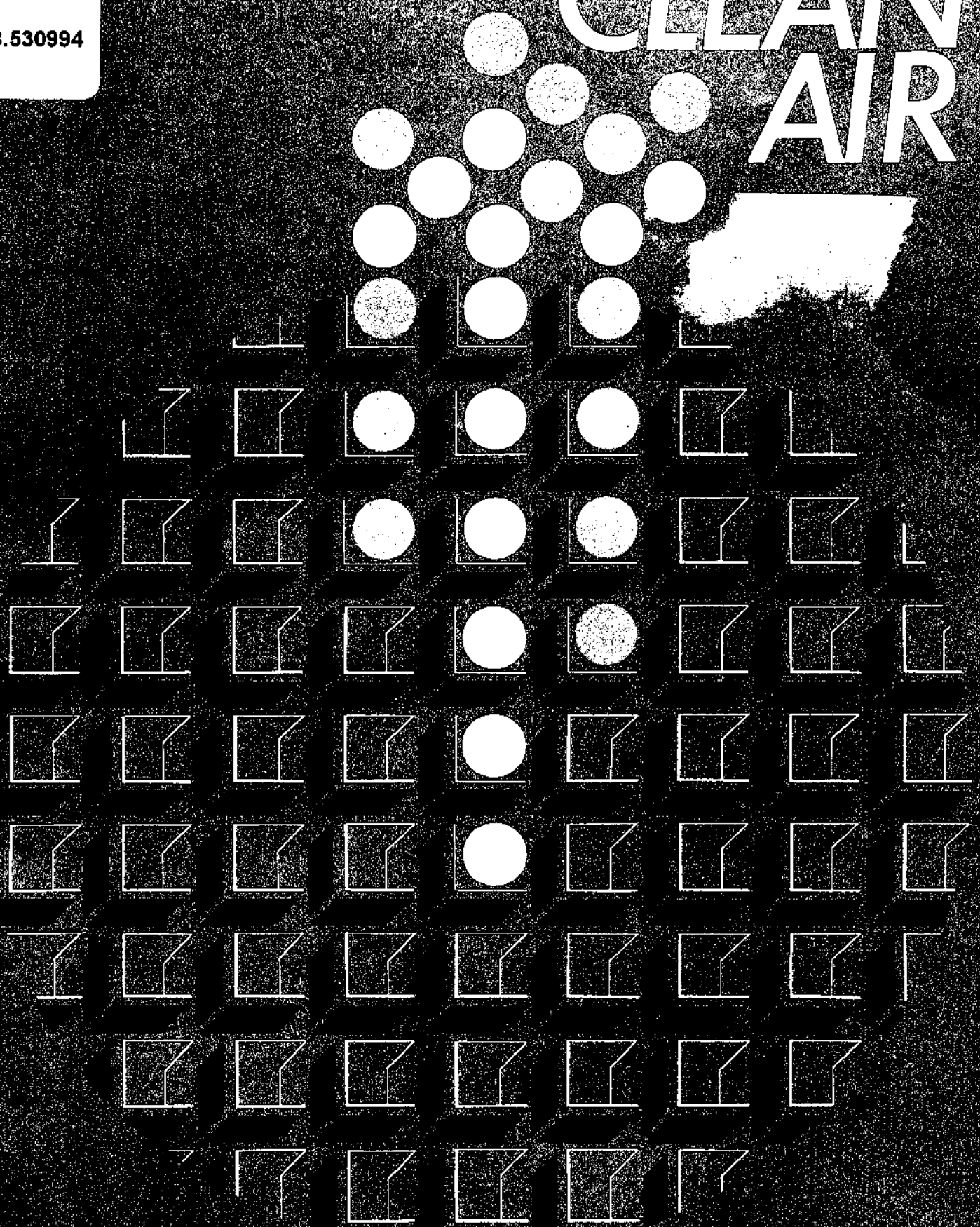
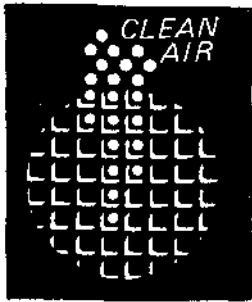


YOUNG & RUBICAM
7000 E. COLFAX AVENUE
DENVER, CO 80231
TEL: 303.733.1200

QUT GP
P
628.530994
1

CLEAN AIR





**JOURNAL
OF
THE CLEAN AIR SOCIETY
OF
AUSTRALIA AND NEW ZEALAND**

President: Dr. K. M. Sullivan

Secretary: R. W. Manuell

Treasurer: Dr. K. S. Basden

Postal Address:

Box 191, Eastwood, N.S.W. 2122.

BRANCH PRESIDENTS

ACT: Dr. N. J. Daly

NSW: J. D. Court

NZ: J. Hickman

Qld: J. S. McFarlane

SA: E. F. Symons

Vic/Tas: Dr. J. B. Robinson

WA: D. G. Saunders

BRANCH CORRESPONDENTS

ACT:

NSW: Steve Stanley

NZ: Ron Pilgrim

Qld:

SA: Allen Gale

Vic/Tas: Jack Chiodo

WA: D. B. Sykes

EDITORIAL

John Todd 84

A MESSAGE FROM NZ

Dudley Ward 89

AIR POLLUTION GUIDE

Sulfur Oxides 86

EIGHTH INTERNATIONAL CLEAN AIR CONFERENCE

Workshop Report — Meteorology 91
Workshop Report — Measurement 102

TECHNICAL PAPERS

A Preliminary Study of Rainwater Acidity
around Newcastle, NSW
R. Avery 94

Studies on the Variation in Dust and Heavy Metal
Fallout in Hobart, Tasmania, 1973-1977
S. A. Shepherd 104

FEATURES

Annual General Meeting 84

Branch News 101

Conference and Courses 85, 89, 90

Council News 84

Interstate News 89

IUAPPA News 89

Overseas News 85, 109

Personal 109

SAA News 109

EDITOR

Dr. R. G. Gillis,
75 Downshire Rd., Elsternwick,
Victoria 3185, Australia.
Phone: (03) 528 2507.

ASSOCIATE EDITOR

Sylvia J. Mainwaring

EDITORIAL BOARD

R. G. Gillis
H. F. Hartmann
Sylvia J. Mainwaring
J. O'Heare

ADVERTISING

Enquiries should be directed to
Miss Ann Sykes,
C/- Appita,
191 Royal Parade, Parkville,
Victoria 3052.
Phone: (03) 347 2377.

PRINTER

Advocate Press Pty Ltd (03) 329 6588

SUBSCRIPTIONS

Enquiries about subscriptions, payment of
invoices, and requests for back numbers
should be directed to the
Circulation Manager,
Mr. A. Crapp, Box 191 Eastwood,
N.S.W. 2122 Australia
Phone: (02) 266 0661

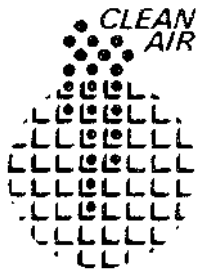
Publication is quarterly in February, May,
August and November.

Annual Subscription rates (Inc. postage) for
non-members and libraries:

Australia and New Zealand \$A12.00.
Elsewhere SA15.00
Single Copies \$A4.00.

CLEAN AIR is listed in *Current Contents*

*The opinions expressed by authors and
contributors are their own and do not
necessarily represent the view of the
Society.*



EDITORIAL

Domestic Air Pollution

Through the past several decades of debate in the scientific and popular press, industrial and transport sources of atmospheric emissions have been emphasised as the causes of air pollution. Community pressures and industry's response to those pressures have led to the establishment of a complex control infrastructure aimed at obtaining and maintaining acceptable levels of ambient air quality. The control system relies on experienced engineers, scientists, and legislators within industry, the control authorities, research establishments, and, to a growing extent, community groups. This aggregation of skilled people is an important resource which could be applied in fields other than industrial and transport emission control.

For example, recent editorials in this Journal have mentioned the need for similar skills in the field of industrial hygiene. The domestic pollution field also requires attention.

There seems to have been some hesitation to tackle the domestic sector and address the possible problems of emissions from domestic sources and indoor air quality. In part, this is probably because a person's perception of what is pollution is influenced by the source of the pollution; there is a reluctance to admit that normal household tasks could be contributing to decreased air quality. This, in turn, means there is less community pressure to establish controls. There is probably also a reluctance by control authorities (or the governments to which they are responsible) to interfere unduly with persons' homes on the grounds of civil liberties. But, given that the principal aim of air pollution control is to minimise adverse effects on human health, it seems illogical largely to ignore the domestic sphere.

Domestic emissions from refuse burning and domestic heating appliances have been shown to contribute significantly to air pollution levels in some parts of North America, Europe, New Zealand and Asia. Some pollutants have been shown to be typically two to five times as high indoors as outdoors, while some indoor pollutants such as formaldehyde and some synthetic or mineral fibres are rarely a problem outside the home. Clearly, these problems need to be addressed but the best approach to take is not obvious.

More local scientific data on domestic emissions and indoor air quality is required. Then, assuming some control is seen to be desirable, how should it be introduced without interfering with an individual's freedom of choice?

How can public awareness of the issues be increased without inducing an over-reaction possibly leading to irrational decisions? Existing control legislation is not well suited to the domestic sector; hence, new emission monitoring and control technologies need to be developed.

The air pollution control fraternity should address these issues and members of CASANZ should use their substantial wealth of skills to seek acceptable solutions to them.

JOHN TODD
*Tasmanian Representative
Victorian/Tasmanian Branch.*

ANNUAL GENERAL MEETING

The 18th Annual General Meeting of the Society was held on 10 May during the 8th Clean Air Conference at the Exhibition Conference Centre, Melbourne. Dr. Ken Sullivan, President of both CASANZ and IUAPPA chaired the meeting.

Council re-elected Dr. Sullivan, Mr. S. McFarlane, Dr. K. Basden, and Mr. R. Manuell, as President, Deputy President, Treasurer and Secretary respectively for the next two years.

The President presented a certificate of Life Membership to Mr. Hanns Hartmann, this is only the third issued, and is very well deserved.

Special thanks were also recorded for Dr. Richard Gillis who would retire as Editor of *Clean Air* at the end of 1984.

COUNCIL NEWS

Retired Members

At the May 1984 Council Meeting it was agreed to let retired members maintain a contact with the Society by giving them the right to receive *Clean Air* free for five years after retirement. It is not automatic and members wishing to avail themselves of this privilege should apply in writing direct to the Secretary.

Emission Control Standards

The draft NHMRC National Stationary Source Emission Control Standards for Air Pollutants were received by the Secretary on 3 December 1983 and were circulated to Branches for comment. The replies were collated and the following comments were returned to NHMRC. They are printed in *Clean Air* by direction of Council for the information of members. No response had been received from NHMRC by June 1984.

1. Introduction

The introduction sets out to explain the basis of the Standards but fails to complete the picture. The fact that the Standards are really recommendations and have no legal standing unless and until adopted in State legislation should be made quite clear. It is also suggested that the phrase, "best practicable means" be defined to indicate whether the Council intends it have an economic factor or not. In the 7th paragraph it is suggested that reference be made to the need to collect particulates isokinetically.

The rather tenuous relationship between the concentration of pollutants in the ambient atmosphere and the concentration at the point of emission has been explained. However, a more detailed explanation is required of the relationship between these Standards and the legal limits that are set by authorities in each State and Territory. The legal limits are set having taken into account the many competing factors, such as the concentration of industry in certain areas, the prevailing meteorological conditions and the proximity of residents to the various classes of industry in the different locations.

The sixth paragraph could be reworded to say, "Detailed requirements governing emissions are in force in each State and Territory. They are set by the appropriate authority, taking into account not only the best practicable control technology, but also the concentration of industry, the meteorology and how remote the industry is from residents and other receptors in different localities."

2. Table 1.

2.1 Opacity. Should not a value be also set for the maximum opacity during the period of exemption from the 20 percent limit. We understand the US EPA allows about a one third increase, that is from 20 percent to 26 percent.

Fugitive emissions from Portland cement plants and other plants with similar problems are scarcely amenable to instrumental measurement. Some comment to this effect may be desirable and a note exempting emissions caused by wind gust.

2.2 Solid Particles. There is a very significant difference between the 0.05 g/m⁵ limit for power stations and the general limit of 0.25 g/m³. However, no lower size limit is quoted for power stations and no explanations given for the 80 percent reduction in the limit for power stations. If the difference is intended to indicate a change from cyclone collection to fabric filtration, it can be argued that fabric filtration represents best practicable control technology for many industrial boilers where spreader firing or pulverized-fuel firing is used. Conversely, fabric filters could be considered unsuitable in certain circumstances for power station boilers and 0.05 g/m³ is not a practicable for electrostatic precipitators, particularly when handling flyash from some NSW and Queensland coals. The applicability of the first category is ambiguous. Does it apply to all solid-fuel fired boilers except power stations, or to all boilers except solid-fuel fired power stations? The words "reference level" should be inserted after 12 percent CO₃ in the notes (as is done in the NO_x section).

2.3 Sulfuric acid mist and sulfur trioxide. There appears to be some ambiguity here. For instance is there to be any limit for acid mist or SO₂, from sulfuric acid plants, and is there to be any limit for SO₂ from plants other than those making sulfuric acid?

2.4 Nitric acid or oxides of nitrogen. Is the standard for fuel-burning units applicable only to those units having a heat input greater than 150 GJ/h? The section proceeds to refer to gas turbines with rated output less than 30MW. Does this apply to all gas turbines less than 30MW or only those with heat input greater than 150 GJ/h (approx. 20 MW output)?

Also, the standard for solid-fuel fired power stations should be noted as, "Nitrogen oxides calculated as NO_x at a 5 percent O₂ (or other) reference level."

2.5 Heavy metals. Vanadium is misspelt, and may warrant a separate entry.

3. Table 2.

3.1 Beryllium. Should not this entry read "beryllium or its compounds," and the "standard" IOgm, as beryllium?

3.2 Mercury. Should not this entry also read "mercury or its compounds," and should not a limit apply to "other" industries as well?

3.3 Asbestos. We suggest you support the recommendation with a reminder of your occupational health and safety recommendations, and that you explain the meaning of FR (US Federal Register).

OVERSEAS NEWS

Britain's Improving Environment

Britain continues to become a better place to live. Latest figures show what is described as a "continuing and steady improvement of environmental conditions." Commenting on the new statistics, Mr William Waldegrave, Parliamentary Under Secretary at the UK Environment Department, said in London: "The continued downward trend in air pollution is particularly noticeable. Sulfur dioxide emissions in 1982 were down to the level found at the beginning of the 1940s, and the amount of smoke emitted has fallen by over 80 percent in the last 20 years. I was also interested to see that the amount of lead from cars has fallen by 20 percent since 1973 — despite a 14 percent increase in petrol consumption. This is encouraging as we move towards unleaded petrol." Britain plans a 60 percent reduction in petrol lead by the end of 1985 with complete elimination as soon as possible after that.

The measurements, which were taken in 1982, show that smoke emissions from coal combustion were around 260,000 tonnes that year. The average urban smoke concentration is now less than a sixth of that in 1960. UK sulfur dioxide emissions fell to four million tonnes a year while the average urban sulfur dioxide concentration has fallen 60 percent since 1960.

Proof that a cut in the permitted lead-content of petrol is already having a beneficial effect on the environment comes from the fact that lead emissions from petrol engined vehicles has fallen by a fifth to 6,700 tonnes a year in the past decade. Emissions of hydrocarbons also showed a slight fall but these successes were tempered by a small increase in nitrogen oxide and carbon monoxide emissions from vehicles between 1981-82.

CONFERENCES AND COURSES

Air Pollution Control Course — A Practical Guide

The N.S.W. Branch is offering a course on air pollution control over five Thursday evenings in February and March, 1985.

The course has been developed in response to the need of many industries to gather up-to-date information on practical techniques for the control of air pollution.

It is designed for people with responsibility for operation and maintenance of air pollution control equipment and the detection and prevention of air pollution problems. It is aimed at providing them with sound, practical information that can be used quickly and confidently as problems arise. It will be run by members in N.S.W. -with intensive control knowledge and equipment operation and design experience. The course will provide an "Air Pollution Control Handbook".

The course will cost \$150.00 which includes tuition fees, the control handbook and a course dinner. It will be run at the Price Theatre, Macquarie University from 7pm-9pm on the evenings of 7, 14, 21 and 28 February, 1985. The final lectures will be from 6pm-8pm on 5 March, 1985, at Curzon Hall, Marsfield, with a course dinner to follow.

For details or for enrolment forms, prospective applicants should phone one of the following:

Alasdair Guthrie (02) 266-0661 (Ex.267)

Chris Eiser (02) 266-0661 (Ex.224)

Ian Ross (02) 266-0661 (Ex.220) up to 12 November 1984. Thereafter (02)235-4911

or write to: The Secretary, N.S.W. Branch, P.O. Box 191, Eastwood. 2122.

Applications close 14 December, 1984.

The main topics to be covered in the course will be as follows: Air Pollution General, Legislation and Licencing, Air Pollution Meteorology, Sizing of Stacks, Oil and Gas Combustion. Solids Combustion, Collectors and Precipitators, Scrubbers and Filters, Odour Control, Hydrocarbon Control.

If the pilot course is successful and demand warrants, it is hoped to run this course in other States.

SULFUR OXIDES

Significant Physical and Chemical Properties.

Sulfur dioxide is a colourless gas with a choking smell (the smell of burning sulfur). It combines with water to form sulfurous acid.

Molecular weight : 64
 Relative density (Air = 1.000) : 2.212
 At 0°C and 101.325 kPa : 1 pphm = 28.6 / $\mu\text{g}/\text{m}^3$ = 1 / $\mu\text{g}/\text{m}^3$ = 0.35 pphm

Sulfur trioxide is a white crystalline metastable solid formed in the atmosphere by oxidation with ozone or catalytically with oxygen. It combines with water to form sulfuric acid.

