SMOG MOVES WEST AS SYDNEY GROWS

Chris Taylor

Smog levels are down over inner Sydney, but the outlook in the expanding western suburbs is causing much concern

Air pollution is the stigma of urban growth. Towns are not seen as cities until their air is under threat and out-of-towners refer to them as 'the big smoke'. Photochemical smog poses easily the biggest single threat to clean air in Australia and, as the cities get bigger, efforts to control smog and associated haze will become more exacting.

In the next 20 years, the nation's most populous city, Sydney, will become home to 4·5 million people, a suburban giant stretching 60 km to the Blue Mountains and encompassing 100 km of coastline. As its area expands beyond 2000 sq. km,

maintaining Sydney's economic activities and the efficient movement of resources, wastes and people will demand longer and longer journeys between major destinations. Getting to and from work will become increasingly time-consuming, with a growing proportion of commuters travelling more than 120 km a day — a distance unimagined by city workers two generations ago.

Although public transport will carry much of the commuter burden, life in a 21st century Sydney, for many, will depend heavily on owning a private car. According to figures compiled by the New South Wales Roads and Traffic Authority, Sydney may have more than two million privately owned motor vehicles by 2011, as well as half a million trucks, 70 000 motorbikes and 50 000 buses.

Managing the movements of a fleet of motor vehicles on this scale presents tough environmental problems for urban planners and regulatory authorities. One of the biggest problems is that cars, and related industries in the transport and storage of fuel, are the principal source of two common urban pollutants — nitrogen oxides and hydrocarbons — that cause photochemical smog.

Controlling smog is important for public and economic health. Under certain conditions, these pollutants will chemically react to form ozone, the principal constituent of photochemical smog and a toxic gas that, at low concentrations, can affect human and animal health, and damage plants and buildings.

In the 1970s, Sydney had a severe photochemical smog problem, typically experiencing dozens of days a year on which ozone levels exceeded the national 1-hour limit of 12 parts per hundred million (p.p.h.m.). Thanks to improvements in vehicle fuel efficiency, tighter controls on car exhaust emissions, factory closures and a range of State government environmental policies affecting industry, the number of high-ozone days fell dramatically.

An environmental success story? Not really. A recent study of air quality in Sydney's west, conducted by researchers at Macquarie University and CSIRO's Division of Coal and Energy Technology, has found that the smog problems of the 1970s were not solved; they simply contracted westwards beyond the then limits of the city.

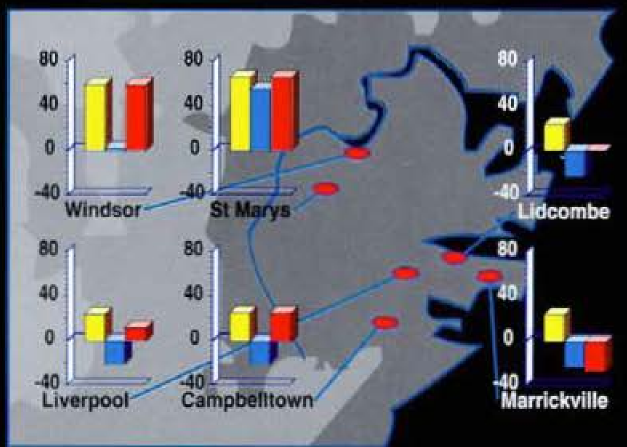
Due to its complex chemistry, smog formation occurs faster or slower, depending on the relative proportions of pollutants that create smog and the amount of sunlight available. If the nitrogen oxides and hydrocarbons are moving on a breeze or a flow of cold air down into a valley, then the ozone may take hours to form, not reaching its highest concentration until the pollutants have travelled many kilometres from where they were first emitted.

This is precisely what the researchers found in Sydney. Since 1976, smog has been reduced in the city's eastern parts, but little or no change has occurred in its far west and south-west. The situation has gone unnoticed before because the New South Wales State Pollution Control Commission (SPCC) has most of its monitoring stations in the eastern suburbs.

