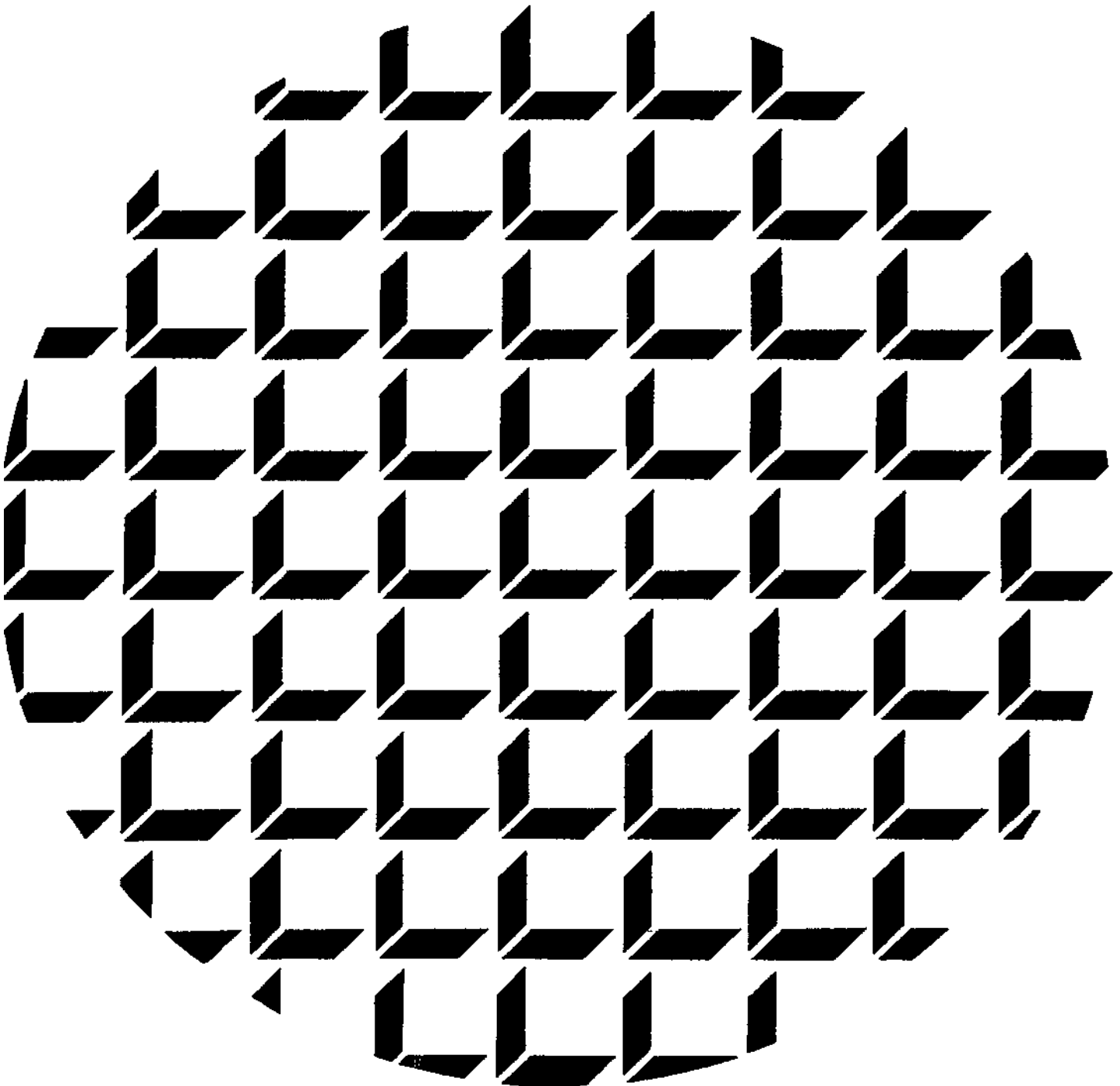


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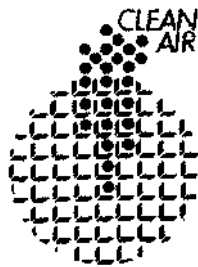
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GUEST EDITORIAL

HORSES FOR COURSES IN THE SCIENCE POLICY RACE

G.B. Tucker

One of the objectives of the New Cooperative (Scientific) Research Centres in Australia is to take maximum advantage of skills already resident in different institutions and to focus these on particular problem areas. Yet currently accepted distinctive scientific roles of university, government department, national research institute and industry laboratory have become quite blurred. Until we rediscover that different types of institution have different principal functions, scientific research will continue in the amorphous mould into which it has been pressed in an attempt to take a short cut to a high technology future. If the different primary functions of different institutions are once again recognised and fostered, the new Centres could prove an effective way to utilise these different skills. But, at present, research funds are not always channelled into areas which provide the best value for money.

Let's look at the history of institutions in science.

From the Middle Ages until the early 17th century, scientific thought was largely confined to monastic orders and somewhat painfully developed in universities which, of course, derived from The Church. The flowering of scientific ideas later in that century owed much to independent means and patronage, and was largely outside or at least peripheral to universities. Nevertheless the two principal scientific institutions at that time were The Church and universities.

In the 18th century the twin influences of agriculture and engineering development began to be felt. The Church withdrew from the scene as the rational and empirical approach to knowledge gained intellectual ascendancy. The social prerequisites for an acceleration in the scientific process developed rapidly: finance, leisure, freedom of thought untrammelled by mystical dogma and opportunities to travel and exchange ideas.

But in the 19th century the big change occurred: an appreciation that the application of science and technology meant wealth and power. The new players entered the game: industry and government; and by the beginning of the 20th century the large scale employment of scientists and the sizeable laboratories, now an accepted feature of both, began to be established. Today private philanthropy and natural philosophers of independent means have virtually vanished. The large formal 'research institute' has become regarded as the appropriate environment for scientific research, replacing the lone investigator; it provides an environment of close collaborators that cannot be matched by universities. Emphasis has shifted from the independent intellectual, pursuing knowledge for its own sake in a context of maximum freedom, to a team directed along profitable lines. Research is increasingly justified by its potential value to the economy rather than by the intrinsic value of knowledge.

Of course, a research laboratory set up within a specific industry to create new marketable products is not ideally conducive to a free exchange of ideas. Industries are essentially competitive, and it is hardly in the interest of shareholders for funds to be spent on strategic research that stands to benefit society as a whole and competitors as much as the industry spending the money.

Universities have always existed primarily to cultivate the next generation of bright young people. They have also acquired associated activities: to be custodians of acquired knowledge and to undertake curiosity motivated research as part of the training process. But in a recent Ockham's Razor radio talk. Professor Don Aitken argued that it is not obviously true that the teaching is the right environment in which to do high quality research, and that for the most part the idea of an inalienable link between teaching and research is a figment of the imagination. Indeed a preoccupation with research is likely to comprise teaching standards - a sometimes neglected requirement for academics. Hence perhaps the development of 'research schools' in some universities which do not seem to teach research technique but rather have the character of a research institute, though maybe less tightly programmed and somewhat less directly accountable.

The government role can be thought of in three parts: to obtain and collate scientific advice for the relevant Minister and to implement science policy, to provide an essential scientific service where this is otherwise unobtainable and to sponsor strategic research institutions. These functions are quite different in type. Indeed the modern trend in several countries is towards making the operational scientific service organisation a quasi-autonomous, largely self-funding executive agency. Maintaining a scientific service certainly demands different skills from undertaking strategic research. The institutional requirements are quite different, each needing its own infrastructure for procedures, management, encouragement and accountability. The flexible management necessary for progressive research is not consistent with sustaining the standard of routine operational performance required to provide a scientific service of consistently high quality.

Accordingly, I would argue that in the modern era in Australia, in terms of principal function (and funding), Universities exist to teach and, in selected specialist Research Schools, to undertake curiosity motivated research,

Industry Laboratories exist to develop new marketable products, ie to make money,

Government Departments exist to respond to ministerial requirements, and to provide an otherwise unobtainable scientific service - if this is to be

retained as a departmental role, and

Research Institutes exist to undertake strategic research, in order to provide the potential from which applications flow, and to ensure the transfer of knowledge and techniques for the national benefit.

We must recognise that there are horses for courses when we put our money on science.

Brian Tucker is Chief, CSIRO Division of Atmospheric Research. Private Bag No 1, Mordialloc, Vic 3195.

BRANCH NEWS

SOUTH AUSTRALIA

RETIREMENT OF ALEC SMITH

Alec Smith, Life Member of the Clean Air Society of Australia and New Zealand, retired on 18th October 1991 from his position of Manager, Air Quality Branch, Department of Environment and Planning.

Born in England, Alec migrated to South Australia with his wife and three children in 1968. In 1970 he joined the SA Health Department as head of the section controlling air pollution. He had one assistant. Since then he has played a major role in controlling air pollution in South Australia and has overseen the growth of the original two man section into the

present Air Quality Branch employing 17 officers.

South Australia's first air pollution legislation was largely formulated by Alec. His guiding philosophy was maintained in the Clean Air Act 1984 which updated and superseded the original legislation.

Alec also made a significant contribution to air pollution control in Australia through his influence on National committees. He is the longest serving member of National Committees concerned with motor vehicle emissions, representing SA on the Advisory Committee on Vehicle Emissions and Noise (ACVEN) and its predecessor on national policy COMVE. Also, he has been a member or deputy member of the NHMRC Air

Quality Committee for many years.

Alec was deeply involved in the formation of the SA Branch of CASANZ and its continued vitality. He was a committee member during the formative years of the Branch and subsequently actively supported the Branch and encouraged his officers to do likewise. In particular Alec and his officers contributed greatly to the success of the International Clean Air Conference held in Adelaide in 1981.

We wish Alec a long, healthy and happy retirement to follow his many interests.

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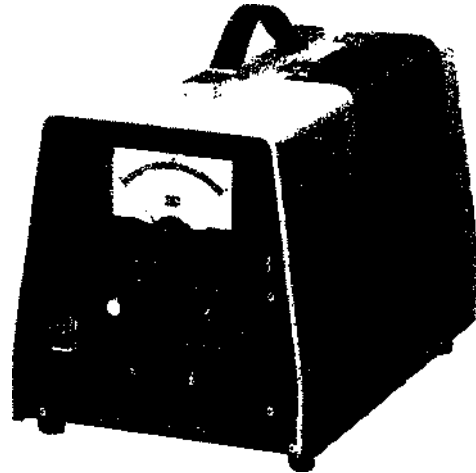
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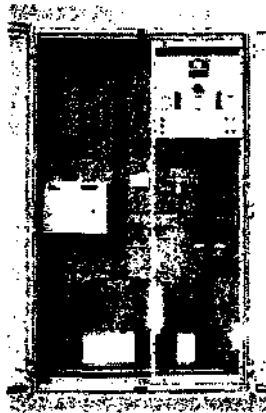
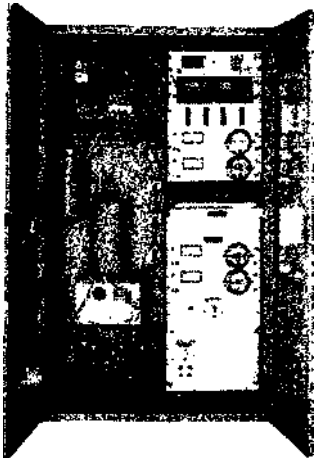
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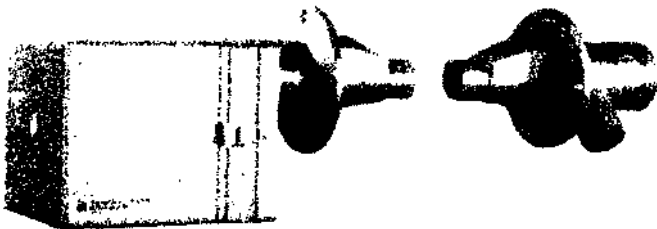
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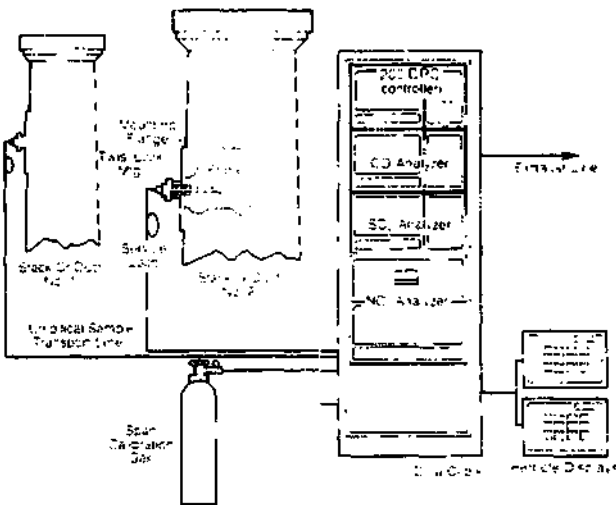
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DO YOU WANT A NEW NAME FOR THE SOCIETY?

At the Annual General Meeting held on 27th August 1991, it was resolved unanimously to move to Incorporation and, almost unanimously, to adopt a new Constitution. The new Constitution was designed to ensure that it met the requirements of the NSW Associations Incorporation Act, 1984 and the opportunity was taken to update and generally revise it.

During the many discussions which led to deciding the format of the new Constitution, there have been suggestions that the name of the Society be changed. Some of the components of a possible new name have merit, while others lacked it and no really suitable combination of ideas resulted. The name put forward at the Annual General Meeting (The Air Quality and Environment Association of Australia and New Zealand, Incorporated) did not receive sufficient support for it to be adopted.

It is clear that there are some strong feelings both for and against a change and there is a strongly-felt need for a further dispassionate discussion of the matter. The Annual General Meeting resolved that cases for and against any proposed change would be prepared and published in 'Clean Air'.

There seem to be two fundamental questions:

- Should the name be changed?
- If so, to what?

The following 'For' and 'Against' cases attempt to summarise the points to which consideration should be given during further discussions between Members, which may well lead to a plebiscite in which all Members would be encouraged to participate.

NO! - LEAVE THE SOCIETY'S NAME ALONE

The name 'The Clean Air Society of Australia and New Zealand' clearly expresses three important things about our Organisation:-

- Our principal aim - CLEAN AIR.
- The type of Organisation - A SOCIETY
- Our geographical sphere - AUSTRALIA AND NEW ZEALAND.

The statement that our principal aim is the achievement of clean air remains true, but does not inhibit us from taking an interest in an ever-widening range of subjects, such as waste disposal - after all we are showing an interest in waste disposal because of the influence of unsound disposal methods on the quality of the atmospheric environment.

Some would have us called an Association, which is defined as 'an organised body of persons'. A Society is more than that, the definition adds that these persons are 'united by a common aim or interest or principle'.

There is no substitute for the precise definition of where we operate - 'Australasia' is an outmoded word and, in any event, not well regarded in New Zealand.

The trend in names for Organisations is, if changing at all, not to change to something longer and not to change for the sake of changing - it is too easy to lose identity in a change. Failing a short, snappy name, it is vital to have a smooth, pronounceable acronym. CASANZ certainly fits that requirement and, indeed it is by that name that we are known throughout the world by virtue of our association with IUAPPA. CASANZ has become a nationally and internationally recognised body. Any name change will impact adversely on an image built up over 25 years.

With Incorporation, only our letterhead, of which stocks are low anyway, needs changing in the short term and then only by adding 'Inc'. In the event of a more significant change, widespread and costly changes will be needed, not the least of which will be to our well established and well regarded journal 'Clean Air'.

We have a well known, respected name with an easy acronym. Let's leave it that way!

A BRIEF STATEMENT OF THE CASE FOR A NEW NAME FOR THE CLEAN AIR SOCIETY

A society is an association of people united by a common aim or interest or principle (OED). Usually the name of the society reflects the interests of its members, eg 'The Society of Automotive Engineers', 'The Australian and New Zealand Association for the Advancement of Science', etc.

The latter half of the twentieth century has been a period of world-wide change. In developed countries it has been host to, the creation of new technologies, major advances in science and medicine, the discovery of new chemicals, the growth of populations and cities, and the adoption of large scale operation in manufacture and construction. The material advantages so gained have been accompanied by a range of social and environmental problems, many of them interrelated. Most people working in the environmental field now have responsibilities that finger out into a range of environmental considerations, rather than being confined solely to, air quality or to water quality, etc. This multi-discipline emphasis is reflected in tertiary undergraduate courses.

People employed in environmentally orientated occupations will be attracted to a broadly based society rather than that indicates its interest as 'Clean Air'. The US Air Pollution Control Association (the world's most powerful air pollution society) recognised this and changed its name to the 'Air and Waste Management Association'. It has been suggested that the International Union of Air Pollution Prevention Associations make a similar change of name.

(continued on page 10)

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We are concerned that the Society has been unable to maintain its membership over recent years, during a period of unprecedented growth in community and industry awareness of environmental issues. Most medium to large organisations now have environmental managers. Unfortunately only a small percentage are members of the Society. We have already lost one Branch (Tasmania) through lack of members, and the ACT Branch is having trouble filling executive positions. The current membership of some 800 people (and decreasing) is insufficient to maintain a healthy society, particularly in a large country like Australia where some Branches are geographically isolated. We believe that a larger membership is desirable and that this could be achieved if the Society was to broaden its interests and indicate this by a change of name. An increase in numbers, would revitalise the Society and provide more speakers at meetings and articles for the journal. The first stage of this process has already taken place with the broadened definition of the Society's aims and objectives in the recently amended Constitution, allowing scope for the examination of issues other than air quality. It is no surprise that some of the most successful technical meetings held by the Society in recent times have had a broader environmental emphasis. The main thrust of the Society's activities should still be on air pollution prevention.

Possible new names for the Society could be:

- 'Air Quality and Environment Association'
- 'Air and Waste Management Association'
- 'Air and Environmental Quality Association' etc

which would maintain the emphasis on air quality. A name change was discussed at the Clean Air Society Council meeting held on 11 and 12 March 1991 but was later rejected at the 1991 Annual General Meeting of the Society, during voting on the amended Constitution. The main arguments against its adoption appeared to be:

1. The Clean Air Society is well known and the Society would suffer a loss of identity if its name was changed.
2. The initials of the Society CASANZ provide an acronym that rolls off the tongue easily and the advantages of this would also be lost by a change of name.
3. The name change of the Air Pollution Control Association to 'Air and Waste Management Association' did not achieve the desired objectives.

In response we contend:

1. We suspect that the name of the Society is not as well known as some people would like to believe, and in any case this consideration did not stop the much more widely known US Air Pollution Control Association from changing its name.
2. We believe no great oral dexterity is required to make a reasonably harmonious sound out of the letters AQEA. or with the initials of any other name chosen with a little thought. Furthermore many societies function successfully without a racy acronym - try saying ACGIH (American Conference of Government Industrial Hygienists). or RACGP (Royal Australian College of General Practitioners).
3. The membership of the Air Pollution Control Association had been in decline. The name change to Air and Waste Management Association arrested this decline. Prior to the ballot for the name change the President of the Air Pollution Control Association wrote that "to ignore or disregard these gains (following the implementation of the waste management program) would be suicide and to not capitalise on these gains by taking the first step of changing the name would be foolhardy".