Molecular weight : 80
 Melting point : 16.8°C
 Both are soluble in water

1. SOURCES

The sulfur compounds in the atmosphere come from both the natural environment and from man made sources. Natural sulfur compound emissions are SO_2 aerosols produced in sea spray, and H_2S from the decomposition of organic matter in swamp areas, bogs, and tidal flats. Areas of volcanic activity are also a minor but variable source of H_2S and SO_2 . The emissions of SO_2 come almost exclusively from man made sources. Some H_2S is also of industrial origin. H_2S in the atmosphere is oxidised to SO_2 and SO_3 .

Annual worldwide man made emissions of SO_2 have been estimated in 1968 to be 147×10^6 tonnes (1) and at 127×10^6 tonnes in 1981 (2). Fossil fuel combustion produces 80 percent of all SO_2 emissions, the remainder coming from refineries and smelters. Ninety percent of the emissions are produced in the northern hemisphere. There are indications that SO_2 emissions at least in the USA are decreasing by about 2 percent annually (3).

The sulfur content of fuels varies widely. In coals, the range is from 0.2 percent to nearly 5 percent with occasional higher figures. Most Australian black coals have sulfur contents below 1.0 percent particularly after washing. Brown coals are mostly below 0.5 percent with some exceptions with very high sulfur contents.

Crude oils vary from 0.06 to 8.0 percent. In refining, sulfur compounds are easily removed from lighter fractions but heavy fuel oils and residual oils still contain 2.0 to 3.0 percent sulfur. Australian crude oils are typically very low in sulfur, e.g. <0.01 percent, and are classified as light crudes.

Natural gases may vary from practically sulfur free to more than 50 percent. Total removal of sulfur is, however, relatively easy.

Estimated world wide emissions of sulfur compounds, expressed as sulfur from natural and man made sources are listed in the following table (for 1968):

Compound	Source	Estimated Emissions in 10 ⁶ Tonnes S/year
SO_2	Coal combustion	51
	Petroleum refining	3
	Petroleum combustion	11
	Smelting operations	8
H_2S	Industrial emissions	3
	Marine emissions	30
	Terrestrial emissions	70
SO_4	Marine emissions	40
Total		220

Sulfur compounds in the air are oxidised to SO_3 and this forms sulfuric acid and sulfates. In daytime under low humidity conditions photochemical reactions involving NO_2 and hydrocarbons predominate in the formation of H_2SO_4 or sulfate aerosol. At night or under all high humidity conditions the most important process is absorption into water droplets with subsequent oxidation to SO_4 . While SO_2 has a fairly low solubility in waters of low pH the presence of ammonia raises the solubility by neutralising the sulfurous acid formed by absorbed SO_2 in the droplets. The resulting sulfite may be oxidised to sulfate in as little as one hour.

Sulfuric acid and sulfate aerosol are removed from the atmosphere by rain. Absorption by the leaves of vegetation is another important scavenging process (1).

Background concentrations in areas remote from pollution sources vary from 'below detectable limit' (about $0.8 \mu\text{g}/\text{m}^3$ or 0.3 ppb) to about $2.6 \mu\text{g}/\text{m}^3$ (1 ppb). An average of $0.5 \mu\text{g}/\text{m}^3$ (0.2 ppb) has been assumed as an average figure. Background concentration of H_2S is about $0.15 \mu\text{g}/\text{m}^3$ (0.2 ppb) and that of SO_4 is $2 \mu\text{g}/\text{m}^3$ (1).

2. AIR POLLUTION LEVELS

In the United States 16 percent of all monitoring stations reported SO_2 concentrations above $80 \mu\text{g}/\text{m}^3$ in 1970. In 1980 only 1 percent of the stations recorded values in excess of this figure which is the present US Primary Air Quality Standard.

However, very high short term concentrations persist in some areas. One hour values of 4000 to $6000 \mu\text{g}/\text{m}^3$ are common near large smelters. Maximum hourly values above $1000 \mu\text{g}/\text{m}^3$ (0.4 ppm) still exist in about 100 US locations. Near isolated point sources, such peaks may be reached very rapidly and be of only short duration (4).

In Australia atmospheric SO_2 concentrations have also fallen due to legislative limits placed on the sulfur content of fuel oils and the widespread use of high chimney stacks, and the replacement of oil fuels by natural gas.

In Sydney's industrial areas annual average concentrations have fallen from $72 \mu\text{g}/\text{m}^3$ in 1973 to about $43 \mu\text{g}/\text{m}^3$ in 1975 and have since remained at this level. During the same period figures in residential areas have diminished from 43 to $32 \mu\text{g}/\text{m}^3$. Maximum hourly peaks vary from 50 to $200 \mu\text{g}/\text{m}^3$. Concentrations of nearly $2000 \mu\text{g}/\text{m}^3$ hourly average have at times been measured near heavy industry sources (5).

Annual average concentrations between 20 and $40 \mu\text{g}/\text{m}^3$ have been recorded in Melbourne in 1974/75. These figures have come down to 3 to $5 \mu\text{g}/\text{m}^3$ in 1980. Maximum hourly concentrations in the same period have

diminished from more than 400 to around 100 $\mu\text{g}/\text{m}^3$ (6).

Concentrations in the Latrobe Valley are low — 3 $\mu\text{g}/\text{m}^3$ annual average with hourly averages below 100 $\mu\text{g}/\text{m}^3$ (6).

3. HEALTH EFFECTS

Health effects are governed by the amount of SO_2 and SO_3 which gets into the lungs. SO_2 may be absorbed on particulate matter and SO_3 may form aerosols as sulfuric acid or metal sulfate.

Whether in gaseous or particulate form, sulfur dioxide and sulfuric acid are largely deposited in the nasal passages when breathing through the nose. At rest 95-99 percent are deposited while during strenuous activity with mouth breathing more than 50 percent SO_2 or sulfuric acid may reach the lungs. Of the total SO_2 and SO_3 inhaled, less than 15 percent is exhaled immediately (7).

As far as particles are concerned it is the larger ones which are more readily deposited. In nose breathing particles smaller than 4 μm and in mouth breathing particles smaller than 10 μm may reach the lungs.

Clearance of particulate matter from the nose is by sneezing or swallowing. This takes place in minutes to hours. Ciliary action removes particulates from the trachea and the bronchi in one to two days and these are then swallowed. Particles in the lungs may remain there for several hundred days before being removed via the airways or the lymphatic system. SO_2 deposited on mucous membranes is rapidly absorbed into the body and is presumably detoxified in the liver and excreted as sulfate in the urine (8).

The main effect of inhaled SO_2 appears to be a constriction of the airways. This has been shown in animal experiments, however, at concentrations in excess of those usually found in polluted air (9).

Some studies have reported respiratory effects at concentrations of SO_2 of 75-100 pphm (10) (2150-2860 $\mu\text{g}/\text{m}^3$) while other studies could find no effects in healthy subjects below 500 pphm (14000 $\mu\text{g}/\text{m}^3$) (11). At the latter concentration one investigator found pulmonary resistance increased by 39 percent. The effect appears to be proportional to the concentration and there is a wide variability in sensitivity. Recent studies have shown asthmatics to be especially sensitive (12).

The effects of SO_3 have been found to be significantly enhanced by association with particulate matter (13). As the composition of particulates found in the atmosphere varies widely from one locality to another, it has been very difficult to

compare the results of epidemiological studies with laboratory experiments using particulate matter of clearly defined composition, particularly as the results of the laboratory studies were not consistent.

It is now widely accepted that increases in mortality occur when either sulfur dioxide or particulate matter levels increase beyond 24 hour levels of 1000 $\mu\text{g}/\text{m}^3$ (36 pphm). Such increased mortality, mainly in the elderly or chronically ill, may logically be most directly attributed to very high short-term peak levels in the pollutants, which have at times increased to several thousand $\mu\text{g}/\text{m}^3$ during some major pollution episodes (14).

Increases in illness and death associated with exposures to SO_2 and/or particulate matter levels below 1000 $\mu\text{g}/\text{m}^3$ (35 pphm) are much harder to establish. Martin (15) in 1969 found a slight indication of likely increases in daily total mortality among persons with existing respiratory or cardiac disease in London at levels of 750 to 1000 $\mu\text{g}/\text{m}^3$ of both SO_2 and particulates. Lawther (16) in 1958 and again in 1970 found that the health status of chronic bronchitis patients was likely to worsen at levels of 500-600 $\mu\text{g}/\text{m}^3$ of SO_2 and 250-500 $\mu\text{g}/\text{m}^3$ of particulates. There was no apparent response below these levels in the same group.

4. EFFECT ON VEGETATION

Sulfur is an essential element in the proteins of both plants and animals. That means that SO_2 and SO_3 can be beneficial to plants in areas where there is a deficiency of sulfur in the soil. Thus, low concentrations of SO_2 in the atmosphere can be beneficial to plants in some cases, provided the plants are not excessively sensitive (17).

As atmospheric concentrations of SO_2 increase, growth and yield of plants are adversely affected and leaves will yellow and eventually tissue destruction will occur.

Extensive investigations in many areas have shown that some plants are far more sensitive to SO_2 than others. The more resistant plants will tolerate 7 to 8 times the concentration which will injure sensitive plants. One study (18) came to the conclusion that 50 pphm SO_2 is the concentration which affects 50 percent of all plants observed. Short term high concentrations appear to be more damaging than the long term low concentrations. Widespread injury to forests and crops has been observed near large sources of SO_2 emission.

5. EFFECTS ON MATERIALS

Oxides of sulfur (as well as H_2S) attack paintwork and erode stonework. Damage functions, i.e. the rates of

deterioration have been estimated for metals and paints. They are mainly related to surface moisture but are of limited practical value because of the many other factors involved such as SO_3 concentration.

Leather, textiles and paper are also attacked but quantitative damage functions have not been determined.

Estimates of economic costs have been made but are necessarily rather arbitrary.

6. RAINFALL ACIDITY

The occurrence of acidic deposition, especially in the form of rainfall acidity has become a matter of concern in many regions of the United States, Canada, northern Europe, Taiwan and Japan. "Acid rain" has been associated with acidification of ponds, lakes and streams with resultant disappearance of fish and plant life. It is also believed to cause leaching of nutrients from sensitive soils and to cause injury to forests. Sulfur oxides as well as nitrogen oxides are most clearly implicated as main precursors in the formation of acidic rain. The emissions which form the acidic rain may originate near where the damage is done or hundreds and even thousands of miles away. While rain formed in geochemically clean environments has a pH of 5.6, the pH of "acid rain" varies between 3.0 and 5.0. The lowering of pH in water and soils may mobilise metals such as aluminium, cadmium and lead with corresponding damage to the ecosystem.

There are, however, a number of unrelated issues, such as the rate at which rainfall is becoming more acidic and the rate at which the problem is spreading geographically; the relative importance of different acids in the overall acidity of the rain; the actual transport distances and others. It should also be stressed that there is significant dry deposition of acidic material besides "acid rain" (19).

7. THE CONTROL OF SO_3 AND SO_2

7.1 Dispersion

The classical method of control is dispersion by higher stacks. This disposes of all pollutants by diluting them higher up in the atmosphere so that concentrations in the atmosphere will be harmless.

Tall stacks have mainly been used in large power stations and have reached heights of 300 metres or more. They typically add 4-5 percent to the average ambient SO_3 even in rural areas with low background pollution levels.

During high atmospheric inversions increased concentrations of SO_2 may occur temporarily and tall stacks are

then not effective during those conditions. The dispersal promoted by tall stacks will improve air quality locally but the dispersed SO₂ and SO₃ is believed to contribute to rainfall acidity both nearby and great distances away. For these reasons tall stacks are already banned in some areas as a means of control.

7.2 Desulfurisations of the Fuel

All natural gas is completely desulfurised before it is supplied to the distributor. Only very small gas quantities of odorous sulfur compounds are added to the gas so that leaks can be readily detected. SO₃ in the combustion products is, therefore negligible. Sulfur removal from heavy oil fractions is feasible but expensive. The removal of sulfur from coal still presents many unresolved technical problems.

7.3 Removal of SO₂ During Combustion

This can be done by injecting dolomite (a mixture of calcium and magnesium carbonates) directly into the fuel bed. This works best with fluidised combustion. The process is, however, not yet developed for industrial use.

7.4 Removal of SO₂ from the Flue Gases

Processes for the removal of SO₂ from flue gases leaving the combustion chamber are in use in many countries either experimentally or on a semi-commercial basis. All processes suffer from technical problems and are expensive.

The following are better known ones: (a) *Water Washing*. This has been practised in the Battersea and Bankstown power stations on the Thames from the 1930's until they were shut down in recent years. While reasonably economical the cooling destroys the buoyancy of the flue gas plumes which then tend to fumigate the neighbourhood. The sulfate in the wash water precipitated as calcium sulfate. This did not cause any problems in the Thames estuary but could do so in smaller bodies of water.

(b) *Scrubbing with Wet Lime/Limestone*. The advantage of this process is that it is fully developed, that its capital and operating costs are relatively low and that it has high potential removal efficiencies. As against that there are the problems of chemical scaling, corrosion, requirements for reheating the plume and the considerable problem of disposing of the calcium sulfate and sulfate waste.

(c) *Scrubbing with Magnesium Oxide*. This operates in a similar fashion to the lime/limestone scrubbing process but has the advantage that the magnesium oxide can be regenerated giving a stream of 10-15 percent SO₂ content which can be converted to sulfur or sulfuric acid. There is thus no waste disposal problem but difficulties arise because of the contamination of the magnesium oxide by ash particles.

(d) *Catalytic Oxidation*. The flue gases are passed through a fixed catalyst bed to convert SO₂ to SO₃ and sulfuric acid. Particulates have to be removed prior to the inlet to the catalyst bed but there is no waste disposal problem.

(e) *Washing with Sodium Sulfate, Bisulfite and Sulfate Solution*. This produces a concentrated stream of SO₂ which can be processed. The advantages are the absence of solid waste and the simplicity of the unit operation. However, the process is very sensitive to contaminant build-up.

(f) *Scrubbing with Mixed Sodium and Ammonium Salt Solution*, followed by scrubbing with lime or limestone which regenerates the alkaline solution and produces a sludge for disposal.

Overall, most processes are as yet not reliable enough. Many technical problems are still to be resolved. Above all, in most cases water pollution problems tend to be created (20).

8. STANDARDS

8.1 Air Quality Standards as SO₂ Victorian Air Quality Objectives

	Acceptable Level	Detrimental Level
1 hour average	0.17 ppm	0.34 ppm
24 hour average	0.06 ppm	0.11 ppm

WHO recommended long term goal
Annual mean 60 µg/m³ (0.02 ppm)
98 per cent of observations should be below 200 µg/m³ (0.07 ppm).

US Primary Air Quality Standard

(a) 80 µg/m³ (0.03 ppm) annual arithmetic mean
(b) 365 µg/m³ (0.14 ppm) 24 hour maximum, not to be exceeded more than once per year.

US Secondary Air Quality Standard

(a) 60 µg/m³ (0.02 ppm) annual arithmetic mean.
(b) 250 µg/m³ (0.1 ppm) maximum 24 hour concentration, not to be exceeded more than once per year.
(c) 1300 µg/m³ (0.05 ppm) maximum 3 hour concentration not to be exceeded more than once per year.

Japanese Standards

(a) daily average hourly values not to exceed 0.04 ppm.
(b) hourly values not to exceed 0.1 ppm.

German Standards

(a) 'Long term' — 24 hour 0.14 mg/m³ (0.05 ppm).
(b) 'Short term' — 30 minute 0.4 mg/m³ (0.14 ppm).

8.2 Emission Standards as SO₂ US Emission Standards

For new fossil fuel fired steam generating plant: of more than 250 million BTU per hour heat input:

Liquid Fuel: 0.08 lbs. per million BTU heat input maximum 2 hour average.

Solid Fuel: 1.2 lbs. per million BTU heat input maximum 2 hour average.

Japanese Emission Standards

According to formula:

$$q = Kx \times 100 \times Hx He^2$$

where q = hourly volume of SO₂ in m³

He = effective stack height
 K = factor varying according to region between 3.0 and 17.5.

REFERENCES

1. E. Robinson and R. C. Robbins, Gaseous atmospheric pollutants from urban and natural sources, Symposium: 'Global effects of environmental pollution', ed. F. Singer, D. Reidel Publishing Co., Dordrecht, Holland, 1970.
2. Energy Projections, in the Global 2000 Report to the President. Entering the Twenty-first Century (Volume 2, Chapter 10, p 161). Council on Environmental Quality and the Department of State, US Government Printing Office, Washington, DC.
3. Sulfur Oxides, National Academy of Sciences, Washington, DC (1978).
4. National Air Pollution Control Administration, Air Quality Criteria for Sulfur Oxides, AP-50, US Department of Health, Education and Welfare, Washington, DC (April 1970).
5. State Pollution Centre Commission of NSW — Annual Reports.
6. Environment Protection Authority of Victoria — Published Air Monitoring Results.
7. E. E. Aharonson, Deposition and retention of inhaled gases and vapors. In: Air Pollution and the Lung. E. P. Aharonson, A. I. David and M. A. Klingberg, eds., pp 13-24. John Wiley and Son, New York (1976).
8. M. Eippmann, Regional deposition of particles in the human respiratory tract. In: Handbook of Physiology, Section 9: Reaction to environmental agents, pp 223-232, 1). H. K. I. cc, ILL. Folk and I). D. Murphy, eds., "the American Physiological Society, Iktlicsda, MI) (1977).
9. M. O. Anidtir, Toxicological appraisal of particulate matter, oxides of sulfur, and sulfuric acid. Air Pollution, Control Assoc. 19; 138. (1969).
10. H. Dreismai, C. A. Mitchell, H. R. Hoscini and A. rtoihuys, Effect on low concentrations of sulfur dioxide on respiratory function in man, *Lamm*, 154, 25 (1976).
11. P. I. LawlHT, Effect of inhalation of sulfur dioxide on respiratory and pulse rates in normal subjects, *Lancet*, 2, 745 (1955).
12. N. R. Frank, M. O. Aindui, J. Worcester and J. L. Wiltcnberger, Effects of acute controlled exposure to SO₂ on respiratory mechanics in healthy male adults. *Appl. Physiol.*, 17, 252 (1962).

