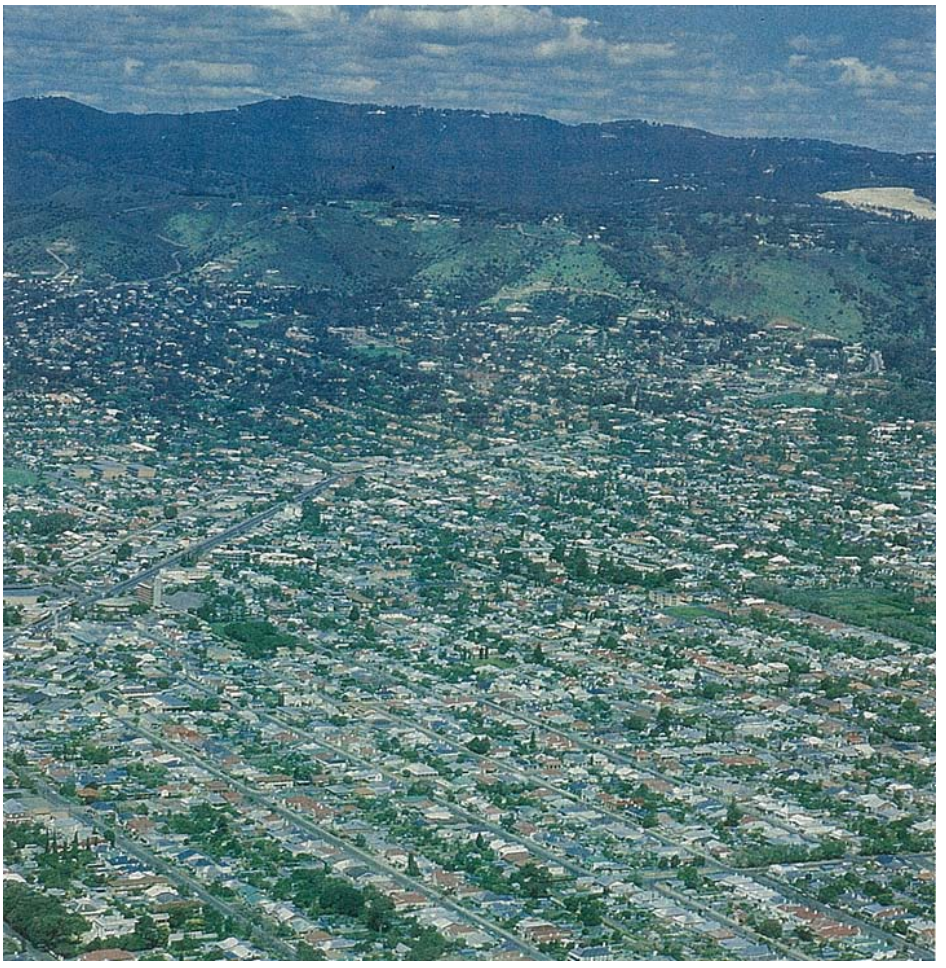
The Romans, we surmise, ingested unhealthy quantities of lead with their drinking water — they used pipes made from lead (*plumbus* in Latin) for their plumbing. Our country's water supply is effectively free of lead; on the other hand we do still have a facility for burdening our bodies with lead through the food we eat (plants take up lead from the soil) and the air we breathe (city air contains up to several micrograms per cubic metre — most of it from vehicle exhausts).

Nobody disputes lead's toxicity in large doses. The most common cause of lead poisoning today is a child's eating of old flaking paint — before the use was banned, house paint contained large quantities of lead compounds (some metal primers still do). But what is now unresolved is whether lead can cause subtle deleterious changes to the developing human brain and nervous system in the lower doses that are experienced in our major cities.

Lead concentrations in the atmosphere remain above the recommended levels.

The National Health and Medical Research Council has set a 'level of concern' of 30 micrograms of lead per 100 millilitres of blood for individuals. For populations, the NHMRC considers that lead levels in blood should not average more than 15 micrograms per 100 mL. Clear symptoms of lead toxicity appear at about the 80-microgram level.