The arguments against a change of name are trivial compared with the need for an organisation's name to reflect the interest of its members or the purpose of its existence. We consider that members whose sole interest is air quality would not be adverse to the Society taking an interest in important national environmental issues and having them covered at meetings or in the journal.

In summary, a new name by being more relevant would attract new members, and would enable existing members with a range of environmental interests to make greater contributions to Society meetings and seminars. The Society could be revitalised and recover ground lost in recent years, and hopefully it would experience renewed member interest in running the Society and greater member participation on Branch Committees and Executives. It is unfortunate that the name Clean Air Society now stands as outdated as the 'International Association for the Prevention of Smoke', the original name of the Air and Waste Management Association during the period 1907-1915.

(Letters to Editor on this topic welcome — less than 300 words please).

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(Continued page 30)

A GOVERNMENT PERSPECTIVE ON AIR POLLUTION:

EPA VICTORIA - THE NEXT TWENTY YEARS

B ROBINSON, ENVIRONMENT PROTECTION AUTHORITY VICTORIA

(Speech presented at the EPA 20th Anniversary Seminar July 1991)

"Can you tell me please which way I should go from here?" asked Alice.

"That depends a good deal on where you want to get to" said the cat.

Deciding where we want to get to environmentally over the next twenty years is a quite an undertaking.

Here we are in the middle of one of the worst recessions we have seen for generations with long term structural problems in the economy, unable to constrain the increasing urban sprawl, but with increasing demands from the community for a cleaner and safer environment. Our rivers and bays, our beaches, our forests and alpine areas are in greater demand than they have ever been for both economic and recreational uses. We still believe in the quarter acre block, our right to drive wherever we choose, that more is better and bigger is best. In such a climate where do we start?

Perhaps with a vision.

Picture a Melbourne made up of a web of interconnected communities rather than an amorphous sprawl. Rapid transit systems connecting the communities together are integrated with each other and with private transport modes. Electric "shopping" cars provide local mobility while the family car has been in most cases replaced by a hire car for recreational travel.

Many people work from home communications terminals and many others work within their community village or in a neighbouring one. Manufacturing is located in related industry sectors in industry parks. Those processes that still produce significant quantities of waste are linked to recycling, reuse or waste exchange systems.

Energy efficient homes, many linked to energy sharing systems, provide for a more diverse range of lifestyles. Localised dewatering and purification provides water for gardens and other uses. The demands on sewer mains is also significantly reduced by the dewatering process and the absence of industrial wastes simplifies and protects final treatment plants. Sewage sludge is used for a variety of purposes and the residual treated effluent is fed through wetland systems providing additional habitats in urban and semi-urban areas.

Rural Victoria has been revitalised with significant decentralisation to Portland, Ballarat, Bendigo, Wangaratta and the Latrobe Valley. Improved irrigation practices, cleaner agriculture, land care and more

sensitive water management have allowed the rivers to recover and improved year round flows have led to ecosystem enrichment.

Extensive air and water monitoring networks across the State provide the community with a high level of confidence in its environment and the security of an effective early warning system.

If indeed we are seeking to achieve and sustain a future comparable to that how should EPA help us get there? A sustainable future can only be achieved with commitment from the whole community. No individual sector can bring it about alone. Indeed, it will only happen through collaboration and co-operation - through a genuine partnership.

EPA is primarily a regulatory agency, but regulation, while it may contribute, cannot of itself bring about such a partnership. Indeed, if inappropriately applied, it may hinder partnership development. Yet, as a society, we are not mature enough to move away from regulation as a means of discouraging unacceptable behaviour. So the regulatory role for EPA will remain an important one. The real challenge is to build an effective bridge to a new approach that will enable us to move towards a partnership model but still retain the comfort and security that all sectors derive from the certainty of regulation.

Waste minimisation and cleaner production provides us with the foundation for such a bridge. It will certainly dominate the thinking of environmental agencies in the 1990s. It is high on the agenda of environmental groups worldwide and has become a significant influence in many of the major international companies.

The European Chemical Industry Federation has published guidelines on waste minimisation. The Australian Manufacturing Council has produced a paper outlining international developments in this area and which could be the starting point for similar guidelines, and the chemical industry's responsible care program will provide a useful vehicle for spreading the word in that industry. International organisations such as UNEP and OECD have similarly taken up the challenge and in some areas are forcing the pace.

The recently announced "Better by Half" program brings waste minimisation squarely into the home and thence to Local Government. A fifty per cent reduction in waste going to landfill by the year 2000 presents us all with considerable challenges. This goal has been deliberately chosen to avoid a simplistic concentration solely on recycling of beverage containers. Consumer habits will need to change and our throw-away lifestyle thrown

away. This in turn will impact on the market place and help the drive for cleaner production based on life cycle product evaluations.

First of all we all need to come out of our bunkers. Partnership must be based on openness, frankness in recognising each other's legitimate roles and a willingness to collaborate.

From EPA's perspective we will continue to use a command and control approach to bread and butter issues. But in doing so we will be seeking to confine it to areas where it is both necessary and effective. Enforcement will be a part of that approach and this will undoubtedly cause tensions from time to time.

Our works approvals process will need to be more effectively integrated with the planning and other approvals processes such as dangerous goods controls. A one stop shop where all of these approvals could be brought together is often talked of but has not yet been effectively implemented. Works assessments will rely more heavily on risk analysis with more pressure being applied for clean technologies including consideration of greenhouse and energy performance. All aspects of waste production treatment and disposal (including to sewer or offsite) will be included.

Licences will be simplified and more flexible, reflecting much more the characteristics of an individual plant on the one hand and the responsibility for self-regulation on the other. Self-monitoring and environmental audits

will grow in importance. A single licence will control all aspects of a site and will incorporate the bubble concept for all wastes. All major sites will prepare an environment improvement plan. The over-riding criterion will be the best net environmental outcome.

Most of that is still on this side of the bridge. Although it includes a number of initiatives that will provide some of the bridge timbers. But the bridge needs to be built from both ends and effective self-regulation will prove essential construction materials.

Industry codes of practice perhaps with some form of built in sanctions, voluntary waste reduction plans for major companies and significant industry sectors, and sectoral agreements on technology or environmental performance objectives will all make important contributions. Solution sharing within the confines of competitive confidentiality is seen by many as essential and perhaps some honest scrutiny of the real need for so much confidentiality is warranted. Finally more openness with the public including candid environmental accounting in annual reports would go a long way to build trust.

On the other side of the bridge lies the world of co-operation and partnership. Its mechanisms replace the command and control approach with market based systems, incentives and collaboration.

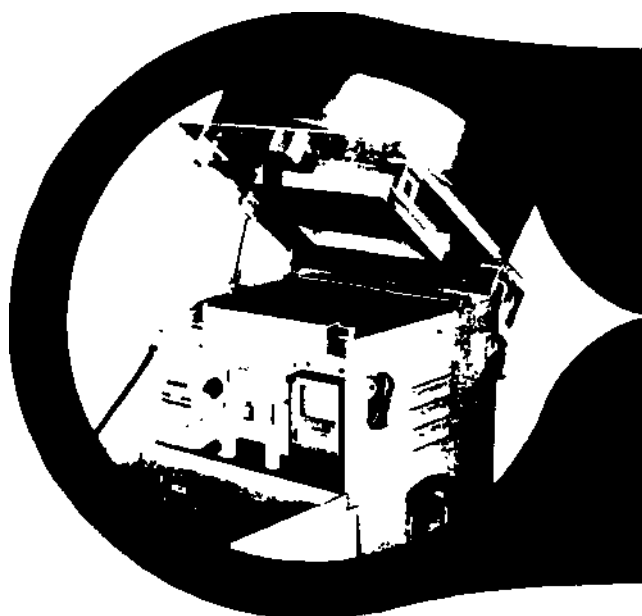
Much has been promised on market based systems over the past fifteen years or so but little delivered.



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Their superficial attractiveness on closer examination reveals a host of difficulties. Yet there is undoubtedly a place for them in the right conditions, but in applying them considerable caution is needed. After all when the all too imperfect financial market fails companies may well go to the wall. Should an environmental market fail species might well go to the wall.

Pressure for the development of market mechanisms in this area is growing as industry tries to come to grips with its environmental responsibilities while trying to avoid even more restrictive regulation. Governments too see the need simply because regulation is becoming no longer affordable. It is timely therefore to pool our resources and, notwithstanding the difficulties work together on evolving these new systems. Since they are too important to be left to the economists we need to ensure a broad spectrum of interests have input to such a process and it is my intention to try and establish a representative working group to explore the options as soon as possible.

Government assistance also has an important role to play on the other side of the bridge. EPA's clean technology incentive scheme is a good example, helping as it does small companies to make significant technological advances. However, many overseas countries provide even more encouragement through taxation incentives. Something which has not been effectively addressed in this country. While there has been some move in recent times to include environmental projects in various government grant schemes it has been slow in coming. The recently published review of environmental research in Australia has highlighted the conservative attitudes even in that area that have resulted in reduced effectiveness of environmental research funding.

Yet it is clear that in spite of the relatively high level of environmental concern in this country, industry in many other countries is taking a more adventurous approach seeing a changing world as providing new market opportunities. The international pressures that are already there will increase further with the UNCED conference in Brazil in 1992 and with the unified Euromarket in the same year. If we cannot rise to the challenge we will be left in recession both economically and environmentally since a sick economy has never provided the impetus for environmental progress.

Much of what needs to be done is best done at the national rather than at the individual State level. The ESD working groups, the Special Premiers Conference process and the proposed national EPA all provide mechanisms to help bring this about. However, the outcomes are still uncertain.

In the practical sense the national EPA would be expected to have the greatest significance for the EPA in Victoria and so we are particularly keen to see the shape of that body. We would prefer it to be a national standard setting and performance monitoring agency that would co-ordinate research and policy development and provide a truly national focus for environmental issues. We do not want simply a further layer of bureaucracy operating from the rarified atmosphere of Canberra on top of the already complex State

bureaucratic systems. Environmental protection is after all a very down to earth activity based in the real world.

So what should EPA's major priorities be for the next decade or two?

Clearly waste minimisation in a cradle to grave sense is top of the list. This will involve bringing about significant changes in attitude not only in industry but in the community and throughout Government.

Next we need to develop strategic management plans for our two major bread and butter areas the Melbourne air shed and the Port Phillip Bay catchment. These are two enormous tasks that EPA could not tackle alone.

Issues of urban development and urban re-development including infrastructure planning, traffic management, contaminated site clean up and development, and industrial land-use planning will become increasingly important as Melbourne and provincial cities develop further.

The ongoing issue of waste treatment and disposal with the special problems of hazardous waste and chemicals will be with us for some time yet.

Finally we need to look across that bridge and provide a real commitment to the development of a new approach - to a true partnership of all parties in reaching our environmental goals. I believe EPA can be the catalyst for this.

Brian Robinson is Chairman of the EPA Victoria, 477 Collins Street, Melbourne 3000

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Categories 1,4,6,7,8.

(Refer to May 1991 issue for category listing).

CHANGE OF ADDRESS

BASF Australia Limited is pleased to announce that from 18th November, 1991, its Australian Head Office and Distribution Centre for Victoria will be located at: 500 Princes Highway, Noble Park.

AN INDUSTRY PERSPECTIVE ON AIR POLLUTION: THE OPERATING ENVIRONMENT OF THE CHEMICAL INDUSTRY

R MICHELSON, AUSTRALIAN CHEMICAL INDUSTRY COUNCIL

A recent report entitled 'Toxic Maze' was produced by the Public Interest Advocacy Centre in New South Wales. The report identified that in New South Wales there are 72 separate pieces of legislation and 20 government departments which impact on the storage, handling and use of chemicals.

Publicity surrounding the release of this report last December concentrated on difficulties encountered by consumers when it comes to chemical regulation. In the several radio stories which covered the findings of the report, and in the broad press coverage received, we did not detect one reference to the fact that industry itself incurs enormous difficulties and costs in dealing with such a large number of government agencies, legislation and regulation. In fact, companies have to comply with separate government departments and legislation across state and territory boundaries within Australia, further complicating chemical laws in Australia as well as complying with an increasing body of Commonwealth chemicals legislation.

The Commonwealth itself has enacted 45 Acts governing chemicals while in Victoria there are 62 Acts and 25 government departments and agencies regulating the chemical industry. This count does not include Acts which simply have a reference to some aspect of chemical regulation. I could have manufactured a bigger number to boost my case but I chose to only count substantively relevant items. One hardly needs exaggeration to demonstrate this point.

The reference to this amount of legislation does not count regulations which are adopted by various Ministers of the Crown. Once one adds regulations of chemicals in Australia, the environmental framework becomes an enormous burden.

In our representations to governments around Australia, the chemical industry has insisted that we do not expect Australia to have weak regulations or regulations which compromise environmental protection. We are willing to comply with sensible and tough regulations. Our two objections are mainly the discrepancies in legislation between the States and the fact that legislation and regulation governing our activities has been in a state of constant change for the past five years. We object to the frequency of the rules being changed and the goal posts being moved.

A good starting point to achieve optimum environmental progress is some general acceptance of industry by interest groups and government. I recently read an Industry Commission information paper which attempted to provide an explanation of East Asian economic success. The IC came to the conclusion that the primary reason to explain the success of East Asian countries was a strong social consensus in favour of growth.

The three other major factors identified were the need

for an effective role for government to ensure that the basics of markets are in place and that the pleas of special interest groups are generally resisted: exploitation of the 'catch-up' factor in the use of modern technology and production methods, vigorous competition underpinned by a plentiful, flexible and competitive labour supply.

There is no such consensus for growth apparent in Australia. It might even be a fair statement that there is not much consensus which recognises the legitimacy of a chemical industry in Australia.

Working in the chemical industry can be like being the meat in the sandwich. On one side we have the generalist exponents of the need to value and add our primary products while on the other it is close to impossible to get permits to build new plants or upgrade existing plants.

The chemical industry is Australia's greatest value added industry.

Two real life and very recent examples of a uniquely obstructive Australian permit process come to mind.

It took 55 months to obtain the permits to build a sodium cyanide plant in Australia. The same plant took less than a year in the United States.

Also the construction of a polypropylene plant in Australia was delayed by 3 months because of one letter of objection. The letter was written in freehand by a woman who did not live locally but who wanted to see this urban industrial area turned into a nature reserve.

Despite common folklore, chemical plants are not built in residential areas. Usually it is rate hungry local councils that allow housing to encroach to unacceptably close proximity to chemical plants.

For another aspect of the difficulty encountered by our industry in coping with policy markets we need only look so far as Coode Island in Victoria.

The chemical industry seems isolated in its view that bulk liquid storage facilities should stay at Coode Island until such time that a safer and cost effective alternative can be found. Political leaders on both sides of the house in the Victorian Parliament have indicated their position that bulk liquid storage facilities at Coode Island should be moved.

The current Coode Island Review Panel inquiry, led by Mr John Landy, is concentrating on issues related to the selection of the most appropriate site for a major bulk liquid import, export terminal in Victoria. Even before the work of looking at selection criteria and prospective sites is underway, the opinion leaders seem to have come to various conclusions that Coode Island itself is not a viable option. Both the Premier, Mrs Kirner and the Opposition Leader in the Upper House. Mr Birrell, have said that bulk liquid storage facilities should

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move from Coode Island.

When I did my Bachelor of Business in Public Administration at RMIT a few years ago. I can quite distinctly remember the golden rule in decision making. The rule is that before you make a decision you consider all your options. As basic as this might appear it is being ignored in the siting of a facility that has been estimated to cost \$500 million and has a downstream effect of 9% of Victoria's employment and \$3.4 billion of Victorian manufacturing industry turnover. The reason appears to be that the Opposition can smell the prospect of winning seats in Melbourne's Western suburbs and so the race is on.

To balance the Coode Island perspective, the Phase 1 Report of the Coode Island Review Panel considered that the operations of the site were below 'best international practice'. In addition the report was quite scathing in its allegations against the terminal companies and also against the Victorian Government for inappropriate enforcement of regulations. There were almost 400 breaches of various regulations by terminal companies on the island. This resulted in 13 charges being made against the Powell Duffryn company.

The difficulty of the operating environment on Coode Island has been a classic example of bad policy making by government. For several years the government has sent conflicting signals as to the length of tenure of Coode Island as a bulk liquid storage facility. It is unreasonable to expect 'best international practice' at a facility which is 30 years old and for which terminal operators do not know whether their leases will run for 6 months or 25 years. How can anybody expect the international Boards of these companies to invest millions of dollars to gain best international practice in these capital intensive facilities if they may be told that they have to move out by the end of the year.

Yet, a perspective of the Coode Island safety record that is not made well known is that in its 30 years of operation with throughput of over 400,000 tonnes per annum, there has been no significant accident or incident at the site except for the alleged sabotage of August 21 and 22, 1991. The fires, which could have been close to the worst case scenario of Coode Island caused no injury, (although there was a degree of luck in this) and although the smoke plume was of low level toxicity, it was a PR person's doomsday. For example, the Flemington Tenants' Association earned major news coverage for their registration of health ailments that apparently occurred immediately after the Coode Island fire. Few people explained however, how the fumes from Coode Island managed to move against 20 knot winds to get to the Flemington Housing Commission flats.

A part of the short term measures to improve the safety of Coode Island developed by the Review Panel included efforts to reduce the inventory of chemicals on the Island. There were unprecedented efforts of cooperation between what are otherwise fiercely competing companies to reduce stocks and share tanks. After a series of arduous efforts, cooperation was achieved to reduce the average Coode Island inventory by some 15%. There have always been commercial incentives to reduce costly inventories, although the fire had prompted a new sense of urgency to further the rationalisation.

To give you an idea of what level of opposition the

chemical industry faces, the Cities of Melbourne, Footscray and Port Melbourne in their formal submission to the Coode Island Review Panel contended inventories should be reduced by 85% rather than 15% by December, 1992. Effectively, we are talking about a reduction of a 54,000 tonne average inventory to an 8,100 tonne inventory at Coode Island. When later questioned, the Councils indicated that a possible short term measure within the next twelve months would be to develop a greenfields site away from the port where material would be transported immediately from and to ships to eliminate most of the Coode Island inventory. It was left to the Chairman to indicate that a greenfields development of this nature would possibly cost in the region of \$500 to \$700 million. This lack of thought was consistent with the Councils' view that an appropriate buffer distance for bulk liquid storage facilities would be five kilometres. When questioned on the rationale for five kilometres the Melbourne City Council representatives answered that the Melbourne CBD was four kilometres from the Coode Island site.

The actual level of environmental regulation in Australia is not in itself overwhelming prohibitive compared to other advanced countries. The major factors affecting the viability of companies in Australia such as chemical companies are the world price of commodities, the cost of capital, the cost of capital equipment and machinery, service costs (which are artificially high in Australia because of the limited implementation of micro economic reforms) and factors of scale and distance from markets.