13. **T. Toyama and K. Nakamura**, Synergistic response of the pulmonary airways resistance of inhaling sodium chloride aerosols and SO₂ in man, *Sangyo Igaku*, **4**, 86, (1962).
14. **W. W. Holland et al.**, Health effects of particulate air pollution: Reappraising the evidence, *Am. J. Epidemiol.* **110**, 525 (1979).
15. **A. E. Martin**, Mortality and morbidity statistics and air pollution, *Proc. R. Soc. Med.*, **13**, 969 (1964).
16. **P. J. Lawther, R. E. Waller and M. Henderson**, Air pollution and exacerbation of bronchitis, *Thorax*, **25**, 525 (1970).
17. **N. Faller**, Effects of atmospheric SO₂ on plants, *Sulfur Inst. J.*, **6**, 5 (1970).
18. **R. P. Dreisinger and P. C. McGovern**, Monitoring atmospheric sulfur dioxide and correlating its effects on crops and forests in the Sudbury area. In: Impact of air pollution on vegetation conference. S. N. Linzon, ed., Ontario Dept. of Energy and Resource Management, Toronto (1970).
19. **N. R. Glass, G. E. Glass and P. J. Rennie**, Effects of acid precipitation, *Environ. Sci. Tech.*, **13**, 781 (1979).
20. **F. C. Riesenfeld and A. Kohl**, Gas Purification, Chapter 7, Sulfur dioxide removal, 262, 2nd Ed., (1974).

CONFERENCES AND COURSES

5th IGAEM Congress

The 5th Congress of the International Society for Aerosols in Medicine (Internationale Gesellschaft für Aerosole in der Medizin, IGAEM) was held in Adelaide, 2-5 April 1984. More than 50 papers were read and there were four satellite meetings. The 6th Congress is planned for Vichy, France in 1986, and the 7th for Rochester, USA, in 1988. Further information from Dr. Allen E. Gale, PO Box 234, North Adelaide SA, 5006.

Proceedings of the 8th Conference.

The Proceedings of the 8th International Clean Air Conference are now available from the Conference Secretary, Mr. H. F. Hartmann, PO Box 481, Hawthorn, Victoria 3122, price \$60 plus \$1.50 packing and postage: \$8.25 Asia and Oceania, \$10.25 other overseas countries; within Australia cost varies according to distance from Melbourne, which should be verified from your local Post Office. The packed weight of the three volumes is between 4 and 5 kg.

IUAPPA NEWS

The IUAPPA Handbook for 1984 is now available. It contains the Statutes and By-laws, biographies of the Officers and of Executive Committee members, reports, balance sheets, and a listing of the member countries with their officers and addresses. A copy is held in Melbourne by the Editor.

A MESSAGE FROM NZ

Written as an Editorial, this was received too late for inclusion in August issue. The message is still timely.

A Salute to Enlightened Government

When attending my first CASANZ Council Meeting at the Melbourne International Clean Air Conference in May, I was told that it was expected of me to produce an editorial. Observing the calibre of my newly met colleagues, I wondered what contribution I could make that was not parochial and yet worthy of the standard already set. How many of our members or subscribers — other than those already in the know — are interested in the air pollution problems in the eighth state?

After all, what is different about the air pollution scene in New Zealand — asbestos dust scare; lead in petrol worry; growing concern about occupational health and environmental air quality standards in the workplace; potential of cumulative atmospheric pollution from major pollution sources — with the advent of more thermal power stations to be located in the Waikato River Basin; uncontrolled and unchecked emissions from diesel engined trucks — increasing unabated with recent deregulation of road transport; urban smog levels in Christchurch, primarily domestic in origin, at times exceeding World Health Organisation criteria.

Here in New Zealand "air pollution and CAS issues" have a lot in common with Australia and have been well traversed in recent *Clean Air* editorials. We too have considered our Society's role in clean air issues related to public health, and discussed whether a more active or lobbying role was appropriate. John Court's August 1983 Editorial discusses the issues involved.

For example, those concerned about the health effects of lead in petrol in New Zealand had for years been using those avenues available to lobby and make representations to parliament. The Clean Air Society, New Zealand Branch, had made its contribution by initiating seminars and reporting summaries of the findings to government — being careful to represent the image of the Society as a body representing scientific evidence — not lobbying opinions.

There seemed to be a singular lack of interest or reaction to submissions. Support was not forthcoming from the bureaucracy. We had looked in admiration at what John Court and his colleagues in New South Wales had achieved. We were about, to ask John for a tutorial or two to guide us on our way to the same goal in New Zealand.

And then it happened, while still searching for that elusive, topical yet not parochial, subject for this editorial, the New Zealand Parliament was dissolved and a snap election announced. The only oil refinery in New Zealand became one of the issues. Fate, or was it coincidence, was just about to provide the now desperately needed inspiration.

With the new administration making history for only two weeks, it announced that lead free petrol will be made available from the refinery — when its current expansion is completed.

This enlightened decision by the new administration to reduce and eliminate lead in petrol is a major public health measure designed to minimize the impact of toxic emissions on the public. The decision recognises the principles of the philosophy that prevention is better than cure and its importance can be compared with such public health measures as piped sewerage disposal and potable water supply to individual homes.

We in the Clean Air Society should remind ourselves that because of our specialised knowledge and skills, we have a responsibility to our fellow beings and the planet earth as a whole. We should never give up pursuing those issues that we believe are important to public and ecological wellbeing. Our role is to provide the necessary information and impetus on which enlightened decision makers can act and then salute their courage when they respond positively to issues that may not appear to them as clear cut as they do to us.

DUDLEY WARD
N.Z. Branch President.

INTERSTATE NEWS

Tasmania

Mr. John Pottinger retired from the position of Director of Environmental Control in Tasmania earlier this year. He has been Director of the Tasmanian Department of the Environment since its establishment in 1972. Mr B. Healey is currently Acting Director. He has been a senior staff member of the Department since 1973.

EIGHTH INTERNATIONAL CLEAN AIR CONFERENCE

METEOROLOGY WORKSHOP

Regional Modulation of the Broad-scale Flow Pattern and its Relevance to Atmospheric Pollution

Reports by Peter Manins, CSIRO Division of Atmospheric Research (topic 1); Phil Morgan, Environment Protection Authority of Victoria (topic 2) and Frank Bradley, CSIRO Division of Environmental Mechanics, (topics 3 & 4). The Workshop was chaired by Dr. G. B. Tucker, CSIRO Division of Atmospheric Research.

INTRODUCTION

Meteorological conditions in the lower layers of the atmosphere at a given location depend both on the broad-scale synoptic situation and on the way in which this is modulated by the geographic characteristics of the region. Over the past 25 years or so skill in predicting the synoptic pattern has improved significantly. This has been due to a better understanding of the physical mechanisms involved and a better technology base, notably involving satellites and computer models. A consequential improvement in general weather forecasts has occurred but increased accuracy in local forecasts is still severely limited by an insufficient knowledge of the regional modulating processes. The greatest local influences concern topography, land-sea differences and the effect of the diurnal variation of solar radiation. Clearly these factors control meteorological parameters such as thermal stability and the local wind field and its turbulent characteristics which directly influence regional air quality.

The aims of the Workshop were:

1. Identify the mechanisms in this category that are potentially significant in terms of influencing air quality;
2. Critically assess the methodologies available for taking account of these phenomena when making air quality analyses/predictions;
3. Compile, in order of priority, a list of topics that require investigation to improve understanding in this area; and
4. Suggest the most effective approaches to such investigations.

REPORT

1. Identification of Significant Mechanisms

Richard Hoy (State Electricity Commission, Victoria) presented an account of mechanisms which change the broad scale flow pattern and generally lead to poor air quality. He divided them into three classes for convenience:

(a) Topographic — mechanical: including flow channelling in valleys, topographic wakes and lee eddies, flow blocking, and lee troughing which evidently occurs down to scales smaller than meteorologists generally acknowledge.

(b) Topographic — thermal: including sea/land breezes, the urban heat island, slope winds (katabatics and anabatics), and valley winds.

(c) Combined — thermal-mechanical: The Ekman spiral, boundary layer profiles, breakup during the morning of nocturnal inversions (particularly in valleys), and enhanced fumigation in valleys due to differential heating, flow channelling, etc.

There are many mechanisms; they are generally understood fairly well, but the assessment of relative importance and the application to a given problem are non-trivial tasks. This point was raised also by Tom Beer (Natural Systems Research P/L) who stressed the importance of defining what objectives are to be met. This then narrows the possible mechanisms which are important, and of course helps in assessing the methodologies which can be employed in studying these mechanisms.

Peter Baines (CSIRO Division of Atmospheric Research) and Mike Raupach (CSIRO Division of Environmental Mechanics) discussed Richard Hoy's classes, with Peter saying that class (a) mechanisms are becoming well understood while class (b) mechanisms are very difficult, particularly if precipitation processes are included. Mike suggested that most problems are actually class (c) — a combination of mechanical and thermal influences which are not separable.

In summary, an attempt was made to rank mechanisms responsible for regional modulation of the broad-scale flow patterns in order of importance to atmospheric pollution problems in the Australian region.

(a) The most important is the sea breeze effect. Most Australians live on the coastal fringe and the sea breeze has an important influence on dispersion — not always deleterious.

(b) Next would have to be flow separation effects, whether these be wakes or lee eddies, or upwind separation or blocking phenomena. Such departures from the broad-scale flow are the most difficult to predict and quantify and cause great trouble in air pollution regulation and control.

(c) Next would be stable thermal stratification effects or their opposite — convective instability. Strongly stable conditions isolate regions from the broad-scale flow leading to suppressed dispersion. On the other hand, strong convective instability leads to motions on length scales comparable with the height or scale of the largest industrial emitters, leading to grounding or effluent before it can be diluted by smaller scale mixing.

(d) Finally, mechanisms involving slope winds, lee waves and flow channelling, are also important in some circumstances.

2. Assessment of Methodologies

(a) Terry Bellair (Caldwell Connel Engineers) identified two basic methodologies, the traditional and the episodic or worst case.

The Latrobe Vally field studies mentioned in the discussion by Peter Manins which will be looking at regional modulation of synoptic scale flow are an example of the traditional approach.

Melbourne Airshed Study field studies likewise follow the traditional approach in gathering data on any meteorological variable thought likely to have any bearing on the processes involved.

(b) The starting point in most studies is always the same. We go to the Bureau of Meteorology for data in

order to identify the synoptic patterns which may be relevant and the vertical structure which may be important.

There are problems with the Bureau's data base in that much of the data are irrelevant to air quality studies. For example we would dearly love to have a 950 mb chart, both analysis and prognosis, as this level is far more relevant to air quality work than, for example, the 850 mb or 500 mb levels. Similarly with radiosonde data, validated significant levels would be of greater use in air quality studies than the standard levels.

(c) Professor Bill Melbourne (Monash University) indicated that the physical modelling work being done by his group is very close to simulating highly convective conditions relevant to plume dispersion in areas like Queensland and on certain occasions in the southern states. However, the industrial centres where most air quality studies are being undertaken are principally in south eastern Australia where we need to be able to physically model across the range of Pasquill stability classes.

(d) As identified by Peter Manins the principal modulating mechanism would appear to be the land breeze/sea breeze. At least on a regional scale this would be a principal component of pollution episodes in the major population centres of Australia, almost all of which are located at coastal sites.

3. Topics for Investigation

4. Suggestions for Effective Approaches

Throughout the workshop, a number of specific problems kept cropping up. Most of these have already been identified by Peter Manins in his summary of significant mechanisms affecting air quality. Here, I shall comment briefly on their status in the research area, as it appeared during the Workshop proceedings.

(a) *The sea breeze*

It is clear that we know a good deal about the characteristics and structure of sea breezes in a qualitative sense. Their occurrence is even able to be forecast with a reasonable degree of success. However, when it comes to predicting the details, strength, height, inland penetration, interaction with other meso-scale flow patterns, our knowledge is limited. Unfortunately, this is the level of detail needed to predict the consequences of a sea breeze for pollutant dispersal.

Research programs should proceed with three broad objectives in mind;

(i) To understand the basic structure of sea (and land) breezes in terms of their controlling physical parameters. This requires a substantial and carefully planned observational

program, backed with theoretical studies in fluid mechanics and heat transfer.

(ii) To determine the role of sea and land breezes in the dispersal and recirculation of pollutants from ground and elevated sources, and assess the consequences for the siting and operation of industrial plants.

(iii) To develop the capability for operational forecasts of the sea breeze in sufficient detail to service the needs of industry. This implies an understanding of the effects of regional variability.

(b) *Channelling of flow by valleys and slopes*

This topic has received a good deal of attention in the past few years, with work in the mountainous regions of USA, Europe, and in Australia in the Albury-Wodonga region by Moriarty, the Latrobe Valley study by the CSIRO Division of Atmospheric Research, and the example given here by Terry Bellair.

Perhaps the most extensive study is the joint venture called ASCOT (Atmospheric Studies in Complex Terrain) by about ten American institutions in the Colorado Rocky Mountains. Measurements have been made of downslope and upslope flow in a network of valleys, with tracer studies included, and more extensive observations are planned. A very large numerical model is also being developed.

The difficulty with this general problem lies in the wide variability in form, scale and complexity of natural valleys. Although a great deal of data have already been obtained, and no doubt, will continue to accumulate it may be difficult to establish general conclusions and formal parameterisation for valley circulations. As Bill Moriarty (Bureau of Meteorology) pointed out, conflicting results have been obtained for apparently similar situations and reality has tended to contradict predictions.

It is certainly worth monitoring the progress of such massive ventures as ASCOT. Australian groups have, indeed, been invited to participate. However, there is also a very important role for careful and comprehensive observations of geometrically simple situations, which may be amenable to theoretical analysis of the flow dynamics. Since much of the interest in this problem involves a stably stratified atmosphere, there is also the possibility of useful work with physical modelling in laboratory water channels.

(c) *Upstream blocking*

This refers to wind flow deflected over a range of hills, thus creating a stagnant, or recirculating region in the foothills. It was discussed here in the

context of the dispersal from or into such a region when a source is located in the vicinity.

This topic is probably best regarded as one aspect of the general problem of wind flow over hilly topography where, if the hills are steep and high enough, separation may occur both upstream and downstream of the obstruction. Since hilly terrain most often occurs as a continuum of hills and valleys of varying scale, separation and wake effects must be generally present and interacting in a very complicated fashion. The fate of pollutants in such an environment is obviously also extremely complicated.

Again, in the long term complete analysis of such distorted flows will only be derived from an understanding of the basic mechanisms involved. Even in the laboratory, studies of separation and curved flows are extremely limited, and the associated theory not well developed. There is a need for continuation of fundamental aspects of the problem through wind tunnel and tank studies. The facilities of the CSIRO Divisions of Atmospheric Research and Environmental Mechanics are being used for such work.

However, to accommodate the large range of atmospheric stability encountered, which plays a dominating role, there seems little alternative at this stage to observational studies in the field. Such field experiments have been undertaken particularly in Canada, the UK, and in Australia by the Division of Environmental Mechanics, but mainly on the mean flow field over hills of moderate slope where separation was not expected to complicate the situation.

Future studies should concentrate particularly on the upstream and downstream separation regions, but again in the vicinity of simple, 2-dimensional ridges whose geometry can be readily described, and simulated in laboratory experiments. Theoretical developments must recognise modern thinking that separation regions are not necessarily closed circulations, a concept which has important consequences for transport of matter into and out of the blocked region.

(d) *The influence of convection*

There is a view that the extremely high rates of surface heating encountered in Australia, particularly in the north of the continent, enhance the significance of convection for turbulent dispersion in the atmosphere. Little enough is known about atmospheric convective processes, and there remains great scope for theoretical models in this area as well as controlled laboratory experiments and full-scale observational studies. Validation must

ultimately depend on the latter, which are particularly difficult given the wide range of spatial and temporal scales involved, so that progress is likely to be slow.

Some aspects of convection which must be considered in the context of pollutant dispersal are:

(i) In uniform terrain, to what height is Monin-Obukhov similarity relevant? This may affect our ability to estimate dispersion parameters from existing validated theory.

(ii) What is the mechanism through which free convection generates large-scale intermittent motions in the atmosphere? These are responsible for the looping and grounding of plumes,

(iii) Following directly from (i) and (ii) are questions asked by those attempting to simulate convective conditions with physical models in wind tunnels and water channels. What relaxations of exact Froude and

Reynolds number scaling can be tolerated? What lapse rates are appropriate? What are the characteristics (time and length scales) of intermittent convective motions in the atmosphere? These are probably responsible for extreme events which may exceed limits set by regulatory authorities,

(iv) It is often the conjunction of topography and stratification which is of particular significance for dispersion: e.g. blocking due to stable stratification, or possible "lock-in" of thermal convection and topographic features in strongly unstable conditions.