Recent evidence presented to a symposium of the American Association for the Advancement of Science devoted to the lead question appears to have strengthened the case against lead. Dr Herbert Needleman of the Harvard Medical School reported that he had found the higher was the concentration of lead



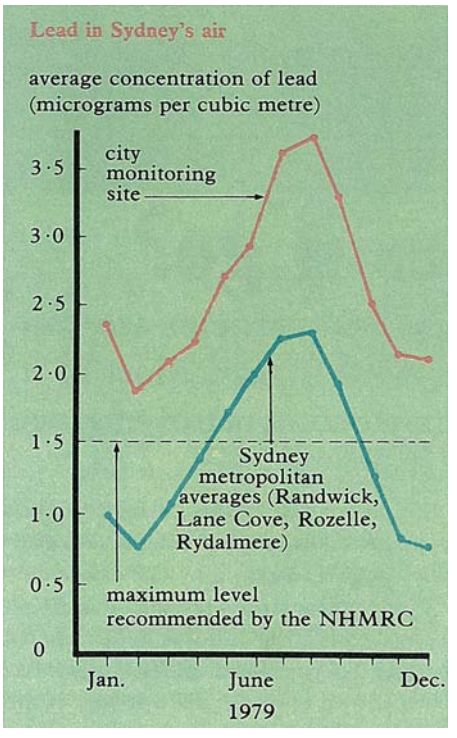
Fine lead particles from Adelaide spread far and wide.

in children's shed milk teeth, the lower were their IQ, their verbal skill, and their ability to concentrate at school.

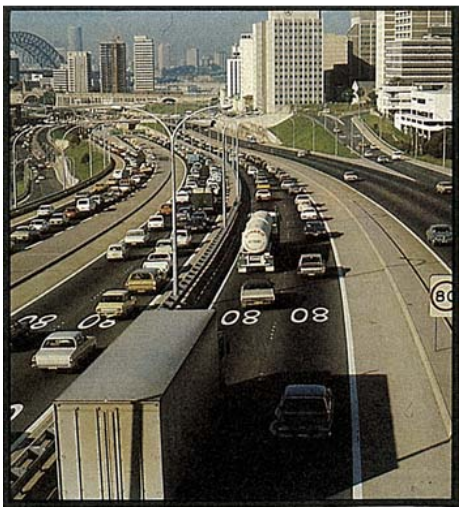
Several other studies have linked high body lead burdens with hyperactivity and learning impairments, but all such studies incriminate lead only by association — no effect due unquestionably to petrol-derived lead has yet been demonstrated.

Nevertheless, there is enough evidence for concern, and the consensus of scientific opinion appears to be tilting towards the view that lead at levels below those causing obvious signs of lead poisoning can exert deleterious effects on children's brain functions.

In one study, by Professor Lloyd Smythe of the University of New South Wales, the blood of 1200 Sydney children was analysed for lead. Of the inner-suburban children, 22% had lead levels above the 30-microgram 'level of concern'. Children from Penrith, on the outskirts of Sydney, were far less affected — only 2% of them had a blood-lead level of similar magnitude.



Lead levels in Sydney's air are often above the NHMRC's recommended maximum. The plotted points show 90-day running-average concentrations.



Cars — spreading lead from their exhausts.

The Victorian Health Commission tested 446 children whose parents 'volunteered' them for testing and found an average blood-lead level of 11·4 micrograms per 100 mL.

