The Port Pirie smelter at the turn of the century.

Measuring the impact of lead

An extended study in South Australia has thrown new light on the effects of relatively low levels of lead exposure

Scientists have suspected for at least 50 years that the common metal, lead, may adversely affect the intellectual development of young children, even at very low levels of exposure. The latest results from an 11-year South Australian study have confirmed that long-held suspicion. The evidence now strongly suggests that environmental lead levels typically found in our urban areas cause subtle but long-term brain damage in children.

Lead is one of man's oldest toxic pollutants — the legacy of centuries of mining and smelting of lead ore. Ice-core samples collected in the Northern Hemisphere indicate that the background level of this metal in the environment, far from smelters and cities, has been rising steadily since 800 BC and is today 400 times higher than before smelting began.

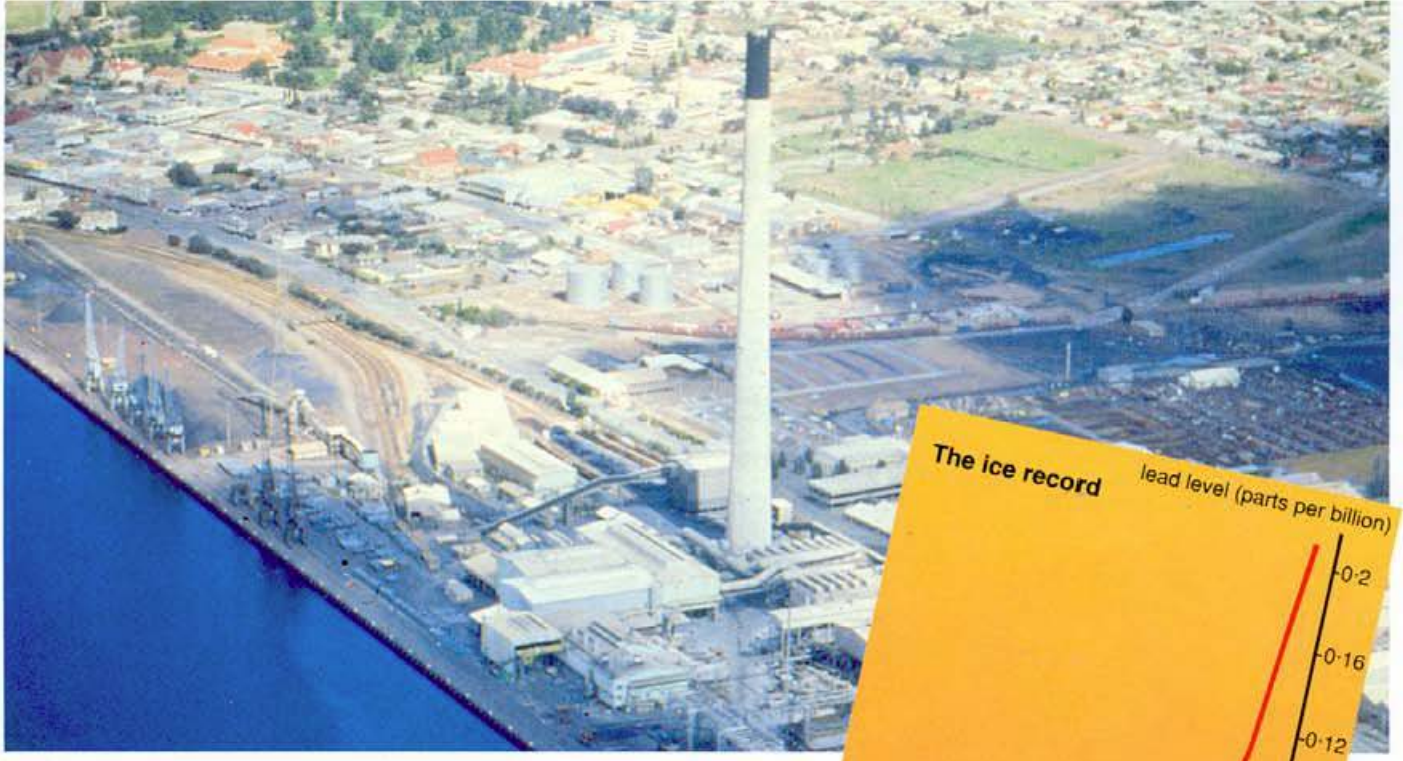
Although smelting is no longer regarded as a major source of lead pollution, lead dust persists in the towns and cities near where the lead ore is mined or treated. Today petrol containing tetraethyl lead — now being phased out as an additive in Australia — is the biggest source of environmental lead. As a result, the metal has a highly uneven distribution in the environment, the typical level in the air over major cities being as much as 100 times as high as the level over the mid-Pacific Ocean.

We absorb lead through the food and water we consume and from the air we breathe. A significant source for young children is the soil they ingest while playing outdoors. Nearly 90% of the absorbed lead is deposited in the skeleton, although small amounts can be found in the liver, kidneys and blood. The metal accumulates in the body early in life until it reaches an equilibrium level at which the rate of adsorption equals the rate of loss.

