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Air Pollution in 20th Century Australia

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Abstract

While air pollution in the early years of the Century was mostly characterised by the smoke and grime from chimney fumes, and a liberal dosing of noxious odours from various factories, later years can be more distinctly categorised:

- The 1940s and 1950s were the decades of smoke-stack industries.
- The 1960s saw heightened public awareness of, and concern for, the environment and air quality. Realisation that the motor vehicle in Australia was indeed a significant pollution source was only dawning.
- The 1970s was the age of environmental legislation and the beginning of modern measurement methods.
- The 1980s was the decade of major air pollution investigations, and the introduction of exhaust catalysts on new petrol vehicles.
- The 1990s saw air pollution modelling become highly developed; the airshed could be treated as one entity; and integrated multi-faceted strategies became common.

There is every reason to be optimistic about the future. However in urban Australia the existing motor vehicle fleet, especially diesel vehicles, continues to be a problem. Must we wait until 2006 or later for Euro4 emission standards to control dangerous particle emissions from diesels cars and vans, and then only on *new* vehicles? What is needed now is a well-designed inspection and maintenance program for all vehicles, as recommended by the recent Inquiry into Urban Air Pollution in Australia (ATSE 1997).

The Present

'Clean air' has been defined as 'a term alluding to the chemical and optical conditions of the atmosphere back in the good old days' (AMS 1968). It can mean what you choose it to.

Further, the Australian Statistician has shown repeatedly that air pollution (unclean air) is the greatest environmental concern of Australians (the most important concern to over 30% of people), particularly to city dwellers in Melbourne and Sydney. (Land degradation was the most important environmental issue in country areas.) See ABS (1997). This should be puzzling, given the history of air pollution worldwide and the fact that industrial and urban air quality has improved greatly in Australia (I will return to this at the end of the article).

An optimistic view of Australian urban air pollution can be sustained by several facts (NEPC 1998; ATSE 1997):

- Most 'classical' air pollution concerns are practically solved — sulfur dioxide is now not an issue in most of urban Australia, 'lead in air' is decreasing strongly and is already well below levels of concern except in a small number of industrial towns, industrial

emissions of smoke and fine particles are under control, and carbon monoxide is no longer a problem.
- Emissions from the dominant urban pollutant source, the motor vehicle, lead to photochemical smog and haze, and although the emissions from new vehicles are decreasing rapidly, the resulting air quality improvement is slower to materialise.

This optimism is supported by several really important recent events:
- For the first time, Australia has national ambient air quality standards. Passed in June 1998, the Air NEPM (National Environment Protection Measure; see NEPC 1998) is a major achievement for our Federal/State system.
- Hundreds of Australian companies have embraced the Greenhouse Challenge (AGO 1999) to reduce greenhouse emissions, and are devoting a lot of time in support of the National Pollutant Inventory (NPI 1998). These both raise awareness of industrial emissions and an attendant expectation of progress to cleaner production methods.
- With the vehicle design rule, ADR37/01, already mandated in 1997, Australia is introducing current and future European pollutant emission standards for motor vehicles. For the first time, advanced standards controlling particle emissions from all new diesel vehicles will eventually apply in urban regions (DOT 1999).
- The Australian Air Quality Forecasting System will, by the end of the year 2000, have been demonstrated to give hour-by-hour, suburb-by-suburb, air pollution forecasts in Sydney and Melbourne (Cope *et al.* 1998, 1999). Developed by CSIRO in collaboration with EPAs and the Bureau of Meteorology with Natural Heritage Trust funding, it will help the EPAs and the public see how to improve air quality. Other applications will include assessing personal exposure to air pollution over long periods.
- In collaboration with Holden Ltd and with aXcessaustralia, a consortium of industry partners, CSIRO has just released two new hybrid motor cars that demonstrate a range of Australian high technology advances (Lamb 2000). Promising uncompromised performance, one half to one third the energy use and as little as one tenth the pollutant emissions, these vehicles are the answer to urban smog. Fuel cell powered hyper cars with effectively zero emissions are around the corner (Manins 1997).
- The Inquiry into Urban Air Pollution in Australia (ATSE 1997) included leading-edge work on the relationship between alternative urban designs and smog- and particle-air pollution. It holds the promise of optimising ways of developing a city's infrastructure to achieve air quality benefits (see AHURI 1997; Manins *et al.* 1998). We can now almost quantify the obvious environmental benefits of public transport and slow modes such as bicycling.
- In a world first, a new prognostic air pollution modelling system for air pollution studies in complex geographies, called TAPM, puts enormous power into the hands of general users (*e.g.*, Hurley 1998, 1999; Manins *et al.* 1999); this should lead to high quality assessments and better environmental planning.