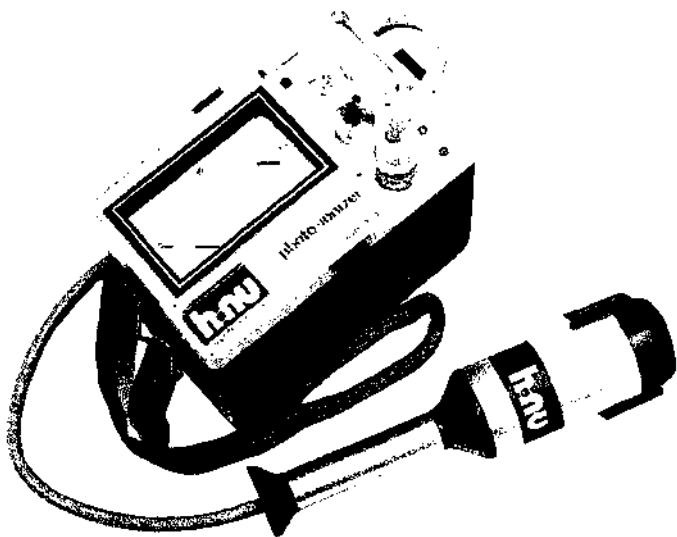
Much of the work on convection calls for detailed and careful experimentation, both on prototype scale in the real atmosphere and with model of simulation in the laboratory. However, the distinction between dry convection and moist convective pro-

cesses of the real world must not be overlooked.

(e) *Analytical and numerical models*
The fact that little discussion took place on the status of models mesoscale phenomena in Australia is significant in itself. Atmospheric dispersion models are notoriously unreliable except under the most ideal circumstances, and it is natural for people to shy away from any suggestion that they can accommodate the sophistication of complex topography and extreme convection without great effort.

Ultimately, however, reliable predictive models will be needed, incorporating such effects, and steady progress must continue on this aspect, alongside the empirical models, ad hoc experiments and engineering solutions which are called for in the short term.

hnu photo-ionizer for trace gas analysis



The HNU PI101 is a new portable trace gas analyser for measuring a wide range of gaseous species in industrial atmospheres. Including: chlorinated hydrocarbons, heterocyclics, aromatics, hydrogen sulphides, ammonia and ethylene oxide.

- battery or mains operation
- simple and safe to use
- electronic zero
- recorder output
- direct reading from three ranges; 0-2, 0-20 and 0-2 000 ppm.

For further information contact:

SELBY SCIENTIFIC

A Division of The ANI Corporation Limited Incorporated in New South Wales

QLD
371 1566

NSW
888 7155

VIC
544 4844

TAS
28 4691

SA
51 4651

WA
451 2577

A PRELIMINARY STUDY OF RAINWATER ACIDITY AROUND NEWCASTLE, N.S.W.

Roslyn Avery

This paper is based on an Honour's thesis in the University of Newcastle. Mrs. Avery's address is 27 Hutcheson Ave., Rankin Park, NSW 2287.

ABSTRACT

Acid rain events were found to occur relatively frequently throughout the Lower Hunter Valley of NSW, but spatial distribution over the 14-month study period was non-uniform. At coastal sites 47 percent of the rainfall had a $\text{pH} < 5.6$ whereas over 80 percent of the rainfall at non-coastal sites had a pH less than 5.6.

NO_3 concentrations were similar to SO_4 levels in a majority of events with the relationship between NO_3 and H^+ being significant in most cases. However, at Lochinvar, a non-coastal site, the only significant relationship occurred between SO_4 and H^+ ions.

Examination of specific case episodes suggests that the degree of acidification of any rainfall sample is the result of complex, spatial, meteorological and chemical inter-relationships.

INTRODUCTION

In recent years a number of overseas regions have experienced severe acidification of rainfall. While acid precipitation has been defined as "rain and snow having a pH less than 5.6" (1,2), i.e. the lowest pH which may result from saturation of precipitation with atmospheric CO_2 , it would seem preferable to restrict this term to rain for which the pH is significantly lower than the regional background level. In Europe, average pH s of 4.0 to 4.5 have been recorded in many regions including Belgium, Netherlands, Germany, Scandinavia, U.K. and France (3,4). Similar pH s are currently being recorded in North America, particularly in south-eastern Canada (5), and the

north-eastern United States (6,7). This phenomenon of recent decades has been attributed by many to the chemical transformation of sulfur and nitrogen oxides released into the atmosphere during the combustion of fossil fuels.

In the presence of moisture (i.e. in rain or cloud droplets), pollutant gases such as NO_x , SO_2 and a number of their oxidized forms (e.g. SO_3 , NO_3) react to produce strong acid species such as sulfuric (H_2SO_4), nitric (HNO_3) and sulfurous (H_2SO_3) acids which dissociate to give hydronium ions (H^+) and counter anions. The degree of acidity of rainwater therefore is primarily a function of the additional H^+ thus developed. However the presence and concentration of other species, including the neutralising NH_3 and CaCO_3 species, will also influence the eventual acidity of rainwater.

On the basis of current information (8), ecological impacts of strongly acid (e.g. $\text{pH} < 4$) precipitation include (a) changes in the nutrient budgets of forests, agricultural lands, lakes and rivers; (b) decreased yields of agricultural crops, forests and fisheries; (c) loss of species diversity and resistance of terrestrial and aquatic ecosystems; (d) inactivation of economically and ecologically important soil micro-organisms; and (e) corrosion and deterioration of materials and increased rock weathering.

Australia fortunately lacks the severe long-range pollutant transportation problems presently experienced in Western Europe and North America. Yet within Australia itself, a few industrial regions and metropolitan areas not only have the potential to emit pollutants for long range transport, but also to experience acid rainfalls. One such region is the Hunter Valley of NSW. The Hunter Region is not only an important industrial, agricultural and mining region, but is the source of approximately 90 percent of the State's electricity (9). In addition, it is located within 150 km of the Sydney metropolitan area, another potential pollution source.

Therefore, in view of the region's potential for an air quality problem such as "acid rain", a small-scale pilot study was undertaken for a period of 14 months between January 1981 and March 1982 in order to determine the acidity of rainfall within the region. This paper will report on some of the results of the study.

EXPERIMENTAL PROCEDURE

(a) Field sites

For the study, a network involving seven monitoring stations was established in the Lower Hunter Valley. The sites chosen were located in diverse directions from the central industrial area of Newcastle (Figure 1) at distances varying from 5 to 25 km from the major pollution source area. As the predominant rainbearing winds were known to be of SW-S-SE origin (Bureau of Meteorology data), the sites were suitably situated to detect any possible acid rain derived from either the industries of Newcastle or from sources to the south.

The sampling device used consisted of a polyethylene funnel of 21.5 cm outer diameter attached to a polyethylene bottle of 2 litre capacity. The use of polyethylene minimised loss of solute species due to sorption on vessel walls.

In the field, the bottle was supported 1.2m off the ground on a fencing stake and protected by an outer polyethylene tubing. Sample contamination was minimised by locating the equipment in open areas.

To minimise dry deposition collected between precipitation events, the funnel and collecting bottle were placed in position only on days when rain was forecast or appeared imminent. At the sites, samples were generally collected over a 12-hourly period, i.e. overnight or during the day (0800-1700). Occasionally, under heavy rainfall, samples were collected at more frequent intervals, e.g. every hour.

(b) Chemical measurements

The pH , electrical conductivity and the concentrations of sulfate, nitrate, sodium and ammonium ions were determined for each sample. pH and conductivity levels were measured using standard pH/mV conductivity

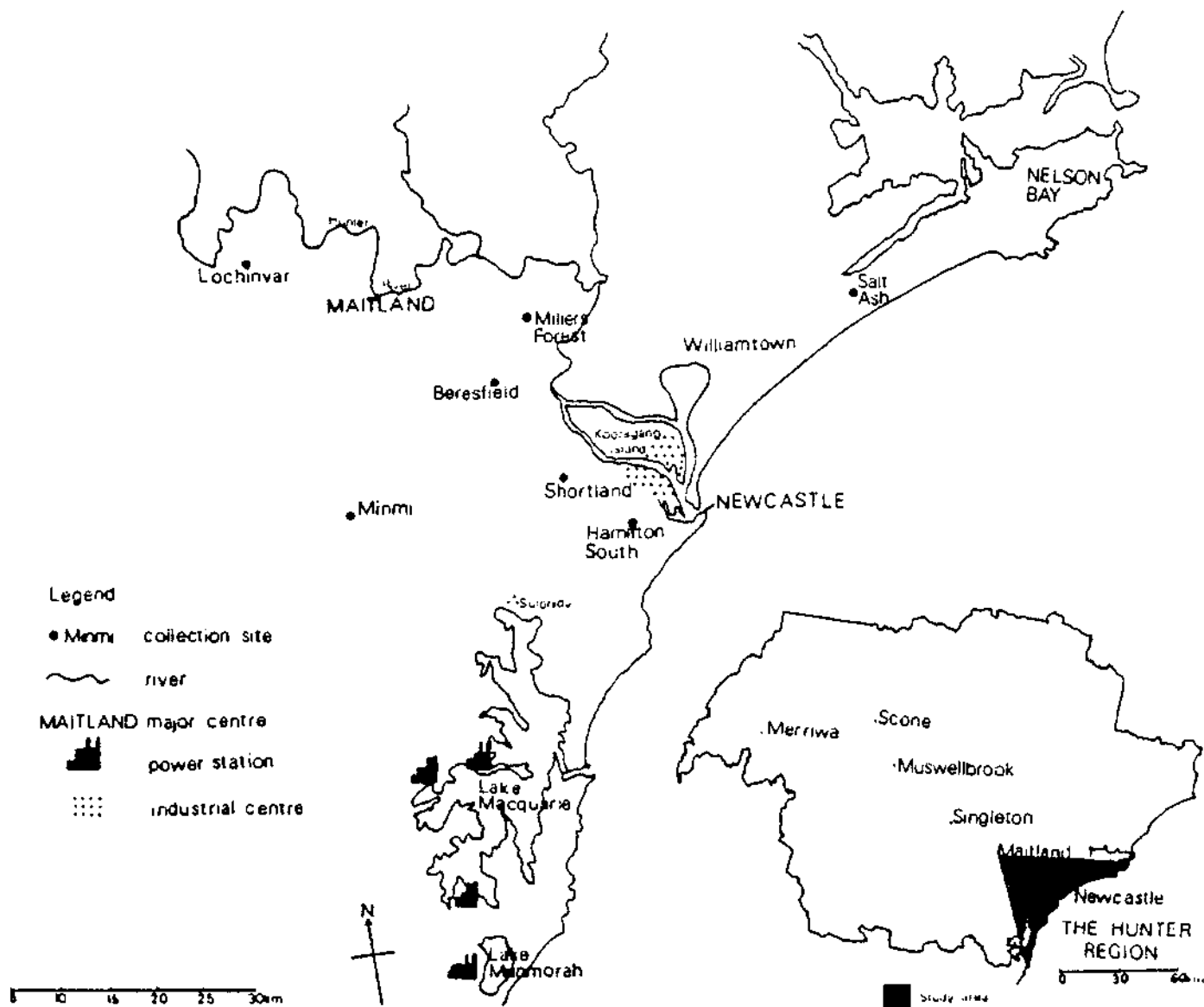


Figure 1: Location of main pollutant emission sources and collection sites.

meters respectively. Sulfate ion concentrations were determined by forming a colloidal suspension of BaSO_4 and then measuring the amount of blue light (λ 450 nm) stopped by this suspension using a UV-visible spectrophotometer. Initially, NO_3^- levels were measured by means of an Ion Selective Electrode technique. Later, samples were analysed spectrophotometrically, using a procedure which is based on the characteristic absorption of ultraviolet radiation (220 nm) by NO_3^- ions in acid media. The NH_4^+ levels were determined potentiometrically, using an ion specific electrode and digital pH/mV meter, whilst flame photometry was used to measure Na^+ (sodium) levels in the various samples.

As rapid analysis is a critical factor in rainwater studies (due to possible changes in species equilibria upon standing) and multiple samples were to be handled, methods were adopted which were relatively simple and allowed all determinations to be made within a few days of collection. The techniques finally selected represented the best available compromises in view of equipment available,
(c) Meteorology

Wind direction and synoptic data were collected from the Williamstown RAAF meteorological station for all the rainfall events which occurred between January 1981 and April 1982.

As rainfall is generally perceived as a continuous process, the samples collected often overlapped two synoptic

situations. To clarify this situation and allow classification of data, the following definitions were adopted: (i) a rainfall *episode* was defined as 'the composite of successive rain 'events' in a given area, perceived as a continuous period of rainfall'. A rain episode may comprise a number of 'events'.

For example, rain samples collected over a 3-day period may include a sequence such as (1) rainfall due to on-shore winds from a high pressure system; (2) rainfall due to the passage of a cold front over the area, and (3) post-frontal onshore winds from another high pressure system. Thus the episode would include 3 separate rain events according to the above definitions.

For the purpose of general comparison rainfall samples representing a given event were credited with the predominant wind direction over the sampling period; directions were drawn from the 3-hourly surface wind directions recorded at Williamstown.

SPATIAL DISTRIBUTION OF RESULTS

A total of 338 samples were collected from the seven sites over the 14-month period from January 1981 till the end of March 1982. As only two sites recorded accurate rainfall volume data for the samples, free H⁺ levels (pH measurements) rather than volume-weighted mean values were utilised. These pH measurements demonstrated that in all, there were 38 rainfall events in which rain of pH<5.6 was received at one or more sites during the study period. Table 1 summarises the observed pH patterns of the various Newcastle sites over the study period.

Figure 2 shows the distribution of pH within four main categories at each site. Distribution patterns derived from combination of the data collected over the entire period indicated that the frequency of acid precipitation is lower for the coastal sites than in urban and residential areas. A similar pattern of coastal vs metropolitan rain acidity was observed in Sydney by Ayers and Gillett (personal communication).

The non-uniformity of "acid rain" distribution throughout the Newcastle area is, in some ways, predictable. The major rainbearing winds in the Newcastle area are onshore winds coming predominantly from the S to E sector, and under these conditions the coastal sites had the least upwind sources of acidity.

No site received a high proportion of 'strong acid' (H₂SO₄, HNO₃) rain (i.e. the pH<4 range). The rain collected at both coastal sites (Hamilton South and Salt Ash) and Millers Forest regularly had a pH>5.6, and from this it may be inferred that the regional background pH may prove in later studies to be of this order. Minmi appeared to be a transitional site, whilst at Shortland, Beresfield and Lochinvar a high proportion of the rainfall was distinctly acidified, i.e. pH<5.0. Thus the test sites may be broadly grouped into 'acidic' (high frequency of pH<5.0 events) and 'non-acidic' (pHs predominantly >5.0) areas.

When all the data from the various sites is combined to give a general area trend (Figure 2 legend inset), the area as a whole appears to experience an even distribution of rainfall between pH 4.0 and >5.6. Yet in fact, nearly 2/3 of the rain had a pH>5.6 (cf. Table 1). Total area generalization therefore tends to conceal the identifiable

Table 1. Summary of Observed Rainfall pH Levels in the Newcastle Area in the period January 1981-March 1982

Site	Percent Occurrence in a Given pH Range		Sample Size n	Region Type
	>5.6	<5.6		
Hamilton South	53.7	46.2	67	coastal
Salt Ash	50.0	50.0	34	coastal
Millers Forest	54.6	45.3	64	rural valley
Beresfield	30.4	69.5	46	residential rural
Minmi	21.8	78.1	32	rural
Shortland	20.3	79.6	59	residential
Lochinvar	5.5	94.4	36	rural
Pooled sites for Newcastle i.e. general area	36.4	63.6	338	

'polluted' areas and 'non-polluted' areas and accordingly it was concluded that the purpose of this study was better served by treating 'acidic' and 'non-acidic' sites separately.

Since much of the rain which fell on coastal sites had pHs in the 5.0 to 5.6 range, it could be argued that pH>5.0 provides a better delineation point for identifying precipitation reasonably unaffected by pollution emanating from Newcastle and the surrounding area. Thus the following pH range classification scheme was adopted for this study: rain with pH 5.0 to 5.6 is defined as "mildly acidified" and pH<5.0 as "strong acid" rain. This scheme acknowledges the limitations of defining acid rain as precipitation having a pH<5.6, and introduces an arbitrary intermediate group which may reflect common local background levels.

ACID RAIN EVENTS BY SYNOPTIC TYPE

During the study period, a total of 65 rainfall events were observed. Prior to the commencement of this study, this area had experienced drought (or below-average rainfall) conditions for over three years, and in the early months of study, rainfall was restricted to single thunderstorm events of short duration. However, heavy rains in October-November 1981 contributed greatly to the easing of this drought. From this period onwards, rainfall episodes were common, with rainfall often lasting for extended time periods, e.g. 10.10.81 - 28.11.81, and 23.2.82 - 25.3.82. These episodes could usually be divided into a number of separate events.

Three main synoptic situations were found to be associated with the occurrence of the observed rain events (Table 2). These include onshore winds onto the Lower Hunter Region from low and high pressure systems in their W to E migration across southern Australia, and the passage of cold

fronts with associated lower atmospheric convergence.

Rainfall arose primarily from either the passage of a cold front or onshore winds from a high pressure system. Rainfall events related to onshore winds from an anticyclone were not only more frequent overall, but were also responsible for over half the acid rain events observed. A similar pattern was observed in the state of Maine, USA, with rainfall pHs of 4.0 - 5.0 being reported when convective showers associated with frontal passages occurred in the region (10).

It appears probable that a slow-moving persistent high pressure system, could accumulate considerable pollutant concentrations in its passage over Southern Australia, especially if light winds were prevalent. If, as Smith & Hunt (11) suggest, some of this polluted air becomes drawn in an active frontal zone along the periphery of the high pressure system, the potential exists for the release of acid rainfall. The Newcastle results may support this idea, for almost half (i.e. 43 percent) of the rainfall events arising from onshore winds from a high pressure system were followed by rainfall from cold fronts, in a sequence of high pressure system — cold front — high pressure system — cold front, rain. Furthermore, as noted in Table 2, those acid rain events associated with the passage of a cold front were predominantly also associated with an influencing high pressure system (21/26 percent), with these fronts possibly associated with the backside of a polluted high pressure system.

