# Sydney's brown haze

Sydney-siders find it hard to remember when they saw their city's first full-blown case of brown haze. It's something that, like old age, just crept up on them.


Sydney immersed in brown haze.

For those unfamiliar with the phenomenon, brown haze is, as its name suggests, a murky layer of polluted air that often hangs over the city on crisp, and otherwise clear, calm mornings from autumn to spring. That it rarely appears in summer is one of the clues to tracking down its cause.

A good case of brown haze can cover the whole of Sydney's urban area and stretch 65 km out to sea. To the international traveller it's often the first (and last) view they catch of the city.

Certainly the malady has become more acute as the city has grown. More people, more cars, more industry — all have contributed to the build-up, which will probably get worse before it gets better.

The brown haze that greets the population at first light is an obvious manifestation of air pollution. It thickens visibly at the time of the morning traffic peak. As such, it differs from that other breed of air pollution known as photochemical smog. This requires gaseous pollution products to stew together for some hours in the presence of sunlight to form ozone and other noxious compounds. Photochemical smog doesn't develop fully until noon; it occurs mostly in summer when sunlight is strong; and its effects on visibility are likely to be much less.

*The haze will probably get worse before it gets better.*

The explanation is that photochemical smog is predominantly gaseous, whereas brown haze is predominantly a suspension of numerous fine particles (an aerosol). Ironically, the largely invisible photochemical smog can, in high concentrations, have decidedly adverse effects on your health; brown haze is free of ozone and, so far as we know, no harmful effects on health can be positively attributed to it.

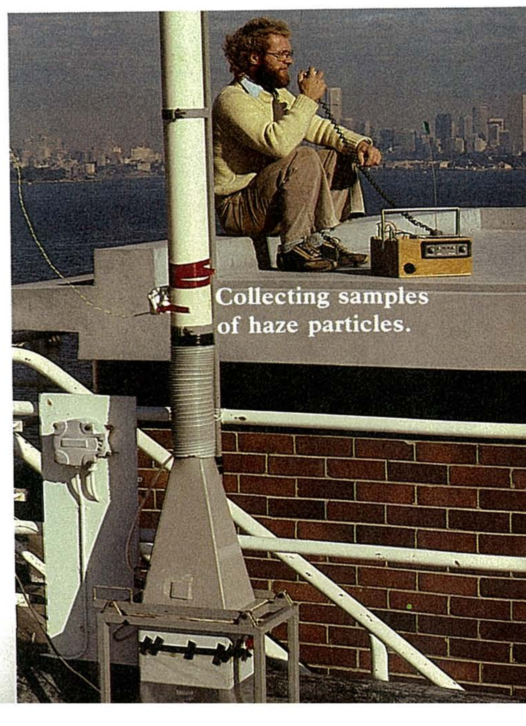
Brown haze is a closer relative of the true 'smog' (smoke and fog) of London in the fifties and sixties. It lacks the fog element, although there's some water adsorbed onto the particles; it's also less concentrated, and lacks the sulfur dioxide and large sooty particles of the London pea-souper — a pea broth, perhaps?

One of the reasons that long-time Sydney residents failed to notice brown haze decades ago was that smoke obscured it! Modern pollution-control regulations prohibit strong smoke emissions: electrostatic precipitators are used to catch the large sooty smoke particles. But some fine particles do escape, and these contribute to that characteristically dirty-brown haze.

### More brown hazes

Brown haze is, of course, not unique to Sydney. Any other large industrial metropolis is susceptible to its visitations. Residents of Melbourne, Brisbane, and Adelaide are, in varying degrees, familiar with its appearance. Many overseas cities are no strangers to it, either.

Yet, it is true that Sydney's geography and latitude predispose it to more frequent occurrences of the phenomenon than most other places. These factors



Collecting samples of haze particles.

contribute to a particular meteorological condition that underlies the haze's occurrence.

Mr David Williams of the CSIRO Division of Fossil Fuels at North Ryde, Sydney, has been studying the nature and origin of the haze since 1975. The study is part of a larger research program on atmospheric pollution at the Division under the direction of Dr Maurice Mulcahy. A number of other scientists are now also involved, including some from Macquarie University's School of Earth Sciences.

The State Pollution Control Commission (SPCC) is helping to fund the research.

