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AIRWATCH — The CSIRO Kit

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SUMMARY

With a lot of help from colleagues, we have prepared a new set of interesting and meaningful experiments as a contribution to the AIRWATCH schools and community program of hands-on learning and investigations of air pollution issues. The CSIRO kit covers inexpensive methods for the measurement of airborne particles, nitrogen dioxide in air, wind information at ground level and to several hundred metres, and use of odours and the wind information to identify pollution sources. We finish the paper by briefly discussing lessons gained from initial trials of the kit in schools and by community groups.

INTRODUCTION

Schools and community groups in Western Australia, Victoria and Queensland are participating in the AIRWATCH project. AIRWATCH was inspired by the *WaterWatch* program being undertaken across Australia (see References (1), (2)). AIRWATCH is a fully structured program, addressing the issues of air quality both locally and globally. It consists of

– the CSIRO kit discussed here
– considerable curriculum/resource materials addressing all aspects of air pollution
– in-service training and support to participating schools and other groups
– on-going backup during the program
– involvement of several agencies including EPAs and Roads agencies.

The planning, organisation and implementation of AIRWATCH have largely originated from the Department of Environmental Protection in Western Australia. It aspires to become an Australia-wide information-sharing network for monitoring data, resources for air quality issues, and to be a contact point for air pollution methods and results, along the lines of *GLOBE* (Global Learning Observations to Benefit the Environment). The five year *GLOBE* program started in 1994 is managed in Australia by the Department of Environment, Sport and Territories (see References (3), (4)) and is a worldwide (24 country) network of students, teachers and scientists working together to study and understand the environment (see References (5)).

AIRWATCH, and the CSIRO kit (Finn and Manins (6)), was launched in Perth and Melbourne in early February 1996. In the second semester of 1996 the Department of Environment in Queensland begins their pilot program. While focussed primarily on secondary school science and geography students, it is also exciting interest through groups such as *Smogbusters*, a Commonwealth EPA-funded community awareness-raising program in each capital city concentrating on pollution from motor vehicles and promoting the use of public transport, in Canberra, Melbourne and Perth; and *EnviroLink*, a City of Melbourne initiative, in Melbourne.

PHILOSOPHY OF KIT DESIGN

While investigating this kit we were repeatedly told (a) it is not possible for non-experts to take useful measurements of air pollution, and contrarily (b) it can be done if only you spend a lot of money on certain proprietary products. The kit described here proves that <u>some</u> important measurements can be made at low cost by just about anybody, but that there are many desirable air pollution measurements that do not yet appear possible without specialist equipment. We also found that many commercial products are so insensitive to ambient levels of pollution commonly found in Australia that they are practically useless.

To be included, candidate kit components had to meet four criteria:

(i) the component must address an important aspect of air pollution of relevance to the community;
(ii) it must be fun to do, by an individual or small team;
(iii) the method must be capable of giving good results if reasonable care is exercised;
(iv) the data obtained must be useful — to concerned individuals, environment protection agencies or to other researchers of air quality issues.

TOPICS COVERED BY THE KIT

We considered many candidate project components, rejecting most for various reasons. Six survived, grouped into three major topics:

(i) Measurement of ambient air pollutants, with emphasis on the most important urban pollutant in Australia—airborne particulate matter
(ii) Measurement of meteorological factors that control mixing and transport of pollutants
(iii) Identification of sources of pollutants in the region of concern.

Figure 1 shows the components of the kit and their relationships.

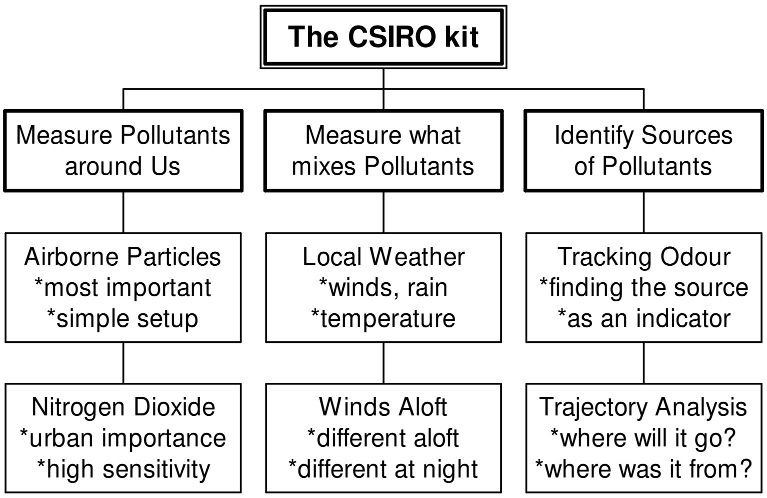


Figure 1. Structure of the CSIRO kit for AIRWATCH.