The toxic effects of lead at the concentrations typical among workers in the lead industry or victims of acute lead poisoning are relatively well-understood and easily diagnosed. They include reducing the ability of brain cells to convert glucose into amino acids, and inhibiting an enzyme affecting the transmission of signals between neurons. However, we do not yet have a proper understanding of the nature and severity of lead toxicity at lower levels. Whether or not lead is a health hazard for the community at large remains an issue of scientific debate.

Two American doctors working in the 1930s and '40s, Elizabeth Lord and Randolph Byers, were the first to thoroughly investigate the possible link between low-level lead exposure and the neuropsychology of children. The two followed the school experiences of 20 children between the ages of 18 months and 4 years who had been admitted to Boston's Children's Hospital with mild lead poisoning. In most of the cases, the young children had developed symptoms of lead poisoning after chewing the lead-based paint on their cots. None, however, had suffered the symptoms of acute encephalopathy (intractable seizures, coma and obvious brain damage) associated with severe lead poisoning, and all made an apparently complete recovery.

But, in a follow-up study, the doctors found that only one of the 20 had progressed satisfactorily in school. The children's IQs ranged from 67 to 103 points. Although statistically insignificant, these findings prompted many of the more sophisticated studies that followed and are continuing today.



The Port Pirie smelter today. Emission levels are well within required health standards.

Lead measurements in Greenland ice show dramatic increases in background levels in the 19th and 20th centuries.

In 1979, Herbert Needleman and colleagues at the University of Pittsburgh published controversial evidence allegedly showing that an elevated level of lead in the teeth of children (without symptoms of lead poisoning) was linked with lower psychological test scores and classroom performance. Subsequent studies in Germany and Britain produced mixed results and failed to resolve doubts about the methods used to study the phenomenon.

Also in 1979, CSIRO and health researchers in South Australia and New South Wales began a study of lead exposure in young children living near a lead smelter in the industrial town of Port Pirie, north-west of Adelaide. Now known simply as the Port Pirie cohort study, it is the most extended investigation of environmental lead in children anywhere in the world. Two similar but smaller studies are being conducted in the American cities of Boston and Cincinnati.

The research team — comprising Dr Anthony McMichael at the University of Adelaide, Dr Peter Baghurst at CSIRO's Division of Human Nutrition, Dr Evelyn Robertson at the Adelaide Centre for Women's and Children's Health, Dr Neil Wigg at Adelaide's Child, Adolescent and Family Health Service and Graham Vimpani at the University of Newcastle — enlisted the co-operation of 831 pregnant women for a long-term investigation of lead levels in the blood. Samples of blood were collected from the mothers twice during pregnancy and at delivery, and from their children (a total of 732) at the ages of 6, 15 and 24 months, and annually thereafter until the age of 7.

At the age of 2, each child underwent a standardised psychological test (known as a Bayley Mental Development Index or MDI) specifically designed for infants. The researchers also interviewed the mothers to determine other factors that are believed to influence the child's development. These include the mother's socio-economic status, IQ, medical history and marital status, the educational attainment of both parents and whether or not the mother smokes. The care-taking environment of the child's home was assessed using a standardised technique that measures the level of stimulation of academic behaviour, language skills and social maturity.

After adjustment of the data for these factors, the statistical analyses revealed an inverse relationship between the MDI at age 2 and the blood-lead concentration at the age of 6 months. The study, published in 1987, found an MDI reduction of nearly two units for every increase of 10 micrograms (µg) of lead per 100 mL of blood.

A follow-up study on 537 of the children at 4 years of age strengthened the evidence supporting a link. The results showed that children with an average blood-lead concentration of 32 µg per 100 mL scored about 7% lower on a general cognition test than those with a blood-lead concentration of 10 µg per 100 mL.

What remained to be established was whether the adverse effect was simply to delay a child's intellectual development. According to the latest results, the answer is no. Further psychological testing on 490 of the children at the age of 7 has indicated that intellectual impairment persists at least to school age and probably beyond.

Using a psychological test known as the Revised Wechsler Intelligence Scale for Children (WISC-R), the researchers claim to have found a consistent, statistically significant inverse relationship between blood-lead concentrations and the intelligence quotient at age 7. The IQ declines by about 5% for a rise in blood-lead levels at age 3 from 10 µg per 100 mL to 30 µg per 100 mL of blood.

Uncorrected data show that, between the mean blood-lead levels of 8 and 32 µg per 100 mL, IQ drops by up to 15 points, equal to the difference between a child of average IQ and one who could be regarded as slightly retarded. After correction for possible confounding factors, the link is weaker but still significant, the researchers say. The WISC-R tests measure vocabulary, general knowledge, memory, visual alertness and the ability to assess spatial relationships or manipulate abstract symbols.

The scientists concluded that exposure to lead — before birth, after

birth or both — has an enduring effect on childhood neuropsychological development, although the effect is relatively small compared with those of factors such as parental IQ and income.

