Where does the sulphur dioxide go?

Sulphur dioxide is one of the main pollutants emitted into the air by industry. It changes gradually to sulphuric acid and other sulphur compounds, and can have a number of harmful effects if concentrations are high enough.

The condition of people with respiratory problems can be aggravated. And rain can turn mildly acid. This hastens the deterioration of stone structures and, as has happened in a few areas in Europe and the United States, can make

The emissions leave one of the Mt Isa stacks . . .

. . . and spread over the country in a ribbon-like plume.

conditions in inland lakes injurious to fish. On the other hand, sulphur finding its way into the soil can benefit vegetation.

The main emitters of sulphur dioxide are industrial plants — notably power stations that burn sulphur-containing coal or oil, and smelters that produce copper, lead, zinc, and other metals from sulphide ores. Some 90% of emissions occur in the Northern Hemisphere, mainly in the heavily industrialized parts of North America and Europe. Those are the areas where the pollution problems have been most severe.

Australia accounts for only about 1% of the world's sulphur dioxide emissions, and these have so far produced no major problems of air pollution or acid rain. We are fortunate in that most Australian coals and oils have very low sulphur contents. Most smelting is carried out in remote locations from which emissions can disperse apparently harmlessly.

The prime example is Mt Isa in north-western Queensland, where copper and lead smelters produce about 1500 tonnes of sulphur dioxide a day when operating at full capacity.

Mt Isa Mines Ltd operates an elaborate meteorological station and sulphur dioxide monitoring system, to ensure that emissions stop whenever a risk arises of the plume being blown into the town. This protects the townspeople from sulphur dioxide pollution. The surrounding country is virtually uninhabited, the nearest major settlements being Alice Springs 700 km to the south-west and Townsville 800 km to the east.

A 270-metres-tall chimney stack has been built recently to encourage greater dispersion of the lead smelter's emissions and reduce the amount of time that the smelter has to be shut down to maintain air quality standards in Mt Isa. It is Australia's tallest structure.

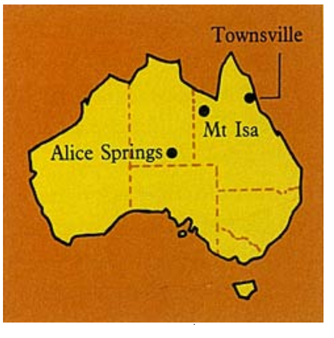
Although sulphur dioxide has long been recognized as one of the most serious air pollutants in parts of the world, there are large gaps in knowledge of what happens to it after it leaves the chimney stack. For scientists looking for some of the answers, Mt Isa provides almost ideal experimental conditions.

Because the town is so remote and contains no other significant sources of air pollution, the plume from its smelter stacks is almost completely uncontaminated by other industrial emissions. And for part of the year, meteorological conditions cause the plume to disperse as a readily studied ribbon that can be traced out, as it gradually broadens, to distances of 500 km and more.

Since 1974, Mr David Williams and colleagues from the CSIRO Division of Process Technology, in cooperation with Mt Isa Mines Ltd, have been examining this plume. Their aims have included finding out how rapidly sulphur dioxide changes to sulphuric acid and how much of it returns to the ground unchanged.

The team made their measurements between May and August each year from 1974 to 1977. In those months, stable anticyclone conditions generally maintain dry easterly winds over northern Australia. Between about 10 p.m. and 10 a.m., a strong temperature inversion often forms, preventing emissions from rising more than 1500 m above the ground. Those are the conditions that produce the stable ribbon plume.

The scientists used a sensitive correlation spectrometer, mounted on a four-wheel-drive vehicle and in a light aeroplane, to work out how much sulphur dioxide was passing along the plume at various distances from Mt Isa. They could detect no change in the sulphur dioxide flux out to a distance of 236 km. That is as far as they followed the plume; by then it was becoming rather dilute.



Mt Isa is very isolated. The nearest major settlement, Alice Springs, is 700 kilometres away.