MEASURING POLLUTANTS

Airborne Particulate Matter

We spent most time on this component in the belief that it is the most valuable contribution the kit can make. Aerosol is collected over 24 hours by low-volume active sampling onto a fibreglass filter paper. Assuming that the visible aerosol on the filter is carbon, we can compare the 'greyness' of the filter with a calibrated 'grey scale' photographic strip. Since we know the volume of air that has been pumped through the filter paper, and the relationship between greyness and mass of carbon on the filter, we can compute the density of the particulate matter in the air and can compare it with air quality standards. The equipment is shown in Figure 2.

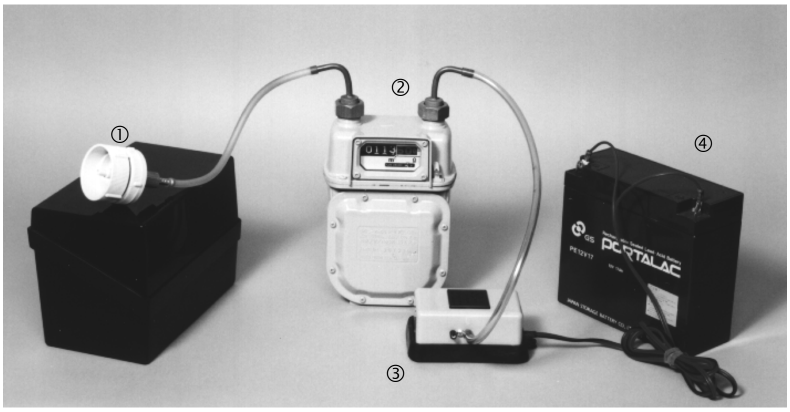


Figure 2. Particle sampling equipment for AIRWATCH
① a paper filter holder
② a small gas flow meter
③ 12 volt fish tank pump
④ deep-discharge battery.

The total cost of parts for the particle sampler is about $300. The vital aspect that obviates the need for a microbalance to weigh the filter paper after exposure for a specified time is the use of the pre-calibrated grey scale. This consists of a photograph of a set of filters that have been exposed to a source of soot for different periods and that then have been accurately weighed so that the relationship between greyness and mass of carbon on the filter could be determined. The relationship so derived is given in Fig. 3. Assuming that the colour of the filter really is due to carbon particles, the expected accuracy is around ± 30 % or better of reading. This is quite adequate for the expected applications.

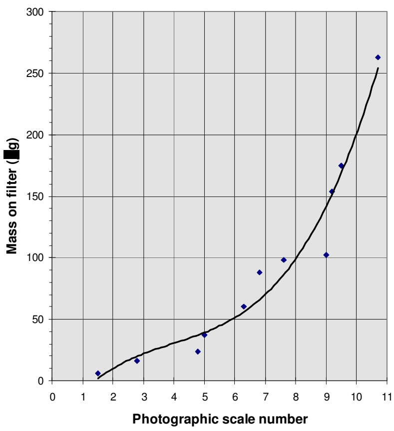
While an adequate sampling time must be used to collect a visibly discernible sample, we have devised sampling strategies that are not restricted to a straight 24 hour sampling period. Community groups have been exploring running the sampler each morning during peak hour traffic time at the roadside over a week until a large enough sample is collected. Others have carried the whole setup on a bicycle on the trip to work over a week to determine on-road exposure to particles. Any variation that permits an adequate sample to be collected can be employed since the device measures the actual flow of air through the filter.