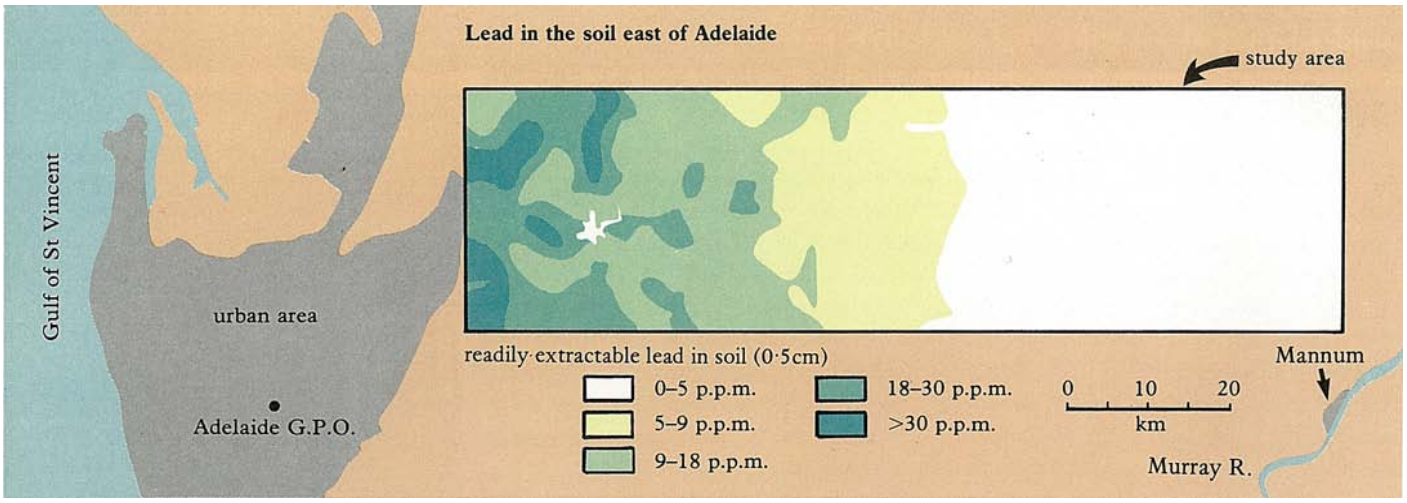
Another survey, by the deputy medical officer for health at Collingwood, Melbourne, compared the lead content in the milk teeth of 30 children in Collingwood with that of 30 children in Sherbrooke Shire just outside Melbourne. The city children's teeth contained about 40% more lead.

We have a facility for burdening our bodies with lead.

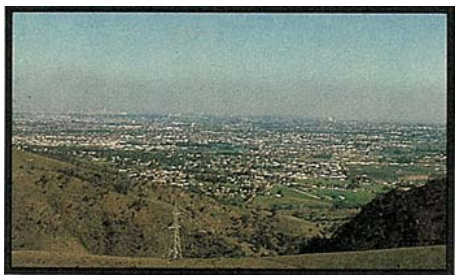
In 1979, the NHMRC reviewed the results of research on the health effects of lead, both in Australia and overseas. It noted that 'lead levels lower than those previously thought to be significant may now be producing adverse health effects'. The Council has recommended that the maximum permissible level of lead in urban air should be 1·5 micrograms per cubic metre, averaged over 3 months.

Victoria's Environment Protection Authority has disclosed that a survey found 160 'hot spots' in and around Melbourne where lead in the air exceeded the NHMRC recommended maximum level, in some cases being up to almost three times that level.

The Collingwood study also included lead-in-air measurements. At a day nursery near busy Hoddle Street, the air contained up to six times more lead than the level set by the NHMRC. At two other sites the NHMRC level was exceeded by a factor of almost three.



Lead introduced into the soil is more prevalent close to the city and its cars.



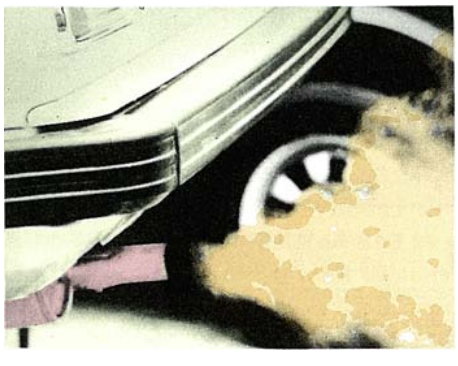
Smog over Adelaide — a sign that cars emit many pollutants, including lead.

In Sydney in 1979, the 3-month average level in the central business district, measured by the State Pollution Control Commission, varied between 1·8 and 3·7 micrograms per cubic metre — always well above the maximum recommended concentration. The maximum recommended level was also exceeded for more than 40% of the time at other monitoring sites in the Sydney metropolitan area.

Taking it out

Since 1975, the New South Wales government has progressively decreased the permitted lead content of petrol. The maximum lead content for petrol sold in Sydney, Wollongong, and Newcastle has dropped from an original oil industry maximum of 0·84 grams per litre in 1974 to a legal limit of 0·4 grams per litre in 1980.

Despite this action, lead concentrations in the atmosphere remain above recommended levels. In July 1980, the State government decided that lead-free petrol was needed. As well as removing lead from the air, this move would allow catalytic converters to be fitted to car exhausts. These anti-pollution units break down exhaust fumes before they are emitted, but they require lead-free petrol to avoid 'poisoning' of the catalyst.