The chemical industry in Australia in fact works to set its own standards which can exceed existing environmental regulation in Australia as shown by our development of Responsible Care: A Public Commitment. Responsible Care is a program by the Australian Chemical Industry Council which entails the development of eight codes of practice, a National Community Advisory Panel and an audit program of companies. Those codes of practice include:

- Transportation
- Emergency Response and Community Awareness
- Waste Management
- Community Right to Know
- Warehousing and Storage
- Manufacturing and Process Safety
- Research and Development
- Generation and Transmittal of Hazard Information

The industry consults with representative community members around Australia to address issues that are of most concern to the community in regard to environmental preservation and other significant aspects of the industry's operations. No other industry has gone to the lengths that the chemical industry has to try and incorporate community concerns in their everyday operations. We have even changed our Articles of Association to make Responsible Care a condition of ACIC membership and to allow for expulsion in cases of non-compliance.

Other forms of opposition to the chemical industry come from organisation such as Greenpeace. We have approached Greenpeace on occasions and we have said: 'What do you want us to do to satisfy your objections?'. Other than to make general comments about moving to organic modes of production etc etc, they cannot give us any constructive tangible advice

as to how we should change our operations. They make it clear that they do not want to do this because it is not their role to do it.

So, our own operating environment is one where many people point the finger but that it is up to us to do the work. We take this responsibility and point to some of the extraordinary improvements in environmental care and environmental practices that have taken place. Such initiatives include Du Pont announcing that they aim to reduce all emissions and discharges from the plants to zero by the year 2000 and other major companies have talked about 50% reductions by the mid 1990s. There will be the continued task

of the chemical industry to work towards continued improvements in the environmental area and we welcome any real contribution to improve our processes from any groups external to the industry. Our Responsible Care philosophy shows that we have this approach as our role as chemical manufacturers.

Rudi Michelson is Public Affairs Manager, Australian Chemical Industry Council, GPO Box 1610M, Melbourne 3001.

A COMMUNITY PERSPECTIVE ON AIR POLLUTION: INDUSTRY'S NEAR NEIGHBOURS

C BLAIR, ALTONA ENVIRONMENT ACTION GROUP

This paper discusses community concerns about industry's environmental management and practice. It draws upon my experiences as a resident of Altona - a Melbourne suburb with an unusually high proportion of heavy industry. This includes a carbon black factory, an oil refinery, and the largest petrochemical complex in Australia.

The paper covers four main areas:-

- Community experience to date.
- Community expectations of industry and government.
- What 'responsible care' means in the eyes of the community.
- Environment improvement plans (EIPs) - the community role.

COMMUNITY EXPERIENCE

The relationship between industry and neighbouring communities has not been harmonious to date. Whilst more publicity is given to community action against industrial pollution these days, the issues are not of recent origin. Residents of Altona have experienced problems from the presence of heavy industries since they were established in the 1950s and 1960s. Many individuals and groups of residents have raised their concerns at various times but without a great deal of satisfaction. Community action groups are now more prevalent because of increased awareness of the environment, and because of the continuing negative experiences suffered by the community. We now have a community demanding the right to not have their lives polluted by the factory down the road.

There is a long list of unresolved community concerns that come to mind at the present time - for example:-

- Chemical storages in Kensington, Footscray and Yarraville (including Coode Island), close to residents.
- Laverton North and Dandenong Offensive Industrial Zones causing problems for nearby residential areas.
- Contaminated Sites eg Ardeer.
- Oil and chemical industry in Altona with the threat of expansion.
- A carbon black factory built on a site set aside

for a technical school despite strong local opposition.

COMMUNITY EXPECTATIONS

Community expectations are quite simple - to be able to live in a residential area without being subject to off-site effects from industrial activity.

Many people naturally assume that if the EPA licences a factory to discharge to atmosphere, then nearby residents will not be affected by that discharge. But in reality EPA licencing by itself is inadequate in protecting a community's environment.

There is no doubt that since the EPA was established in 1973, the situation for residents has improved markedly. But community standards have changed. People no longer accept pollution levels they previously endured. They demand that they no longer be ignored by government and industry. I believe that EPA standards will eventually reflect community concerns. However, the community sees the following problems in the present system:-

- The licencing system cannot cover every potential problem.
- Licencing can only achieve its objective when compliance is enforced. Rightly or wrongly the community perceives monitoring and enforcement by the Authority to be inadequate.

For example the community is extremely cynical when it discovers that EPA monitoring is to a large degree self assessment by industry. This issue needs to be seriously addressed by the State Government.

- Proper enforcement action must be taken against polluters, enforcement to date has left a lot to be desired.

The major constraints to effective enforcement appear to be a weak legislative framework combined with a lack of resources, which results in a disincentive to take enforcement action, particularly prosecution through the courts.

The fines currently being applied by the magistrates court are considered by many to be farcical. There have been major incidents in Altona, for example, a world record leakage of 670 tonnes of vinyl chloride monomer and an oil spill of 80,000 litres into Port Phillip Bay, threatening the lives of mangroves and wildlife, and killing fairy penguins. More recently there has been a major fire at a chemical storage depot at Coode Island.

The fines imposed were:-

- \$2000 for the first offence
- \$7000 for the second.

It is worth noting that the second of these offenders had received six good behaviour bonds before their first conviction.

Obviously something is wrong. The first step is to have legislation that reflects community concerns. There have been new provisions initiated recently, most notably EIPs and charges for reckless pollution. However, most environmental offences carry a fine of \$10,000. This low amount combined with the difficulty the EPA has in proceeding with a prosecution, doesn't provide a great enough deterrent. There should be minimum fines across the board, combined with a specialist legal body to hear environmental charges. The magistrates court is an inappropriate body to hear environmental offences. A 'Land and Environment Court' that has specialist knowledge is required to deal competently with these issues.

Environmental policing by the EPA is only one half of the government's role - the other is proper planning. We must realise that there are certain types of industry that are incompatible with residential uses. These particular industries will cause environmental problems for neighbouring residents even when operating according to their licences, for example, from excessive noise or from fugitive emissions.

In Altona the community is saddled with a planning disaster. An oil refinery and the largest petrochemical complex in Australia situated within 150 metres of large established residential areas. Offensive industries also cause problems for residents near Laverton North and Dandenong, where buffer zones are proving inadequate.

Disasters such as these occur through a lack of appreciation of how suburbs grow, lack of planning controls, and the absence of logical planning strategy. The responsibility for these mistakes rests with the State and Local Governments. Councils disregard proper planning because of their desire for an increased rate base.

The question of relocation often arises, either of industry or of residents. People in the community are realists. They are conscious of the employment question, as well as the practical problems that would be associated with relocation of any kind. Therefore.

relocation of industry is usually not seen by the community as a viable option, unless industry is creating an intolerable situation.

We need to recognise sensitive areas and develop appropriate strategies to deal with the problems caused by past bad planning. For example by fostering EIPs, good neighbourhood policies, and by EPA blitzes. But more importantly we need to learn from our mistakes and ensure that proper planning takes place in the future. Offensive industrial zones have no place near residential areas.

The message to Government is clear. The best way to reduce conflicts between industry and neighbouring residents is to have planning processes that ensure that industries with the potential for off-site environmental effects are established in areas where there is little chance of them affecting residential communities.

RESPONSIBLE CARE

I try to be optimistic about new programs or approaches that might improve the environmental performance of the Chemical Industry, as I believe them to be crucial. However, many in the community have expressed a great deal of scepticism about the Responsible Care program of the ACIC. I share some of this scepticism, because industry with a history of very poor performance is putting forward a 'bold new plan of self regulation'. I don't wish to discourage the industry from making a group effort to clean up its act. My major concern is that this may be a purely defensive action produced in the hope that it will deter the Government from imposing strict controls on the industry.

A key feature of the program is that the industry communicates improvements in performance by a company. Individual company managements will evaluate their own performance, and the ACIC states that commitment to the program will be ensured by peer pressure, executives comparing notes, and an internal audit every 18 months. I don't see this as a credible process, and have little faith in the measurement procedures.

The community has strong reservation about the structure and intent of Responsible Care. It is aware that it will be all too easy for the government to take the soft option, and rely on industry self-regulation when it is a government responsibility to provide a regulatory framework that will protect our environment.

ENVIRONMENT IMPROVEMENT PLANS (EIPs)

Communities are involved in EIPs through Community liaison committees (CLCs). EIPs are a new concept accompanied by legislative requirements. As to be expected with new processes, EIPs have been and continue to be a learning process for all involved. EIPs and the associated community consultation process are tremendously positive steps and provide a real opportunity for industry, government and residents to work together to improve the environmental performance of a particular industry.

Experience has shown that industry can have difficulty with 'working together'. Thus there has been a tendency to regard consulting with the community to consist of a glossy presentation of a new project, or presenting a document at a committee meeting and asking 'well, what do you think of our proposal?' To

be constructive, the residents should actively participate in the resolving of certain issues. Industry should not underestimate the ability of community members to provide competent ideas. Cooperation is more desirable than unproductive confrontation.

Companies might like to keep the following in mind when dealing with community liaison committees:-

- Don't be condescending to community representatives, even if they initially find it difficult to understand your operation.
- Be open with the committee, it will be appreciated.
- Operate on a 'right to know' basis rather than a 'need to know' basis.
- Do not provide an information overload.
- Ensure minutes etc are circulated well in advance of meetings.
- Ensure continuity, perhaps by having community representatives elected for twelve months.
- You cannot rely solely on word of mouth of the community representatives to communicate the existence of a CLC and its progress.
- Allow a resident, who makes a complaint to the EPA or Council, observer status at the next meeting.
- Make sure that resident representatives are chosen by the community, preferably at a public meeting.

- Ensure a rotating Chair.
- Finally, and without being facetious, there is no need to wine and dine residents before a CLC meeting. Residents want to get on with the work in hand.

To sum up, the community has now found its voice. It says to Government, protect us in our homes from danger, smells, noise, fallout, and emissions, through a properly equipped watchdog. It pleads with our leaders to recognise community problems, so that Government can plan properly for the future and we will all be better off. It urges industry to improve its performance and its communication with nearby residents. The environment belongs to us all, and if we can improve it, we can look forward to a future where communities don't have to endure off-site effects from industry.

We believe that EIPs and the community consultation process to be a positive step forward, and we will participate enthusiastically but watchfully, in the hope of a brighter future.

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Altona Environment Action Group
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SOLAR, ELECTRIC AND HYBRID POWER - PROSPECTS FOR FUTURE CARS

F.R. POUND, General Motors-Holden's Automotive Limited

ABSTRACT. Environmental concerns are driving policy makers in Australia and other countries to consider the potential benefits from alternative automotive fuels.

The potential for solar power and electric power for future cars is being explored by several vehicle manufacturers. Solar power is a possible alternative, but is seen as a longer term development. Electric power is another alternative that can be seen as a medium term development.

This paper outlines the programs that General Motors Corporation is involved with in development of solar cars and electric cars for the future.

INTRODUCTION

Two key factors driving the automotive industry through the 1990s and into the twenty first century are environmentalism and consumerism. (Pound 1990). Both are causes of our customers, the public. Their voice is loud and clear, and government certainly hears it. The automotive industry has heard the call and adopted a pro-active stance.

The need for change and a positive response to environmentalism has already been accepted by the automotive industry.

Some of the key environmental factors that will influence the future products of our industry are urban air quality, the greenhouse effect, ozone layer depletion and energy conservation.

On the consumerism front, the public seeks better quality in all products, minimum maintenance requirements, and faith and trust in the suppliers of the products they use.

Electricity has excellent long term potential to provide large reductions in greenhouse gases. This long term benefit requires that energy used by the car be derived from non-fossil fuel sources, like nuclear or some renewable energy resource for electricity. Currently there are not plans to change significantly the way electricity is generated, that is by burning coal.

SOLAR CAR TECHNOLOGY

The engineering and design philosophies embraced by General Motors in the development of the world record setting solar car, the Sun-



GM's electric car, Impact

raycer, certainly exhibited to the world that a solar powered car was a feasible product, (GMH 1990).

The GM Sunraycer, back in 1987 won the World Solar Challenge by crossing 3000 km of rugged Australian Terrain, finishing two days ahead of the nearest competitor.

Strictly speaking, the Sunraycer is an electric car, with electricity generated by the light of the sun.

A great deal was learned from the Sunraycer, especially in the approaches to vehicle efficiency and systems engineering.

While there is no short to medium term outlook for a production version of a solar car, much of the experience gained from the GM Sunraycer has been used in the design of an actual

battery powered electric car.

ELECTRIC CAR TECHNOLOGY

In 1990, General Motors released their electric car, Impact, providing solid evidence of GM's commitments to caring for its customers, caring for the environment and being the industry's technology leader.

With the introduction of the Impact, an electric car with acceleration performance that rivals cars powered by internal combustion engines and range capabilities suitable for most urban driver's daily needs, GM took another step ahead in electric vehicle technology.

The Impact powers past other electric vehicles, due to new devel-

opments in electronics, motor design, structural materials, tyres and batteries, coupled with careful attention to weight and aerodynamic and rolling design efficiencies.

General Motors has applied for several patents on various innovations in the car.

Rather than being converted from petrol to electric, Impact was specifically designed as an electric vehicle, (Ancker-Johnson and Schwochert 1990). Very importantly, its design intent has to meet all current US Federal Safety Standards for mass produced passenger cars. The vehicle includes heating and airconditioning as well as other driver and passenger conveniences. Impact also has one of the slipperiest drag coefficients ever recorded in the General Motors wind tunnel. These factors enable it to achieve a range of 200 km at average highway speeds of 90 kmh.

The Impact accelerates from 0 to 100 kmh in eight seconds and has a projected top speed of over 160 kmh. Actual top speed is limited at 120 kmh by an electronic revolutions limiter.

Developments in battery technology perhaps present the greatest challenge. The battery pack for the Impact consists of thirty two 10 volt lead-acid batteries which use gas recombination technology, allowing them to be sealed for life. Total battery weight is 395 kg and their energy capacity is 13.5 kWh. This battery design was selected for the Impact application because it is easily manufactured at a reasonable cost. However, major increases in battery life, energy storage capabilities and reduced cost are still desired to make electric vehicles more competitive with current petrol vehicles.

The motor drive electronics of the GM Impact delivers current to two AC induction motors which are coupled to the front wheels through planetary gear reduction units and conventional drive shafts. Considerable effort was devoted to achieving high efficiencies in motor and controls design and to minimising the friction losses in the mechanical systems.

HYBRID VEHICLE TECHNOLOGY

A final electric vehicle technology issue which deserves discussion is the comparison of the characteristics of a dedicated vehicle versus a Hybrid configuration. A dedicated

vehicle like the Impact, has the best emission characteristics; essentially zero emissions at the vehicle. However, the vehicle driving range limitations may raise customer acceptance concerns with some vehicle owners. An electric internal combustion engine Hybrid should reduce these customer acceptance concerns because it would be a more versatile vehicle. However, a Hybrid configuration brings with it some additional considerations. Since the vehicle would require the equivalent of two power plants, it would be more costly and complex than a dedicated vehicle. Combining an electric with an internal combustion engine would also bring back some of the internal combustion engine emission concerns.

General Motors have now developed a Hybrid vehicle called the HX3 (GMH 1991). It uses much of the same technology as the Impact, but it is not a substitute for it. Instead the HX3 is designed for a different duty cycle; more passengers and longer travel distances.

The HX3 uses both electric and internal combustion engines. Two electric motors provide city propulsion using a battery pack. For highway driving, a 900 cc auxiliary petrol engine is operating. It runs at a constant 2,500 rpm and has very low exhaust emissions.

SAFETY CONSIDERATIONS FOR ELECTRIC CARS

The safety engineering of electric vehicles, encompassing the application of motor vehicle safety standards, includes the same basic considerations which are currently given to our petrol vehicles. In a petrol vehicle, the engine is the most massive component in the propulsion system; in electric vehicles it is the battery pack. The major safety consideration for electric vehicles will be management of the battery pack during collisions. Location and mass of the battery pack must be comprehended during vehicle design to provide occupant protection during crashes at least comparable to that achievable in

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current petrol vehicles. New concerns regarding occupant exposure during crashes of stored electrical and chemical energy must also be considered in the final designs.

Since it is very important to manage the use of electrical energy in an electric vehicle like the GM Impact, heating, ventilating and air conditioning systems present an engineering challenge to the development of these vehicles. The challenges include the safety considerations associated with these systems.

CUSTOMER ACCEPTANCE

The most important factor surrounding the introduction of alternative fuel vehicles is customer acceptance of these vehicles. Many factors have an influence on the acceptability of alternative fuel vehicles in the market place. Some of the factors thought to be important are fuel costs and several vehicle utility issues.

FUEL COSTS

The operating costs of electric vehicles are influenced strongly by the state of battery technology. At the current state of battery development

and the type of customer usage that GM expects from the Impact, it is estimated that batteries would need replacement about every 32,000 km. When amortisation of the replacement battery packs is included in the fuel costs, the impact would cost about twice as much to operate as a petrol car. This estimated cost is highly dependent upon the replacement interval which in turn is influenced by driving habits. The electric vehicle fuel cost would be less than petrol if the replacement interval could be doubled as a result of technological improvements.

VEHICLE UTILITY

Vehicle performance, vehicle driving range, fuel availability and refuelling time are four factors that are expected to influence greatly the acceptability of alternative fuel vehicles.

VEHICLE PERFORMANCE

The 8.0 second 9-100 km/h performance of the Impact has already been described as superior to most vehicles and is expected to enhance its customer acceptability. Engineers associated with the development say

it is 'great fun' to drive, thus the Impact is expected to be highly attractive to driving enthusiasts.

VEHICLE DRIVING RANGE

The Impact has a 90 km/h maximum cruising range of 200 km, about one-fourth that of a comparable petrol vehicle. However, the range is significantly improved over previous experimental electric vehicles and is expected to meet the needs of many urban commuters.

FUEL AVAILABILITY

Electricity is generally available in locations where a commuter vehicle would be used. There have been suggestions of having specific parking areas with electric power meters available for recharging electric cars in central business districts.

REFUELLING TIME

Perhaps the most negative vehicle utility parameter of electric vehicles is the time it takes to recharge the batteries. Based upon available

(Continued page 44).

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BENZENE REDUCTION IN MOTOR SPIRIT

THE ISO/SAT PROCESS

i LSALUSINSZKY AND N.KRISKO, ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY

INTRODUCTION The Chemical Engineering Division of RMIT was expecting for several years, like many others, stricter limitations for benzene content of motor spirit. Several methods for benzene reduction were investigated but none looked industrially attractive. At the end of 1990 we tried a novel approach which resulted in the new ISO SAT process.

BENZENE IN MOTOR SPIRIT

The benzene content of most crude oils is very low. However, benzene is formed in several refinery operations. In most refineries the main source is catalytic reforming, a necessary step in producing the high quality motor spirit required by modern automotive engines.