Nitrogen Dioxide Measurements

A second filter holder loaded with a paper treated to react with NO_2 can be added downstream of the particle filter. The result is a very sensitive monitor for this combustion-derived urban air pollutant. The filter is coated with a NaI-NaOH solution that is easily made in a school chemistry laboratory. When the coating is exposed to NO_2 it converts to $NaNO_2$.

Back in the laboratory, the $NaNO_2$ is extracted and treated with chemicals that result in a pink-coloured solution. Comparison of the 'pinkness' of the solution and a supplied photographic 'pink scale' can then be made. The method is well proven and is the basis of the passive gas measuring method for NO_2 that CSIRO has been using for several years.

Since the method is very sensitive, sampling times can be as short as an hour or two if the ambient NO_2 concentrations are around 20 ppbv or more. Again, sampling strategies can be devised to give the data that the user is most interested in.



MASS ON FILTER (µg)	CONC in 24hr (µg/m³)	CONC in 12hr (µg/m³)
6	1.25	2.5
16	3.3	6.7
24	5.0	10
37	7.7	15
60	12	25
88	18	37
98	20	41
102	21	43
154	32	64
175	36	73
263	55	110

Figure 3. Masses and equivalent atmospheric particle concentrations running the CSIRO kit pump for 24 or 12 hours.

MEASURING DISPERSION OF POLLUTANTS

Local Weather Conditions

Interpretation of air pollution conditions requires information on the winds and mixing in the atmosphere. After considerable investigation we have recommended a commercial weather station for the task, due to its value for money and its use in some schools. It is the Weather Monitor II and Weatherlink software from Davis Instruments, Hayward CA, USA, and costs around $1,200. It is a comprehensive weather station, data management, analysis and display system.

The weather station sensors measure wind speed, wind direction, station temperature and humidity, ambient temperature, ambient pressure, and rainfall. It is powered by a supplied mains power pack, a small 9 volt battery, or the battery that is part of the pollution sampling kit. It also includes a data logger that can store several days or even weeks of data (depending on sampling interval) and a simple remote display and control panel. A PC can be used to give an attractive real-time display, to unload the data from the logger for later analysis, and for graphing the results of the sampling .

Winds Aloft

Particularly at night in clear conditions, the winds at the height of industrial sources of pollution are very different to the wind conditions measured at the ground. The winds also vary greatly aloft in valleys and mountainous regions (katabatic, anabatic, mountain and valley winds) and near the coast during sea breezes. It is important to know something about winds aloft for characterising the air pollution potential of a region. Surveys of the winds in the lowest 100–500 m above the ground are usually important. The CSIRO kit includes an elementary tethered balloon system described by Moriarty (7), (8). Moriarty has used the methodology in several places around Melbourne, Albury-Wodonga and in the Latrobe Valley, with considerable success.

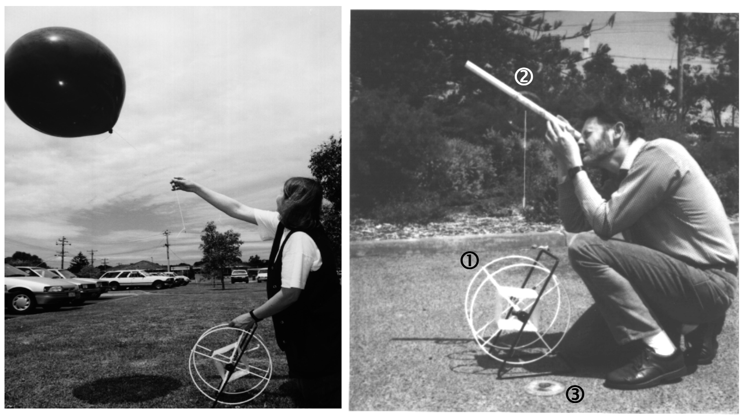


Figure 4. Launching the tethered balloon (left) and (right)
① hose reel and line
② elevation sighting
③ azimuth protractor

The system is little more than a helium-filled balloon, a calibrated fishing line, and a garden hose reel; a simple sighting tube acts as a theodolite. Figure 4 shows the balloon being launched and also how the elevation angle of the balloon can be measured. Noting the elevation and azimuth angles as the balloon line is played out, allows a determination of the wind speed and direction as a function of balloon height. Moriarty's algorithms have been coded and are included with the kit.