**About one-quarter of the haze's effect on visibility can be attributed to vehicle emissions.**

Mr Williams and his team of scientists have found that brown haze is caused by minute suspended particles, 80% of which are less than 1·5 micrometres in diameter. Some larger particles up to 5 $\mu$m across are also present, but beyond that size the particles soon settle out (as soot).

A decent episode of brown haze contains 50 $\mu$g of minute particles per cubic metre of air. Roughly, that means each cubic metre contains a billion suspended particles. It is the ability of these myriad particles to scatter light that reduces visibility, sometimes to less than 6 km.

Mr Williams' experimental strategy was to monitor haze intensities at several selected sites throughout the Sydney region. The intensity was measured by a nephelometer, a device that detects the amount of light from a bright xenon flash tube that is scattered by the aerosol particles.

### Sifting the evidence

At the same sites, air samplers sucked the haze through fine filters. The air was sampled 6 m above the ground to avoid contamination by dust stirred up by nearby activities.

*A particular meteorological condition underlies the haze's occurrence.*

A high-volume sampler passed 1·5 cu m of haze a minute through fine glass-fibre filters. After the haze had passed through this unit for 2 hours, some 10 mg, more or less, of grey material had been lodged on the filter, and it was ready for analysis by a variety of sensitive analytical techniques.

A low-volume unit sampled 20 L of air (0·02 cu m) a minute for about 4 hours. After particles larger than about 1 $\mu$m had been removed, the air was forced through very fine filters (with a stated pore size of 0·4 $\mu$m). An X-ray technique was used to analyse the very small amount of material collected on them.

The idea of using the two units was to allow the composition of the fine-particle fraction to be compared with that of the coarser one. To help in characterizing the particles, sampling sessions were undertaken in the Cahill Expressway tunnel (to see what cars were emitting) and during a bushfire in the Ku-ring-gai Chase (to see what burning vegetation gave rise to).

**What causes the haze?**

| source | contribution | |
|---|---|---|
| | weight (%) | haziness (%) |
| sea salt | 17 | 3 |
| motor vehicles | 17 | 24 |
| burning vegetation (bushfires and backyards) | 10 | 10 |
| soil dust | 4 | <1 |
| cement dust | <1 | <1 |
| process heating, refuse incineration, and other sources | 52 | 62 |

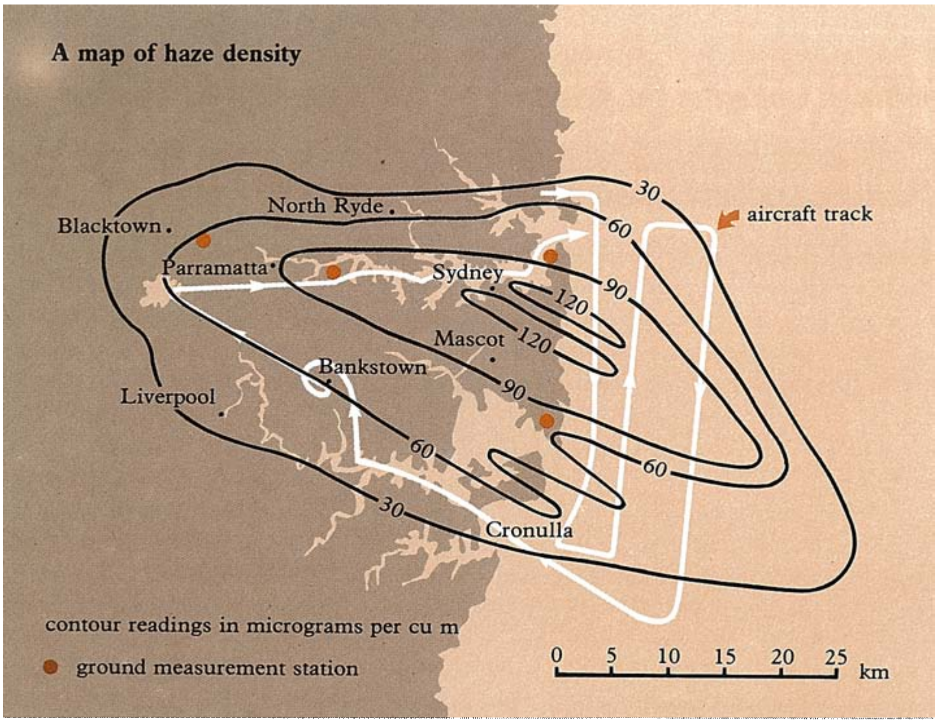
**The top five lines of the table have been arrived at from measurements of tracer substances. Arithmetic (summing to 100%) gives the bottom line.**

The used filters were stored in aluminium bags prior to analysis, and Mr Williams has found that, over time, the collected material can cause the aluminium to pit and corrode. This may say something about the possible effects on people's lungs, and suggests the need for further investigation.