For petrochemical use specially produced 'reformate' is the raw material for the important aromatic solvents: benzene, toluene and xylenes (BTX). However, there is a limited world market for BTX and it is well supplied.

Of the three main components of the aromatics in 'reformate' only benzene is highly carcinogenic. Accordingly, by international agreement, benzene concentration in motor spirits is limited to 5 vol %. This limit is readily met by most oil refineries. In the USA, where most refineries have relatively lower catalytic reforming capacities than refineries in other parts of the world, average benzene content of motor spirit is 1.5 to 2 vol%.

Even this lower benzene content is now considered unsatisfactory and the November, 1990 US Clean Air Act requires a reduction to 1 vol % in 'non-attainment areas' by 1995. 'Non-attainment areas' are the regions where the present EPA air quality requirements are not met. They include most American cities and consume about 75% of the nation's motor spirit demand.

BENZENE DISTRIBUTION

The 'reformate' used as blendstock in motor spirit contains 6 to 8 vol % of benzene. By fractionation it can be concentrated in the lower boiling one-third of 'reformate' leaving most of the toluene, which is a high quality component and non-carcinogenic, in the 'heavy reformate'. The 'light reformate' contains about 20% of benzene, further concentration would be expensive.

BENZENE SATURATION

In the petrochemical industry pure benzene is saturated, that is hydrogenated, to cyclohexane which is the raw material in the production of nylon.

Benzene is hydrogenated in the presence of a metal catalyst, usually nickel. As shown in Figure 1 in the hydrogenation reaction, methylcyclopentane (a contaminant in nylon manufacture) can be formed along with cyclohexane. In order to minimise its formation usually an additional processing step is required and the hydrogenation reactions is carried on at relatively low temperature.

On the other hand if benzene were hydrogenated for engine fuel, methylcyclopentane is in fact the preferred product. In the engine both components perform equally but the lower density of methylcyclopentane means that hydrogenation of benzene results in a larger volume gain. In spite of its low density methylcyclopentane provides higher energy output than benzene (Table 1) because in the reaction high energy hydrogen is added to the molecule.

The above indicates that benzene saturation for engine fuel use by the above process would be simpler than conventional practice, but it was unknown whether the reaction could be carried out when benzene was diluted with other hydrocarbons as in 'light reformate'. To clarify this question we built a small hydrogenation plant (capacity up to half litre per hour) and an Australian oil refinery assisted by providing 'light reformate'. We established that with a suitable catalyst benzene content can be reduced well below 1 vol%.

ISOMERISATION

As an engine fuel, benzene has a high octane number and its removal could affect engine performance. 'Light reformate' would be particularly affected because it contains other low-octane components, namely normal paraffins.

Normal paraffins are also present in light naphtha, a crude oil distillation product used in motor spirit blending. Since the phasing out of lead additives used

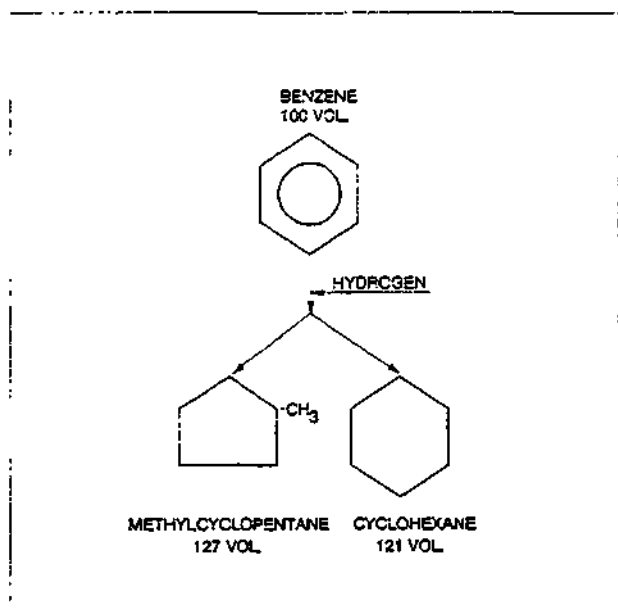


FIGURE 1.
Hydrogenation of Benzene

TABLE 1.
Heat of Combustion of Key Components

COMPONENT	HEAT OF COMBUSTION		
	KJ/mole	KJ/litre (net)	KJ/kg
Benzene	3,170	25,900	40,600
Cyclohexane	3,690	34,360	43,860
Methylcyclopentane	3,700	33,190	44,050
Hexane (avg.)	3,960	29,640	44,910

for octane number improvement, most oil refineries have difficulties accommodating the normal paraffins in the motor spirit mix.

Normal paraffins can be converted to their higher performance isomers (iso-paraffins) and many oil refineries have built or are building 'isomerisation' units. These units use platinum containing catalysts and operate under similar conditions as applied in the hydrogenation of 'light reformate'.

To make use of the potential for octane number improvement a second reactor was coupled to the hydrogenation reactor. As expected, a shift from normal paraffins to isoparaffins occurs in the effluent from the hydrogenation reactor.

INDUSTRIAL APPLICATION

The ISO/SAT process comprises three main steps (Figure 2):

- (i) Splitting the reformate into light and heavy reformate;
- (ii) hydrogenating the benzene in the light reformate to a mixture of cyclohexane and methylcyclopentane and
- (iii) partial isomerisation of the normal paraffins.

When the processed 'light reformate' is remixed with the 'heavy reformate' the product shows 3 to 5% volume increase and to 2 points of octane improvement. Benzene content is well below 1 vol%. The lower than specified benzene content is of importance because

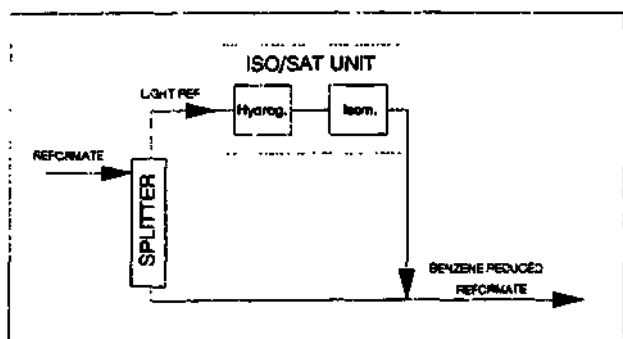


FIGURE 2.
ISO/SAT Process Flowsheet

the USA Clear. Air Act permits the trading of 'benzene credits' with other oil refineries unable to meet the strict benzene limits

MARKETING

The hydrogenation pilot plant was started up in April, 1991. The isomerisation reactor was added a couple of months later, so experiments for establishing optimum operating conditions are still in progress. But we have started market exploration in parallel to the investigation.

At the World Petroleum Congress in October, 1991, in Buenos Aires we presented a poster together with Engelhard Corporation, an American company well known in the oil industry as process licensor and catalyst manufacturer. An agreement between Technisearch, the business arm of RMIT, and Engelhard has been discussed at a visit to New Jersey and a two visits to Melbourne by Engelhard experts.

Nearer to home an Australian refinery is studying the proposal for constructing an ISO SAT plant. With perseverance - and some luck - we hope that within a few years ISO SAT will be established as a conventional step in environmentally acceptable motor spirit production.

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QUANTITATIVE HEALTH RISK ASSESSMENT

G. J. SMITH

ENVIRONMENTAL SCIENCE UNIT, SHIRE OF SUTHERLAND.

INTRODUCTION

Environmental regulatory agencies worldwide have traditionally used 'end-of-pipe' strategies to minimise environmental pollution. These have frequently proven ineffective in satisfying society's demands to identify and minimize human health impacts of pollutants. Disagreements exist over the standards for environmental contaminants because societal, and often regulatory agency, perceptions of priorities may differ from priorities ranked by strict scientific analysis (Reilly 1991). The approach is currently being replaced in the United States, and in Australia and elsewhere, by Health Risk Assessment. This fundamentally involves combining an estimation of the toxicity or hazard-potential of a given pollutant with an estimate of the likely human exposure or intake for any given situation. The strategy aims to prioritize pollutants based on the relative human health impacts. In this way, the most dangerous matters may be dealt with more urgently within a framework of limited financial resources. The Health Risk Assessment also allows scientific consideration of the options available to minimize health impacts for any particular pollution situation or development.

This article considers the approach taken by the United States Environmental Protection Agency (USEPA), which has a highly formalized risk assessment procedure (Figure 1). The structured nature of the USEPA system, and its reliance on inherently conservative (safer) assumptions during risk assessment, have important advantages both when uncertainties exist in toxicity or exposure measures, and in communicating risk to the end-user.

RISK ASSESSMENT

The USEPA defines 'risk assessment' as the characterization of potential adverse health effects of human exposures to environmental hazards. Risk assessment includes: description of the potential adverse health effects based on the evaluation of results of epidemiologic, clinical, toxicologic and environmental research; extrapolation from those results to predict the type and to estimate the extent of health effects in humans under given conditions of exposure; judgements as to the number and characteristics of persons exposed at various intensities and durations; and summary judgements on the existence and overall magnitude of the public health problem. Risk assessment also includes characterization of the 'uncertainties' inherent in the process of inferring risk.

Several clearly defined steps in risk assessment can be identified:

'Hazard Identification' is the process of determining whether exposure to an agent can cause an increase in the incidence of a health condition (cancer, birth defects, etc). It involves characterizing the nature and strength of the evidence of causation. Because cancer causation is not often (USEPA 1989) a clear yes-no situation with respect to humans, some carcinogenic activities are stated as the ability of the agent to cause cancer in laboratory animals or other test systems.

'Dose-response Assessment' characterizes the relationship between the dose of a given agent and the incidence of an adverse health effect in exposed populations, and estimates the incidence of the effect as a function of human exposure to the agent. It takes account of intensive exposure, age pattern of exposure,

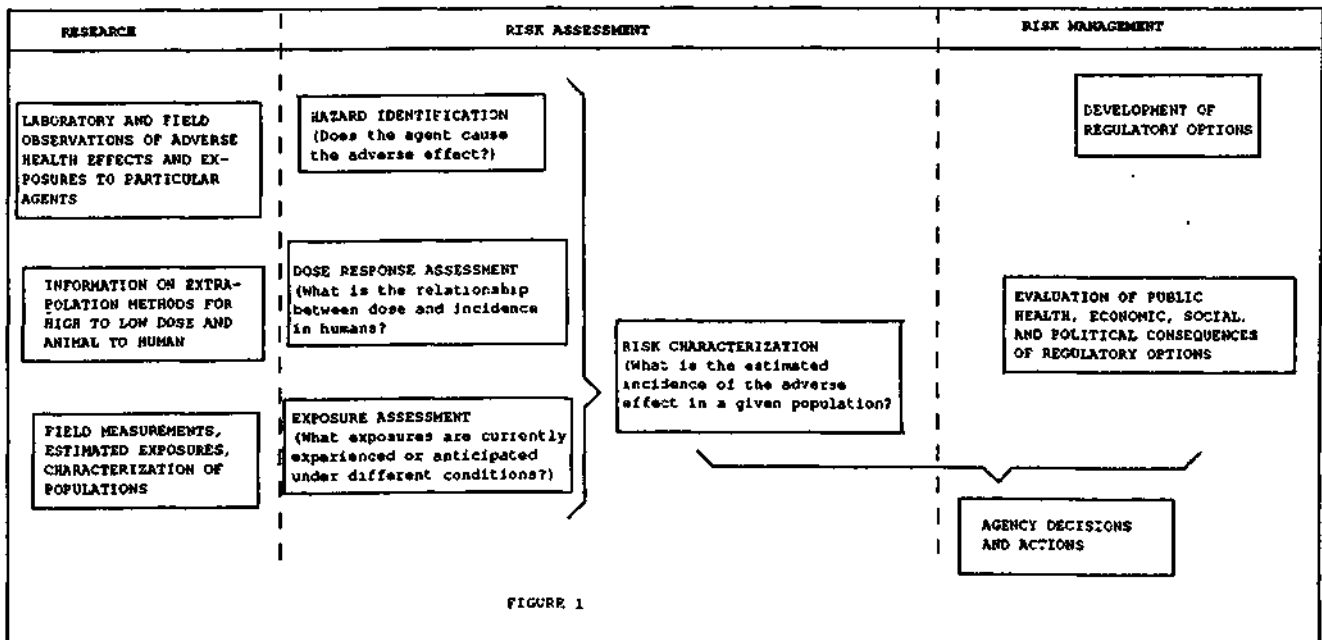


FIGURE 1

and other potentially important variables such as sex, lifestyle and modifying factors. Extrapolation from high to low dose and extrapolation from animals to humans is often required. Such extrapolations must be justified and uncertainties characterized.

'Exposure Assessment' is the measurement of estimation of the intensity, frequency and duration of human exposures to an agent currently existing or of exposures which might arise. It describes the magnitude, duration, and route of exposure as well as the size, nature and classes of human populations exposed. It also should include consideration of uncertainties in all estimates. Exposure assessment is an important tool in considering control options and predicting the effects of available control technologies in exposure, and in assessing the utility of land use planning methodologies in minimizing human exposures.

Exposure is the contact of humans with the chemical or agent of interest. The degree of exposure is defined by measuring or estimating the amount of the chemical available for absorption during a given period of time. Accurate and representative estimates of human exposure can often be the rate-limiting step in risk analysis, particularly as not all pollutants which contact humans will be bio-available or absorbed. Studies can be based on field-measurements or can be estimates obtained using dispersion modelling (or both). Exposure assessments should include consideration of the physical and chemical aspects, the nature of potentially exposed populations and the exposure pathways for each given scenario. A quantitative summation approach is generally required for complex multi-chemical examples.

'Risk characterization' is the summation of the risk assessment and exposure assessment, to determine estimated health impacts for the given pollution scenario. The assumptions, estimates of uncertainty and scientific judgements used throughout, should also be presented. Risk characterization serves as a basis for 'risk management' decisions (see below).

CANCER TOXICITY

Hazard identification consists of a review of relevant biological and chemical information on whether an agent poses a specific hazard. Sometimes there is enough information for the qualitative evidence to be combined into a formal weight-of-evidence determination (in other words, it is possible to make clear decisions about toxic effects). In carcinogen risk assessment, the information evaluated would desirably include: physical chemical properties and routes and patterns of exposure: structure/activity relationships; metabolic and pharmacokinetic data; the influence of other toxicologic effects; short-term tests; long-term animal studies; and human studies. Once these data are reviewed, the animal and human data are each divided into groups by degree of evidence as being; sufficient evidence of carcinogenicity; limited evidence of carcinogenicity; inadequate evidence of carcinogenicity; no data available; or no evidence of carcinogenicity. The animal and human evidence is then combined into a weight-of evidence classification scheme similar to the one developed by the International Agency for Research on Cancer. More weight is given in this scheme to human evidence when it is available (Figure 2). The USEPA scheme includes the following groups:

- Group A - A Human Carcinogen
- Group B - A Probable Human Carcinogen
- Group C - A Possible Human Carcinogen
- Group D - Not Classifiable as to Human Carcinogenicity
- Group E - Evidence of Non-carcinogenicity towards Humans.

In the absence of human epidemiological data, it is appropriate to rely on data from experimental animal systems, as long as the limitations of using these alternatives are clearly stated. This may require a large number of in vitro and in vivo tests.

In the dose response part of an evaluation, given that the chemical is a known or probable human carcinogen, a toxicity value that defines quantitatively the relationship between dose and response (the 'slope factor') is calculated.

The slope factor is an upper-bound estimate of the probability of a tumour response per unit intake of a chemical over a lifetime. It is used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen.

In deriving slope factors, the available information about a chemical is evaluated and an appropriate data set is selected. Human data of high quality are preferable to animal data. For animal data, the species that responds most similarly to humans (with respect to factors such as metabolism, physiology, and pharmacokinetics) is preferred. When no clear choice is possible, the most sensitive species is given the greatest emphasis.

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen.

The slope factor converts estimated daily intakes averaged over a lifetime of exposure, directly to incremental risk of an individual developing cancer. Because relatively low intakes are most likely from environmental exposures, it generally can be assumed

HUMAN EVIDENCE	ANIMAL EVIDENCE				
	SUFFICIENT	LIMITED	INADEQUATE	NO DATA	EVIDENCE OF NO EFFECT
SUFFICIENT	A	A	A	A	A
LIMITED	B1	B1	B1	B1	B1
INADEQUATE	B2	C	D	D	D
NO DATA	B2	C	D	D	E
EVIDENCE OF NO EFFECT	B2	C	D	D	E

FIGURE 2

that the dose-response relationship will be linear in the low-dose portion of the multistage model dose-response curve. Under this assumption, the slope factor is a constant, and risk will be directly related to intake. This linear low-dose equation is described (USEPA 1989) as:

LINEAR LOW-DOSE CANCER RISK EQUATION

$$\text{Risk} = \text{CDI} \times \text{SF}$$
$$\text{Risk} = \text{CDI} \times \text{F}$$

Where:

Risk = a unitless probability (eg, 2×10^{-6}) of an individual developing cancer,

CDI - chronic daily intake averaged over 70 years (mg kg-day): and

SF -- slope factor, expressed in (mg. kg-day)⁻¹.

NON-CANCER TOXICITY

A reference or Rf, is the toxicity value used most often in evaluating noncarcinogenic effects resulting from exposures. Various types of Rfs are available depending on the exposure route (oral or inhalation), the critical effect (developmental or other), and the length of exposure being evaluated (chronic, subchronic, or single event).

For example, an RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily oral exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Prior to the development of RfDs, noncarcinogenic effects of chronic exposures were evaluated using acceptable daily intakes (ADIs). While ADIs are similar in concept to RfDs, the latter have been derived using a more strictly defined methodology and represent the USEPA's preferred toxicity values. Furthermore, many chronic RfDs have been reviewed and verified by an intra-Agency RfD Workgroup; these verified RfDs represent an Agency consensus and are preferred over the RfDs that have not undergone such review.

In contrast to cancer risk, the potential for non-cancer toxicity in an individual is not expressed as the probability of an individual suffering an adverse effect. The USEPA does not at the present time use a probabilistic approach to estimating the potential for noncarcinogenic health effects. Instead, the potential for these effects is evaluated by comparing an exposure level over a specified time period (eg, lifetime) with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is called a 'hazard quotient' and is described (USEPA 1989) as:

NONCANCER HAZARD QUOTIENT

$$\text{Noncancer Hazard Quotient} = \text{E} / \text{RfD}$$

Where:

E = exposure level (or intake)

RfD = reference dose; and

E and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or shorter-term).

The noncancer hazard quotient assumes that there is a level of exposure (i.e., RfD) below which it is unlikely for even sensitive sub-populations to experience adverse health effects. If the exposure level (E) exceeds this threshold (i.e., if E/RfD exceeds unity), there may be concern for potential noncancer effects. As a rule, the greater the value of E/RfD above unity, the greater the level of concern.

Developmental toxicity assessments bring their own special requirements including consideration of the relevance of the route of entry of the chemical, timing in pregnancy of the exposure, and the effects of maternal influences.