Most significantly, the researchers — CSIRO's Mr Graham Johnson and Macquarie's Dr Robert Hyde — pre-

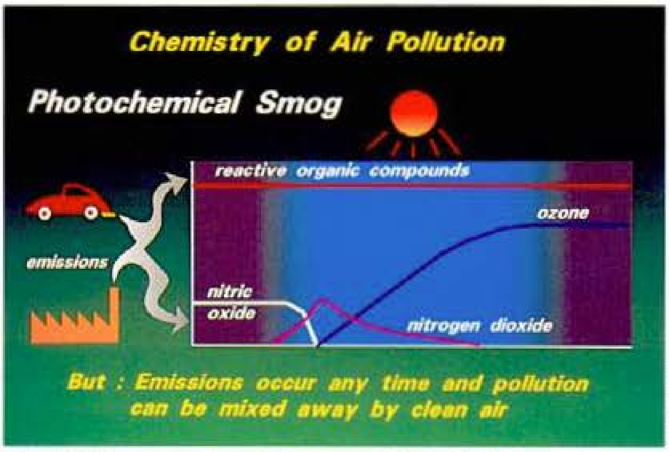
LOOKING 20 YEARS AHEAD

Comparing 1976 levels with calculations for 2011 (% change)



While smog should remain under control near the city, the researchers expect levels to rise substantially in the outer western suburbs. The calculations are for typical days conducive to smog formation.

Computer illustration by Phil Cleaver



Geoff Lane

The initial concentration of nitrogen oxides in the air controls the maximum level of ozone or photochemical smog produced. The reactive organic compounds, chiefly hydrocarbons, control the rate of smog formation. The chemical reactions require the presence of sunlight.

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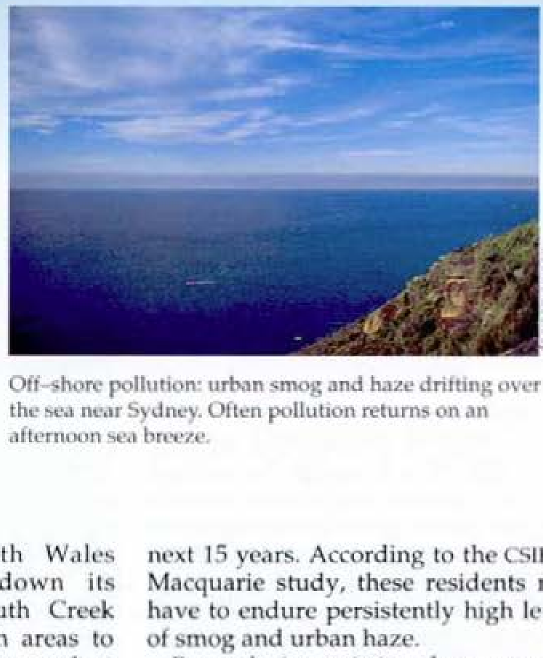


Off–shore pollution: urban smog and haze drifting over the sea near Sydney. Often pollution returns on an afternoon sea breeze.

dicted that, without new pollution-control measures, the smog in Sydney's west would get worse not better. Paradoxically, they also found that efforts to control smog in western Sydney would, in some circumstances, lead to higher ozone concentrations in eastern Sydney.

The implications for policy-makers are obvious. As Sydney expands, with more people building homes in the largely rural areas on the western and south-western fringe of the city, a return to the air pollution of the 1970s is becoming steadily more likely.

Already, the New South Wales government has scaled down its housing plans for the South Creek Valley and Macarthur South areas to the south-west, promising to conduct air-pollution assessments before making any major commitment to residential expansion. However, the State's Department of Planning has warned that 'a significant proportion' of Sydney's population growth in the next 20 years 'could be housed only in new residential areas'.

Up to a million people may move into new areas in Sydney's west in the next 15 years. According to the CSIRO/ Macquarie study, these residents may have to endure persistently high levels of smog and urban haze.

By analysing existing data on ozone levels at Campbelltown and Camden, and combining these with wind data collected by Macquarie University and additional data from CSIRO's Airtrak pollution-measurement system, the scientists found that locations in the planned western growth areas were already recording ozone levels in excess of the acceptable limit of 12 p.p.h.m., and would experience severe photochemical smog whenever the weather was suitable.

In order to assess trends in ozone levels, Mr Johnson developed a numerical model of smog formation, known as the Integrated Empirical Rate (IER) model. Drawing on estimates of emissions of nitrogen oxides and hydrocarbons in 2011, prepared by the SPCC, the scientists were then able to make preliminary predictions about ozone concentrations in Sydney in 20 years time. The results predicted rises in ozone levels of up to 50% in the western parts of Sydney, representing — the researchers claim — a serious pollution issue.

Mr Johnson concluded smog days would become more frequent and more severe. In 2011, areas in the west such as Penrith and St Marys would experience ozone levels as high as 20 p.p.h.m., well above the national limit and above the Victorian Environment Protection Authority detrimental level of 15 p.p.h.m. that, under Victorian State law, should never be exceeded. At an ozone concentration of 20 p.p.h.m., parents would be advised to keep children indoors. Campbelltown, in the south-west, can expect levels of up to 18 p.p.h.m..