Four sampling sessions, each of 6 weeks' duration, have been carried out so far: in the autumn in 1978, 1979, and 1980, and the spring of 1978.

An instrumented aircraft was also employed to fly through the haze and char-

**Burning vegetation — bushfires and backyard incinerators — contributes about 10% of the brown haze.**




**An aircraft was used to measure the density of the haze on the morning of May 8, 1978. The contours indicate that strong sources exist near the centre of the city.**

acterize its composition and density. Because of the dense air traffic over Sydney, the aircraft was seldom allowed to travel where the scientists would like. In particular, they frequently found it frustrating not being able to descend low enough to get into the polluted layer, except over water and at Bankstown and Hoxton Park air strips. Nevertheless, maps revealing the density of the haze over wide areas of Sydney were produced from the aircraft flights on a number of occasions. They show several localized sources of emissions. One such map is shown on this page.

Analysis of the more than 2000 samples is still continuing, although sufficient work has been done to enable some conclusions about the origin of the haze to be drawn.

Both the ground-based and air-derived measurements revealed that the haze is remarkably uniform, suggesting that it derives from numerous sources. However, greater haze levels frequently surround the industrial areas of Matraville, Silverwater, and Balmain, singling them out as sources of strong emissions.

### What causes it?

Chemical analysis of the haze allows the general source of the particles — whether they originate from cars, boilers, or whatever — to be tracked down. However, before we look at this aspect, remember that each business day the same pollutant stream pours forth into the air. Whether a haze is evident on any one day is determined by meteorological factors.

Dr Robert Hyde and colleagues at Macquarie University have investigated this angle and have found out why the haze only forms on cool, calm mornings.

During the long nights of the cooler months when there is a clear sky and little wind, a cold layer of air, 150 to 300 m deep, forms on the ground. Pollutants become trapped in this layer.

The air in it is colder and heavier than air over the sea, and so tends to drain down the Paramatta River valley, beginning in the Blue Mountains and flowing down and out past the Heads. As the graph at the top of page 15 shows, whenever this westerly 'drainage flow' establishes itself, haze levels rise.

*An instrumented aircraft flew through the haze.*

The flow, and haze, continues until it is dispersed by a breeze or by the sun's heating and the resulting turbulence.

One interesting aspect is that haze levels can be very high at night. This could be caused by recirculation of pollutants from the previous day. An evening sea breeze blows pollutants inland, then they move back to the coast when drainage conditions are established. Come the morning, the city air is set to receive a double dose of pollutants.

*Of the brown haze particles, 80% are less than 1·5 micrometres in diameter.*

### What's in it?

The general uniformity of the haze shows up in the chemical analyses. The elemental compositions remain fairly steady, and even the percentages of fine and coarse particles remain relatively constant too.

The results of analysis so far indicate that carbon is by far the major element in the haze, contributing about 30% by weight. Some 24% is elemental carbon; 6% is present in an organic form.

Other components, in decreasing abundance, were found to be sulfate (12%), sodium (9%), nitrate (8%), chlorine (7%), silica (3%), and lead (2%). Smaller quantities of potassium, calcium, zinc, aluminium, and iron were found, as well as traces of other metals.