Looking back over the past century, I was somewhat surprised to discover a number of antecedents to what I thought were new ideas and approaches. It was also brought home to me just how slowly change occurs! My approach here is that of a scientist working in the area. I leave for others a discussion of the changing societal settings over the years, the roles of EPAs and health authorities in responding to and driving through legislation, and the tensions with commerce and industry. I am also conscious of my failure to cover many facets that others may believe are important. A first hand account of aspects of the mid-Century years may be found in Sullivan (1995).

The Beginning of the Century

In 1889 'Banjo' Paterson published 'Clancy of the Overflow' in *The Bulletin*. The fifth stanza gives a vivid image of urban air pollution at that time:

> I am sitting in my dingy little office, where a stingy
> Ray of sunlight struggles feebly down between the houses tall,
> And the foetid air and gritty of the dusty, dirty city
> Through the open window floating, spreads its foulness over all.

Queenstown in western Tasmania was an early example of adverse industrial impact. The smelting of copper had been so intense that by 1900 all the surrounding hills had been stripped of trees for fuel. The sulfur fumes from the smelter and the heavy rainfall in the area (which washed away the topsoil) ensured that the whole valley looked like a deserted moonscape. It remains much the same today. " By any measure Queenstown is one of the wonders of the world. It is a profound reminder of humanity's capacity to destroy and pollute and, in that sense, it deserves to be seen by everyone." (quoted from an Australian Travel Guide)

The Early Years

Victoria

On 1 May 1957, the first specific air pollution legislation was introduced by the Honourable Buckley Machin into the Victorian Legislative Council as a Private Members Bill (Hansard 1957). Based on US legislation (enacted in the city of Pittsburgh) and the industrial provisions of the UK Clean Air Act of 1956, this bill was subsequently taken over by the Government of the day and became the Clean Air Act of 1958. It was concerned in the main with the control of combustion processes, relying on regulations for the control of other pollutant sources.

Until then, air pollution matters were dealt with by a scattering of regulations across Australia by various Health Acts (dating from 1919 in Victoria). Smoke regulations made in the 1920s and '30s under these Health Acts were generally unworkable, having been left in the hands of ill-equipped local councils for enforcement (Cock 1965).

The Hon. Member had acted on the concerns of a physician friend who was alarmed at reports of cancer– health effects of diesel fuel, and of bronchitis– air pollution links. He quoted the eminent physician to King George VI — 'Lung cancer is predominantly a disease of the city and urban dweller.'

Of particular relevance here is the Hon. Member's description, recorded in Hansard, of conditions in parts of Melbourne.

'Residents of Williamstown have for many years endured nightmare conditions due to air pollution, and recently action was taken. The State Electricity Commission has been a source of annoyance for a considerable period of time. For the occupiers of dwellings adjacent to the works, conditions have been heart-breaking. Nothing will grow in their gardens, but despair, and considerable effort must be expended in continually cleaning the houses. What is happening there is really pathetic.'

(By the way, the Newport power station was again to feature as a major focal point for air quality concerns in the early 1980s, with intense debate over the construction of a new gas-fired power station on the site.)

The Hon. Machin went on to say 'I have seen the conditions that exist in dirty, little hovels in South Melbourne adjoining foundries. It is possible to scrape the grime off the walls and windows. Children from that area have been admitted to hospital, suffering from bronchitis and other respiratory complaints which are caused by impurities in the air.'

New South Wales

The Hon. Machin noted that the investigations into air pollution by Dr John Sullivan of the NSW Department of Health were particularly pertinent. This same Dr Sullivan was to continue to play a leading role in NSW, being a key activist in setting up the Clean Air Society of Australia and New Zealand, the inaugural meeting of which took place in Sydney on 3 March 1966. Dr Sullivan was the Society's first President and Mr Ken Sullivan became the President of the first Branch of the Society in NSW, formed in 1967 (Sullivan 1995).