The key factor is the proportion of the body's lead burden that comes from lead in vehicle exhausts.

From 1 July 1985, 92-octane lead-free petrol is to be available for sale at all retail petrol outlets in the State. More significantly, all new petrol-engined cars sold in New South Wales after 1 January 1986 will have to be designed to run on this fuel.

At a meeting of State and Federal Transport Ministers in February this year, other States decided to follow New South Wales' initiative (although the dates for implementation are a year later than New South Wales originally planned).

The decision was not clear-cut; strong arguments were put forward that such a move is unnecessary and a waste of large amounts of money. The box on page 6 discusses some of the pros and cons.

Will it work?

A crucial question is: what reduction in blood-lead levels will this move bring about? In 1976 West Germany reduced the lead content of its petrol from 0·4 grams per litre (the current New South Wales level) to 0·15 grams. Blood-lead levels have remained virtually unchanged.

The key factor is the proportion of the body's lead burden that comes from lead in vehicle exhausts. Lead gets into our blood from the air we breathe and the food we eat. Almost all the lead breathed in comes from vehicle exhausts. The lead ingested with our food comes from both natural lead in the soil it is grown in and petrol-derived lead that settles on the leaves or in the soil. It is difficult to sort out the contribution to our blood-lead levels from each of the sources. However, a number of recent studies cast some light on the question.

In Britain, the Department of Health and Social Security undertook a study of the effect of lead on health. Its report, called the Lawther report, concluded that lead in petrol contributed, on average, between 10 and 20% of body-lead levels (the proportion depends on your particular environment) and found no evidence that this contribution caused any harm. It affirmed that most lead in the body comes from food, and that most of the lead in food comes from naturally occurring lead and sources other than leaded petrol.

But according to a more recent study commissioned by the British Conservation Society, as much as 90% of lead found in food is fall-out from vehicle exhausts.

A Monash University chemist, Dr Frank Burden, last year found lead levels in some Melbourne vegetables above the NHMRC draft standard of 4 parts per million — a standard the Council has since halved. Dr Burden believes most of the lead came from exhaust emissions.

Lead fingerprints

The difficulty is that lead first appeared in petrol in 1923, and it has spread far

Lead in petrol — take out or leave in?

Lead compounds are added to petrol to increase its 'octane rating'. Cars with high-compression engines need high-octane fuel so that the engine won't 'knock'.

Additional refining can also increase the octane rating of petrol. Adding lead isn't necessary, it's just simpler and cheaper than extra refining; it also makes more efficient use of crude oil, as the extra refining uses up energy. It is estimated that refining 92-octane lead-free petrol would consume 1% more crude oil than producing the leaded equivalent. At present, 'standard' petrol (87 or 92 octane) contains only slightly less lead than 'super' (97 octane).

About half of the cars on the road today will run just as well on 'standard' as on 'super' — the energy content of the fuel is about the same. However, only 8% of the petrol currently sold in New South Wales is 'standard' fuel.

The New South Wales State Pollution Control Commission estimates that use of lead-free fuel would save considerable amounts of energy, far more than the extra quantity needed for the refining process.

It bases this belief on its conclusion that catalytic converters allow fuel economy to be improved at the same time as reducing emissions of hydrocarbons and nitrogen oxides. Catalytic converters are placed in a car's exhaust system and break down these products. However, they require lead-free petrol, as lead will 'poison' the all-important catalyst (usually the expensive metal platinum). Catalytic converters are common in America and in Japan for dealing with the problem of car-exhaust pollution. They add $100–$200 to a car's cost.

The Commission quotes American figures that show that catalyst-equipped cars there used about 16% less petrol than cars of equivalent weight not so equipped. Compared with Australian 1980 models, the American 1978 catalyst-equipped models of equivalent weight used about 10% less fuel — despite the fact that the emission standards for the American cars were more than twice as stringent as the Australian ones.

The Commission has fitted a current-model six-cylinder Holden Commodore with a catalytic converter to observe its effects on exhaust emissions, fuel consumption, performance, and durability. After carburettor and other adjustments to suit the lead-free petrol, the car had a 12% better fuel consumption than when it was in factory trim without the catalyst.

Its hydrocarbon and carbon monoxide exhaust emissions were reduced by 60% and the car passed the stringent exhaust emission standards to be introduced in New South Wales in 1985.