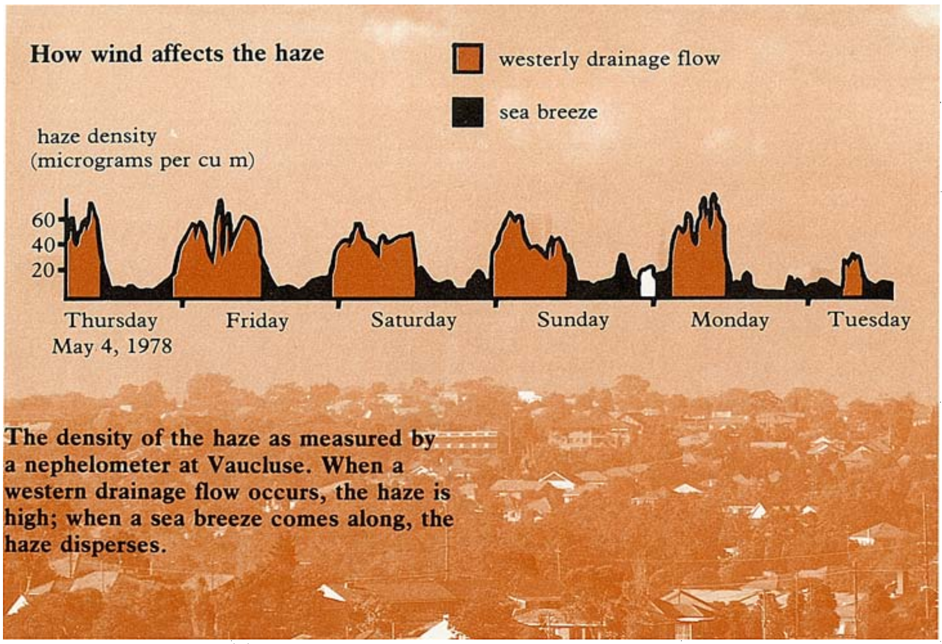
Fine particles (less than 1·5 $\mu$m) comprised some 80% by weight of the haze. By numbers, they are therefore even more dominant; and they have about five times the light-scattering power of an equal weight of the coarser particles.

The coarse fraction (20% by weight) was found to consist mainly of sea salt (sodium and chlorine), with a small contribution from soil dust, and both would seem benign. Certainly it would be impossible to prevent their occurrence.

One must point therefore at the fine-particle fraction as the main cause of brown haze. And particles as fine as the ones in the fine fraction can only be produced by combustion, Mr Williams notes, so this considerably narrows down the possible major sources. Some minor variations detected in the composition of the haze provide further clues.

Peaks in the concentration of lead observed during the morning rush hour could only be produced by leaded petrol from motor vehicle exhausts, and this points to cars as being among the major contributors. Averaging the results of the analyses performed so far, Dr Williams calculates that motor vehicles contribute 17% by weight of Sydney's brown haze, but, because of the size factor, 24% of the impact on visibility.

By contrast, sea salt (represented by the sodium and chlorine) amounts to 17% by weight also, but it occurs as large particles, so in terms of haziness it contrib-




**The density of the haze as measured by a nephelometer at Vaucluse. When a western drainage flow occurs, the haze is high; when a sea breeze comes along, the haze disperses.**

utes only 3%. Similarly, other forms of dust, including soil and cement dust, may contribute less than 5% by weight, and less than 1% to haziness.

Bushfire smoke was found to be distinctive in having 80% of its total carbon content in organic compounds; the remainder occurs as elemental carbon. Sydney brown haze has only 25% of its carbon in the organic form. Taking account of the organic carbon contributed by petrochemicals, Mr Williams calculates that burning of vegetation (which would include bushfires and backyard incinerators) contributes roughly 10% of the brown haze.

*Each cubic metre contains a billion suspended particles.*

The scientists found a slightly higher level of carbon in the air on Mondays, suggesting that this might be due to backyard burning over the weekend.

### The balance sheet

Doing the arithmetic, the sources so far mentioned (motor vehicles, sea salt, dusts, and burning vegetation) account for 48% of the haze by weight and 38% in terms of effect on visibility. These are shown in the table.

That leaves 52% of the haze by weight (and 62% in terms of visibility) to be accounted for. As mentioned, this contribution must come from combustion, so we are drawn to the conclusion that industrial boilers and incinerators are responsible for at least a substantial part of this slice.

Nevertheless, scientists are always careful and, to finalize the case, Mr Williams and his colleagues are taking samples of emissions from industrial chimneys to check the extent to which the particles involved indeed fill the vacant slot.

When work is completed, it will aid government agencies to carry out controls that will reduce the intensity of the haze.

*Andrew Bell*

### More about the topic

'The Nature and Origin of Sydney Brown Haze.' Third Report to the State Pollution Control Commission of New South Wales. D. J. Williams, J. W. Milne, D. B. Roberts, D. H. Philipp, D. J. A. Jones, and R. Cosstick. (CSIRO Institute of Earth Resources: Sydney 1981.)

Summer smog and winter haze. M. F. R. Mulcahy. In 'Choices and Challenges'. (Australian Institute of Petroleum Ltd: Melbourne 1980.)

**Some 17% (by weight) of the haze is sea salt. However, the salt particles are large, and so contribute only 3% to haziness.**