In 1962, Dr Sullivan's measurements of concentrations of sulfur dioxide[‡] in parts of east Port Kembla (south of Sydney) showed levels as high as 250 ppb daily mean (Sullivan 1962), a value that rivals the worst anywhere abroad. There are also reports that he measured shorter term (approximately 10-min.) concentrations as high as 3,000 to 4,000 ppb, with occasional maximum readings in excess of 10,000 ppb in the vicinity of the copper smelter at Port Kembla (Bell 1965). These values may be contrasted with the Air NEPM (NEPC 1998) 1-hour standard of 200 ppb and 1-day standard of 80 ppb for the protection of human health. (The Air NEPM Impact Statement suggests a 10-min. value of no more than 250 ppb for design purposes.)

NSW had taken a slightly different approach to air pollution management than Victoria. In 1961 the Clean Air Act was passed (Sullivan 1965). It required the use of 'best practicable means' for preventing air pollution. It was based on the British Alkali Act introduced in 1863 in England in an attempt to control emissions from the then rapidly growing chemical industry. While the British Clean Air Act had become law in 1956 and had attracted wide public attention, this Act was largely directed towards the problem of domestic pollution and was seen not to be relevant to the needs of NSW at the time. Instead, NSW followed in general principles the recommendations of the World Health Organization (WHO) in a 1957 report by a 'Committee on Environmental Sanitation'.

The NSW act seems to have been difficult to implement since there was not then a clear idea of what it was trying to achieve in a quantitative sense. However, 'best practicable means' gave lots of scope to regulate emissions. In practice the dominant rubric was 'the solution to pollution is dilution' with a crude reliance on tall stacks, not backed by a good scientific knowledge of turbulent dispersion. 'Cleaner production' systems designed, to reduce pollution at source, generally were years away from being implemented.

‡ Because of the measurement methods used at the time, this is likely actually to have been acid gases, of which sulfur dioxide would have been only one, albeit the dominant one.

Lessons from Abroad

Events abroad in the middle of the Century had thrown the spotlight here onto air pollution. Deaths and severe acute illness were reported from disastrous episodes of high pollution concentrations in the Meuse Valley, Belgium in 1930 (60 deaths), Donora, Pennsylvania in 1948 (20 deaths), and London, England on 5– 9 Dec. 1952 (approx 4,000 deaths) and to a much lesser extent in 1956. These provided stark evidence that ambient air pollution can seriously endanger public health. In each case, deaths occurred among people who had existing respiratory and/or cardiovascular disease. In London, many of the 4,000 deaths were caused by pneumonia in young children and old people. These were industrial pollution episodes, involving sulfur dioxide and particles from coal burning, and possibly heavy metal fumes in the case of Donora (Godish 1997; Davis 2000).

No wonder Australian legislators acted.

A New Threat: The Motor Vehicle

A new problem observed in the 1950s was photochemical smog. This is characterised by poor visibility and high concentrations of ozone, the powerful respiratory irritant gas. Photochemical smog also contains a very complex mixture of other toxic species. Discovered in Los Angeles in the late 1940s and confirmed in 1966 to be occurring in Melbourne by CSIRO's Mr Ian Galbally (Select, 1970), this was a problem due to the motor vehicle.

At the time of the first measurements of photochemical smog in Australia, the Health Departments were hostile: their own (inadequate) measurements and (incorrect) predictions suggested that a smog problem *may* occur by the end of the Century! They were preoccupied with other pollutants and other health issues.

Dr J Goldsmith of WHO, Geneva, at the 1965 Clean Air Conference in Sydney (Goldsmith 1965) pointed to a growing international concern with motor vehicle emissions of carbon monoxide. He also noted that 'while they may not be a serious hazard for physical well-being, diesel emissions are a serious source of public objection' — he was right about the cause, but greatly underrated the serious public health consequences of emissions from both petrol and diesel motor vehicles.

The 1970s — The Beginning of Modern Measurement Methods

The 1970s saw the growth of purpose legislation, policies and air pollution control and management. In Victoria the Environment Protection Act was introduced in 1970 and the EPA was established in 1971 to administer the Act. In NSW, the State Pollution Control Commission (SPCC) was established in May 1974 as a separate entity from the Health Commission. A licensing system for industry was the main tool for managing air quality. These developments brought with them the need for thorough monitoring programs.

Historically, the practice of air pollution management has been governed by what it was possible to measure, reliably and routinely. Prior to the 1970s the old British technology was the standard in Australia — Ringelmann charts for smoke opacity, lead dioxide candles for sulfation rate, dust-fall gauges for deposition, wet chemistry methods for the measurement of oxidants, and bubbler tubes for sulfur dioxide and nitrogen oxides (NOx).