CASE STUDIES OF ACID RAIN EVENTS

(a) 23.2.82 - 26.2.82 — a strong acid episode (Table 3)

Under the influence of a high pressure system centred near New Zealand, a period of calm preceded the passage of a cold front on 23.2.82. With the front

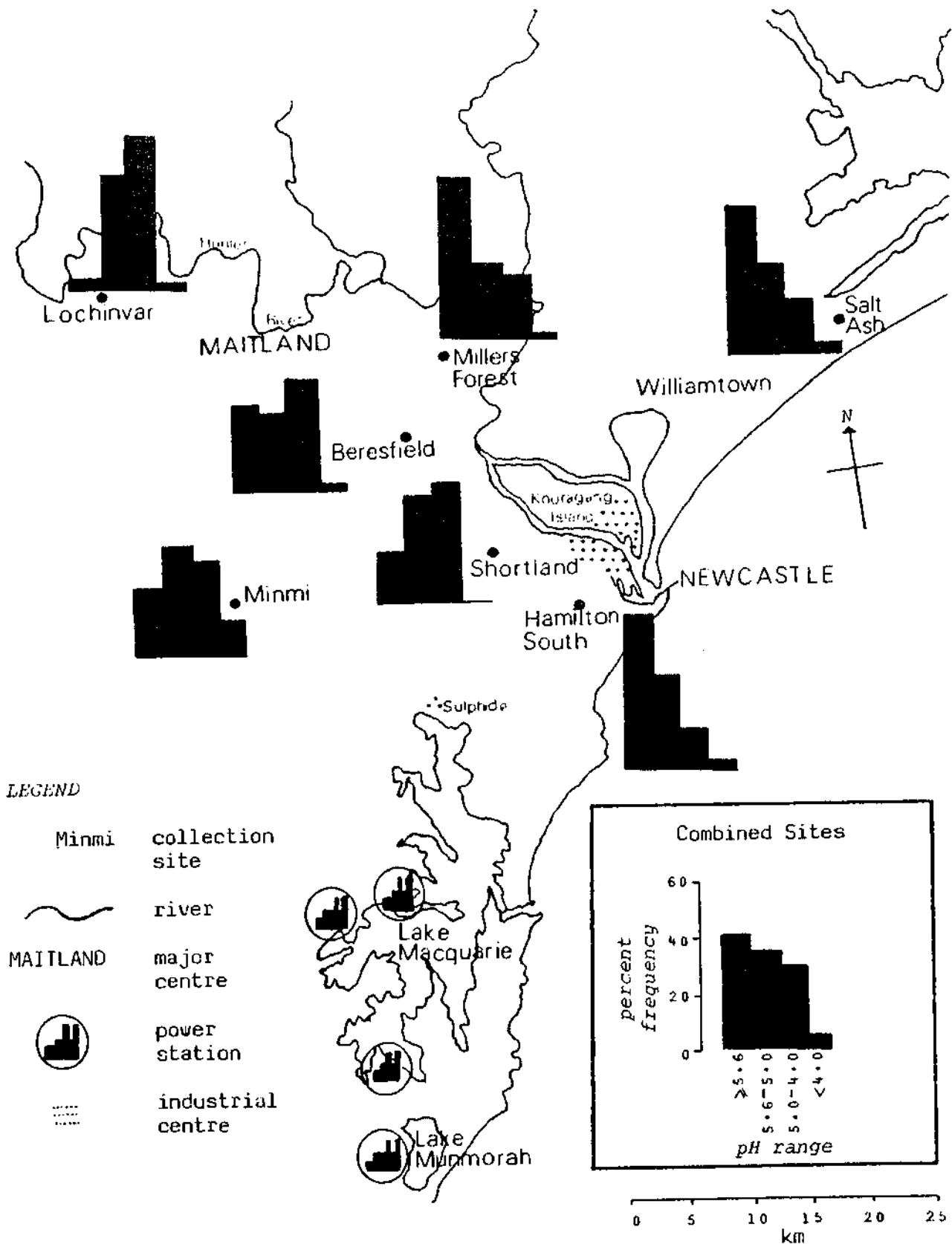


Figure 2: Percent frequency of pH levels in rainfall around Newcastle.

Table 3. pH Analysis of Rainfall during Sample Events and Episodes.

<u>ACID RAIN EPISODE</u> 23.2.82 - 26.2.82			<u>ACID RAIN EPISODE</u> 17.3.82 - 19.3.82			<u>ACID RAIN EVENT</u> 24.3.82 - 25.3.82				
<u>23.2.82</u>			<u>17.3.82</u>			<u>24.3.82</u>				
<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>		
4.90	Hamilton South)	calm	4.73	Millers Forest)	N	5.17	Hamilton South)	NE		
4.05	Beresfield)		5.00	Minmi)		4.45	Millers Forest)			
4.35	Minmi)		5.20	University)		4.51	Beresfield)			
4.79	University)		4.76	Lochinvar)		4.68	Minmi)			
<u>24.2.82</u>			<u>18.3.82</u>			<u>25.3.82</u>				
<u>ph</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>		<u>Wind Direction</u>	
5.02	Hamilton South)	E	5.87	Hamilton South)	S	4.55	Millers Forest	WNW		
3.90	Beresfield)		4.98	Millers Forest)		4.50	Salt Ash	WNW		
3.95	Minmi)		4.72	Salt Ash)		4.20	Salt Ash	WNW		
4.40	University)		4.83	Beresfield)		5.26	Beresfield	WNW		
5.55	Millers Forest)		4.36	Minmi)		5.17	University	NNW		
<u>25.2.82</u>			<u>19.3.82</u>			<u>24.3.82</u>				
<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>		
4.70	Hamilton South)	SSW	4.50	Beresfield)	SSW	4.30	Lochinvar	NNW		
4.45	Millers Forest)		4.23	Lochinvar)		4.30	Lochinvar	NNW		
4.25	Beresfield)		4.40	University)						
4.40	Minmi)									
4.25	University)									
<u>26.2.82</u>										
<u>ph</u>	<u>Site</u>	<u>Wind Direction</u>								
4.10	Hamilton South)	S								
4.00	Millers Forest)									
4.47	Minmi)									
4.30	University)									
<u>NON-ACID RAIN EVENT</u> 2.4.81 - 4.4.81			<u>RAIN EPISODE</u> 29.1.81 - 1.2.81			<u>RAIN EVENT</u> 21.11.81 - 22.11.81				
<u>2.4.81</u>			<u>29.1.81</u>			<u>21.11.81</u>				
<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>		
7.11	Hamilton South)	ESE	5.40	Hamilton South)	SSW	4.95	Millers Forest)	E		
5.96	Millers Forest)		5.50	University)		4.82	Beresfield)			
6.17	Salt Ash)		30.1.81				5.00		Minmi)	
5.80	Minmi)					4.90	University)			
<u>3.4.81</u>			<u>31.1.81</u>			<u>22.11.81</u>				
<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>		
6.12	Hamilton South)	E	5.90	Hamilton South)	SSW	5.70	Hamilton South	SE		
5.98	Millers Forest)		4.20	Millers Forest)		5.10	Salt Ash	E		
6.11	Salt Ash)		3.80	Williamtown)		5.10	Minmi)	SE		
6.30	Minmi)		3.60	Minmi)		5.35	Minmi)			
<u>4.4.81</u>			<u>1.2.81</u>							
<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>	<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>					
6.00	Hamilton South)	E	5.65	Millers Forest)	S					
5.65	Beresfield)		6.30	Williamtown)		5.70	Minmi)			
			<u>1.2.81</u>							
			<u>pH</u>	<u>Site</u>	<u>Wind Direction</u>					
			6.24	Williamtown	S					

came rain and showers, acidic in nature at all sites (as seen in Table 3). Although the general tendency throughout this study was for inland sites to receive the more acidic rain, on this occasion the coastal Hamilton South site also received acid rain. The rainfall at Lochinvar and Salt Ash was not sampled during this episode, and on this date (23.2.82) neither was the Millers Forest site monitored. The convective showers associated with the passage of the cold front may have caused considerable below-cloud scavenging of pollutants accumulated over Newcastle during the preceding days of calm conditions and very light winds.

On the following day, 24.2.82, the predominantly easterly winds from the offshore high pressure system continued to bring rain. On this occasion both the Hamilton South and Millers Forest sites received only mildly acidified rain, due to the direct onshore nature of these winds, while the other sites received highly acidic rainfall, with minimums of 3.90 and 3.95 being recorded at Minmi and Beresfield respectively.

Throughout the period 24.2.82 - 26.2.82, the entire area was under the continual influence of the same high pressure system offshore. Acid rain was recorded throughout the entire duration of its influence over the Newcastle area. On this occasion, the surface winds around Newcastle changed from predominantly easterly on the 24th, to SW and S on the 25th and 26th respectively. With local pollutant sources to the south, possibly adding to that already associated with the existing synoptic system, all sites received highly acidic rain during this period, including the two coastal sites. Passage of another cold front over the area, on the 26th, brought this particularly acid episode to an end.

(b) 17.3.82 - 19.3.82

Once again the area was under the influence of migrating high pressure systems. Onshore winds brought a late evening thunderstorm associated with the backside of the departing high pressure system, with resulting strong acid to mild acid rainfalls in the area.

By the 18th, another high pressure system to the SW had become dominant, remaining that way for 2 days (the 18th and 19th March, 1982). Showers and drizzle, i.e. light rain from the S-SSW, produced strong acid rainfall at virtually all monitored sites except Hamilton South, on these days.

(c) 24.3.82 - 25.3.82

By 24th March, a trough had drifted south from Queensland creating shower activity across the area. Acid rain was deposited throughout the area, the lowest pH at Lochinvar, the highest (mildly acidified) being at

Hamilton South. During the 25th the previously dominant influence of the low pressure system waned. The assortment of acidity levels appears to reflect this mixture of winds on this day, with dominant wind directions of samples varying according to the exact sampling period. Lochinvar received acidic rain, as did Millers Forest and Salt Ash; however Salt Ash recorded an unexplained abnormally high pH (8.20).

(d) 2.4.81 - 4.4.81

Although the majority of rain events resulted in a number of sites receiving strong acid, and a number mildly acidified rain, on a few occasions episodes occurred in which rain fell at near neutral pH levels. Between the 2nd and 4th March, 1981, moist onshore easterly winds from a stationary high pressure system centred near New Zealand released non-acid rain throughout the area. The pH ranged between 7.1 (Hamilton South) and 5.65 (Beresfield).

(e) 29.1.81 - 1.2.81

Frequently an episode could be initially classified as non-acid, then with a change of synoptic situation, e.g. passage of a front, it rapidly became acidic or vice versa. The first rain producing activity for many months resulted in continual drizzle and showers for two days (30th and 31st). On 30th January, the Hamilton South site received non-acid rain, yet all the other monitored sites received highly acidic rainfall, with a minimum pH of 3.6 recorded at Minmi. Predominate winds during this period were from the SSW. In view of the long period without rain it appears likely that these initial light rains acted as efficient pollutant scavengers (mainly via below-cloud scavenging of acid particles) resulting in highly acid rains. This interpretation is supported by the change in pH observed in the rain samples collected the next day (31st).

Although apparently under the same synoptic and wind regimes as the previous day, none of the samples collected were even mildly acidic. However, while it appears that the below cloud and perhaps some in-cloud scavenging processes were very effective in clearing the local air of pollutants, it has to be recognised that a slight shift in wind direction, e.g. from SSW to S might have moved a major source plume away from the collection site zones,

(f) 21.11.81 - 22.11.81

A similar episode of pollutant scavenging, modified by a probable dilution effect, was observed on 21-22.11.81. A high pressure system was directing E winds on to the Newcastle area. Rains were light and the initial pHs at the four sites located down-wind of the Kooragang Island NO_x and other pollutant emission sources were all low. By the next day, all or most, pollutants and acidifying substances had apparently been washed out, since observed pH levels were much higher (Table 3). A dilution effect is indicated by the pH level of three samples collected sequentially at Minmi. During the day of 22.11.81 the rainfall acidity at this site changed from mildly acidic to definitely non-acidic — a pH change of over 1.0 unit.

PREDOMINANCE IN PRECIPITATION

In both 'strong' acid rain events and combined rain events NO_3^- concentrations matched SO_4^{2-} levels in the rainfall most of the time. Furthermore, a significant relationship (1 percent level Students' *t*-test) was observed between H^+ and NO_3^- concentration in the combined site data (where correlation coefficient $r = 0.14$, sample size $n = 374$). This is in contrast to the Lochinvar data in which a significant correlation (2 percent level) was found between SO_4^{2-} and H^+ concentrations

Table 4. Synoptic situations associated with Rainfall during the period 30 January 81 — 31 March 82.

Prevailing Synoptic Situation	Percent Occurrence	
	All Rainfall Events	Strong Acid (pH <5.0) Events
i) Onshore winds from a low pressure system	17	21
Onshore winds from a high pressure system	46	53
ii) Passage of a cold front of this, (a) with associated low pressure system	37	26
(b) cold from alone	9	0
(c) associated with a high pressure system in an event sequence	20	5
	8	21
	37	26

Table 4. Ionic Levels in Rain Samples. Mean \pm S.D.*

SITE	pH RANGE	Ionic Concentrations $\mu\text{mol-L}$				Conductance μmho
		SO_4^{2-}	NO_3^-	NH_4^+	Na^+	
Hamilton South	3.90 - 5.60	70 \pm 160	22 \pm 24	55 \pm 166	255 \pm 263	61 \pm 182
	\geq 5.60 - 6.65	66 \pm 115	24 \pm 27	40 \pm 67	435 \pm 597	66 \pm 78
Millers Forest	3.95 - 5.60	48 \pm 101	25 \pm 25	34 \pm 38	216 \pm 283	49 \pm 64
	\geq 5.60 - 6.60	60 \pm 148	33 \pm 29	85 \pm 136	235 \pm 265	51 \pm 46
Williamtown: Salt Ash	3.80 - 5.60	60 \pm 102	13 \pm 8	11 \pm 6	150 \pm 117	49 \pm 49
	\geq 5.60 - 10.3	35 \pm 32	31 \pm 44	26 \pm 42	243 \pm 134	73 \pm 54
Beresfield	3.90 - 5.60	29 \pm 72	25 \pm 18	31 \pm 38	267 \pm 330	27 \pm 25
	\geq 5.60 - 7.21	13 \pm 13	28 \pm 27	25 \pm 28	211 \pm 167	67 \pm 75
Minmi	3.60 - 5.60	14 \pm 16	27 \pm 35	17 \pm 18	405 \pm 524	36 \pm 58
	\geq 5.60 - 6.30	37 \pm 49	13 \pm 8	21 \pm 21	133 \pm 121	17 \pm 12
University	4.10 - 5.60	35 \pm 66	39 \pm 47	21 \pm 19	328 \pm 442	42 \pm 51
	\geq 5.60 - 6.11	24 \pm 18	38 \pm 28	39 \pm 40	113 \pm 71	41 \pm 21
Lochinvar	3.60 - 5.60	25 \pm 30	23 \pm 21	14 \pm 12	113 \pm 107	28 \pm 23
	\geq 5.60 - 5.80	4 \pm 3	20 \pm 20	—	—	11 \pm 4

*Rira normal distribution, about 67 percent of the results fall in the range. Mean \pm S.D. and about 45 percent within the limits Mean \pm 2 S.D.

(where $r = 0.38$, $n = 37$). The differing Lochinvar results may be related to its greater distance upwind from major local sources, i.e. greater transformation of SO_2 to SO_4^{2-} and a lesser influence of NO_x emissions from Newcastle.

The high proportion of NO_3^- in the precipitation suggests that nitric acid is a major component of Newcastle rain, a situation similar to that reported by Liljestrang and Morgan (12) for the California region. The greater majority of European and North American studies however (e.g. (13), (14)), have found H_2SO_4 to be the dominant acidifying component of rain. On occasion, SO_4^{2-} levels have been shown to be highly correlated ($r = 0.86$) with the rainfall pH or acidity (15).

However, such studies usually refer to situations in which: (1) high S fuels are being used, and therefore for a given amount of fuel burned far greater concentrations of SO_2 are present in the atmosphere awaiting the transformation, and (2) these sites experience considerable SO_4^{2-} acidic input from long-range transport of pollutants which have travelled over both long distances and periods of time.

Rodhe et al (16) proposed that due to the common dependence of NO_3^- and SO_4^{2-} on the OH radical, a higher concentration of NO_3^- tends to reduce the level of OH and H_2O_2 close to the source area, thereby delaying and decreasing the transformation of SO_2 to H_2SO_4 . It has been estimated (17) that maximum SO_4^{2-} production (or intensity) occurs within 50-100 km of a source, and if this view is valid most of the Newcastle sampling sites were located on the periphery of the area likely to receive H_2SO_4 fallout generated in the Sydney metropolitan area. A more detailed study in this area incorporating both atmospheric gas concentrations and rainfall parameters will have to be undertaken if the proposed ideas are to be confirmed or disproved.

RELATIONSHIPS BETWEEN IONS

The suggestion that the study area can be divided into two categories according to acid rain occurrence is supported by trends apparent in Table 4. These trends include: (1) higher NO_3^- and SO_4^{2-} concentrations and lower NH_4^+ concentrations occurring in acid events than in non-acid events at the Lochinvar, Minmi, Beresfield and Shortland sites. These observations imply that while sulfuric acid and nitric acids contribute to the rainfall acidity within these areas, the NH_4^+ levels reflect the degree of neutralisation by ammonia emitted by natural and local anthropogenic sources; (2) consistently high conductivities and Na^+ concentrations at the Hamilton South, Salt Ash and Millers Forest sites indicating high salt contamination, that is, strong coastal influences; and (3) higher SO_4^{2-} concentrations in non-acid events at the three coastal sites, an occurrence most probably due to high sea salt contributions of sulfate salts rather than H_2SO_4 .