When lead is added to petrol, other chemicals must be added as well to prevent the lead from depositing in the engine. These 'lead scavengers' have been blamed for extra engine wear and for producing corrosive acids in the exhaust gases. Significant maintenance cost savings, equivalent to 4–8% of fuel costs, have been claimed for lead-free petrol.

The petrol industry strongly disputes the need for introducing lead-free fuel. The Australian Institute of Petroleum claims that such a course of action would cause massive misallocation of resources. It estimates that the switch would cost the community $1760 million, most of it in the next 15 years.

This would be made up, it says, of $1200 million additional costs in vehicle manufacture, $300 million in additional fuel consumption, $60 million from energy penalties at refineries, and $200 million for changeover of storage, distribution, and dispensing facilities for unleaded petrol.

In its booklet, 'Why Keep Lead in Petrol?', the Institute says that, next to the provision of sewerage systems and clean water supplies, the switch to lead-free petrol would probably be the largest single public health program ever undertaken in Australia. Yet it denies the existence of any hard evidence that the program deserves priority, that the benefits would be commensurate with the costs, or that the money could not be better spent on other measures to improve public health and road safety.

The Institute also argues that removing lead from petrol would mean that those areas with no pollution problems would have to subsidize motorists in Melbourne and Sydney, where traffic density is high. 'We Australians live in an industrialized society and want maximum freedom to own and use cars', it says. 'We cannot at the same time expect to have pristine mountain air in our large cities.'

Controversy over the cost, and many other factors, continues, although the question of lead's effect on health remains the most important aspect. Mention was made in the main story of some of the indications that lead from vehicle exhausts can be harmful. The Institute of Petroleum argues that:

- there is no evidence that air-borne lead originating in petrol has caused adverse health effects
- no Australian health authority has advocated lead-free petrol
- of the small amounts of lead that people absorb, most is excreted

The controversy will rage for some time yet.

'Lead-free Petrol: How You Will Benefit.' (New South Wales State Pollution Control Commission: Sydney 1980.)

'Comparison of Fuel Consumption of Catalyst and Non-catalyst Equipped Motor Cars.' (New South Wales State Pollution Control Commission: Sydney 1980.)

'Why Keep Lead in Petrol?' (Australian Institute of Petroleum: Melbourne 1981.)

Why keep lead in petrol? *Petroleum Gazette*, 1981, 22, 110–13.

and wide since then. How do we tell whether lead found in the environment is natural or introduced?

Dr Brian Gulson of the CSIRO Division of Mineralogy is using a technique that could help sort out the situation, as it can determine the source of a lead sample.

He uses a mass spectrometer to analyse the relative abundance of each of the four lead isotopes — lead 208, 207, 206, and 204. Lead mined from a particular locality has its own particular isotope 'fingerprint', and so can be traced.

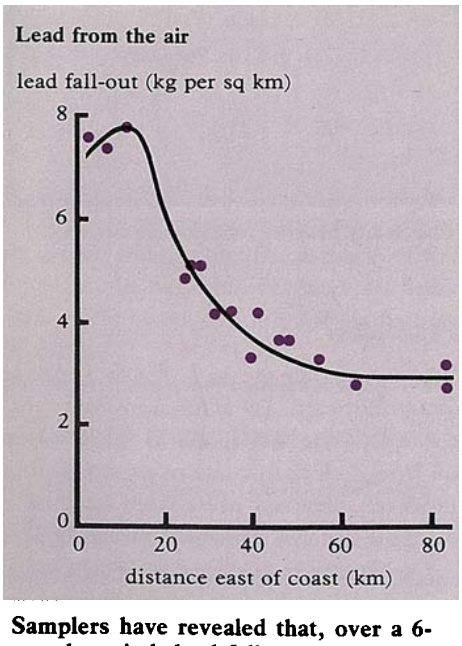
The lead compounds added to petrol in Australia have been manufactured mainly from lead mined at Broken Hill and Mt Isa or from Missouri, U.S.A. Lead from these sources, broadcast about the country through vehicle exhausts, can thus be readily identified and differentiated from the soil's native lead content. Lead from Broken Hill and Mt Isa has a lead 206:lead 207 ratio of 1·04:1,

This mass spectrometer was used to examine the 'fingerprint' of lead isotopes. Lead from petrol was identified in soil samples in the Adelaide hills.

whereas lead from Missouri has a value for this ratio of 1·18:1.