Appropriate for the times, these routine monitoring techniques played a major part in overcoming the severe air pollution that was largely due to the unregulated burning of coal and high-sulfur fuel oil. However, they eventually proved totally inadequate in dealing with the growing problem of motor vehicle pollution.

For the measurement of the gaseous pollutants sulfur dioxide, nitrogen oxides and ozone, the major breakthrough came with the development of gas-phase measuring techniques in place of wet chemical methods. Spectroscopic methods for the routine measurement of small concentrations of carbon monoxide and organic compounds were also being developed for routine use; these and related laboratory methods have improved in sensitivity and ease of use ever since (*e.g.*, Manins 1993).

The new ability in the 1970s to measure carbon monoxide in Australia uncovered some problems. Readings as high as 30 ppm were measured in Sydney (*i.e.*, over three times the current Air NEPM standard). These and other measurements were usually short-term snapshots with mobile monitors to assess the pollution problems. The data justified the more extensive monitoring and studies that took place in the following decade.

It has been said that in the mid 1970s in Adelaide, Rundle Street was permanently closed and made into a mall, largely because of the concern about high readings of carbon monoxide there (Mr Alec Smith, personal communication).

"Clean Fuels" — Natural Gas in Australia

While coal continues to be the principal energy source in eastern Australia, in the middle of the Century in South Australia and Western Australia imported heavy oil was the major source with concomitant air pollution due to high sulfur content.

Large gas reserves had been discovered at Moomba, and in 1966 the South Australian Gas Company and the Cooper Basin Producers signed the first contract in Australia for the supply of natural gas. The decision to use natural gas in the Torrens Island Power Station guaranteed the viability of the project, and gas was first supplied to Adelaide in November 1969. Smoke-stack industries were quick to change to natural gas; the change became a stampede during the oil crisis of 1973.

In Western Australia, large gas reserves were discovered in 1971 off the North West Shelf, but it wasn't until 1984 that the Kwinana Industrial Region south of Perth substantially switched over to natural gas. This ended what was until then a serious ambient sulfur dioxide pollution concern (Paparo *et al.* 1982; Rayner 1993).

By April 1969 natural gas was also being reticulated into the Victorian market from the fields that had been discovered four years earlier in Bass Strait. However, the low cost of electricity generated from the extensive Latrobe Valley brown coal deposits meant that the switch to natural gas from town gas led to only a small change in overall energy use, and hence air pollution, in Victoria.

The Australian Air Pollution Equipment Industry

The 1970s, modern measurement methods, and the establishment of specialist supply companies, went hand in hand. One of the few survivors from that decade is Ecotech Pty Ltd. Founded in 1972 by Mr Robert dal Sasso, Ecotech began by building data loggers and importing monitoring equipment from the USA. The equipment was hard to service and quickly broke down due to the company's failure to realise that 50 Hz power was not the same as the USA's 60 Hz power! The first of these modern analysers was built around 1965 in the USA, so Australia was not far behind in adopting them. However, staff in CSIRO and in the NSW Health Commission early on were building advanced research instruments.

The first exports of Australian air pollution equipment were also by Ecotech. In 1989 they supplied 10 high-volume particle samplers and six monitoring stations to measure sulfur dioxide and nitrogen oxides to India. Following many other exports successes, and in a major vote of confidence in Australian technology and quality, Ecotech was commissioned by Monitor Labs in 1999 to manufacture a range of its most complex air pollution monitoring instruments for local and export use.

Another survivor of that period is Dr Ian Bourne and his world-leading Doppler acoustic sounders. The sounders measure wind velocity and turbulence up to 1,000 m above the ground — newer variants also employ radio waves to determine the temperature profile. Dr Bourne sold his first sounder in 1973, built at the RAAF Academy Physics School, Melbourne University. I had direct experience with one during the Latrobe Valley Airshed Study. It is still in use at Thoms Bridge near Yallourn. For the past five years, his designs have been marketed by Atmospheric Research Pty. Ltd., Canberra (ARPL 1998).

The 1969 Senate Select Committee on Air Pollution

This Committee (Select 1970) took evidence of the high pollution levels in industrial parts of Australia, the discovery by CSIRO of photochemical smog in Australia, and the dominant role that the motor vehicle was by then playing in urban air pollution.

They noted alternative approaches to air quality standards:

(i) Standards that are based on what pollutant levels can be tolerated without harmful effect. Such standards had been prescribed by the WHO and by the National Health and Medical Research Council. This approach had been incorporated into the 1970 Environment Protection Act in Victoria: its 1981 Air Policy brought in the concept of 'beneficial use' of the environment.