Dr Baghurst said it had been thought earlier, when the children were 4 years of age, that they might be able to catch up intellectually. But as the deficit is still evident at age 7, he thinks this is now unlikely, and that the adverse effect of the lead may be permanent.

The study raises a host of public health issues. For example, how applicable are the Port Pirie results to children in other areas? The children in the Port Pirie study recorded mean blood-lead concentrations (in µg per 100 mL) of 14·3 at 6 months of age, 20·7 at 15 months, 21·1 at 2 years, 19·2 at 3 years, 16·6 at 4 years, 14·5 at 5 years, 12·6 at 6 years, and 11·6 at 7 years. A study in 1980 — before the introduction of unleaded petrol — of 446 children of pre-school and school age in city and country Victoria found a mean blood-lead level of 11·4 µg per 100 mL. The children 7 years or younger had mean levels ranging from 12 to 14·9, at least as great as those in Port Pirie — although Dr Baghurst believes it unlikely that the Victorian children would have 'experienced equivalent exposure between the ages of 1 and 4 years.

Aspects of the Port Pirie study have heightened concerns about the health risks for children generally. Because of the statistical methods used in the analysis, the researchers believe the findings are conservative. Correcting the data to remove the possible influence on IQ of factors such as parental smoking, maternal IQ, the care-taking environment and socio-economic status may have produced an under-estimate of the link between IQ and lead burden, as these other factors may themselves influence lead exposure for the children.

Dr Baghurst also says the study was unable to detect a threshold level below which the blood-lead concentration had no observed effect on IQ, even though the levels recorded were as low as 7 µg per 100 mL at 6 months of age. The implication is that hundreds of thousands of Australian children living in urban and industrial areas may be suffering mild intellectual impairment due to leaded petrol, lead dust from discontinued or current mining and smelting operations or old lead-based house paints.

At present, the Australian safety level for lead exposure, set by the National Health and Medical Research Council, is 25 µg per 100 mL. The limit set by the United States Centers for Disease Control is 10 µg per 100 mL.

Public attention in recent months has focused on lead exposure among children in the New South Wales mining community of Broken Hill. Blood tests there have revealed that one-third of the children between the ages of 1 and 4 years exceed the NHMRC limit, and more than two-thirds are above the more stringent United States limit. Health authorities believe a community education program may be needed to reduce the level of exposure among young children.

Because the children in the Port Pirie study have remained in the town throughout their lives, the researchers could draw no inferences about the effect that moving away from a high-lead area at an early age would have on intellectual development. However, in cases where exposure is unabated, they conclude that the effect at relatively low blood-lead levels is persistent and 'socially important'. They recommend the adoption of measures for reducing the amount of lead in the environment and limiting lead exposure among children.

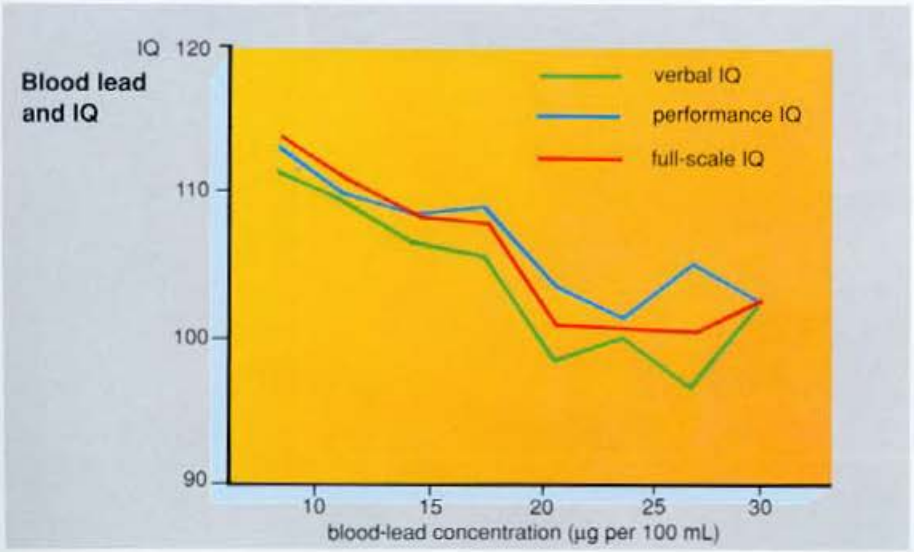
Brett Wright

More about the topic

Port Pirie Cohort Study: environmental exposure to lead and children's abilities at the age of four years. A.J. McMichael, P.A. Baghurst, N.R. Wigg, G.V. Vimpani, E.F. Robertson and R.J. Roberts. *New England Journal of Medicine*, 1988, **319**, 468–75.

Late effects of lead poisoning on mental development. R.K. Byers and E. Lord. *American Journal of Diseases in Children*, 1943, **66**, 471–94.

'Health and Environmental Lead in Australia.' Report of a committee established by the Australian Academy of Science. (Australian Academy of Science: Canberra, 1981.)



The graph shows the (unadjusted) relationship between average verbal IQ, performance IQ and a combination of the two for 490 7-year-old Port Pirie children and the level of lead in the blood at age 3.