REGULATION AND RISK

In the 1980s the USEPA moved towards a risk management risk reduction framework for making regulatory decisions. It was in 1976 that interim procedures and guidelines for health risk impact assessments of suspected carcinogens had been published. These included the EPA's approach to regulatory action for 'suspect carcinogens'. Regulatory action against chemical carcinogens was relatively new, dating from the late 1950s. It was becoming clear in 1976 that, despite the fact that many carcinogens could not be demonstrated to have a threshold below which they were not toxic, it would be socially and economically 'unacceptable' were risk to be totally eliminated by banning the agents (as had the Delaney Clause of the Pure Food and Drug Act, with respect to food additives which showed evidence of tumorigenic activity for humans and animals). The USEPA therefore tried to achieve a balancing of risks and benefits as the basis for final regulatory action.

There followed an attempt to determine whether an agent constituted a cancer risk and, secondly, what regulatory action, if any, should be taken to reduce that risk. It was at this time that the government agencies attempted to work closely with each other and with experts outside the government in the field of carcinogenicity in the development of government procedures and policies concerning cancer.

In 1983, the US National Research Council published 'Risk Assessment in the Federal Government; Managing the Process' (US National Research Council 1983). It considered, in the light of criticisms of the conduct and use of risk assessment by regulatory agencies to that time, whether alterations in institutional arrangements or procedures, particularly separating risk assessment from regulatory decision making and the use of uniform guidelines for inferring risk from scientific information, could improve Federal risk assessment activities. It also included a useful examination of the state of risk assessment and the regulatory environment in which it was performed.

The complexity and time-delay involved in obtaining accurate scientific information and applying it to risk assessment has been criticised from some quarters. Criticism has been forthcoming because, despite considerable effort, many risk factors contain uncertainty and may be misinterpreted by non-specialist users. Many factors have been derived for single-dose effects and do not take into account complexities with different doses. Nevertheless, hazard identification and dose-response assessment under the current guidelines represents a first attempt to define hazard, and use it, in plausible risk assessment methodologies.

The Risk Assessment Guidelines (USEPA 1986) are an effort to make risk assessment uniform and reliable across the USEPA. This is particularly important considering the diversity of programs undertaken at the Agency, including air and water pollution control, pesticide regulation, and, more recently, toxic substances and hazardous waste control.

The guidelines were formulated to ensure the quality and consistency of the risk assessment component of regulatory decisions. Agency-wide guidelines have been published for Carcinogenicity, Mutagenicity, Developmental Toxicity, Chemical Mixtures and Exposures. Initially, drafts were developed by agency-wide workgroups of scientists, these were then circulated to academics, other government agencies, industry and public interest groups i.e. wide peer review was obtained.

The guidelines are not regulations and are intentionally flexible in order to encourage the use of all data, and the appropriate scientific methods and judgements. These naturally change with increasing scientific knowledge about such things as toxicology and dose-response effects.

The guidelines influence the regulatory process by making EPA's risk assessments more consistent and of higher technical quality; familiarizing risk assessors throughout the country with the approach; and aiding experimenters who collect information which the USEPA would like to have available when conducting a risk assessment. The latter is clearly an important aspect at present, considering the relative lack of knowledge about certain types of toxicity, for example in carcinogenesis.

RISK DATABASES

An important tool in USEPA risk analysis has been the development of data-bases for use in risk assessment and other activities. This is aimed at combating concerns over quality assurance of hazard and risk evaluations, particularly where any 2 groups of scientists may develop different assessments. Several different Program Officers within the EPA had, in the past, developed RfDs and it became necessary to review all those which has been calculated to reconcile differences between conflicting values, and to make certain that they used appropriate information. Since 1985 such a review has been undertaken and over 200 RfDs have been approved for inclusion in the Agency's Integrated Risk Information System (IRIS). A similar review process is underway for carcinogen risk estimates, and over 50 chemicals are now on file.

IRIS is organised in a readily accessible electronic mail system on a chemical-by-chemical basis. Each item of information is reviewed for consistency and quality prior to entry to the system. IRIS collects information for a compound and constructs a file in which all numbers fit into a particular format. Information is provided by several ongoing efforts, each of which periodically supplies updated assessments and information to the central IRIS Management Unit. One effort contributes the reviewed RfDs referred to above, while a second does the same for the carcinogen reviews. In Australia, access to IRIS may be purchased via the National Library in Canberra, which is linked to the US National Library of Medicine via TOXNET. It should be emphasized, however, that accurate quantitative health risk analysis requires familiarity with limitations to the data.

RISK REVIEW

Risk Assessment guidelines do not exist in isolation. Several additional tools are used to make the US

Agencies' decisions more consistent and reliable. One of these is the Risk Assessment Forum. This is a group of senior scientists who meet regularly to provide discussion and decisions on, for example, chemicals for which there may be differing scientific interpretations, chemicals which the guidelines do not now cover or which may need some alteration, and to provide for changes in scientific theory with time or as experimental techniques develop. The Forum assembles risk assessment experts from throughout the Agency in a formal process to study and report on these issues from an Agency-wide scientific perspective. Forum activities may include developing scientific analyses, risk assessment guidance, and risk assessment methodology development; use of scientific and technical analysis to propose risk assessment positions: obtaining consensus on these issues. The Forum generally focuses on developing methods for data analysis and methods for achieving consensus. They do not generally peer review of completed risk assessments. A Risk Assessment Council provides executive 'oversight' of the development, review and implementation of EPA Risk Assessment Policy. The Council brings together senior officials from throughout the Agency in a formal manner to consider these matters from an Agency-wide management perspective. Activities may include co-ordination of risk assessment activities: improvement of risk assessment processes: guidance on interpretation of risk assessment information; and referral of risk assessment matters to appropriate EPA officers.

RISK MANAGEMENT

'Risk Management' is the process which aims to avoid risk, avert risk or reduce it. Regulatory options, developed and evaluated with respect to public health, economic, social and political consequences, and in the light of risk variability for different situations, are used to produce government decisions and actions. Risk management therefore involves a balancing of health and economic factors in the light of scientific knowledge and political judgement. Zimmerman (1990) provides an extensive discussion of the theories which underlie risk management in the US context. Different parameters for management may be expected to apply in other countries, including Australia. Monitoring and feedback or readjustment of policies in the light of risk outcomes is also an important ongoing component of the risk management process.

Because policy considerations may affect, and perhaps determine, some risk management choices, the USEPA has taken steps to establish and maintain a clear conceptual distinction between assessment of risks and consideration of risk management alternatives. That is, 'the scientific findings and policy judgements embodied in risk assessments should be explicitly distinguished from political, economic and technical considerations that influence the design and choice of regulatory strategies'. This approach, in part, generated the risk assessment guidelines (USEPA 1986) which later emerged from the USEPA. It was concluded that guidelines, if properly designed, were desirable because a clear statement of the requirements would be an advantage to the regulatory agencies, to the industries concerned, and to the general public.

The US National Research Council document (US National Research Council 1983) strongly emphasizes that risk management policy should not be allowed to control the risk assessment process itself. It stresses that if case-specific considerations, such as economic impact, influence the judgements made in the risk assessment process, the integrity of the process will be seriously undermined. It further notes that 'even the perception that risk management considerations are influencing the conduct of risk assessment in an important way, will cause the assessment and regulatory decisions based on them to lack credibility'.

One of the most important aspects of risk assessment is specifying and reducing the uncertainty of the estimates. The USEPA conducted several peer-review workshops attempting to achieve consensus in uncertainties, particularly with respect to developmental toxicity. Pharmacokinetic modelling in risk assessment, attempting to make dose-response assessment more accurate, is an area of ongoing research. All of the risk assessment guidelines emphasize the importance of building-in a measure of uncertainty to the assessment.

Overall, these methodologies, used within the guidelines, make the USEPA approach to risk assessment for cancer probably the most conservative in the world, i.e. erring on the side of safety in the event of lack of available knowledge. Clearly, this allows greater margin with respect to environmental protection, and also facilitates risk communication to the public.

The Quantitative Health Risk Assessment Methodologies have a variety of uses. They may be used in assessing the potential for both acute and chronic impacts on human health from existing levels of environmental contamination, given accurate performance of environmental monitoring and of the risk assessment. Potential health impacts within a given distance from polluting facilities may be performed, and the expected reduction in risk associated with modified pollution control technologies may also be estimated. These approaches are relevant to land use planning and best available technology options in development regulation. QHRA has also been used in the occupational health context in order to develop strategies for health protection during development of land sites contaminated by prior industrial or waste dumping activities. The methodologies are currently being discussed in Australia and have been used in a limited number of public health and occupational risk assessments at Local, State and Federal Government levels.

POLLUTION INVENTORIES

The Emergency Planning and Community Right-to-Know Act of 1986, or Title III of the Superfund Amendments and Reauthorization Act (SARA) established several precedents for collecting and sharing information about hazardous substances used in US communities. An important component of this was the provision that all sections of society - government, industry, academia, and the public-would have access to a common set of data regarding the annual releases of toxic chemicals into the environment. This access has considerably facilitated risk assessment with respect to toxic chemicals in the USA. The data are readily available through a nationally computerized

database called the Toxic Chemical Release inventory (TRI) and through computer-generated microfiche data sets at County libraries. This is the first national inventory of toxic chemical storage and releases to all environmental media - land, air and water - from industrial facilities. Over 300 toxic chemicals and chemical categories are subject to reporting under Title III. Listed chemicals and or chemical categories that are components of mixtures are also subject to reporting. The company may use the name of the mixture or the product trade name instead of the chemical's actual name only if the specific identities of the chemicals in the mixture are not known. Companies can claim a chemical's identify as a trade secret but they must substantiate such a claim. A 25,000 US dollar fine for frivolous trade secret claims has been established under Title III. If a firm claims a chemical is a trade secret, it must provide a generic name for that chemical, and that name must be descriptive of the chemical structure. Companies may withhold only the specific chemical identity of the compound - including chemical name and Chemical Abstract Services (CAS) number. Releases subject to reporting include those to air from fugitive or non-point sources (those not released through stacks, vents or any other confined air stream), to the air from stack or point sources, to the water directly discharged to a stream, wastes that are injected underground, to land on site (including land fills, etc), to water, and to wastes transferred off site for treatment or disposal. Releases of the chemical to the environment are given in pounds per year. The release quantities represent the total amount of the chemical released from all possible sources for each medium (air, water etc). Not all industrial releases of listed chemicals are covered by the reporting requirements. Facilities with fewer than 10 full-time employees, those producing, importing, processing or using the designated chemicals below threshold amounts, are not required to participate in release reporting. In addition, few facilities are required to report in the first year. Not everyone who is obliged to report does so. USEPA is currently undertaking investigations and enforcement actions to increase the rate of compliance. Many sources of toxic chemicals besides industrial processes are not covered by the reporting requirements, for example, consumer products, agricultural uses and automobiles.

RISK AND POLLUTANT PRIORITIZATION

Risk analysis has traditionally been used for case-specific human effects studies. However the USEPA now perceives a further use for risk analysis: prioritization of pollution control strategies within the (inevitable) framework of limited resources. Past control strategies are viewed as having been fragmented with each problem addressed separately and without reference to effects, risks and costs. Risk studies are seen as giving coherence to decision making. It may also be possible to move risk approaches in the direction of region-wide integrated pollution management.

THE NEW US CLEAN AIR ACT

The amendments to the US Clean Air Act which were recently legislated significantly change the way in which

Hazardous Air Pollutants are regulated. A list of 189 Hazardous Air Pollutants has been designated by Congress in order to short-circuit the existing regulatory process, which has tended to become overly time-consuming. Focus will instead be on development of suitable control technologies for the specific pollutants, rather than establishing ambient standards per se. Clearly however, RfC generation (see earlier) for chemicals will be important as a basis for assessing control technology performance.

The concept of 'Maximum Achievable Control Technology Emission Standards' will require the USEPA Administrator to promulgate regulations establishing emission standards for new and major sources of the 189 listed chemicals. The standards will require the maximum degree of reduction by technological and non-technological means. In the event that standards are not achievable, the Administrator may simply require specific technologies to be used. An important additional feature of the Act will be a 'Residual Risk' requirement whereby, not later than 8 years after the date of enactment, the Administrator is to investigate and report to Congress on methods for calculating remaining risks to public health. Provision is made to subsequently adjust standards to provide 'an ample margin of safety to protect public health'. New chemicals may be added to the list as necessary.

In addition to the standards, States may issue 'permits' to industry, as outlined in the Act. These will be in lieu of standards where the owner-operator 'presents evidence sufficient to demonstrate that emissions from the source . . . do not cause a lifetime risk of cancer greater than one in 1,000,000 to the actual person most exposed to emissions . . . (or) . . . adverse health effects in humans other than cancer... with an ample margin of safety'.

Risk Assessment will clearly be an important feature of the new Act, in assessing whether control technologies are satisfactorily protecting the public. Thus, both cancer and non-cancer risk assessment have received

considerable attention with the USEPA, and the United States generally.

The proposed new Clean Air Act 1990 appears to represent a compromise between standard setting and implementation. Economic as well as scientific factors will contribute to the process. The new Act clearly results from both the bureaucratic difficulties involved in setting and enforcing standards, and the continuing scientific debate over the effects of air pollutants on health. Nevertheless, if enacted and implemented, the Act will arguably remain the best technological policy for air pollution control in the world, largely due to its risk-assessment provisions.

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(Continued from page 10)

NEW PRODUCTS

LANDFILL GAS ANALYSER

An infrared gas analyser with independent sensors for methane and carbon dioxide, the Analox 1200 is unaffected by the absence of oxygen. The unit is housed in a tough, lightweight fibreglass enclosure, with comprehensive digital display and membrane keypad. As landfill gas measurements often require determination of the concentration of oxygen, this facility is available as an option.

Available in Australia through Analysis Automation, the analyser is designed to continuously sample methane in two ranges. 0-100% Lower Explosive Limit (LEL) and 0-100% concentration. Carbon dioxide is measured in the range of 0-100%. The unit can measure changes in atmospheric pressure and make automatic corrections to measured gas concentrations.

A data logging function is also available as an option. This option allows readings to be obtained automatically at variable intervals in the absence of an operator. This is particularly useful if continuous records of gas concentrations are required.

The keypad on the face of the unit controls a small pump which draws the sample gas through an in-line water trap and a replaceable filter into a sample chamber. An infrared beam is projected through the gas sample to the other side of the chamber. This is sensed by four detectors - two for CO₂, one for CH₄, and one for on-board calibration checks. A microprocessor calculates the amount of infrared energy absorbed at different wavelengths to determine the concentrations of the gases in the sample.

The Analox 1200 comes with an automatic battery charger, 1.0 m sampling tube with probe, spare inlet port filter and water trap. Atmospheric pressure measurement is also available as an option. Full service and spares back-up are available through Analysis Automation.

For more information please contact:
Mr Keith Finley, Analysis Automation Pty Ltd,
10 Salisbury Road, Castle Hill NSW 2154:
Telephone (02) 634 6255: Fax (02) 899 9481.

BENZENE CONCENTRATIONS IN THE MELBOURNE METROPOLITAN REGION

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ABSTRACT

Benzene levels in the Melbourne Metropolitan Region have been estimated using data available from a 1990 air emissions inventory for the Port Phillip Control Region. While benzene concentrations may be locally elevated due to industrial activities, the major sources of exposure for the general public to this aromatic hydrocarbon are exhaust and evaporative emissions from motor vehicles. During periods with inadequate atmospheric dispersion, regional benzene levels due to motor vehicle emissions are predicted to accumulate to levels which may be significant in public health terms. In the absence of an air quality objective the design ground level concentration of 100 ug m³ has been used as a bench mark. This value is also predicted to be exceeded adjacent to major roads within the Melbourne region whenever peak traffic densities coincide with light wind, stable meteorological conditions. The predicted annual average benzene concentrations and the WHO risk factor for benzene have been used to estimate the likely incidence of acute myeloid leukaemia. Although the average predicted incidence is in close agreement with the actual incidence rate, the age-standardized incidence of acute myeloid leukaemia in Melbourne for the period 1982-1986 shows poor spatial correlation with the predicted incidence rates. Benzene concentrations are expected to decline generally in the Port Phillip Region due to a gradual 30% reduction in motor vehicle benzene emissions by the year 2000 as a result of the introduction of catalytic convertor technology.

INTRODUCTION

Aromatic hydrocarbons such as benzene are produced on a large scale in many industrialized countries and are employed in a variety of applications as chemical intermediates, solvents and as a component in petrol. Major sources of these aromatics in the environment are losses during the production, transportation and processing of petroleum, the refuelling and operation of motor vehicles, and their use as solvents. There is a broad potential for the exposure of both industrial workers engaged in the use of these agents as solvents and chemical intermediates and of the general public through evaporation to the environment, vehicle emissions, consumer products etc. Indoor concentrations of benzene, arising primarily from tobacco smoke, have also been measured at levels which can exceed those outdoors (IARC.1988).

Under ambient conditions, benzene is a relatively persistent compound. Unlike more reactive hydrocarbon species, benzene is only slowly removed from the lower atmosphere through reactions with either hydroxyl or nitrate radicals. This non-polar compound is also only slowly removed from the atmosphere through rain washout or dry

deposition.

Benzene is capable of producing both acute and chronic health effects. Acute effects require the exposure to relatively high concentrations (300 ug m³). While chronic effects may include chromosome aberrations and the depression of blood-cell formation, the most important effect of long term exposure to benzene is to increase the risk of acute non-lymphatic leukaemia (acute myeloid leukaemia).

A major source of benzene for a non-smoking, non-occupationally exposed member of the public is through the inhalation of benzene present in the ambient air. Benzene is also present in water, a variety of common food items and cigarette smoke. The combined contributions from both diet and cigarette smoking

may exceed the intake from atmospheric benzene sources (CONCAWE, 1989). About 50% of the inhaled benzene is absorbed through the lungs into the blood. Once absorbed into the body, the benzene is then either stored in the body fat, excreted via the kidneys or converted by the liver to water soluble toxic metabolites.

Emission inventories for benzene have been compiled for a number of industrialized countries (Table 1). Motor vehicle emissions account for 76% to 85% of the benzene present in the ambient air of these countries.

Typical average and expected maximum ambient concentrations of benzene (CONCAWE 1981, CONCAWE 1989) are given in Table 2. However levels much higher than these typical values may occur during

Source %	Germany	USA	Canada
Vehicles	81	85	76
Chemical industry-	4	9	14
Petrol distribution	4	3	1.5
Solvent operations	2		1
Coke ovens	0.5	1	1
Petroleum Refineries	0.5	1	0.7
Other	8	C	6.8

Table 1 Atmospheric benzene emission sources.

Location	Average	Maximum
Industrial	20	300
Urban	12 - 25	150
Rural	0.1 - 3	5
Service Station	100	2100
Inside Vehicles	54	2500

Table 2. Typical benzene concentrations ($\mu\text{g}/\text{m}^3$)

periods in which atmospheric dispersion conditions are poor or concentrations are measured at points close to major roads or chemical spills.