(ii) Standards that are based on maximum allowable emissions of pollutants from particular sources, which it is expected will ensure acceptable ground level concentrations. The approach was the core of the 'best practicable means' approach of NSW and other States from 1961 until the 1990s.

The Committee recommended the former as the preferred approach, but recognised that, in the absence of clear health data, the second was certainly the simpler and probably the safer approach to the problem.

In practice, in Victoria, though the concept of 'beneficial use' was well entrenched, and though it helped clarify *when* and *why* controls were necessary, the *means* of control were not well defined and tended to follow NSW in employing 'best practicable means'.

The Committee recommended the formation of a Commonwealth-State Bureau of Air Pollution with functions including the establishment of uniform standards for the measurement of pollutants and the recording of data. It took until 1998 for uniform standards to be achieved (NEPC 1998); there is as yet no Bureau of Air Pollution.

The Committee recommended that CSIRO establish an Air Pollution Division to undertake basic research into air pollution problems of particular relevance to Australia and to execute investigations recommended by the Bureau of Air Pollution. This has not been done explicitly, though a significant amount of work is carried out by two CSIRO Divisions: Atmospheric Research in Melbourne and Energy Technology in Sydney.

The Committee also recommended that the Bureau of Meteorology should run a national network of monitoring stations to gather the required meteorological data to relate meteorological processes to air pollution, the continuous measurement of air pollutants, and eventually the setting up of a predictive service for the warning of potential air pollution hazards. Although the measurement aspects continue to be in the hands of the State Agencies, the important NEPM Peer Review Committee is currently chaired by a Bureau chief scientist, Dr Michael Manton. As for a predictive service for the warning of air pollution events, the States do issue alerts in major urban areas. It has taken 30 years, however, to realise a detailed response: a predictive system has now been developed by the Bureau of Meteorology, CSIRO and EPAs in collaboration, and is being demonstrated through the period of the 2000 Olympics — the Australian Air Quality Forecasting System mentioned in the opening of this report.

Motor Vehicle Emissions Controls

The Senate inquiry into air pollution in 1969 struggled to identify a role for the Federal Government. Even vehicle emission controls, a federal issue through Australian design rules (ADRs), occurred only because of strong pressure from NSW by Mr Peter Murphy, with support from Victoria and Mr Paul LeRoy.

The first design rule to cover vehicle emissions was introduced in 1973 and dealt with crankcase ventilation. Then, in 1976, ADR27 tackled tailpipe emissions by exhaust gas recirculation and other means — but until 1986 ADRs were not enforced, and the technology was implemented poorly, leading to much abuse and tampering by vehicle owners and operators.

In tackling motor vehicle emissions, there were some real tensions between the oil industry and the motor vehicle industry. The latter were keen on catalysts to control carbon monoxide and the precursors to ozone. There would be the incidental benefit of reducing lead emissions. In Victoria, the issue of lead in air was greatly alleviated by reducing lead in petrol to 0.35 g/L while in other States levels were as high as 0.8 g/L in the early 1980s. The introduction in June 1985 of exhaust catalysts on all new petrol vehicles put the issue to rest. From 1 January 2002, no leaded petrol will be available in Australia (EPG 2000).

Though slow to act on vehicle pollution and then by introduction of mundane standards, Australia got the conversion to unleaded petrol right. The low Research Octane Number (RON) of 90– 93 was good for Australian refineries and good for the environment by ensuring that excessive levels of aromatics (benzene and similar) were not needed to give a higher RON. This was in contrast to Europe, which only later introduced unleaded petrol and this with a higher RON of approximately 98. So, in Australia, each of urban carbon monoxide, airborne lead, petrol vapours and to some extent nitrogen oxides were being controlled, and levels of aromatic compounds were not much exacerbated. We also got it right in the pricing — unleaded fuel was required to be sold at a lower price than leaded petrol. This has been reinforced in recent years with a surtax on leaded petrol. Again, this was at first not the case in Europe and greatly slowed the adoption of unleaded fuel.

With the introduction of ADR37/01 in 1997 and soon the Euro3 standards (DOT 1999), Australian motor vehicles emissions standards are at last becoming rigorous. Australia also is demonstrating its capability to provide the technology to meet the challenge: the hybrid electric vehicles mentioned in the opening of this report.

The 1980s — Major Air Pollution Studies in Australia

Various studies across Australia, mostly undertaken in the 1980s, played a large part in the development of air quality management policy. I discuss only a selection here.