CONCLUSION

Acid rain events were observed to occur relatively frequently within the Lower Hunter study area, however the distribution of lower pH rainfall tended to be non-uniform throughout the study area during this period.

The results indicate that the study area can be divided into two categories. Firstly, coastal sites (including Salt Ash, Hamilton South and Millers Forest) in which 47 percent of the rainfall had a pH $<$ 5.6; and secondly, non-coastal sites (Lochinvar, Minmi, Beresfield and Shortland sites) in which over 80 percent of the rainfall samples had a pH less than 5.6. Of these sites, Lochinvar received the most acid rainfall most frequently (pH $<$ 5.6, 94.4 percent).

The non-uniform distribution of acidic contaminants throughout the study area can probably be attributed to three major factors: prevailing rain-bearing wind direction, synoptic con-

ditions, and the location and size of NO and SO_2 emission sources with respect to wind direction.

Acid rainfall events were observed to occur predominantly under the influence of onshore winds from an anticyclone (high pressure system) and the passage of cold fronts to a lesser degree, with winds from the S, SE or E quadrants.

A number of trends were observed following cation and anion analysis of rainfall. Firstly, NO_3^- and SO_4^{2-} levels were of similar order which suggests that both acids are equally important contaminants in this area.

Secondly, the NH_4^+ ion concentrations tended to be lower in acid events than in non-acid events throughout the area, a trend consistent with acid neutralisation by ammonia emissions. Thirdly, coastal sites displayed high Na^+ ion and SO_4^{2-} ion concentrations and high conductivities. This implies that at these sites the SO_4^{2-} was derived primarily from sea salt rather than being of anthropogenic origin. This could partially account for the non-acid rainfall often observed there.

The case episodes discussed in this article illustrate the wide range of factors which can influence the acidity of rainfall at any given site. It appears that the degree of acidification of any sample is the result of a complex inter-relationship of (a) spatial, (b) meteorological, and (c) chemical factors. That is, there is a strong case for the argument proposed (3) that many components of precipitation contribute to the eventual acidity. For example, even though the more acid chemicals such as HNO_3 and H_2SO_4 appear to be of greatest significance, other neutralising species such as NH_3 and carbonates also influence the final balance of rainfall acidity. Furthermore, meteorological parameters such as wind direction and pollution dispersion, rainfall amount and type, and prevailing synoptic conditions, and local meteorology (particularly down-valley winds) will appear to play some role in the final spatial expression of rainfall acidity.

Whilst no attempt was made to determine specific local or long-range pollutant sources, the results of this study certainly warrant further detailed analysis along these lines. Further research involving an extended network and examination of local wind and trajectory patterns in this region also appears to be justified.

ACKNOWLEDGEMENTS

The author wishes to thank all those who assisted during this study, with particular thanks to Mr. G. Avery, Prof. W.F. Pickering and Dr. H. Bridgman (for their support, encouragement and discussion), and Ms. M. Carlile for typing.

REFERENCES

1. Likens, G. E., Wright, R. F., Galloway, J. N. and Butler, T. J., Acid rain, *Sci. Amer.*, 241, 39 (1979).
2. Vermeulen, A. J., Acid precipitation in the Netherlands, *Environ. Sci. Tech.*, 12, 1017 (1978).
3. Hales, J.M., Precipitation chemistry investigations in the continental US, *Sci Total Environ.*, 16,1 (1980).
4. Eishout, R. J., Wiljeer, J. W. and Van Duuren, H., Sulfates and sulfuric acid in the atmosphere in the years 1971-1976 in the Netherlands, *Atmos. Environ.*, 12, 785-790 (1978).
5. Shaw, R. W., Acid precipitation in Atlantic Canada, *Environ. Sci. Tech.*, 13, 406 (1979).
6. Brezonik, P. L., Edgerton, E. S. and Hendry, C. D., Acid precipitation and sulfate deposition in Florida, *Science*, 208, 1027 (1980).
7. Galloway, J.N. and Whelpdale, D. M., An atmospheric sulfur budget for eastern North America, *Atmos. Environ.*, 14, 409 (1980).
8. Kramer, J. R., "Acid precipitation" in "Sulphur in the Environment Part I: The Atmospheric Cycle," pp. 325-371, John Wiley and Sons, NY (1978).
9. Dick, H. W., The Hunter Valley. Development or Indigestion?, *Current Affairs Bull.*, 58, 4 (1981).
10. Boyce, S. D. and Butcher, S. S., The effect of a local source on the composition of precipitation in South-Central Maine, *Water, Air and Soil Pollut.*, 6, 375 (1976).
11. Smith F. B. and Hunt, R. D., Meteorological aspects of the transport of pollution over long distances, *Atmos. Environ.*, 12, 461 (1978).
12. Liljestrand, H. M. and Morgan, J. J., Chemical composition of acid precipitation in Pasadena, California, *Environ. Sci. Tech.*, 12, 1271 (1978).
13. Oden, S., The acidity problem — an outline of concepts, *Water, Air and Soil Pollut.*, 6, 137 (1976).
14. Sembe, A., Measurement of acid precipitation in Norway, *Water, Air and Soil Pollut.*, 6, 231 (1976).
15. Raynor, G.S. and Hayes, J. V., Acidity and conductivity of precipitation on central Long Island, New York in relation to meteorological variables, *Water, Air and Soil Pollut.*, 15, 229 (1981).
16. Rodhe, H., Cruizen, P. and Vanderpol, A., Formation of sulfuric acid and nitric acid in the atmosphere during long-range transport, *Tellus*, 33, 132 (1981).
17. Hidy, G. M., Mueller, P.K. and Tong, E. Y., Spatial and temporal distributions of airborne sulfate in parts of the US, *Atmos. Environ.*, 12, 735 (1978).

BRANCH NEWS

The New South Wales Branch held two successful meetings in August and October. Dr. Greg Ayers of CSIRO gave us a fascinating insight into the physical and chemical complexities of the formation and deposition of acidity from the atmosphere. The "acid rain" field appears to hold just as many "mysteries" as "photochemical smog".

Dr. Graham Pearman, also of CSIRO, outlined for us an even broader picture of the fate and effect of air pollutants on a global scale. CSIRO is playing a leading part in the study of long-term global trends in pollutant levels and possible resulting weather modifications. Their scientists are making fundamental contributions as well as operating the base-line station at Cape Grim in Tasmania as part of a world-wide monitoring network. Lively discussion following Graham's talk ranged as far afield as the "nuclear winter."

The NSW Branch thanks both these scientists from Aspendale for their contributions to our programme for 1984.

HUYGLAS™ FILTER FABRIC

The First Fibreglass Felt for High Temperature Air Filtration.

Widely used in pulse jet fabric filters applied to coal fired boilers for the following reasons.

- HIGH TEMPERATURE RESISTANCE. CONTINUOUS 260°C SURGES TO 290°C
- ACID RESISTANT
- DIMENSIONAL STABILITY
- HIGH FILTRATION EFFICIENCY
- HIGH AIR TO CLOTH RATIO
- GOOD FILTER CAKE RELEASE AND RESISTANCE TO BLINDING

For more information contact Peter Schouten

Huyck Australia

Fellmongers Road, Breakwater, Geelong, Victoria 3219.
P.O. Box 757, Geelong, Victoria, Australia, 3220.
Ph: Geelong (052) 21 7011 Telex: 31373 Cable: "Huyck Geelong"

This brochure will tell you all about it.

EIGHTH INTERNATIONAL CLEAN AIR CONFERENCE

MEASUREMENT WORKSHOP

Report by David Horsman. The workshop was organized by Dr. Horsman and Mr. Len Ferrari.

The workshop discussions were divided into sessions on ambient air monitoring and source monitoring.

AMBIENT AIR MONITORING

Reference Methods

Methodology was seen to be quite well catered for by the work of the joint AEC/NHMRC committee which is about to publish a document entitled "Recommended Procedures for Monitoring Air Pollutants in the Environment, 1984 Revision". This document will refer to Australian Standards where possible for the detailed procedures which should be adopted for individual pollutants. SAA Committee CH19 — Methods for Examination of Air has developed methods for many of the common air pollutants:

- 2330 — 1980 Ambient Air — Determination of Hydrogen Sulfide — Automatic Intermittent Sampling — Gas Chromatographic Method.
2447 — 1981 Ambient Air — Determination of Oxides of Nitrogen — Chemiluminescent Method.
2509 — 1981 Ambient Air — Determination of Acid Gases (expressed as Sulfur Dioxide).
2521 — 1982 Ambient Air — Determination of Gaseous Pollutants — Definitions for Instruments and General Requirements.
2522 — 1982 Ambient Air — Preparation of Reference Test Atmospheres Containing Sulfur Dioxide, Using Permeation Tubes.
2523 — 1982 Ambient Air — Determination of Sulfur Dioxide — Direct-reading, Instrumental Method.
2524 — 1982 Ambient Air — Determination of Ozone — Direct Reading, Instrumental Method.
2573 — 1982 Ambient Air — Preparation and Use of Reference Test Atmospheres — Compressed Gas Method.

2618.1 — 1983 Ambient Air — Determination of Gaseous and Particulate Fluorides — Selective Ion Electrode Method.

Part 1 — Gaseous Fluorides and Acid — Soluble Particulate Fluorides ($1/\text{Lig}/\text{m}^3$ or greater) — Automated Double Paper Tape Sampling.

2618.2 — 1984 Ambient Air — Determination of Gaseous and Particulate Fluorides — Selective Ion Electrode Method.

Part 2 — Gaseous Fluorides and Acid — Soluble Particulate Fluorides ($0.1/\text{m}^3$ or greater) — Manual, Double Filter Paper Sampling.

2695 — 1984 Ambient Air — Determination of Carbon Monoxide — Direct — reading, Instrumental Method.

2724.3 — 1984 Ambient Air — Particulate Matter.

Part 3 — Determination of Total Suspended Particulates (TSP) — High Volume Sampler Gravimetric Method.
2724.1.-1984 Ambient Air — Particulate Matter.

Part 1 — Determination of Deposited Matter Expressed as Insoluble Solids, Ash, Combustible Matter, Soluble Solids and Total Solids.

It was considered that these methods should be used where possible to provide a common data base.

The manner in which the ambient air was sampled was raised in terms of manifold materials, residence times, laminar or turbulent flow. Where special precautions should be taken this should be addressed in the standard.

The problems in classifying the siting of monitoring stations/instruments (e.g. peak, neighborhood, rural) was raised as probably the most important feature affecting the comparison of data from different areas considering that most organisations were now using similar methods of measurement and calibration. It was agreed this aspect should be further investigated. SAA Committee CH19 has an approved work programme to draw up a standard for instrument siting.

Choice of instrumentation was raised and it was considered that it would be useful for a register to be compiled of instrument type, brand name, organisation and contact officer. Prospective purchasers of instruments could at least then be able to check on the performance of instruments as an aid to making their final decision. The Department of Home Affairs and Environment agreed to be the central point for receipt of this information and initial contact point for subsequent referral of enquiries. Organisations wishing to participate should send a list to Peter Cheng, Department of Home Affairs & Environment, PO Box 1252, Canberra City, ACT. 2601.

Quality Assurance

The value of interlab comparisons in helping to achieve a common data base was recognised. Various organisations had already been involved in comparisons relating to ozone, lead, carbon monoxide and hydrocarbons.

It was agreed that this should be extended to include sulfur dioxide and oxides of nitrogen. Details would be finalised between staff from various state regulatory organisations and the Department of Home Affairs & Environment.

Particulate Monitoring

The need for measurement of inhalable particulates, or more precisely PM₁₀, has led to a proliferation of instruments such as size selective inlets, medium flow samplers and dichotomous samplers. This highlighted the difficulties in achieving uniformity in measurement and subsequent comparison of data from various areas when different organisations were purchasing different instrumentation. The situation was compounded by the uncertainty of proposed US EPA standards and procedures.

Advantages and disadvantages of using the various instruments were discussed. The filter medium used for collection of the particulates received a deal of comment. In general, Teflon was considered the best but expensive, cellulose was good if chemical

characterization was to be carried out but care had to be taken with moisture content in gravimetric analysis. Quartz filters avoided the moisture problems but tended to disintegrate unless handled very carefully. A type of Teflon coated glass fibre filter for use in hi-vol samplers is being evaluated by EPA Victoria. The cost of these is not prohibitive at US \$140/100 filters.

Non-Methanic Hydrocarbon Measurement

It was agreed that these instruments were very difficult to keep operational for a variety of reasons. In Australia the Byron model NM301 is widely used.

Specific chromatographic problems were discussed with emphasis being placed on errors generated by variations of the tailing edge of the NMHC peak which were significant particularly when measuring low levels of hydrocarbons. This was noted to have several causes and therefore several remedies. These were:

1. Base line shift caused by leaks in the valve which varied on valve actuation and the solution was to first replace the valve seals and if the problem persisted to alter the carrier air restrictor to allow the same flow to be maintained at a lower pressure.

2. Electronic base line shift — due to faulty capacitors in the amplifier; this problem can be isolated by turning off the flame and determining if the problem persists i.e. a gradual ramp up of the base line during NMHC cycle.

3. Contamination of the system. This was found to be a general problem but no satisfactory answers were forthcoming to its solution.

The calibration of the instrument was also covered with particular attention to the non-linear relationship of the F.I.D. to carbon. The instruments are calibrated using propane and the response multiplied by 3 for expression of data in terms of carbon. Some organisations adjusted the final stage amplifier to enable a direct reading as carbon to be made. It was noted however that this factor was questionable and for some instruments a figure of 2.5 may apply. It was determined that all users are using the same basis for their calibrations (i.e. x 3) although the final results were being determined by different methods. The use of alternative instruments was discussed but it was generally agreed that the Byron NM 301 was the only instrument that was suitable.

It was noted that Byron Model 401 is now available which converts the non-methane hydrocarbons to CO then reduces to CH₄. As yet there was no Australian experience with this instrument but Division of Air Pollution Control, Qld. were about to purchase one of these units.

SOURCE MONITORING

This session dealt almost exclusively with uniformity of methods. It was noted that some sampling and analytical techniques employed in source monitoring were similar to those used in the Occupational Health

and Safety field. It was considered that a set of guidelines for source monitoring would be an appropriate starting point. The monitoring techniques used vary greatly, depending on the pollutant being measured and these guidelines should include such aspects as:

1. Sampling provisions, gas velocity and flow measurement.

2. Extractive sampling techniques (including isokinetic sampling) and laboratory analysis of the collected sample by accepted published methods.

3. Continuous sampling and measurement techniques, addressing such issues as gas sample conditioning from stack to analyser.

4. In-stack monitoring techniques.

Various State organisations in Australia have adopted, or are in the process of formulating, standard procedures covering some of the above aspects. Others have some aspects covered by regulations which would not be appropriate to amend in the short term. In addition the NSW Branch of the Clean Air Society has developed a Training Course and Handbook on Air Pollution Measurement which includes source monitoring techniques.

It was agreed that the State organisations would evaluate appropriate means for producing such guidelines possibly via the AEC Advisory Committee on Air Quality and SAA which are also concerned with standardizing procedures for ambient air quality monitoring as mentioned above.

ENVIRONMENTAL & INDUSTRIAL POLLUTION CONTROL

Stack, ambient & in-plant air testing
Analytical services
Air pollution control design
Occupational health and safety
Industrial noise and vibration



**Peter W. Stephenson
& Associates Pty. Ltd.**
(Incorporated in NSW)

Suite 4, 569 Pacific Highway
PO Box 88
Chatswood NSW 2067
Telephone (02)411 2114

STUDIES ON THE VARIATION IN DUST AND HEAVY METAL FALLOUT IN HOBART, TASMANIA, 1973-1977.

Sally A. Shepherd

This paper is based on a thesis which Sally Sheprerd submitted for an Honours Degree in Atmospheric Chemistry in the University of Tasmania. She is at present a graduate student in the Department of Geography, University of British Columbia, 217-1984 West Mall, Vancouver V6T 1W5.

ABSTRACT

A study was made of the spatial and temporal characteristics of dust and heavy metal fallout in the Hobart area. This involved analysing historical data on dust and heavy metal fallout for the period June 1973-May 1977. The results indicated a general annual trend in fallout with a summer maximum. The fallout pattern was shown to be a function of wind direction and the distance of the sampling site from the source. A significant decreasing trend in fallout was identified over the four year period. The main source of the fallout was identified as the stockpiles of the Electrolytic Zinc Company's metallurgical works at Risdon.

INTRODUCTION

Hobart, the capital city of Tasmania with a population of approximately 160,000 (1) is situated near the mouth of the Derwent Valley. It has a maritime climate with mild summers, cool winters and rainfall well distributed throughout the year. The main factors influencing Hobart's climate are the latitudinal position of the cyclone belt (2) and the strength of the westerly winds. The city's location and climate pose several distinct air pollution problems as the dispersion of air pollutants may be hindered by temperature inversions and katabatic winds when high pressure conditions prevail.

Some pioneering studies have been conducted in Hobart, on dust and heavy metal pollutants of the atmosphere (3-12). Studies on the spatial and temporal variations of dust and heavy metal fallout on a seasonal and yearly basis have been carried out (8,12) but no long term trends have yet been identified. Little work has been done to relate dust and heavy metal fallout levels to meteorological and other environmental parameters and to identify sources of pollution (7,8,11,12).

The availability of dust and heavy metal fallout data on a monthly basis (13) for the period June 1973 C May 1977 made possible more detailed statistical analysis of the dust and heavy metal fallout in Hobart for that period. Samples were taken in 5-L acid washed Pyrex bottles fitted with a 15 cm diameter glass funnel. The gauges were mounted 1-3 m. above the ground.