Benzene is classified as a class 3 indicator under the Victorian State Environment Protection Policy (The Air Environment) (SEPP) with a maximum allowable 3 minute average design ground level concentration of $100 \mu\text{g m}^{-2}$ (33ppb). It must be emphasised that this design level concentration is not an air quality objective but is a level applied in the regulatory plume calculation procedure for predicting the ground level concentration of benzene in the vicinity of sources. The results of the predictions are then used in establishing licence conditions covering chimney heights and emission rates to ensure that design ground level concentrations are not exceeded. The life time risk of leukaemia due to exposure to benzene concentrations of $1 \mu\text{g}\cdot\text{m}^{-2}$ has been estimated by the World Health Organisation (WHO) to be 4×10^6 although other reports (Paustenbach 1990, Swaen and Maeijers 1989) suggest either higher or lower risk factors. Analysis of ambient air samples taken at Pt. Cook (Galbally 1989) have recorded benzene concentrations reaching levels as high as $55 \mu\text{g m}^{-3}$.

The presence of high concentrations at Pt. Cook, which is essentially

a rural location and some distance from recognized industrial and urban sources of benzene, prompted an investigation into the sources and concentration distribution of benzene throughout Melbourne. Since health effects due to exposure to relatively high intermittent levels of benzene are so well documented, the possibility of the increased incidence of illness due to exposure to continuous but lower concentrations of benzene needs to be considered.

BENZENE EMISSIONS FROM MOTOR VEHICLES

The benzene content of Melbourne's petrol is in the range of 4 to 5% (Dillon, 1991. Heading, 1991). Benzene is released into the air both during the production of fuels and during vehicle refuelling and may lead to locally elevated benzene levels.

However a larger and ubiquitous source of benzene is motor vehicle exhaust and evaporative emissions. Motor vehicle exhausts are known to contain a number of carcinogens (such as benzene, formaldehyde, 1,3-butadiene) whose emission rates vary with the vehicle speed, fuel composition and type of emission controls. Benzene is released into the air in the engine exhaust (76%), in evaporative emissions from the fuel tank, carburettor and fuel system

(22%) and during vehicle refuelling (2%). Benzene in the exhaust is due both to the unburnt benzene which was originally present in the fuel and to the formation of benzene from other fuel aromatics during combustion.

Vehicle exhaust emissions, from both catalyst and non catalyst equipped vehicles, have been analysed for benzene content under a variety of driving cycles. These tests showed that 7% carbon of the exhaust non-methanic hydrocarbon concentration (NMHC) was present as benzene (Galbally, 1990). Although diesel engines were not tested in this study, emissions from diesel engines have been reported as containing 1.9% benzene (Jacques 1990). The hydrocarbon evaporative emissions were found to contain 3.5% carbon benzene (Seizinger et al. 1986).

Ambient air samples, taken during an EPA hydrocarbon speciation study in the western suburbs of Melbourne (Galbally 1989) were found to consist of approximately 7% carbon benzene but there is evidence to suggest that this slightly higher average value was due to added contributions of benzene from chemical industry feedstock emissions. Analysis of ambient hydrocarbon air samples taken in the CBD, where the major source is predominantly from motor vehicles, have varied from 5.3% carbon (Evans et al. 1986) to 6.8% (Galbally 1990).

Benzene emissions from motor vehicles were estimated using data on annual vehicle kilometres travelled (VKT) obtained from the EPA's 1990 emissions inventory (Carnovale et al. 1991). This inventory had been compiled for the Port Phillip Control Region, an area of 14,000 square kilometres. VKT data are available, based on 3km x 3km grid cells throughout this area.

Table 3 gives the estimated benzene emissions per kilometre for the 1990 vehicle fleet and the total VKT for the Port Phillip airshed for each of a range of road types. These emission rates were used to calculate an average exhaust emission rate of 0.115 g VKT. Evaporative emissions were estimated to be 0.034 g VKT, giving an average benzene emission rate from vehicles of 0.15g VKT. Evaporative emissions released while the vehicle is in operation

Road type	Exhaust g/km	Evaporative g/km	VKT $\times 10^{-6}$
Arterial	0.11	0.034	42.1
Residential	0.13	0.034	16.2
Over-dimensioned	0.12	0.033	12.7
Freeway	0.11	0.034	8.1

Table 3. Benzene emissions from motor vehicles.

(running losses) may also contribute significantly to normal evaporative losses whenever ambient or engine compartment temperatures are high. However, in the absence of firm data on which to quantify these emissions, running losses have not been considered in this study. Although the proportion of each road type varies from one grid square to the next, the actual emission rate per VKT for any particular 3 km grid square is estimated to be within 10% of this average value.

Estimates of benzene emissions based on the measured ambient benzene NMHC ratios were also in the range 0.15g VKT to 0.19g VKT and are consistent with emissions based on vehicle emission test results. The value of 0.15g VKT has been used in this modelling study.

The vehicle benzene emission rate and the 1989 emissions inventory VKT information for each grid square were used to generate a benzene emission distribution (Figure 1) which showed emissions to be greatest in the vicinity of the Central Business District and the inner residential areas to the east of the CBD. The maximum benzene emission flux from a 3km x 3km grid square was 213 kg/day. Total benzene emissions from motor vehicles into the Port Phillip Control Region are estimated to be 12,000 kg/day.

MAXIMUM BENZENE CONCENTRATIONS DUE TO VEHICLE EMISSIONS

The EPA gaussian plume dispersion model, AUSPLUME, was used to estimate benzene concentrations due to emissions from motor vehicles in the Melbourne metropolitan region, an area of 5100 sq. km, by treating it as over 1800 volume sources.

Emission rates in each grid square were allowed to vary during the day to reflect the normal diurnal variation in traffic density. Hourly emission rates are shown in Figure 2 as a fraction of the total daily emission rate.

Over an area the size of Melbourne, the frequencies of wind speeds and directions can vary significantly. Therefore rather than considering a single meteorological file as being representative of the entire region, three model runs were performed with

Benzene Emissions (kg/day)

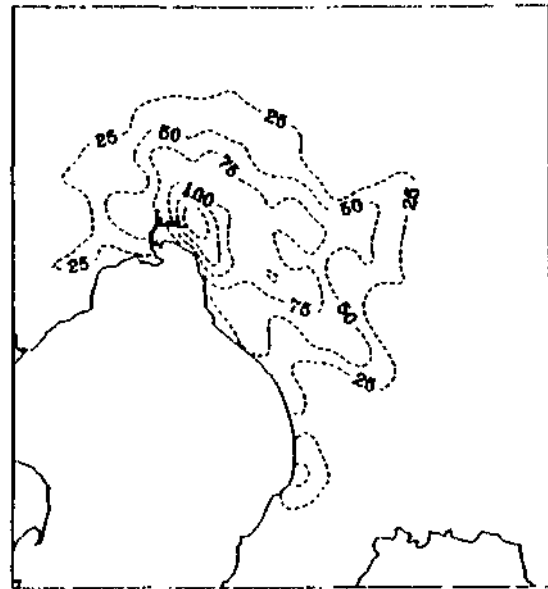


Figure 1 Benzene emissions/grid square due to motor vehicles in the Port Phillip airshed.

three separate meteorological files.

Hourly meteorological data files were generated using 12 month periods of hourly data recorded during 1987 at three EPA suburban monitoring sites (Figure 3). Meteorological files from Paisley and Dandenong were considered representative of the meteorology in Melbourne's western and south-eastern suburbs. A meteorological file from Alphington monitoring station was selected as being typical of the eastern residential areas. Upper air data from the Laverton airbase were used to estimate hourly stability category and mixing height.

Using each of these meteorological files and the vehicle emission data, the model calculated the hourly average ground level concentration of benzene for each location on a 3 km receptor grid. Although each meteorological file resulted in similar maximum benzene concentrations for the Melbourne region, the shape of the concentration contours produced using the different meteorological files showed variations which reflected the local predominant direction of light katabatic flows under very stable conditions.

Model predictions are expected to be more accurate at those grid

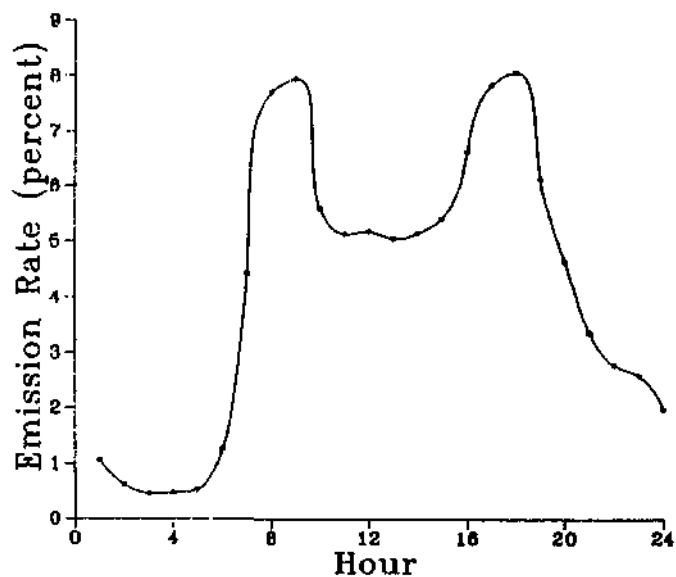


Figure 2. Diurnal variation of vehicle benzene emissions

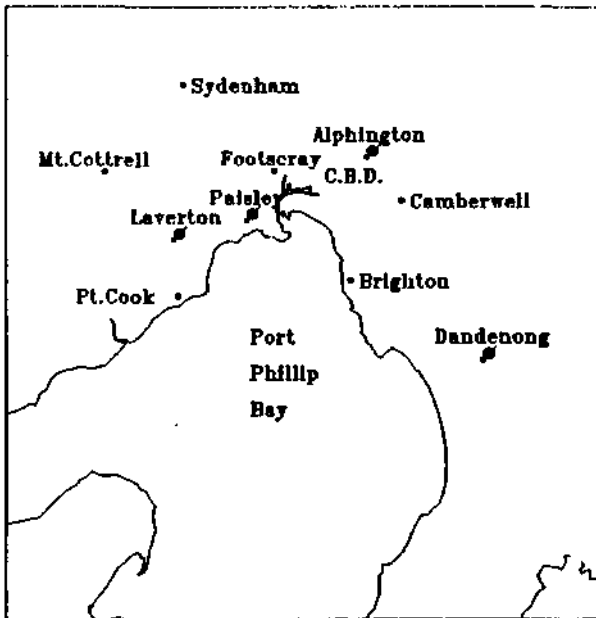


Figure 3. Location of Monitoring and Meteorological sites

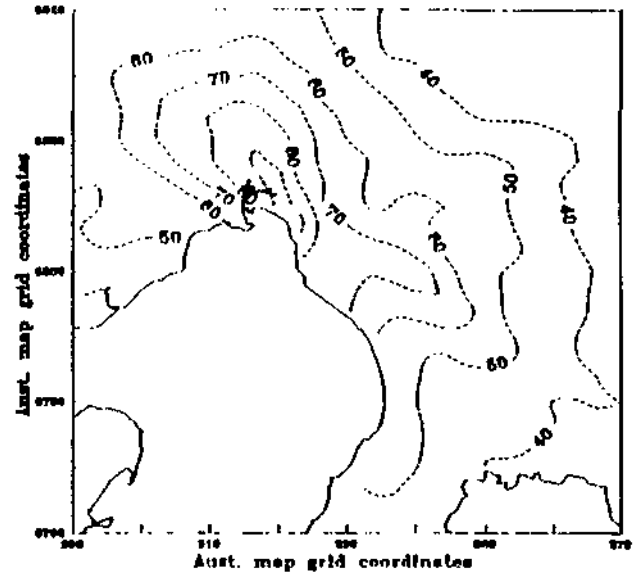


Figure 4 Predicted hourly concentration contours 99.9 percentile ($\mu\text{g}/\text{m}^3$)

locations which were close to the original source of the meteorological data. Therefore at any particular grid location, the concentration was calculated as a weighted average of the three runs. The weighting given to each run model estimate was inversely proportional to the square of the distance of that grid location from the source of the meteorological data.

The 99.9 percentile level is a relatively robust statistical measure of the expected maximum benzene level. Since the model used a meteorological file containing almost 9000 hours of data, the 99.9 percentile corresponds to the predicted 9th highest hourly concentration which would be expected to have occurred at each grid location during 1987.

The maximum 99.9 percentile one hour average for the airshed was $98 \mu\text{g}/\text{m}^3$. The predicted contours are shown in Figure 4. The model predicted the maximum 1 hour concentration of benzene in the Melbourne metropolitan area to be $140 \mu\text{g}/\text{m}^3$.

Gaussian plume dispersion models, such as Ausplume, assume a uniform wind field which persists while the emission moves from the source to a distant receptor. While the models have been shown to be fairly robust when used to predict statistics such as the 99.9 percentile concentration value, they have obvious deficiencies when used to model specific events. Maximum concentrations are predicted to occur during stable, light wind conditions, when

plume meander and recirculation are likely. The model makes no allowance for these effects and predicted concentrations may be underestimated during recirculation conditions. Nor does the model allow for terrain effects which, during stable meteorological periods, often distort the wind field and which may significantly affect the concentrations downwind of ground based sources. Even for an area as flat as Melbourne, topographic effects are important and concentrations higher than those predicted for flat terrain would be

expected due to the funnelling of vehicle emissions along valleys (RCA 1985).

Moreover in practice, areas adjacent to roads carrying large traffic volumes or in the vicinity of large point source emissions of benzene (refineries, petrochemical complex sites) would also experience higher concentrations than those predicted from the area source vehicle emission inventory. The model assumes the emissions from major arterial roads to be uniformly distributed throughout the 3 km grid square and point

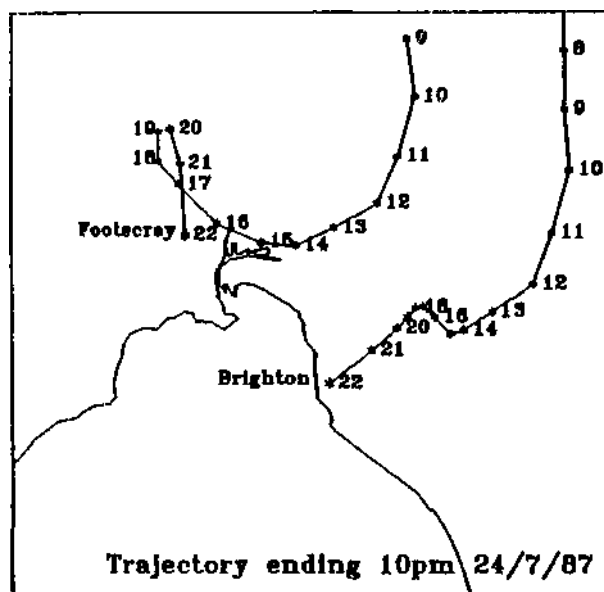


Figure 5 Trajectories of air parcels arriving at the Footscray and Brighton EPA monitoring sites.

sources of benzene have not been included.

A STUDY OF BENZENE CONCENTRATIONS UNDER RECIRCULATION CONDITIONS

A typical example of worst case meteorological conditions occurred on 24 7 1987 and was selected for study because concentrations of nitrogen oxides, mainly originating from vehicle emissions, were elevated over the whole airshed and were amongst the highest measured during 1987. This day can be considered as representing a 'worst case' scenario and roughly equivalent to Ausplume's 99.9 percentile situation. Maximum levels of pollutants were measured at the air quality monitoring stations between 7 pm and 10 pm.

Figure 5 shows the trajectories which air parcels had followed prior to arriving at the EPA's ambient air monitoring stations located at Footscray and Brighton at 2200hr on this day.

Since entering Melbourne's northern suburbs that morning, both these air parcels had been influenced by a range of wind speeds and directions. In particular the 'Footscray' air parcel was observed to recirculate between 1700 and 2200hrs. Between 1300hr and 2200hrs, winds had become light and variable. These conditions would have proved especially difficult (if not impossible) to model accurately using a Gaussian plume dispersion model.

In order to more accurately model this episode, a Gaussian puff model was used to track the movement and dispersion of contaminants as they were released into the airshed.

PUFF DISPERSION MODEL

The puff model used was a variation of that proposed by Zannetti (1981) in which emissions are represented as gaussian puffs of material released at short time intervals. These puffs are transported through the airshed under the action of the local windfield and are allowed to disperse both horizontally and vertically at a rate controlled by the current atmospheric stability.

Benzene emissions, with the diurnal

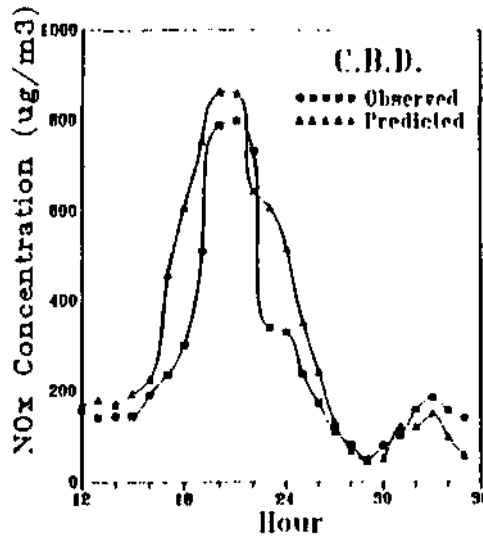


Figure 6 a.

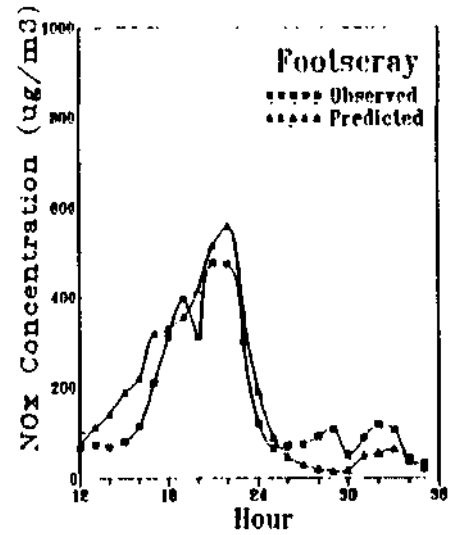


Figure 6 b.

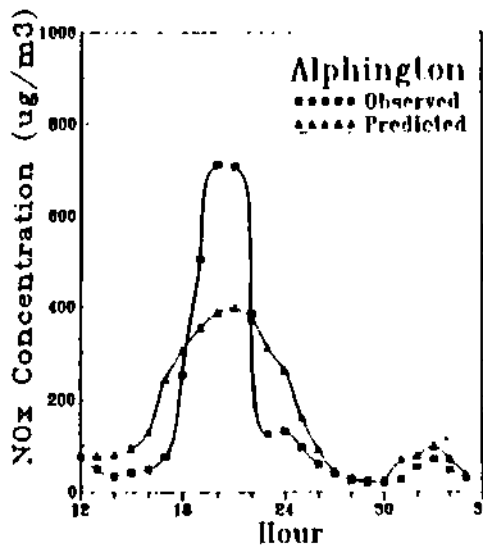


Figure 6 c.