Study of ozone formation in Sydney began in 1971, following observations of significant levels of photochemical smog (SPCC 1979). Ongoing work was co-ordinated into the multi-disciplinary Sydney Oxidant Study (SOS), which ran from 1975 to 1980 with Mr Len Ferrari a key driver. It was a first in Australia, identifying the balance between nitrogen oxides and VOCs (volatile organic compounds). Measurement platforms included aircraft and balloons, supplemented by modelling. The result provided evidence to support control technologies on industry, and ultimately support for the most profound changes of all: the introduction of unleaded petrol and catalytic converters on motor vehicles. At the time, only VOC controls were possible. There was no technology to control nitrogen oxide emissions: three-way catalysts were to come later. Water-based paints and covered storage tanks were other outcomes.

The composition and occurrence of particulate haze in the Sydney Basin was the subject of the overlapping Sydney Brown Haze Study (1978– 1982: Williams 1983), jointly performed by CSIRO and Macquarie University. It found that haze was widespread in the Sydney region and identified the important sources of winter visibility degradation as (Milne *et al.* 1983) incineration (45%), motor vehicles (36%), and sea salt (7%). An outcome that made a very large improvement in local air quality was the banning of back-yard incinerators across Sydney by councils in the mid 1980s. This study was followed by the comprehensive ANSTO Aerosol Sampling Program which monitored fine particles over four years from July 1991 at up to 24 sites across eastern NSW (Cohen *et al.* 1993). In particular, the strong reduction of lead in air in Sydney was well documented (Cohen 1996).

The next major occurrence was in 1990. CSIRO's Mr Graeme Johnson (the inventor of the unique smog monitor Airtrak: Johnson 1984; Johnson & Quigley 1989) and Macquarie University's Dr Robert Hyde were commissioned by NSW Department of Planning, SPCC and Commonwealth Aviation Division to do a Pilot Study of plans for land development in the southwestern Sydney basin (Hyde and Johnson 1990). Whereas air pollution had been falling in the eastern suburbs, they drew attention to the fact that air pollution was increasing in the west. The explanation lay in the very success in the east: VOC control strategies had led to a slowing down of the development of photochemical smog during the day so that it reached a maximum later on, at about the time the sea-breeze borne morning air mass reached Campbelltown in the southern part of the Sydney basin, and beyond.

Much resulted from this study. It came at a sensitive time for the NSW Government and created a major pressure for the inception of the three year Metropolitan Air Quality Study (MAQS) in 1992. The monitoring aspects continue today. MAQS has provided the core science base (*e.g.*, Hyde *et al.* 1997) for the development of air management policy in NSW over the past eight years (EPA 1996), particularly that which is focussed on smog management. And it led to a substantial curtailment of land development in the south-western suburbs of Sydney.

Also in this period in Victoria, the Melbourne Haze Study (1980–82), the big Latrobe Valley Airshed Study (1977–1988: Manins 1986, 1988) and the Melbourne Airshed Study (1982–85: *e.g.*, MAS 1985) all took place with EPA Victoria in the lead. The studies were instrumental in crystallising the realisation that an airshed had to be treated as a whole. Management of air quality needed to recognise that pollutants build up because of adverse regional weather conditions, and can recirculate, perhaps transformed by photochemical reactions in the atmosphere. The computer modelling tools able to inform and make good use of these findings were not available until the late 1980s in Australia, and then in large part as a result of the Latrobe Valley Airshed Study and the other Melbourne studies. They were a central component of the plan for MAQS in NSW.

With its genesis in the Latrobe Valley Study, one modelling system in particular was greatly advanced under the patronage of the Electricity Commission of New South Wales in investigations of pollutant circulations in the Hunter Valley and Central Coast of NSW (Physick *et al.* 1992). This was the leading-edge Lagrangian Atmospheric Dispersion Model (LADM: see Physick 1993).

The Bureau of Meteorology conducted the Albury-Wodonga Study (Moriarty 1985) in the early 1980s to provide meteorology and air quality data for the planners of that designated growth region. Queensland researchers spent a lot of time in the 1970s and 1980s developing an understanding of the weather's control of air pollution in Brisbane, and in 1994 using the CSIRO modelling expertise, redesigned and expanded pollution monitoring around Brisbane and Gladstone to address photochemical smog (see Physick *et al.* 1994). Also in the 1980s, studies for Queensland Electricity Generating Board of the Callide (in 1981–83), Gladstone (in 1979–82), Stanwell (in 1981–83) and Tarong (in 1978–80) power station plumes were made, as well as extensive studies of Mt Isa smelter operations. Most of these included CSIRO aircraft plume tracking methods developed by Mr David Williams and Dr John Carras. In particular, in the Mt Isa study, the plume was identified and tracked for over 1,800 km downwind (Carras and Williams 1988)!