IDENTIFYING SOURCES OF POLLUTANTS

Odour as a source indicator

Odours can be used to map sources of pollution in the community. An area may have a recognisable odour and the community may already know its source. If the source of an odour is not know, then this procedure can be used to discover the source. The method is very simple but powerful: collect, over a number of days or weeks, the location of an observed odour and at the same time, the wind direction. Combine this information on a map to pinpoint the source of the odour by triangulation.

Figure 5 shows an example of how to determine the source of an odour from wind direction observations at locations A to D, when a particular odour is sensed at these places.

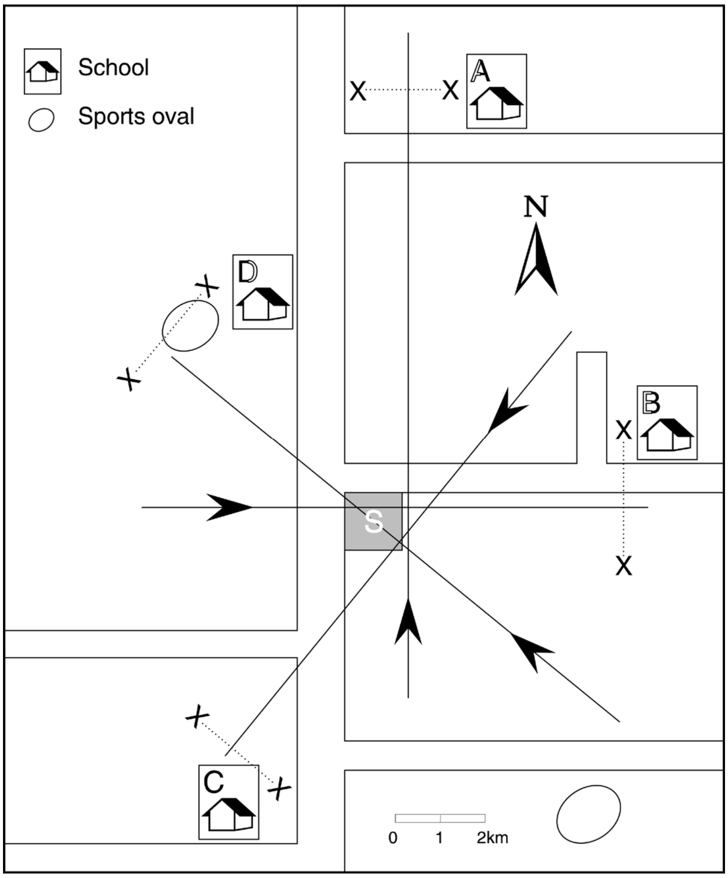


Figure 5. Measurements of wind direction when the same odour is smelt under different conditions at locations A, B, C and D allow identification of the source at S.

Wind Trajectory Analysis

A forward trajectory is a line describing the movement of an air parcel in time from the monitoring station. It tells us where the air parcel is going. A backward trajectory shows where the parcel has come from. This is useful and is often used by EPA complaints investigators. The wind data measured by the weather monitoring station can be used directly to give a good first estimate of an air pollution parcel trajectory. A special computer program is included in the CSIRO kit to calculate the forward and backward trajectories and display them on a PC screen. The trajectory program takes as input, data exported from the weather station logger. A picture of the screen is shown as Fig. 6. It is from a study at Caversham monitoring station in eastern Perth. The outline of the coast is shown, as are Rottnest Island, the Swan River, and the Perth CBD. Wind data from a record over two days are plotted, centred on Caversham at 1500 hr on the first day. The trajectory makes two loops as the wind changes from easterlies to a sea breeze and back. It shows that pollutants can return to Perth a day after they are emitted.

The heavy, near-vertical line marks the coast: the Indian Ocean is to the west. The numbers on the trajectory show time of day for a parcel released at 1500 hours from Caversham on Day 1 of the data set.