Sydney on average can expect rises in ozone levels of between 25 and 39%, the study found. Photochemical haze — the fine particles formed when polluted air is exposed to strong sunlight — will also increase noticeably during the summer months, giving the sky a whitish appearance.

'There is a real danger we will get long-duration episodes of photochemical smog and haze, rather than an odd day now and then', Mr Johnson said.

The reason the city's west, which is sparsely populated compared with the east, suffers the worst of the city's smog problem stems from the regional wind patterns. Sydney's air can be divided into three interacting regions: the Hawkesbury Basin, centred on the Hawkesbury River, to the west and the Parramatta River Valley and Liverpool Basin in the east. During the night, the Hawkesbury Basin, which extends from Mittagong in the south to north of Windsor, fills up with cold, relatively clean air moving from higher ground in the south. The cold air displaces polluted air to higher elevations, eventually forcing a 'spillover' at about Blacktown into the adjacent Parramatta River Valley.

As the 'spillover' air flows down

towards eastern Sydney it picks up the pollutants of the morning peak traffic period. This air then moves out to sea, but, depending on weather conditions, can return to shore further south on an afternoon sea breeze.

The onset of the sea breeze carries the pollutants westwards, back through the Parramatta River Valley or Liverpool Basin to the south-west, returning to the Hawkesbury Basin by late afternoon.

As the air travels across the city, sunlight reacts with the collected hydrocarbons and nitrogen oxides accumulated from the emissions of motor vehicles and factories, forming ozone. Because the chemical reactions take place slowly, the gases don't build up to peak concentrations until the breeze reaches the western suburbs. So, even though most of the motor vehicle emissions occur in the east, the west suffers most of the consequences.

An extra implication is that, as Sydney's west becomes more populated, local emissions of pollutants may add to the previous day's photochemical smog recirculated from the eastern suburbs.

During the late 1970s and '80s, the SPCC controlled photochemical smog in eastern Sydney by cutting the amount of hydrocarbons emitted — especially from motor vehicles. Cars and other vehicles account for about 46% of hydrocarbon emissions in Sydney. The introduction of unleaded petrol in 1986 made possible the use of a catalytic converter to cut hydrocarbon emissions in cars by nearly half. By 1990, the emission of reactive hydrocarbons in the Sydney air-shed had declined to 35 tonnes an hour in the morning hours, a reduction of 22% on 1976 levels.

Hydrocarbons control the rate of smog formation. In relatively clean air, the concentration of ozone is kept in check by a chemical balance between oxygen (O_2) and two nitrogen compounds, nitric oxide (NO) and nitrogen dioxide (NO_2). The key chemical reactions work like this:

1. NO_2 + ultraviolet light $\rightarrow$ NO + O (atomic oxygen).
2. $O + O_2 \rightarrow O_3$ (ozone).
3. $O_3 + NO \rightarrow NO_2 + O_2$.

These reactions mean that in creating nitrogen dioxide (reaction 3), nitric oxide destroys ozone, thereby limiting its production. However, sunlight causes reactive hydrocarbons to produce many compounds that also oxidise NO to NO_2, but without destroying any ozone. In urban air the hydrocarbons react in this way, increasing production of NO_2 and then the production of ozone by reaction 1.

The more hydrocarbon the air contains, the quicker the nitric oxide is consumed and the faster the rate of ozone production. Less hydrocarbon means a slower rate of reaction, allowing more time for air-mixing and wind to disperse the pollutants or shift them westwards.