Drawing on the Victorian and MAQS experiences, Western Australia undertook the Perth Photochemical Smog Study (Rayner *et al.* 1996) and the Perth Haze Study (DEP 1996) in the early 1990s to inform management of vehicle controls, hazard reduction burning and backyard burning. These studies followed the important pioneering 1977–1982 Kwinana Air Modelling Study (Paparo *et al.* 1982), an investigation that defined the capacity of that airshed to cope with sulfur dioxide emissions from the approximately 40 stacks in the region. The Kwinana study has been revisited several times, including during a major CSIRO campaign in 1995 (Sawford *et al.* 1996; Luhar *et al.* 1996). The licensing of emissions to air in Kwinana relies on a unique model-based assessment of available capacity devised by Dr Ken Rayner (Rayner 1993) and refined with information from the above studies.

Also resulting from the experience of MAQS, the Department of Health in South Australia greatly expanded its air pollution monitoring network in the mid 1990s, guided by LADM simulations (Physick *et al.* 1996), to allow surveillance of smog events around Adelaide.

The late 1990s

It would be easy to spend a lot of time here discussing developments in the past few years because there have been many. However, I will just touch on those that appear to be of national significance.

Australia State of the Environment – December 1996

The first national State of the Environment Report (SoE 1996) covered a wide range of issues, including the atmosphere. The Report has been influential in identifying problems and successes in environmental management across Australia. It has set the benchmark for State reporting. National reporting became law in 1999 with the passing of the Environment Protection and Biodiversity Conservation Act (EPBC 1999). Required every five years, the next one is due in 2001.

Inquiry into Urban Air Pollution in Australia – October 1997

Led by Dr Alan Reid, the Inquiry was commissioned by the Federal Government (ATSE 1997). Its main recommendations were:

- Adopt 'integrated planning systems which predict conditions leading to high urban air pollution and provide that deliberate burns for hazard reduction are avoided in such periods.'
- Take up without delay European emission standards for vehicles, set for the in-service life of the vehicles and backed by effective inspection and maintenance programs in the major urban airsheds. Focus attention on diesel vehicles, and facilitate the use of CNG and LPG as transport fuels.
- Reduce the need for vehicle travel by better urban planning and investigate tolling road usage according to traffic congestion.
- Move away from a current policy trend that encourages the location of NOx-emitting gas turbines in urban airsheds.
- Adopt and tighten Australian Standards for emissions from domestic wood burning. And ban backyard burning where it is a problem and still permitted.

The Air NEPM – June 1998

The ATSE Inquiry reinforced the work of the National Environment Protection Council and its development of air quality standards that incorporate harmonised methods of monitoring and reporting (NEPC 1998). The result is that now, for the first time, Australia has air pollution standards that apply across the nation. The consequences are still being worked through, but one will be consistent air quality monitoring across Australia.

The National Pollutant Inventory – 1998

Actually the first National Environment Protection Measure to be ratified (NPI 1998), the National Pollutant Inventory is expected to demonstrate trends in the emissions to air and water of 36 substances (expanding to 90 substances by July 2002), and to highlight areas where data gaps currently exist.

Natural Heritage Trust, Clear the Air Component – 1998–2002

Amongst other things, the NHT (2000) is providing funding for

- Development of the Australian Air Quality Forecasting System;
- Ongoing support for SmogBusters, a community-based campaign to reduce vehicle usage and promote alternatives;

- Funding to take the schools-based AirWatch national from its origin in Western Australia;
- Development of retrofit emissions standards, a Diesel NEPM, and strategies for new fuels for transport;
- New emphasis on indoor air pollution and air toxics including fine particles.

Pressing Issues

Indoor air pollution

The Australian Statistician indicates that on average 95% of our time is spent indoors (ABS 1996). Thus indoors (including in-vehicle) is the most important potential exposure environment. Issues include: ingress of ambient pollutants; the opposite problem of sick building syndrome due to lack of ventilation; outgasing from construction and furnishing materials; use of unflued gas cooking appliances and unvented space heaters; wood-burning heating appliances; chemical cleaners and insecticides; and tobacco smoke from parental smoking as a major risk factor for asthma in children. CSIRO and some EPAs are increasing attention to these problems: the first issue is simply to characterise the situation since so little is presently known, even with the crusading work of people such as Mr Len Ferrari (Ferrari *et al.* 1988) and Mr Steve Brown (*e.g.*, Brown 1997).