ANALYSIS

Various methods were used in the analysis of the historical data set. One method involved the use of the MICROMAP 2 computer programme, a 3 digital terrain model to gain a visual understanding of the spatial and temporal trends. The method showed how the dust and heavy metal fallout (hereafter referred to by the general term 'pollution' unless otherwise stated) varied over time along a transect of the Derwent Valley. The sites along the transect (see Figure 1) were chosen to take advantage of the directional flow of the predominant NW wind down the valley. The sites also included the Electrolytic Zinc Company's metallurgical works at Risdon which many believed to be the major source of pollutants under consideration (8, 11, 12). Sites within the city and residential areas were excluded to reduce to a minimum topographical channelling of the winds which would complicate the observed pollutant patterns.

Another more quantitative time series method employed was the Whittaker-Henderson curve-smoothing technique. This method reduced the random variations of the

individual data values due to site representatives, chemical analyses, etc. so that the underlying characteristics of the new data values could be highlighted. In analysing the data the monthly average of all 20 sampling sites in the Hobart area were used as no one site was considered truly representative of all the pollutants (72,74,75).

The Whittaker-Henderson formula, which is discussed in detail in the appendix of Spinis and Levin's paper (14) is based on the optimisation of a mathematical expression combining weighted measurements represented by a weighting parameter 'a' of smoothness and fit. In the present study values of 2 and 20 were selected for 'a' to represent the time series on a seasonal and long-term basis respectively. The significance of the long-term trends at the $a = 0.01$ level was also determined as discussed in (14).

The effects of various meteorological and environmental parameters which influence pollutant levels were determined by a third method involving the use of multiple linear regression equations.

The fourth and final method used was principal component analysis to identify the sources of pollutants. The computations were carried out using the principal component analysis programme from the Statistical Package for the Social Sciences (16). By means of orthogonal transformations this method rotated a set of intercorrelated variables into a set of independent, uncorrelated variables⁷). The first component accounted for the greatest possible proportion of the variance of the system, the second component the remaining residue and so on. Interpretation of components as sources were made from particular combinations of pollutants which had high loadings on the same component. Only those components which had eigenvalues greater than one were considered significant.

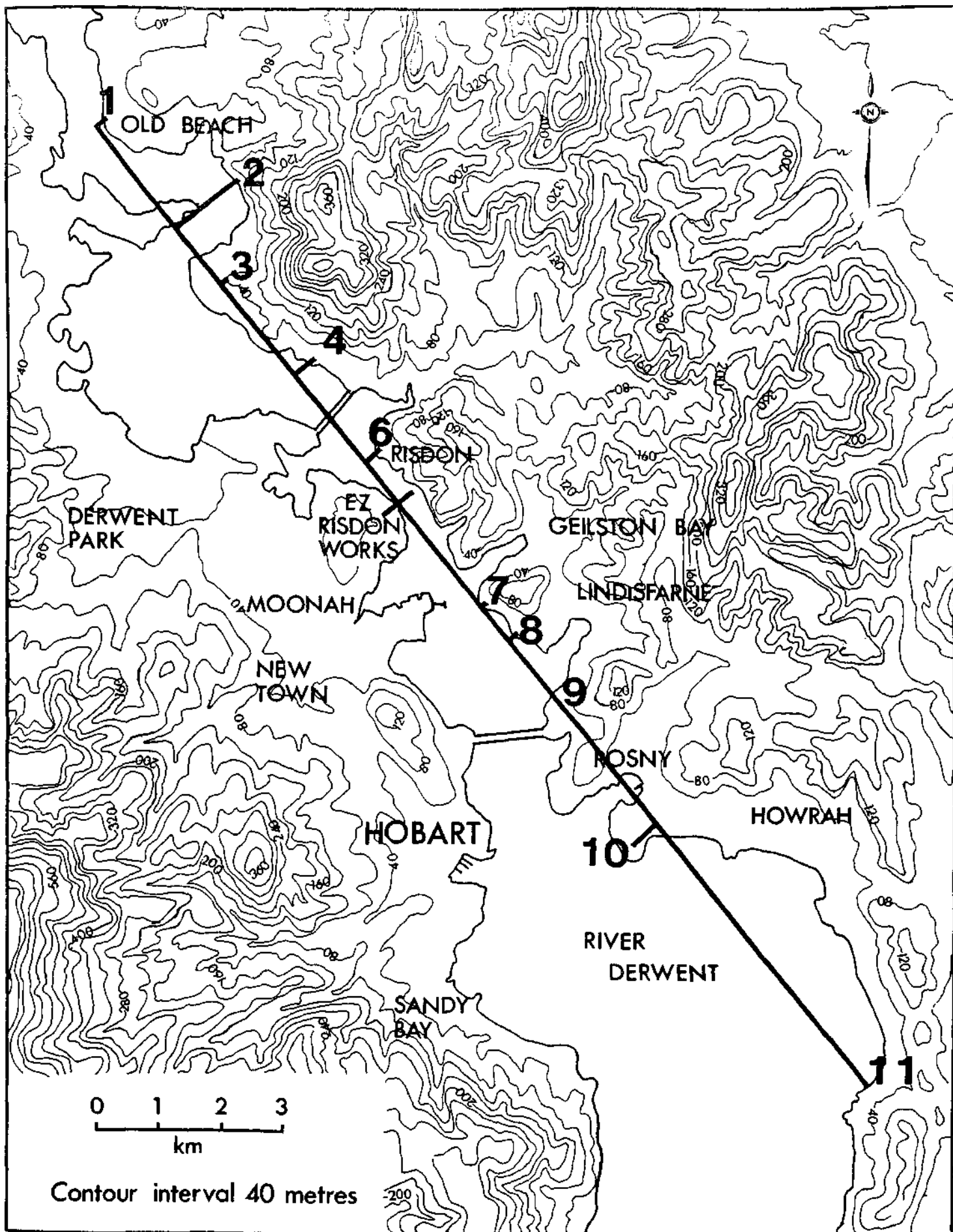


Figure 1. Base-line used for computer-drawn maps to determine distance of sites from the Risdon Works. The locations of the various sampling sites along the base-line are indicated by numbers.

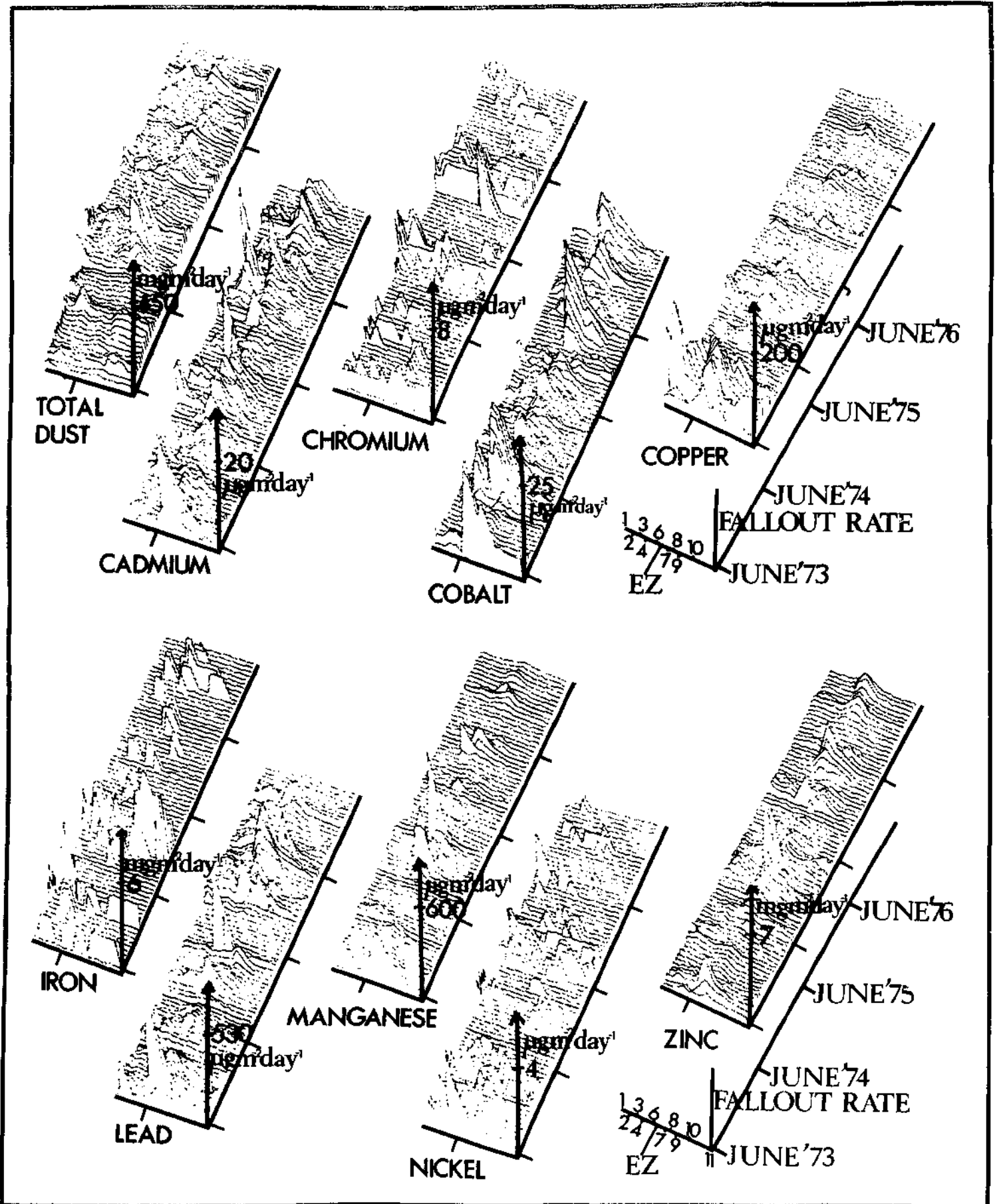


Figure 2. Computer-drawn maps showing spatial and temporal variations of dust and heavy metal fallout along the base-line.

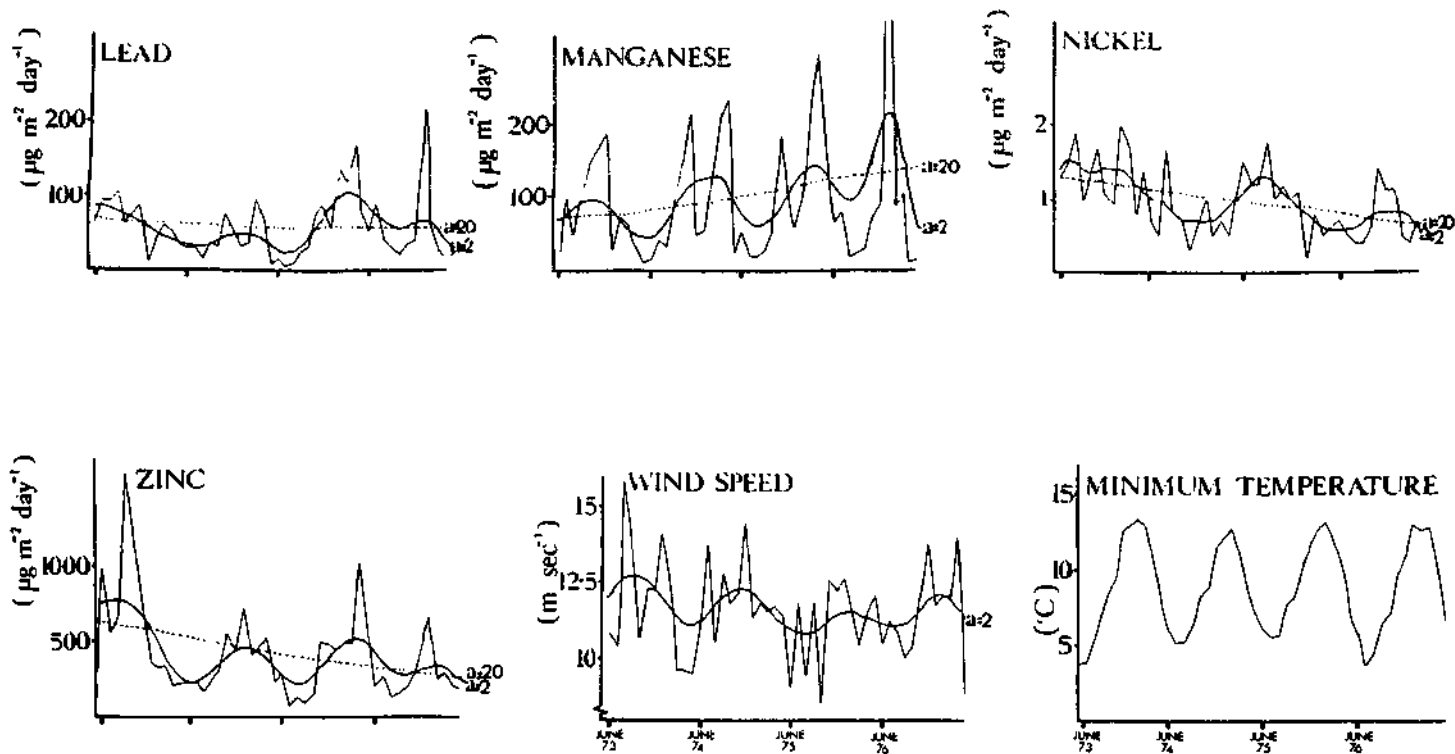
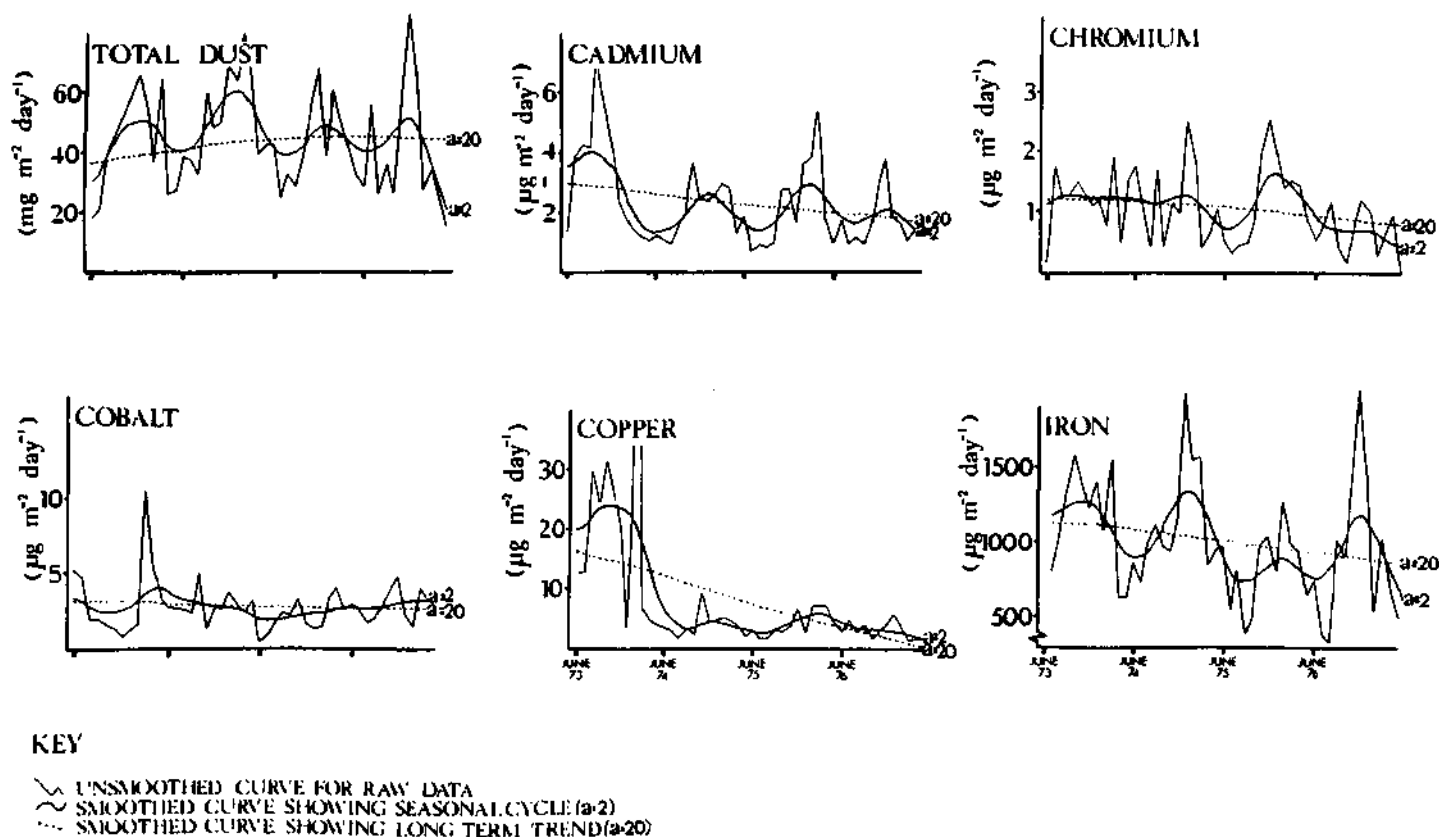


Figure 3. Seasonal patterns and long-term trends using composition values derived from all sites in metropolitan Hobart and its environs for total dust, cadmium, chromium, copper and iron fallout.



KEY

- UNSMOOTHED CURVE FOR RAW DATA
- - - SMOOTHED CURVE SHOWING SEASONAL CYCLE (a=2)
- ... SMOOTHED CURVE SHOWING LONG TERM TREND (a=20)

Figure 4. Seasonal patterns and long-term trends using composite values derived from all sites in metropolitan Hobart and its environs for lead, manganese, nickel and zinc fallout. The seasonal patterns for wind speed and temperature are also shown.