Any decrease greater than about 15% should have been detectable. So the readings show that the gas does not react to form other compounds or return to the ground rapidly. In typical winter-wind conditions, the emissions would take about 12 hours to travel the 236 km.

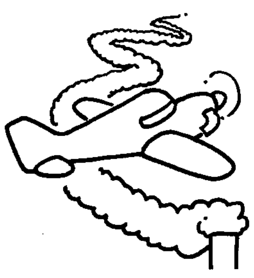
Flying through the plume, the scientists sought more-precise information with a flame photometer. In this instrument, a hydrogen flame, colourless when it burns in clean air, turns an increasingly bright blue as the concentration of sulphur atoms in the air rises. Photomultipliers, measuring the intensity of the blue, give readings of the sulphur concentration.

The scientists filtered some of their plume samples to remove the sulphuric acid droplets. Having done so, they could use the instrument to find out what proportion of the plume was made up of sulphur-containing gases, mainly sulphur dioxide. Close to the stacks, this was never less than 98%. Out along the plume, the lowest value encountered was 89%, confirming that sulphur dioxide is only gradually lost from the plume.

They used another method to measure the sulphuric acid build-up directly. By blowing large amounts of plume air through specially treated glass-fibre filters, they collected sulphuric acid together with trace quantities of lead, copper, and other metals. Lead levels in the plume remain fairly constant, so measurement of the ratio of sulphuric acid to lead in the filters gives a good picture of changes in concentrations of the acid.

The scientists concluded that, in the absence of rain, it takes about 4 weeks for 90% of the emitted sulphur dioxide to return to the ground or change to sulphuric acid over northern Australia. This rate is 5–10 times slower than those measured in similar experiments in the United States and Europe.

They found that the amount of sulphur dioxide in the plume fell during the day, but hardly at all at night. No similar finding has come from overseas studies. Two factors seem to be involved, the most important being chemical reactions that convert sulphur dioxide to sulphuric acid, but only in sunlight. The other is the fact that the night air is very stable; this means that the plume is



unlikely to hit the ground then, so sulphur dioxide will not be absorbed by vegetation or soil.

Confirming the role of light-induced reactions, they found a close correlation between the build-up of sulphuric acid along the plume and the amount of light the smelter emissions had been exposed to. Their measurements suggest that chemical conversion accounts for about three-quarters of the sulphur dioxide lost from the plume.

To see whether absorption by plants and soil could account for the rest, they performed another series of tests. An essentially airtight teflon tent, about 1 m square and 1·5 m high, was erected on typical plots of ground under the plume path. Then sulphur dioxide was pumped in until it reached a concentration of about one part per million. The air inside was stirred, and the rate at which the sulphur dioxide concentration fell was measured. Uptake by plants and soil could be deduced from this.

In some tests, the tent was put over small trees. In others, the ground was either grassed or bare. In all cases, the uptake was 5–10 times slower than rates recorded in Europe. Despite this, the scientists think it is sufficient to account for the loss of sulphur dioxide not attributable to the chemical reactions.

Some tests by the team in Sydney showed that sulphur dioxide absorption by plants and soil can be much greater in wetter parts of Australia. But the Mt Isa pattern is probably similar to that for most parts of the continent.

If other pollutants were present, different chemical reactions might take place in a plume, altering the rate of removal of sulphur dioxide. This would almost certainly be the case in city air. Different reactions would probably also take place in plumes from coal-burning power stations, even in remote regions. This is because they contain nitrogen oxides and sooty material as well as sulphur dioxide. The CSIRO team hopes soon to carry out similar tests on a power station's emissions, to see what differences can be detected.

The dry deposition of sulphur dioxide — field measurements with a stirred chamber. J. W. Milne, D. B. Roberts, and D. J. Williams. *Atmospheric Environment*, 1978, **12** (in press).

Atmospheric oxidation of sulphur dioxide. D. B. Roberts and D. J. Williams. In 'Proceedings of the Sixth International Clean Air Conference', ed. E. T. White. (Ann Arbor Science Publishers: Ann Arbor 1978.)