Asthma

Although the death rate from asthma in Australia is decreasing due to improved diagnosis and treatment, there is evidence of increasing prevalence and severity. Asthma affects more than two million Australians: one in ten adults, one in seven teenagers and one in four children. As already noted, at least for children, air pollution is an implicated causative factor. As buildings become less well ventilated to conserve energy, it is important that indoor air pollution is better controlled.

Air toxics

These include a range of carcinogens, acute toxicants, reproductive, mutagenic, immunotoxic and neurotoxic compounds. Implicated are fine particles, benzopyrenes, benzene, chlorinated organics, dioxins, aromatic amines, arsenic, chromium, nickel, and many other individual compounds. Several of these are indoor pollutants. Concentrations are generally uncertain in urban areas and require determination. Farm chemicals also are a potential concern that deserves more attention. A review of studies (EPA 1999) and a first State of Knowledge Report (EA 2000) have been prepared.

Particles

One of the present mysteries is the widely observed relationship that an extra 1% deaths occur for every 10 $\mu g\ m^{-3}$ increase in ambient concentrations of particles less than 10 μm aerodynamic diameter (*e.g.*, NEPC 1998), even though there is no clear mechanism. Since indoor levels are generally well correlated with ambient levels (*e.g.,* Mage *et al.* 1999), this relationship expresses the total exposure of people to particles, whatever their composition. This issue is inseparable from air toxics and other issues mentioned here.

Highly polluting vehicles

Recognised also as a problem in many developed countries (UNEP 2000), older passenger vehicles that are poorly maintained, including many light and not-so-light commercial vehicles, are a particular urban pollution problem. The average fleet age in Australia is over

10 years; older cars tend to have generally higher fuel consumption and higher emissions of VOCs and NOx (FORS 1996). Deterioration is such that, after eight to ten years, emission levels for vehicles fitted with catalytic converters are on average similar to well maintained non-catalyst vehicles. However, studies have found that between 50 and 80 per cent of VOCs come from about 20 per cent of the fleet and that high pollution emitters tend to be distributed throughout the fleet: approximately 20 per cent of 1- to 2-year old cars have been found to be high emitters (reviewed in BTCE 1996). These observations underpin the ATSE (1997) recommendation for effective inspection and maintenance programs in the major urban airsheds, a recommendation echoed in UNEP (2000).

Summary and Discussion

Air pollution in the early years of the Century was mostly characterised by the smoke and grime from wood- and coal-combustion and metal-processing chimney fumes, along with a liberal dosing of noxious odours from rendering, printing and food processing plant. Later years can be more distinctly categorised:

- The 1940s and 1950s were the decades of smoke-stack industries where production was paramount.
- The 1960s saw heightened public awareness of, and concern for, the environment and air quality. The motor vehicle in Australia was still a little-recognised pollution problem: carbon monoxide and photochemical smog levels were growing.
- The 1970s was the age of environmental legislation and the beginning of modern measurement methods, though the paucity of modelling tools meant that full use of the results could not be made.
- The 1980s was the decade of major industrial and urban air pollution investigations, and the beginning of the end of motor vehicle pollution with the introduction of exhaust catalysts, at least on new petrol-fuelled vehicles.
- The 1990s saw growth in an emphasis on cleaner production methods, better air quality modelling tools and management, and a switch in focus to more intractable pollution problems. The airshed was often now treated as an entity. Substantial improvement in air quality in urban and rural areas has been achieved throughout the era, and this is evident from Inquiries and State of the Environment Reports. Nevertheless the Australian community continues to rate air quality as the number one environmental concern, probably because dirty air is often so visible or smelly.

There is every reason to be optimistic about the future. However in urban Australia there is still much that needs to be done, and done now. Motor vehicle congestion is growing rapidly in those cities that are not already close to saturation and an increasing fraction of that traffic is light commercial, usually diesel, vehicles. Must we wait until 2006 or later for Euro4 emission standards to control dangerous particle emissions from diesels, and then only on *new* vehicles? Fiddling with the fuel composition to reduce emissions by a few percent is one action, but it is a poor substitute for a well designed inspection and maintenance program, as recommended by international experience and by the recent Urban Air Pollution Inquiry.

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