RESULTS AND DISCUSSION

Time Series and Regression Analysis

The results from the MICROMAP 2 computer programme (Figure 2), the curve-smoothing approach (Figures 3 and 4) and the regression analysis are summarised and discussed below.

(a) *Spatial Pattern*: The maximum fallout rate for all the pollutants except nickel and iron occurred around the Risdon works and decreased rapidly as distance from the Risdon works increased. The importance of distance decay in fallout rates was also illustrated by regression analysis. To reduce the effects such as wind channeling and winds associated with sea breezes, the data from the sites located along the transect in Figure 1 in the winter months were chosen in an attempt to make basic relationships more evident. Zinc fallout was used as the dependent variable in the regression analysis as it is a good indicator of emissions from the Risdon works (8,12). It was found that the natural logarithm of distance from the Risdon works accounted for 71 percent of the total variance in the zinc fallout rate. When other meteorological parameters of wind speed, temperature and rainfall-evaporation were included they only accounted for an extra 3 percent of the total variance. The results indicate the Risdon works is the likely source.

(b) *Seasonal Effects*: A distinct summer peak exists for all fallout pollutants with the exception of nickel and cobalt. This is in direct contrast to the results reported by Goodman et al. (6) which showed suspended particulate matter having a maximum in winter. Goodman et al. observed that concentrations of suspended particulates increased when the minimum temperature decreased and more specifically that levels of suspended zinc particulate matter increased if a temperature inversion occurred. This was not found in the analysis of zinc fallout levels in the present study as the minimum temperature explained only 3 percent of the total variance when the urban average was used. No accurate data were available on inversion heights for the four year period under study. The results, although of a preliminary nature, tend to suggest that fallout pollutant particles may not be influenced by the presence of inversions as they do not reach the same height as the suspended particulate matter due to their greater weight. Bloom and Noller (9) estimated that the majority of suspended particulate are found in the first 300m of the atmosphere whereas fallout is found in the layer very close to the ground.

(c) *Wind direction influence*: The position and number of peaks along the base-line (Figure 2) could be due to the different wind directions as suggested by Low (12). Regression analysis showed that when the frequency of N-WNW winds increased fallout rates decreased whereas the converse applied to the frequency of S-ESE winds, this may in part be attributed to the fact that when the winds are blowing from the S-ESE sector the pollutants are initially moving up the valley but in the evening with the onset of the katabatic winds the pollutants may then be transported back down the valley, become dispersed and fall out over the city. This would not happen to the same extent with winds from the N-WNW sector as the pollutants would tend to be blown downstream and out of the air-shed.

(d) *Longterm trends*: Each pollutant with the exception of total dust and manganese showed a significant decrease over the four years considered (Figures 3 and 4). This decreasing trend may, in part, be explained by the more effective control programmes which have been implemented by the Electrolytic Zinc Company since 1973 (Spencer, pers. comm.). One programme is to spray the stockpiles of residues and concentrates which contain various heavy metals with water during the summer to reduce the amount of dust becoming airborne. The decrease in lead is interesting as it implies that industrial sources must dominate car emissions, another major source, as the number of cars registered during the study period increased (18,19). The increase in total dust and manganese in comparison to the other pollutants can be attributed to their multiple sources. (11,12).

2. Source Information

To identify sources of pollutants in the Hobart area principal component analysis (PCA) was used. Since the PCA is derived from the correlation matrix, the matrix is reflected in PCA. For conciseness, only PCA is presented. Only components one and

two which had eigenvalues greater than one are discussed here. Hopke et al.

(20) point out there is no universally applicable method for establishing the eigenvalue cut-off value. The two components shown in Table 1 explain 44 percent of the total variance.

Component one, explaining 30 percent of the total variance, has high loadings for zinc, cadmium and lead and moderate to high loadings for chromium, manganese and nickel. The high correlation between zinc and cadmium can be explained as cadmium is usually present in sphalerite (zinc sulphide) because of isomorphous substitution of cadmium for zinc in the crystal lattices. Zinc sulphide is a major constituent of many of the stockpiles at the Risdon works (Spencer, pers. comm.). The other elements significantly loaded on component one are also found in the stockpiles at the Risdon works (see Table 2) indicating the works is the most likely source.

The second component which accounts for 14 percent of the total variance shows high loadings for total dust, nickel and chromium. These elements are found in various amounts in the local bedrock (21) as well as in the stockpiles at the Risdon works (see Table 2).

Table 1. Principal Component Matrix (unrotated) for Dust and Heavy Metal Fallout in Hobart and its Environs, 1973/74 to 1976/77.

Principal Component No.	1	2
Variance explained, percent	26.6	14.2
Total dust	0.41	0.67
Zinc	0.78	-0.24
Cobalt	0.56	-0.10
Cadmium	0.84	-0.30
Copper	0.25	0.05
Nickel	0.47	0.69
Lead	0.80	-0.32
Chromium	0.58	0.56
Manganese	0.62	-0.39
Iron	0.19	0.16

Table 1. Chemical Composition of the Risdon Works stockpiles (all results expressed as percentages by weight).

Type of Stockpile	Heavy Metals (Percent byweight)							
	Zinc	Cadmium	Lead	Copper	Cobalt	Iron	Manganese	Nickel
Broken Hill Concentrates	51.9	0.18	13	0.13	0.021	10.17	1.1	0.0014
Rosebery Concentrates	52.2	0.15	4.0	0.35	0.002	7.22	0.19	0.0004
Mt. Isa Concentrates	49.4	0.16	3.0	0.20	0.005	5.45	0.04	0.0006
Elura Concentrates	45.0	0.1	4.5	0.22	N.S.	15.5	N.S.	0.0005
Manganese Dioxide	1.95	0.0002	3.9	0.002	0.0025	0.01	42.3	0.0002
Calcine	56.0	0.18	2.7	0.24	0.011	9.35	0.59	0.0010
Primary Residue	22.4	0.28	6.0	0.24	0.023	29.3	2.2	0.0036

N.S. Not significant.

CONCLUSIONS

A historical data set spanning four years on fallout of dust and heavy metal pollutants in metropolitan Hobart was analysed. The analysis involved using a range of techniques and yielded useful information on air quality and helped pin-point sources of pollution. The following are the main findings.

(a) Various statistical and graphic techniques verified distinct seasonal patterns. Summer maxima were obtained for all the pollutants with the exception of cobalt and nickel.

(b) The statistical techniques verified a decrease in fallout rates for most of the pollutants over the four year period. This is probably due to tightening of environmental controls by government authorities.

(c) Principal component analysis indicated that the various stockpiles at the Risdon works were the main source of fallout in the study area. The pattern of fallout was found to be significantly correlated with wind direction and the distance of sampling sites from the sources.

ACKNOWLEDGEMENTS

I wish to thank the Department of the Environment and Bureau of Meteorology for providing the air quality data. Thanks are extended to Dr. M. Nunez and Mr. R. R. Shepherd for reading the draft of the paper. Mrs. Gill typed the manuscript.

REFERENCES

1. Cameron, R. J., Persons and Dwellings in Local Government Areas and Urban Centres, Tasmania, Australia Bureau of Statistics, Cat. No. 2406.0, (1982).
2. Langford, J., Weather and climate in J. L. Davies (Ed.) *Atlas of Tasmania*, Lands and Surveys Dept., Hobart, 2-11 (1965).
3. Bloom, H., Lewis, I. C. and Kishimoto, R., A study of lead concentration in blood of children (and some adults) of Southern Tasmania, *Med. J. Aus.*, 2, 275 (1974).
4. Bloom, H., Ayling, G. M., O'Brien, T. R. and Todd, J. J., An investigation of atmospheric lead particulates from motor vehicles, mining and other sources, 6th International Clean Air Conference, Clean Air Society of Australia and New Zealand, Brisbane, Australia (1978).
5. Noller, B. N. and Bloom, H., The determination of atmospheric particulate lead using low volume sampling and non-flame atomic absorption, *Atmos. Environ.*, 9, 505 (1975).
6. Noller, B. N. and Bloom, H., Sampling of metal air particulates for analysis of furnace atomic absorption spectrometry, *Anal. Chem.*, 49, 346 (1977).
7. Noller, B. N. and Bloom, H., The application of graphite furnace absorption spectrometry to the determination of metals in air particulates, *Clean Air (Aust.)*, 14, 9 (1980).
8. Goodman, H. S., Noller, B. N., Pearman, G. I. and Bloom, H., The heavy metal composition of atmospheric particulates in Hobart, Tasmania, *Clean Air (Aust.)*, 10, 38 (1976).

9. Bloom, H. and Noller, B. N., Application of trace analysis techniques to the study of atmospheric metal particulates, in "Symposium on Analytical Techniques for the Determination of Air Pollutants," p. 98, Clean Air Society of Australia and New Zealand, Melbourne (1977).
10. Noller, B. N., and Bloom, H. and Arnold, A. P., Sampling and analysis of metals in atmospheric particulates by graphite atomic absorption spectrometry, *Prog. Anal. At. Spectrosc.*, 4, 181 (1981).
11. Ayling, G. M. and Bloom, H., Heavy metal analyses to characterise and estimate distribution of heavy metals in dust fallout, *Atmos. Environ.*, 10, 61 (1976).
12. Low, P. S., Dust and heavy metals fallout in Hobart and its environs, Tasmania — A summary of 8-year monitoring data, *Clean Air (Aust.)*, 17, 3 (1983).
13. Department of the Environment — unpublished data.
14. Spirtas, R. and Levin, H. J., Patterns and trends in levels of suspended particulate matter, *J. Air Pollut. Control Assoc.*, 21, 329 (1971).
15. Weisman, B., Matheson, D. H. and Hirt, M., Air pollution survey for Hamilton, Ontario, *Atmos. Environ.*, 3, 11 (1969).
16. Nie, N. H., Hull, C. H., Jenkins, J. G., Steinbrenner, K. and Bent, D. H., *Statistical Package for the Social Sciences*, McGraw-Hill Inc., 2nd Ed. (1975).
17. Henry, R. C. and Hidy, G. M., Multivariate analysis of particulate sulfate and other air quality variables by principle components — Part I. Annual data from Los Angeles and New York, *Atmos. Environ.*, 13, 1581 (1979).
18. Australian Bureau of Statistics, Motor Vehicle Registration — Tasmania, 1973-1974 (1974).
19. Australian Bureau of Statistics, Motor Vehicle Registration — Tasmania, 1977-1978 (1978).
20. Hopke, P. K., Gladney, E. S., Gordon, G. E., Zoller, W. H. and Jones, A. G., The use of multivariate analysis to identify sources of selected elements in the Boston urban aerosol, *Atmos. Environ.*, 10, 1015 (1976).
21. Tiller, K. G., The distribution of trace elements during differentiation of the Mt. Wellington dolerite sill, *Pap. Proc. R. Soc. Tasmania*, 93, 153 (1959).

PERSONAL

Mr. Bernard Collins of 5 Bourke St., Melton South, Victoria 3338, has left the Environment Protection Authority — Victoria and set up as an independent consultant specialising in vehicle emissions, emission control programmes, and fuel and emission inventories.

Dr. Allen E. Gale P.O. Box 234, North Adelaide 5006, has been appointed a consulting editor to *the International Journal of Biometeorology*.

SAA NEWS

Particulate Lead in Air

Lead poisoning has long been recognized as a disease of specific chemical aetiology. The syndrome is characterized by clinical conditions, including anaemia, acute abdominal colic, acute and chronic encephalopathy and peripheral neuropathy (nervous disorder). Most of the lead compounds we ingest or inhale emanate from motor vehicle exhausts although some contribution can be made by industrial processes (lead smelting, lead recovery).

Committee CH/19 — has prepared an analytical method for the determination of particulate lead in ambient air. The sample is collected using a high volume sampler (AS 2724.3). Air is drawn through the sample and particulate matter including lead compounds are deposited on the filter. The filter is removed; steeped in nitric acid and any lead present allowed to leach from the filter pores. On dilution, the sample is then aspirated into an atomic absorption flame and the concentration of lead determined by comparison with known aqueous lead standards. The method is amenable to most lead compounds, however lead in its organic forms is not effectively collected by the high volume sample procedure.

CH/19: Methods for Examination of Air

Chairman: Mr. J. O'Heare

Exec. Officer: Terry Flynn (Sydney)

Reprinted with permission from *The Australian Standard* Vol. 5, p. 12, July 1984.

OVERSEAS NEWS

APCA Transactions

The American Air Pollution Control Association (APCA) has published in book form the first of a series of *Transactions*. Entitled "The Meteorology of Acid Deposition", it includes reviewed papers by US and Canadian authorities on transport and deposition processes presented at an APCA meeting held in October 1983. It covers such topics as interpretation of field studies, vertical transport and mixing, scavenging processes, long range transport and dispersion; model application and verification. Price to APCA members US \$25.00; non-members US \$35.00. Mail orders to APCA Publications Department, PO Box 2861, Pittsburgh PA 15230.

CONFERENCES AND COURSES

University of Melbourne Environmental Engineering

Prospective candidates for the multidisciplinary Master's degree course in Environmental Engineering are advised that applications for this course close on 25 January 1985. The course can be taken part-time (3 years) or full-time (1 year), and offers elective streams in Air Pollution, Water Resources Engineering, Solid/Liquid Wastes, Traffic Engineering, and Industrial Hygiene including Noise and Vibration. Applicants should have an undergraduate degree in either science or engineering. Prospective candidates are advised that the Faculty has proposed to the University that entry to this course be biennial. If this proposal is accepted, applications will not be called for again until 1987. Further information and application forms can be obtained from the

Course Coordinator, Dr S. J. Mainwaring, Faculty of Engineering, University of Melbourne, Parkville, Victoria 3052. Telephone (03) 341 6879 or 341 6876.

EDITOR

Applications are invited for the position of Editor for the *Proceedings of the 7th World Clean Air Congress*, to be held in Sydney, 25-29 August, 1986. Provisional duties include:

1. Receive all proposals for papers.
2. Acknowledge their receipt.
3. Pass them on to Programme Sub-committee.
4. Advise successful proposers and issue author's and typist's instructions.
5. Remind accepted authors of official deadline and ask for definition to any delay.

6. Receive papers from authors and pass on to reviewers with detailed instructions. These should include editing.
7. Return reviewer's comments to authors with detailed instructions as to any changes.
8. In case a reviewer rejects a paper, arrange through Publication Committee for a second reviewer.
9. Carefully inspect all papers for conformity with instructions.
10. Have any short-comings corrected by authors.
11. Collate all papers for printer.
12. Pass on to printer and make sure printer reforms.

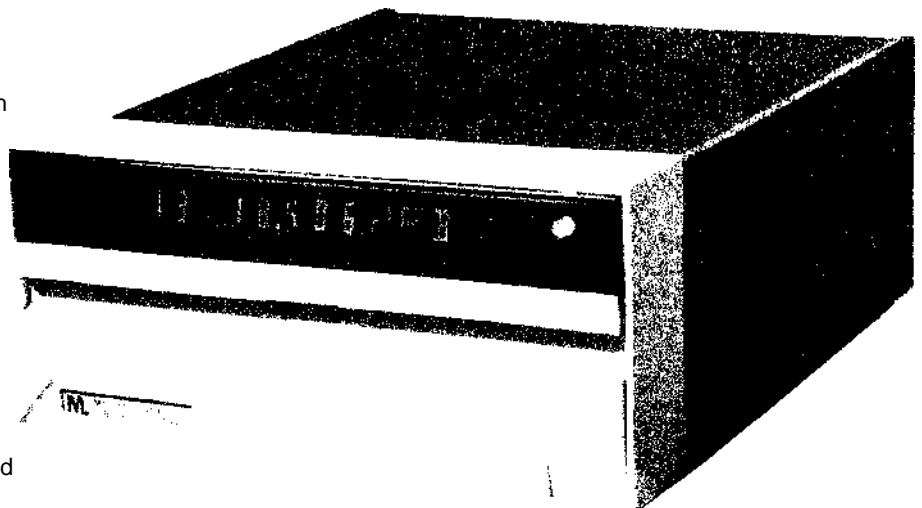
The Editor will also be involved in the design of the volume(s) and selection of the printer.

It is envisaged that a contract will be negotiated after discussion with the selected person.

Please apply to the Secretary, including a current Curriculum Vitae and other pertinent information, by 28 February 1985.

ENVIROLOGGER THE LATEST AND MOST ADVANCED DATA ACQUISITION SYSTEM

- Local or remote Span/Zero Calibration control.
- Stand alone or remote Telemetry Operation.
- Two selectable averaging periods with Vector or Scaler Treatment of Wind data. Automatic calculation of standard deviation.
- Mains or battery powered with auto-power fail recovery.
- Digital I/O for status, events calibration, controls Hi-Vol samplers etc.
- Configuration via built in keyboard or remote via Rs 232. English language programming with menu questions and answers.



ECOTECH Pty

AIR POLLUTION MONITORING IS OUR BUSINESS. FOR FURTHER INFORMATION CONTACT ROBERT DAL SASSO,
P.O. BOX 202, BULLEEN 3105. PHONE 03-439-5222, 03-439-5639 OR TELEX AA-31604.

Esso. Getting on with the neighbours.

It was back in 1967 Esso first discovered oil in Bass Strait. Vital oil that Australia needed.

But the question was raised about the effect on marine life in the area. How would it be affected?

Would the seals, for instance, move away?

A lot of people thought they

would. But the seals felt differently. The water around the platform fast became their new home, the seal population and other marine life continue to multiply healthily.

This is because the Esso/BHP platforms themselves attract a variety of marine life and the seals are taking advantage of this.

In fact the platforms are virtually reefs of steel.

The oil in Bass Strait is needed by all of us. The seals need Bass Strait.

It's good to know that Esso and BHP have shown that oil production and the environment can live happily together.



Energy for Australia