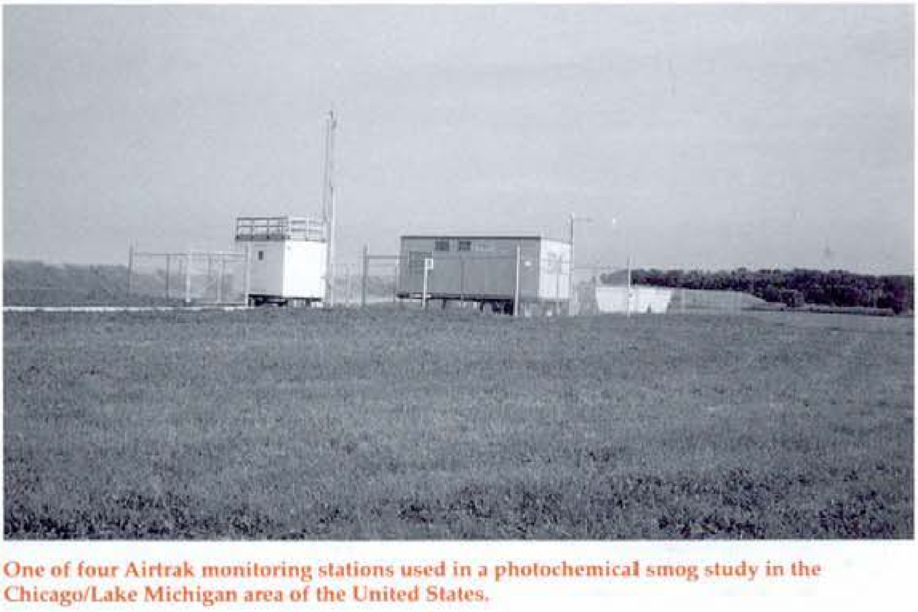
Lowering hydrocarbon emissions is an effective and relatively cheap way of tackling photochemical smog, especially for smaller cities that, in effect, 'export' their smog to non-residential areas beyond the urban limits. The CSIRO/Macquarie study argues, however, that Sydney is too big for hydrocarbon controls on their own to be sufficient. In the Hawkesbury Basin, photochemical smog does not depend on hydrocarbons or sunlight. Under what Johnson calls an 'NO_X-limited regime', ozone levels have reached their maximum, maintained at a concentration determined by the initial quantity of nitrogen oxides in the air.

In such areas, control of photochemical smog requires a lowering of the emissions of nitrogen oxides, a considerably more difficult strategy than existing pollution controls.

Since 1976, little has been done to lower nitrogen oxide emissions. Indeed, emissions have grown slightly — from 12 tonnes an hour to 13 for the Sydney air-shed in the morning hours — and are expected to reach 18 tonnes an hour by 2011, with most of the increase coming from motor vehicles.

The federal legislation in 1986 requiring catalytic converters on new petrol-driven vehicles did not stipulate any tightening of the limit on nitrogen oxide emissions, and whatever improvements have occurred in private cars are being offset by increased use of diesel-powered vehicles such as trucks and buses. Motor vehicles contribute about 85% of nitrogen oxide emissions in Sydney, with trucks and buses contributing about one-third of the total.

Under the New South Wales Clean Air Act, new cars are required to emit less than 1·93 grams of nitrogen oxides per km travelled. At present about one-third of the motor vehicle fleet has to meet this standard and, as older cars are retired, the proportion will rise. But the emission estimates produced by the SPCC make it clear this will not be enough for Sydney — without new legislation, emissions will continue to increase, leading to worse and more frequent smog events in the western suburbs. The construction of new industries and an airport at Badgery's Creek can also be expected to add to the pollution burden in the west.



One of four Airtrak monitoring stations used in a photochemical smog study in the Chicago/Lake Michigan area of the United States.

In 1989, the Office of Technology Assessment, an agency of the United States Congress, estimated that it would be technologically feasible to lower nitrogen oxide exhaust emissions from cars to 0·25 gram per km, barely more than one-eighth of the current Australian standard.

Such a measure, says the SPCC, would be 'very expensive' and may achieve at best a 20% cut in nitrogen oxide emissions by 2011. A new exhaust-emission standard, even if introduced tomorrow, would take up to 5 years to be adopted into the manufacture of new cars, and a further 10 to 12 years to reach 50% of the fleet. By then, Sydney could already be suffering the levels of photochemical smog predicted by the CSIRO/Macquarie study.

To make matters worse, Mr Johnson and Dr Hyde point out, any measure to reduce nitrogen oxide emission may worsen the smog problem in eastern Sydney.

Because nitric oxide destroys ozone and delays the onset of ozone production, a lowering of its concentration in the Parramatta River Valley, in an effort to limit smog in the west, would accelerate ozone production in the east, creating more smog events in that region than occur now.

With these sobering thoughts in mind, the researchers have called for a more detailed investigation of the dynamics of Sydney smog events and a review of pollution-control options, including car use and guidelines for urban development.

Brett Wright

More about the topic

'Pilot Study: Evaluation of Air Quality Issues for the Development of Macarthur South and South Creek Valley Regions of Sydney. Final Report.' G. M. Johnson and R. Hyde. (CSIRO and Macquarie University: December 1990.)

'The Urban Atmosphere — Sydney a Case Study.' J.N. Carras and G.M. Johnson, eds. (CSIRO: Melbourne 1983.)

'Catching Our Breath: Next Steps for Reducing Urban Ozone.' United States Congress, Office of Technology Assessment. (Government Printing Office: Washington DC, 1989.)

The monitor provides information on the speed of smog formation as well as current levels.