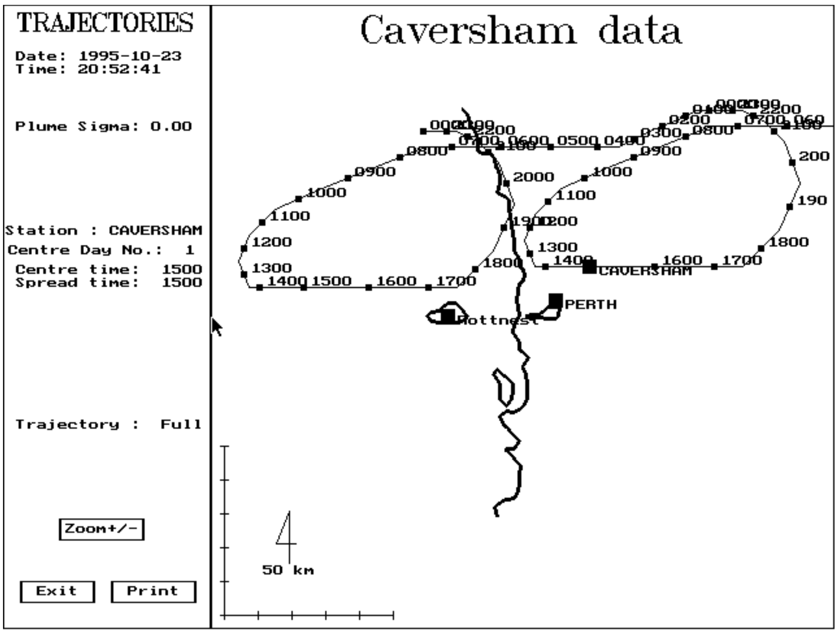


Figure 6. A screen dump from the trajectory program using wind data from east Perth.

EXPERIENCE FROM TRIALS

Some groups have experienced many small problems and some major ones. The most striking has been that in several instances practically no pollution could be measured. While hardly a real problem, it aught to have been very informative in correcting false impressions about the general air quality in most localities of Australia. It is also an important lesson: particulate air pollution is not high in cool damp windy conditions.

Other problems include: While community groups have been particularly interested in the measurements of particles and NO_2, they need access to a chemical laboratory if they are to succeed with the latter. Schools have found problems with the tethered balloon system — the logistics of organising an excursion, air space and the weather all at the same time, make this a difficult exercise to implement. The charger takes too long to recharge the special high-capacity deep-discharge battery and this has been a source of frustration. Use of odour as a source has proven to be a good illustrative exercise for students, but usually the odour source needs to be known already. The description of the procedure for doing the wind trajectory analysis, particularly the instructions for adapting the map to a new locality, is proving too difficult for some students and teachers. We are sure that other problems will be identified. The in-service training and ongoing support are essential components assuring success in the longer term.

DISCUSSION AND CONCLUSIONS

The methods employed in the CSIRO kit are simplified compared with modern EPA practices. The resulting data are thus not necessarily the most relevant for modern air pollution assessment procedures. For example, the kit can be used to measure concentrations of suspended particulate matter (TSP) over 12 or 24 hours, or can be used to measure TSP for a particular event repeatedly until a measurable sample is obtained. Nowadays, EPAs are more concerned with PM_{10} or $PM_{2.5}$ (the fraction of particulate matter that is aerodynamically smaller than 10 µm or 2.5 µm in diameter), and these particles can only be measured using expensive equipment. The method for measurement of NO_2 is so sensitive that it rivals EPA air monitoring station performance. But EPAs generally want time series of pollutant gas data, not the spot measurements that the kit can provide.

As the success of the *GLOBE* program shows, there is great interest in school to do hands-on measurements. However, continual monitoring (a *GLOBE* objective) is a problem for some teachers and students, as well as for many community concerns. This is where the AIRWATCH materials and the kit described here have a role. The kit can be used to obtain meaningful data on air quality, the dispersion of pollutants, and their sources, that are of considerable value to the users and to researchers. Indeed, in Western Australia, the Main Roads Department is particularly enthusiastic and is sponsoring the appointment of an AIRWATCH coordinator and the production of a new curriculum package for schools and community groups. Soon, AIRWATCH will be on the World Wide Web with chatboard facilities, and an advertising campaign targeted at schools is being planned for 1997.

ACKNOWLEDGMENTS

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