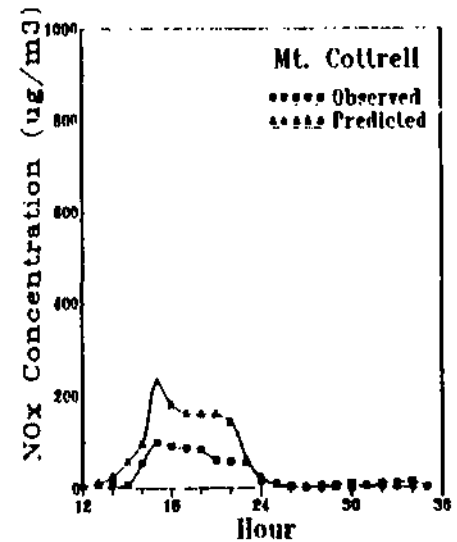


Figure 6 d.

variation shown in figure 2, were assumed to originate from a 3km square grid of ground based area sources. At short time intervals, a mass of benzene was released which was calculated by reference to the emission inventory VKT estimate for that grid square and the time of day. Each puff was given an initial vertical dispersion by assuming it had already travelled one grid square (i.e. 3 km) under the current meteorological stability. The initial horizontal dispersion of each puff was chosen to be 1320 metres which allowed the puff area sources to behave as if they were a smoothed image of the actual cell emissions.

The path which each puff followed was determined by the wind field

generated from meteorological data measured by the EPA monitoring network at eight locations in the Melbourne region. The wind speed and direction were interpolated from the station sites to each grid point location using an inverse radius squared interpolation scheme.

The stability category and mixing heights for each hour were estimated using meteorological data from the EPA net/ork and the Bureau of Meteorology station located at Laverton. Since extremely stable conditions are less likely to occur in an urban environment compared to a rural site, hours with an estimated stability category F were considered to have the slightly less stable category E. Mixing heights estimated

for the EPA Paisley monitoring site each hour were scaled against the local wind speed at each grid point.

The model assumed total reflection of pollutants at the ground but did not allow for reflection at the top of the mixed layer. Instead, a puff was allowed to disperse both horizontally and vertically at a rate controlled by the current stability category until σ_z , a measure of the vertical dispersion, equalled the mixing height. At this point, further vertical growth was restricted as long as the mixing height remained either unchanged or decreased in the following hours. If the mixing height subsequently increased, then the puffs were again allowed to grow. The transport and dispersion of each puff is determined independently. The final concentration distribution of the continual release situation is obtained by summing the contribution of the many individual puffs at each grid location for each hour.

PUFF MODEL VERIFICATION

The model was first validated by predicting the concentration distribution of nitrogen oxides (NO_x) and comparing this to the continuous measurements of NO_x which were available from the EPA monitoring network.

The NO_x emission data required by the model were again estimated from the emission inventory VKT data. These data closely estimated the NO_x

ground level sources but under estimated total emissions by about 20% since they did not include industrial point source emissions. When NO_x concentrations reached their maximum, these elevated buoyant industrial stack emissions would have been isolated to some extent from causing an impact at ground level due to the presence of the strong surface inversion and the highly stable atmospheric conditions. In all other respects, the benzene and NO_x model runs were identical.

The concentrations predicted by the puff model at the grid points surrounding a monitoring site were interpolated to that site location to provide an estimated hourly concentration. These predicted values are compared to the measured hourly averaged NO_x concentrations for some monitoring sites in Figure 6a-d.

The model was capable of accurately predicting both the variation over time and maximum concentration of pollutant emissions from motor vehicles when compared with the observed concentrations at most sites in the EPA monitoring network. The correlation was acceptable for the urban sites in the CBD (Figure 6a), Footscray (Figure 6b), Brighton and Paisley.

Predicted concentrations at Alphington (Figure 6c) were less than those actually observed. The increased concentrations observed at this site were possibly due to the

funnelling of pollutants along the Yarra valley.

Concentrations at the two remaining rural sites at Mt. Cottrell (Figure 6d) and Sydenham were lower than predicted by the model. Wind speeds at both these sites were higher than for the rest of the Melbourne urban area and rated a less stable category than that estimated from the Paisley site. Although it would have been feasible to have estimated a local stability, relative to that estimated at Paisley, by making it wind speed dependant, this refinement was not considered necessary since concentrations at these sites were low compared to urban areas. Larger local stability variations would have been encountered during trajectories which followed paths out over Port Phillip Bay.

PUFF MODEL PREDICTED BENZENE CONCENTRATIONS

The puff model predicted benzene concentrations in excess of 50 µg/m³ persisting from 6pm on 24/7/87 till 4am on 25/7/87. The maximum hourly benzene concentration predicted was 97 µg m³. The maximum 3 minute average would exceed this value. The benzene concentration distribution at 8 pm due to motor vehicle emissions is shown in Figure 7.

The maximum concentration predicted by the Puff model for this day (97/igm⁵) is close to the 99.9 per-

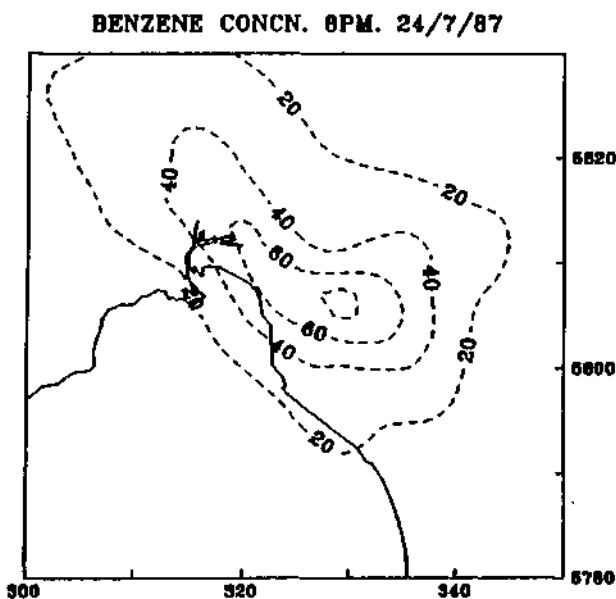


Figure 7. Predicted benzene concentrations

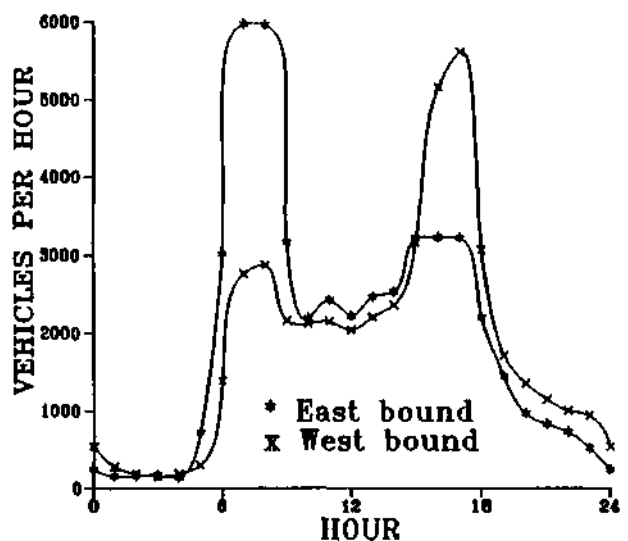


Figure 8. Traffic densities on the Westgate Freeway

centile concentration predicted by the AUSPLUME model ($98 \mu\text{g}/\text{m}^3$). The fact that the Puff model, using a better physical representation of the wind field and subsequent advection of pollutants, gives predictions of maximum concentrations similar to those derived using the relatively simple Gaussian plume dispersion model allows more confidence to be placed in AUSPLUME results.

Although there was no benzene analyses of ambient samples during this period, the predicted results can be verified to some extent by reference to other pollutants that are routinely measured by the EPA monitoring network. The only available information on non methanic hydrocarbons (NMHC) levels was obtained from the EPA monitoring site at Point Cook. Peak levels of benzene ($16 \mu\text{g}/\text{m}^3$) were predicted to occur at Point Cook at 11 pm on 24 7 87. At this time measured NMHC levels reached 580ppbC. This results in a benzene NMHC ratio of 5.5% carbon which is in the range measured by Evans (5.3%C) and Galbally (6.8%C).

At 10pm, measured NO_x levels in the CBD reached 630ppbv when predicted benzene concentrations peaked at $65 \mu\text{g}/\text{m}^3$ giving a benzene NO_x ratio of 0.21. Simultaneous measurements of both nitrogen oxides and benzene in the CBD (Galbally 1990) have found benzene (ppbC) NO_x (ppbv) ratios to vary between 0.20 and 0.32 (mean 0.26).

NEAR ROAD CONCENTRATIONS

Near road concentrations of pollutants from vehicle exhaust can be significantly higher than concentrations measured as a regional background. A general rule of thumb is that concentrations, due to emissions from a road carrying high traffic densities, will approach the regional background within 100m of the road. People who live or are employed very close to a major road may be exposed to higher risks than would be predicted from regional background models such as AUSPLUME or the Puff model.

Benzene concentrations in the vicinity of the Westgate Freeway were modelled using a simple line source model originally developed by Chock (1978). The model is a modified Gaussian model and represents the emissions of benzene from each lane of the Freeway as a series of line sources. This model allows for the buoyant plume rise due to heated vehicle exhausts and the additional dispersion due to the turbulence generated by the vehicles using the Freeway. The Chock model was originally based on measurements of emissions from a road with controlled traffic volumes and has since been validated for vehicle NO_x emissions during studies for the Road Construction Authority (RCA 1985) in Melbourne.

Accurate traffic volumes for both east and west bound traffic were

available for June 1989 (Fantin 1990) at a location near Todd Rd. in Port Melbourne (Figure 8). At this point, the freeway consists of 4 lanes in each of the east and west bound directions. Information on the traffic densities and benzene emission rates for each lane, lane dimensions, the width of the median strip and the width of the emergency stopping lanes were required to initialise the model.

As the Westgate Freeway is an over-dimensioned route, vehicle hydrocarbon exhaust emissions are estimated to be 1.97 g VKT and evaporative emissions 0.94 g.VKT. The combined benzene emission (assuming benzene emissions are 6% of exhaust and 3.5% of evaporative hydrocarbon emissions) was estimated to be 0.15 g VKT.

Near road concentrations of benzene were predicted for an early morning situation when stable, light wind conditions are not uncommon. During 1987, the nearby Paisley monitoring station recorded 250 hours of very stable conditions (stability category F) with winds less than 1ms. Very stable periods with winds less than or equal to 0.5m/s occurred for 110 hours with 30 hours occurring during the peak traffic flow periods from 6am to 8am and 5pm to 7pm.

The model used benzene emissions fluxes typical of the morning peak traffic flow (6am - 7am). At this time traffic volumes on the Westgate Freeway are 6000 vehicles-hour on

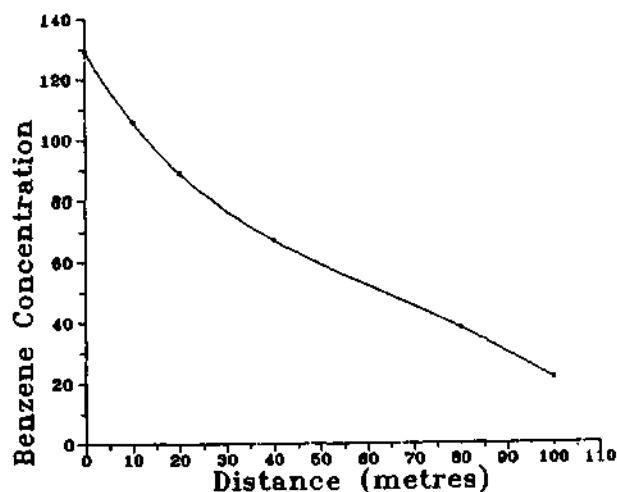


Figure 9. Benzene concentration adjacent to the Westgate Freeway ($\mu\text{g}/\text{m}^3$).

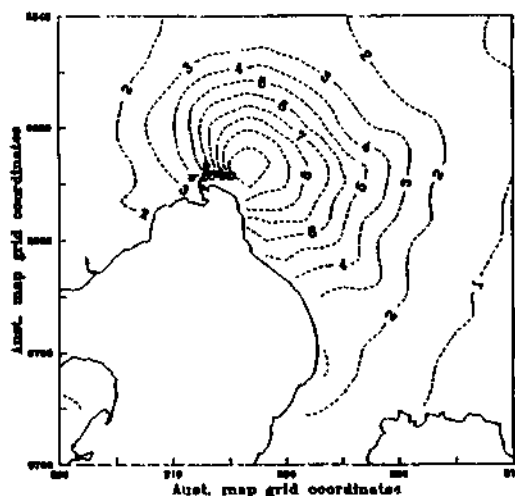


Figure 10. Annual average concentrations of benzene ($\mu\text{g}/\text{m}^3$) due to vehicle emissions in the Melbourne region.

the east bound lanes and 3000 vehicles hour on west bound lanes. This volume of traffic emits a total of 1.4 kg km of benzene.

The meteorological conditions were assumed to be stable with light winds of 0.5 m s blowing at right angles to the road. The benzene concentration predicted by the Chock model as a function of distance from the northern boundary of the freeway is shown in Figure 9.

Under these meteorological conditions, people using the freeway or within 15m of the emergency stopping lanes would probably experience benzene concentrations greater than 100 µg m³. Benzene levels experienced by drivers or passengers inside the vehicle may also be higher than ambient levels (CONCAWE 1981). Simultaneous measurements of benzene and other volatile organics inside and outside of vehicles have shown that engine running loss emissions and tail pipe emissions in addition to exterior concentrations may have a significant impact on in-vehicle levels (Chan 1991).

Benzene concentrations are predicted to decrease rapidly as the distance from the road boundary increases. At one hundred metres from the road, levels are only 15% of the levels predicted at the Freeway. However under these light wind, stable conditions, regional concentrations would also be expected to be high. The additional contribution of the background emissions to the near road benzene levels would extend the distance from the road over which the SEPP design ground level concentration would be exceeded.

The Westgate Freeway is only one of several major roads which have similar traffic densities. Some sections of these roads may experience higher concentrations than this section of the Westgate Freeway if maximum morning traffic densities are higher or the road passes through valleys which allows funnelling of emissions along the road during light wind, stable conditions.

HEALTH EFFECTS

The AUSPLUME model was used to estimate the annual average concentrations of benzene in the Melbourne

Metropolitan area due to emissions from motor vehicles (Figure 10). The annual average was calculated as the weighted average of three model runs using meteorological data files from Alphington, Dandenong and Paisley monitoring stations.

The calculation of a lifetime risk due to exposure to benzene is dependent on a number of assumptions which are open to a degree of uncertainty. The predicted incidence of acute myeloid leukaemia (AML) determined here is for a non smoking, non occupational exposed member of the population. The degree of exposure to benzene from cigarettes, diet or to high intermittent levels in the work environment is essentially an unknown factor. The exact level of exposure is also uncertain since the population is not static but highly mobile.

The benzene risk factor is itself based on the assumption that the relative risk calculated from data on occupational exposure to high intermittent benzene concentrations and that of a person in the general population who is exposed to a much lower, relatively constant concentration are essentially the same. Risk factors are also based on the assumption that there is no threshold value for carcinogens and that the relationship between relative risk and acumulative dose, based on high occupational exposures, can be linearly extrapolated towards zero.

The majority of benzene damage is due to metabolites formed primarily in the liver (OSHA 1987). If the body has defensive mechanisms against these metabolites and these defence mechanisms are only overwhelmed when benzene concentrations are high, then a zero threshold, linear extrapolation assumption is invalid (Paustenbach 1990). People exposed to very low ambient concentrations of benzene may well be at negligible risk due to protective biologic mechanisms. However it would be difficult to demonstrate this supposition unequivocally.

The predicted incidence of acute myeloid leukaemia due to vehicle benzene emissions in the Melbourne region was obtained by multiplying the predicted annual average benzene concentration within each 3 km grid square by the WHO risk factor

for benzene of 4×10^{-6} (Figure 11). The predicted incidence of AML varied from 4 per 100,000 in the inner metropolitan area to 1 per 1 00.000 in the outer suburbs. From the data on population size for each grid square, the total incidence for the Melbourne population was estimated to be 62 cases year.

Information on the incidence of AML in Victoria was obtained from Anti-Cancer Council of Victoria records for the period 1982 to 1986. During this period, 502 cases of AML occurred with a slightly higher incidence in males (54%) than females (46%). Of these cases, 342 incidences occurred within the Metropolitan area with an average incidence of 68 cases, year. The incidence of AML in each Local Government Area (LGA) and population size in each LGA (obtained from the 1986 Census data) were used to estimate the incidence per year of the population. This distribution is shown in Figure 12. The distribution is similar to that predicted in Figure 11 with the incidence 100,000 per year decreasing from 4 per 100,000 in the inner suburbs to 1 per 100,000 in the outer suburbs.

The distribution of the incidence AML in Figure 12 has not been age-standardized. The Anti-Cancer Council of Victoria data, which are available in 5-year age groups, shows that the incidence of AML, like that of most leukaemias, is strongly dependant on age. The total incidence in each age group (Figure 13) reflects a marked increase in the incidence in people aged more than 50 years.

The 1986 Census data were used to obtain the percentage of the population which were aged more than 50 years in each LGA (Figure 14). The more established inner metropolitan areas contain a significantly higher proportion of people aged more than 50 years (30%) than the newer rapidly expanding outer suburban areas (15%).