Dr Gulson was asked to perform lead isotope analyses on samples of topsoil collected by a team of scientists from the CSIRO Division of Soils. For some years Dr Kevin Tiller, Mr Richard Merry, and their colleagues of that Division had been investigating the quantities of heavy metals occurring in the soils of South Australia. *Ecos* 7 and *Ecos* 28 described their work in analysing toxic metals in soil and plants surrounding the Port Pirie lead smelter.

Recently they turned their attention to an area — approximately 100 km by 30 km — to the east of Adelaide. They soon found that topsoils from the western half of the area showed elevated lead levels. They suspected lead from vehicle exhausts to be the culprit because of the way that the lead levels seemed to decrease away from the city area. Elevated levels up to 50 km distant did seem unlikely, though, since most earlier investigations reported that most lead from vehicle exhausts was deposited less than 100 m from roadways.



Samplers have revealed that, over a 6-month period, lead fall-out reached nearly 8 kg per square kilometre close to Adelaide. Further inland, fall-out levels declined.

But, sure enough, when Dr Gulson analysed the soil samples, lead isotope ratios characteristic of petrol additives were plainly evident. Coarse lead particles from vehicle exhausts are deposited close to the road, but few studies have taken account of the less numerous, but still appreciable, smaller particles.

Lead and more lead

The CSIRO team found that the introduced lead particles represented a significant proportion of the total lead in the topsoil. Obviously, native lead levels vary a lot, depending on geology, but petrol-derived lead often accounted for as much as, or more than, the long-resident lead.

Petrol-derived lead in the topsoil often accounted for as much as, or more than, the long-resident lead.

More significantly, the lead from cars was deposited in the top few centimetres of soil and was much less tightly bound to soil constituents than most of the inherent lead. It could be easily extracted with dilute hydrochloric acid. To measure the inherent lead bound into the soil minerals, the scientists needed to attack soil samples with a powerful mixture of hydrofluoric and nitric acids.

The scientists found that, generally, the hydrochloric acid fraction constitutes from one-quarter to one-half of the total soil lead. And, significantly, within this fraction they found that the contaminant lead in the top 10 cm of soil was three or four times more plentiful than the natural lead.

The fact that foreign lead is less tightly bound into the soil raises the possibility that plants, vegetables in particular, may take it up more readily than naturally occurring lead. This possibility, combined with the discovery that lead from vehicle exhausts spreads out many kilometres from roadways, suggests that a far higher proportion of the lead found in food may be attributable to leaded petrol than previously believed.

Contamination

A factor that has sometimes masked the deposits of fine lead particles from vehicle exhausts is contamination of the soil from other sources — agricultural sprays, lead smelters, and coal-burning power stations.

For many years, orchards in the CSIRO team's study area were sprayed with lead arsenate for killing various insect pests. Soil taken from an orchard showed a lead content of 200–600 p.p.m. However, analysis of nearby soil showed that lead from sprays does not drift more than 50 metres. Furthermore, this chemical is no longer used as a commercial insecticide.

As mentioned before, the scientists have studied fall-out of lead from the lead smelter at Port Pirie (200 km from the study area) for a number of years. But it seems that air-borne lead from this source doesn't contribute appreciably to soil lead beyond about 40 km.

The coal that is burnt for generating power does contain some lead, but measurements indicate that, for South Australian coal anyway, lead contamination from this source can be ignored.

Fall-out measurements

Dr Tiller and his colleagues at the Division of Soils are now taking direct measurements of what falls out of the sky in the way of rain and dust. Only preliminary data are available so far, but they confirm that lead fall-out is highest close to the city and tails off some 50 km or so from the coast (see the graph at left).

Meanwhile, Dr Gulson is working on Sydney's lead fall-out. His measurements show that about 90% of the lead in the air comes from vehicle exhausts. In the near future, Dr Gulson plans to begin measurements of the isotopic composition of lead in food so as to gauge whether or not the lead comes mostly from petrol. Food samples will come from experimental plots in various parts of the metropolitan area and away from the city.

Andrew Bell

More about the topic

Use of lead isotopes in soils to identify the sources of lead contamination near Adelaide, South Australia. Brian L. Gulson, Kevin G. Tiller, Karen J. Mizon, and Richard H. Merry. *Environmental Science and Technology*, 1981, 15 (in press).