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At last, the universal smog meter

A recent report by the United Nations Environment Program estimates that more than 80% of the world's city-dwellers breathe air polluted at levels above what UNEP considers acceptable. Ozone and particulates are the major offenders.

In this context, an intelligent smog-monitoring system recently launched onto the world market by an Australian company is a timely development. After counting up all the polluted cities, its maker — Mineral Control Instrumentation Pty Ltd — reckons that this world first can earn up to $100 million in export sales over the next 10 years.

Not only does the system simultaneously measure all the key components of photochemical smog — a leading innovation itself — but it combines these data with information on weather conditions and so predicts how smog will develop as the day progresses. In this way it can provide an early warning of a possibly dangerous ozone build-up.

The same computer analysis of the smog reactions can be run backwards in time — in this mode the program can calculate how long a polluted air parcel has been stewing in the atmosphere. By matching this information with data on wind speed and direction, the user can locate the source of the polluted parcel. Watch out, air polluters, wherever you are!

The universal photochemical smog monitor, called AIRSCAN, was invented by atmospheric chemists at the CSIRO Division of Coal Technology in Sydney. Over several years, a research team led by Mr Graham Johnson has carried out extensive investigations into the causes of photochemical smog, using large outdoor smog chambers (see *Ecos* 34 and 54).

This work has been supported by the State Pollution Control Commission of New South Wales and the Australian Institute of Petroleum. Two innovations arising from this research are fundamental to AIRSCAN.

First came Mr Johnson's development of an accurate, but simple, model of smog formation. Called the Integrated Empirical Rate model, this set of equations takes the concentration of smog precursors — nitrogen oxides (NO_x) and reactive organic compounds (ROC) — and shows how, under a scheme of light-driven reactions, the level of 'primary smog product', or PSP, varies.

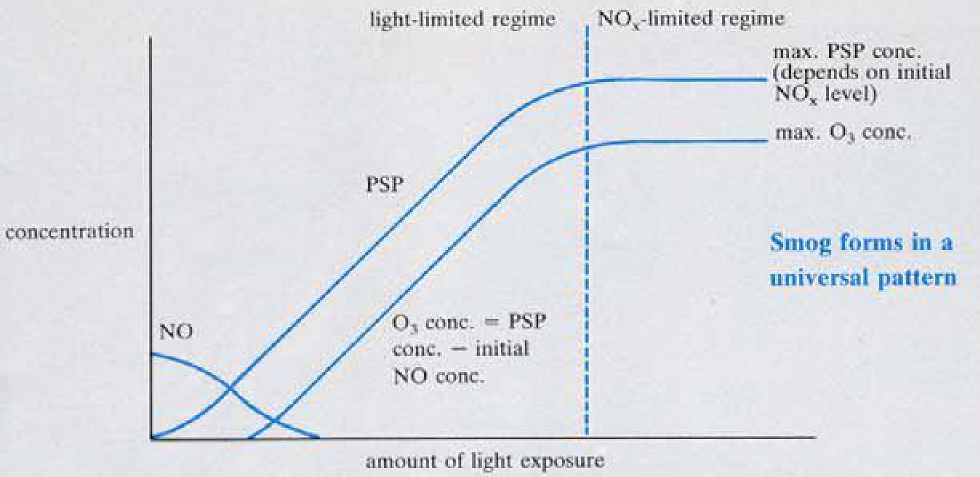
Essentially, the figure for PSP equals the ozone concentration plus the amount of nitric oxide consumed, and it's a simple function of the dose of sunlight the smog has received since daybreak. The diagram shows how the concept of PSP allows the smog-formation process to be seen as a progression through two basic phases — a 'light-limited' regime and a 'NO_x-limited' one.

Second was the development of a totally new approach to getting a handle on the ROC content of an air sample. Whereas good methods presently exist for measuring concentrations of nitrogen oxides and ozone, until now no satisfactory method has been available for routine monitoring of the compounds (predominantly hydrocarbons) that comprise ROC.

Reactive organic compounds are important because, together with temperature and sunlight intensity, they determine the rate at which the smog reactions proceed. Each ROC species reacts at a different rate and yields a range of partially oxidised products that undergo further reaction. Methane reacts very slowly, propylene reacts very quickly (more than 1000 times faster than methane), and most others are somewhere in between.

The only method in current use for routine hydrocarbon monitoring gives a summed value of all hydrocarbons minus methane. Moreover, because of limitations in the method's sensitivity and the wide range of ROC compositions, this 'non-methane hydrocarbon' figure has limited usefulness.

The new CSIRO technique denies the chemist's innate urge to analyse individual hydrocarbon components. Instead, it measures what really matters — the propensity of a ROC soup to produce smog. It does this by the radical but simple method of inducing smog to form in the sample under test.



Smog formation goes through two stages — the 'light-limited' regime and the 'NO_x-limited' one. AIRSCAN measures all the parameters necessary to predict what the smog level will be at any time.

Essentially, AIRSCAN is an automatic two-stage chemical reactor and analyser. In the first stage, it measures the current extent of smog formation; in the second, a bank of sunlamps drives smog reactions in the same way as sunlight does in the atmosphere.

Putting the data from these stages together, AIRSCAN's in-built computer calculates the current ozone, NO_x, ROC, and PSP concentrations, and the speed of smog formation.

Once we know that, we know the slope of the smog-formation graph depicted above, and also the present position on the graph. From this, and the NO_x content of the air, the whole course of the reaction — including the maximum level of ozone (and PSP) that will be reached — is now fixed. Constant monitoring of light intensity provides the final factor needed for running the computer program.

The AIRSCAN instrument is compact and self-contained, and it operates unattended. It gives a complete picture of air quality: on the one hand it indicates the locations of emission sources; on the other it lays down the prospects for future ozone production as the day progresses and the air blows away from the neighbourhood of the monitor.

Read-out from AIRSCAN is simple and direct, allowing ready interpretation by a competent technician. A team of PhD specialists is not required!

Yet this one instrument, costing \$75 000 or so, also gives accurate data on nitrogen oxides, ozone, and the ROC content of the air.

Extensive comparisons between AIRSCAN and calibrated laboratory instruments have verified the accuracy of the new system. Last year, a prototype AIRSCAN operated beside conventional gear at a monitoring site in Melbourne; good performance was always seen.

In addition to its normal watch-dog function, AIRSCAN can also be used to evaluate the smog-forming potential of industrial emissions. By drawing vapours from stacks and ducts, it can predict how strongly these samples will induce ozone-producing reactions.

Andrew Bell

How AIRSCAN works

Essentially, AIRSCAN is a multi-stage chemical reactor in which samples of air are subjected to a series of tests so that each of the smog-forming characteristics of the air can be independently evaluated. Here is what happens.

- At A the NO and NO_x concentrations of the air are measured.
- Excess NO reagent is added to the air and the mixture allowed to react (in reactor 1) in the dark. Here ozone (O_3) in the sample is consumed by reaction with NO.
- At B the NO and NO_x concentrations of the mixture are measured, giving the PSP and O_3 content of the air.
- The mixture is passed to a special photochemical reactor 2 where sunlamps drive the smog reaction in the same way that sunlight does. In the presence of excess NO, the rate of smog formation in this reactor is governed by the ROC content of the air. This rate is determined from the NO/NO_x analyser at B and C.

The computer calculates, from the analysis results and the meteorological data, the current and expected levels of PSP, O_3, NO, NO_x, and ROC as the day progresses. It can also calculate the average time that the hydrocarbons have been in the air. Together with wind speed and direction, this information allows an operator to pinpoint the source of the smog precursors.