Due to the small sample size, it was not possible to distinguish between the high incidence in the older population being due to the likelihood of their living in areas with elevated benzene levels and the high incidence in these areas being due only to the increased susceptibility of the older population to AML. The effect

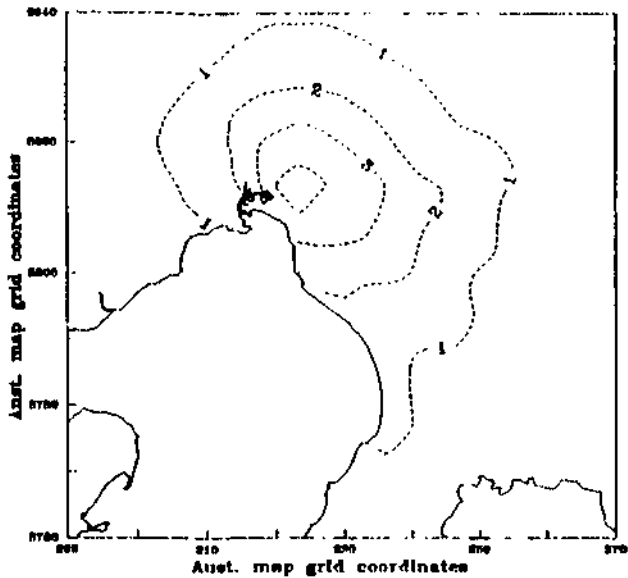


Figure 11 Predicted incidence of AML/100,000 due to exposure to benzene from vehicle emissions

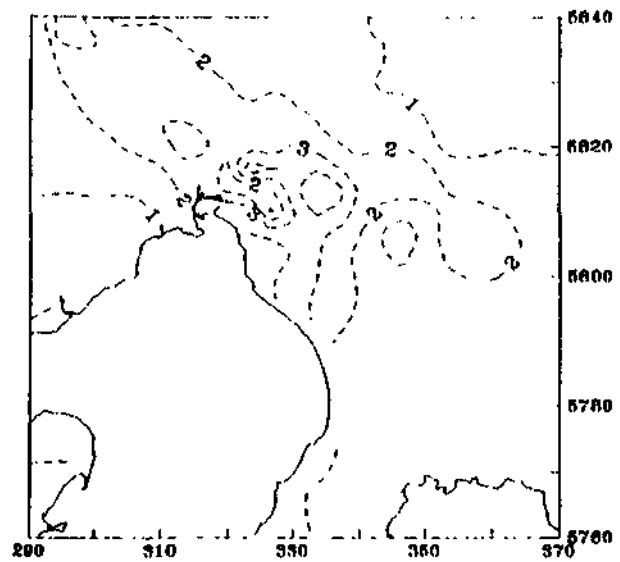


Figure 12 Incidence of AML/100,000 in the Melbourne Metropolitan region 1982-1986

on AML incidence due to differences in the age distribution of populations indifferent LGAs may mask any real effect due to annual benzene levels. The incidence rate was age-standardized against a 'standard' population obtained from the 1986 Census data for the Melbourne region.

For each LGA, the observed incidence per 100,000 per year in each 5-year age group was multiplied by the number of people in the corresponding age group in the Melbourne standard population. This results in an expected incidence in the standard population which when summed over all the age groups results in a

standardized incidence 100,000 for each LGA. When this was done the age-standardized distribution of AML incidence (Figure 15) shows no clear spatial relationship between atmospheric benzene concentration and the incidence of AML. This result is consistent with other reports on the health risk of exposure to low levels of benzene.

One reason for this lack of correlation may be due to a possibly significant benzene contribution from diet (up to 250 μg day), smoking (15 μg cigarette), vehicle refuelling (20mg fill) or due to exposure to benzene while commuting (30mg/1 hr trip) or occupational exposure (CON-

CAWE 1989). The maximum annual average concentration predicted for the Melbourne area is around 11 $\mu\text{g}\cdot\text{m}^{-3}$. If on average a person inhales 24 m³/day and 50% of the inhaled benzene is absorbed into the body then an average ambient concentration of 11 $\mu\text{g}\cdot\text{m}^{-3}$ contributes 130mg day to the total benzene daily intake. Also a failure to take account of any biological defence mechanism against low levels of benzene will overestimate the risk of the population in developing this type of leukaemia.

DOMESTIC SOURCES

Hydrocarbons, including benzene,

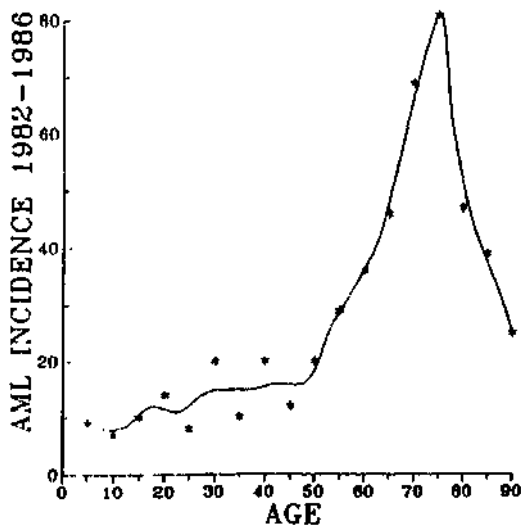


Figure 13 Age distribution AML incidence in Victoria 1983-1986 (Cases/year)

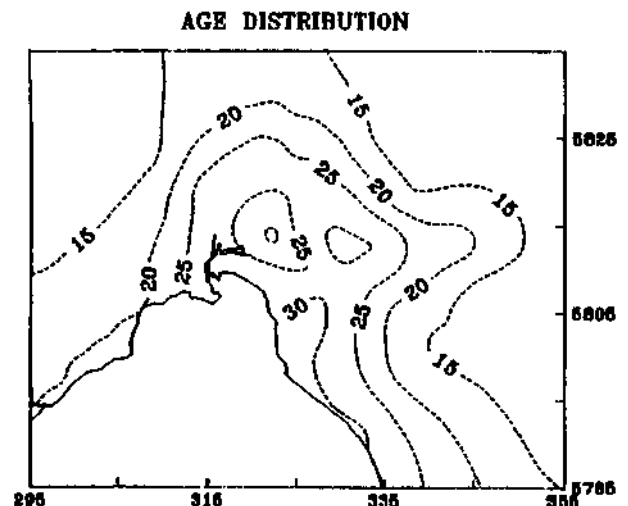


Figure 14. Percentage of the population aged more than 50 years.

are released whenever wood or other vegetation is burnt. Benzene constitutes between 4% and 6% of the non-methane hydrocarbon emissions from wood combustion (Greenberg and Zimmerman 1984, Jaques 1990).

However an accurate estimation of benzene emissions from this source is difficult due to the lack of reliable Australian data. In the absence of specific data for the Melbourne region, estimates of the amount of wood burnt as fuel have had to be made in the air emissions inventory for the Port Phillip region (Carnovale et al. 1991) on the basis of apportioning Victorian fuel usage (DITR 1990) on a per capita basis. This approach is likely to lead to an overestimate of the usage in Melbourne's urban areas compared to rural areas which have easier access to wood supplies.

Published hydrocarbon emission factors also vary by more than an order of magnitude. Assuming benzene constitutes 5% of the non methanic hydrocarbons emissions, estimates of benzene emissions (Table 4) have been calculated using hydrocarbon emission factors from both the USEPA (USEPA, 1987) and Canadian sources (Jaques 1990). Benzene emissions based on Canadian emission factors are only 15% of the emissions obtained by using US values.

The relative amounts of wood burnt as fuel in conventional and slow combustion stoves and in fireplaces has a major effect on the total mass of hydrocarbons released. Emission factors for wood burnt with an unrestricted air supply (fireplaces) may be an order of magnitude less than emissions produced with a restricted

air supply (slow combustion stoves).

Emissions from wood fireplaces, and to a lesser extent from stoves, are expected to peak in the early evening during winter months when meteorological conditions are often unfavourable for the dispersal of these pollutants. Since benzene from these sources may be appreciable, further information is required to determine the amount and type of wood fuel used and how the usage varies both within the airshed and throughout the year. The relative use and hydrocarbon emission factors of typical Australian fuels (eg. Eucalyptus hardwoods) when burnt in conventional and slow combustion stoves and fireplaces for instance is also required.

Emission Source	Quantity Burnt kt/yr	US Emission Factors kg/t	Benzene (US EPA) t/yr	Canadian Em'n. Factors kg/t	Benzene (Canadian) t/yr
Stoves	675	2.5	1690	0.40	270
Fireplaces	290	0.6	190	0.04	10
Incinerators	49	2.5	120		
Garden waste	38	0.2	9		
Agriculture	16	0.5	7		
Leaves	6	0.7	4		

Table 4. Estimates of benzene emissions from biomass burning using US EPA and Canadian Emission Factors.

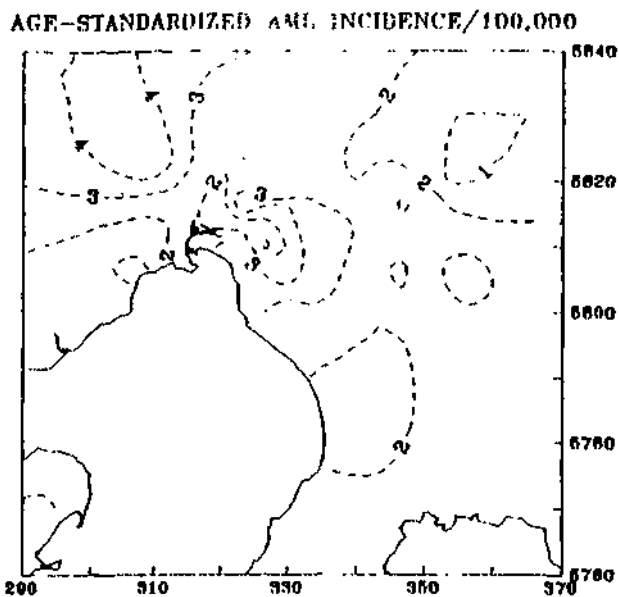


Figure 15. Age standardized AMI incidence in Melbourne 1982 1986

INDUSTRIAL SOURCES

A study aimed at identifying the ambient concentrations of the major hydrocarbon species in the Melbourne area was carried out during February and March 1988 at an EPA monitoring site at Point Cook (Galbally et al. 1988). Point Cook is essentially a rural coastal site with no major roads or industry for some kilometres from the monitoring site. Ambient air samples were automatically analysed each hour by an on site gas chromatograph.

Some hydrocarbon species, such as benzene and ethylene, were found to increase during north easterly flows. Back trajectories, using the interpolated wind data from the EPA monitoring network, were used to locate the possible sources of these emissions. This procedure was carried out for 60 hours of data for which benzene concentrations exceeded 3/xg,m' at Point Cook. Most of the back trajectories tended to implicate the area of the Petrochemical Complex at Altona as the likely emission source for benzene.

The maximum measured benzene concentration, recorded on the morning of 26/2 88, was 55 µgm³ Plume dispersion during this period was minimal with low wind speeds and mixing heights and stable meteorological conditions. The area between the Petrochemical Complex and

Point Cook is flat grassed terrain with a low surface roughness.

The low level of NO_x recorded at this time suggested that the majority of these hydrocarbons originated from a point source rather than motor vehicle area sources. From the measured vehicle benzene NO_x ratio, the motor vehicle contribution to the total benzene concentration was estimated to be approximately 8 µg-m³.

The EPA regulatory model Ausplume was used to estimate the contribution from known emission sources of benzene from within the Petrochemical Complex for 26-2 88. Meteorological data for this period were compiled from the EPA monitoring network and estimates of the atmospheric stability and mixing height were obtained from data from the Bureau of Meteorology station located at the nearby Laverton airbase.

Emission characteristics (stack height and location, exit velocities and temperatures, etc.) and emission rates for the major benzene sources at the Petrochemical Complex were obtained from EPA licences and stack testing data.

The model predicted that a further 11 µg-m³ could be explained by contributions from known sources emitting at the maximum licence rates. However, at that time, some licence limits were thought to have been exceeded for approximately 25% of the time with excursions up to twice the licensed emission rate.

The discrepancy in the predicted and measured benzene concentrations could be due to the difficulty in correctly estimating the meteorological parameters or to the existence of fugitive sources at the Complex. A fugitive source, emitting benzene at a rate of approximately 2 g s for at least two hours, would be required to account for the measured concentration at Point Cook under these meteorological conditions.

Point Cook is some 10 kilometres from the Petrochemical Complex. Assuming emissions originated at the Complex, the model estimated that plume concentrations close to the Complex would have exceeded the benzene design ground level concentration, possibly by a factor of 10, in order for benzene concentrations

to have reached 55 µg-m³ at Point Cook. However the error in this estimate is large due to the combined uncertainties in the model, the meteorology and the source of the emissions.

Emissions from industrial stack sources at the Complex have been significantly reduced since 1988 through the installation of additional emission controls such as after-burners. However the possibility remains that significant, although perhaps intermittent, fugitive sources of benzene still exist. Data gathered for the 1990 emissions inventory suggested that a minority of hydrocarbon emissions are from regulated sources and 50% - 75% are from unregulated fugitive sources such as tanks and valve seals (Carnovale 1991).

A recent ambient sampling program for benzene carried out over 64 hours downwind of the Petrochemical Complex recorded mainly low benzene concentrations. Mean benzene concentration were of the order of 3 -4ppb with a peak concentrations reaching 20ppb. NO_x measurements in the area suggest that between 1.5ppb and 5ppb of the benzene originated from vehicle emissions with up to 15ppb possibly due to emissions from within the Petrochemical Complex. Unfortunately there was no information on concurrent upwind benzene concentrations which would have allowed positive identification of the source or an estimate of fugitive emission strengths.

Industrial sources burning wood waste have benzene emissions whose flue gas concentrations may vary from 1 to 100 µg-m³ (Jaques 1990). Depending on the quantity burnt and stack characteristics, there is the possibility that these premises may also produce locally exceed the benzene design ground level concentration.

ESTIMATION OF PAST BENZENE LEVELS USING MONITORING DATA.

There is only limited information on measured benzene concentrations in Melbourne. However the few measured benzene, NO_x ratios and benzene'hydrocarbon ratios may be

applied to historical monitoring data. Both NO_x and non methanic hydrocarbon (NMHC) data have been available from the EPA monitoring network for a number of years. The network has been sited away from major point sources of emissions and major roads in an attempt to provide data on regional background levels.

The NO_x monitors are capable of registering concentrations up to a maximum of around 600ppbv. At this level, the measured benzene (ppbC) NO_x (ppbv) ratio of 0.26 implies benzene concentrations of at least 80 µg/m³.

Based on measured one hour average NO_x levels over the last five years, benzene has reached or exceeded 80 µg/m³ in the CBD and the suburbs of Camberwell, Alphington, Brighton, Dandenong, Paisley and Footscray.

Although fewer stations are equipped to monitor NMHC levels than NO_x, routine measurements have been taken at a number of sites. From the measured benzene NMHC ratio of 6.8% carbon (Galbally 1990), the benzene design GLC of 100 µg/m³ is exceeded whenever NMHC levels are greater than 2.9ppmC.

Since elevated NMHC levels may originate from large local sources (eg. a refinery, accidental spills), for which the benzenehydrocarbon ratio is unknown, the data were screened on an hour by hour basis to ensure that the monitored NMHC levels were consistent with the pollutants having originated primarily from motor vehicle emissions.

The Benzene'NMHC ratios have been determined for a pollutant mixture largely due to emissions from motor vehicles. The 1990 emissions inventory for motor vehicles estimates NO_x emissions to be 2.1 g/km and hydrocarbon emissions to be 2.95g./km. This implies a NMHC NO_x (ppmC ppmV) ratio of around 7. Hydrocarbon concentration with Hydrocarbon NO_x ratios appreciably greater than 7 were not considered since this implies a significant contribution of hydrocarbons from a source other than motor vehicles. Hydrocarbon concentrations at Paisley, and to a lesser degree Footscray, were largely influenced by emissions from industrial hydrocarbon emissions, mainly from the Petrochemical

refinery and Petrochemical complex at Altona. Hydrocarbon NO_x ratios from these sources were in the range 10-800.

After screening on the basis of hydrocarbon NO_x ratios it was found that hydrocarbon levels, due mainly to vehicle emissions, exceeded 2.9ppmC at Paisley, Footscray, Alphington and Brighton. These elevated levels of both NO_x and hydrocarbons, which indicated the probable high levels of benzene, generally occurred in the winter months between 10pm and midnight. Although these were not common events, occurring at any one site for only a few hours each year, it must be assumed that the benzene level had been exceeded at these locations.

ESTIMATION OF OTHER AIR TOXIC CONCENTRATIONS

The EPA regulatory model, AUS-PLUME, has been used here to estimate the concentrations of benzene, one of a range of volatile organic compounds originating from motor vehicle emissions. The concentration of other air toxics, whose presence in the ambient air is due primarily to emissions from motor vehicles, can also be estimated from the predicted benzene concentrations once the predicted benzene/air-toxic ratio is known.

For example, 1-3 butadiene is another suspected carcinogen present in vehicle exhaust emissions. While there are no known measurements of butadiene in Australian vehicle exhausts emissions or in the ambient air, benzene, butadiene ratios have been estimated from overseas measurements to be in the range between 4 (Chan 1991) and 8 (Dann 1989).

If these ratios are applicable to the Australian vehicle fleet, then direct scaling of the benzene predicted concentrations gives estimated maximum hourly concentrations of 1-3 butadiene of around of 12 - 25µg/m³. Since the maximum risk for a lifetime exposure to 1µg/m³ of 1-3 butadiene is 1.4 x 10⁻⁴. (cf. risk factor for benzene of 4 x 10⁻⁶) the health risk may be 4 to 9 times that for benzene and warrants further attention.

Similarly other air toxics, such as formaldehyde, can be estimated. However concentrations of formaldehyde due to vehicle emissions would present a lower bound to the actual ambient concentration since formaldehyde is also formed from other hydrocarbons as an end product of photochemical oxidation.

VEHICLE EMISSION CONTROL

Vehicle emissions are the major contributor to ambient benzene concentrations. Even in the USA, despite vehicle emission controls stricter than Australian standards, a recent emissions inventory estimated that 85% of benzene emissions originated from mobile sources (Dasch and Williams 1991). Exhaust and evaporative emissions account for the bulk of emissions from the Melbourne vehicle fleet with a small contribution from vehicle refuelling activities (Table 5). Total removal of benzene from petrol would result in an approximate reduction of 45% in vehicle benzene exhaust emissions (CONCAWE 1989) and the elimination of benzene from evaporative and refuelling sources. This results in a total reduction in mobile source emissions of 57%.

Since 1976 car hydrocarbon emissions have been progressively controlled by the introduction of more stringent design rules and the installation of catalytic converters (1986).

As the Melbourne fleet ages and more vehicles in the fleet comply with the newer emission regulatory standards (ADR 37), emissions are expected to decrease.

Assuming catalytic converters experience no performance deterioration while in service, exhaust hydrocarbon emissions should fall by 87% from 0.115g/km for the 1990 vehicle fleet to 0.015g/km as vehicles manufactured after 1985 progressively replace older cars. Similarly evaporative hydrocarbon emissions should fall by 57% from 0.034g/km to 0.012g/km (Table 6). Since the benzene hydrocarbon ratios are similar for both pre-catalyst and catalyst equipped vehicles, benzene levels should decrease by 80% following the gradual conversion of the Melbourne vehicle fleet to one complying with the ADR 37 regulations.

However the estimated reduction assumes no deterioration of the emission control equipment either through loss of combustion efficiency or deterioration of catalyst efficiency due to deliberate tampering or catalyst poisoning. Unfortunately studies by the NSW State Pollution Control Commission (SPCC) and the ANZEC Advisory Committee for Vehicle Emission and Noise (Collins 1989) report hydrocarbon exhaust deterioration factors of 0.1-0.12 g/km* 10,000km travelled (cf. US EPA

Source	g/km	Percentage
Exhaust	0.115	76
Evaporative	0.034	22
Refuelling	0.003	2

Table 5. Motor vehicle emission source contributions

Car Age	Exhaust g/km	Evaporative g/km	Total g/km
Pre '76	0.201	0.069	0.270
'76 - '80	0.066	0.036	0.102
'81 - '85	0.063	0.036	0.077
Post '85	0.015	0.012	0.027
'90 Fleet	0.115	0.034	0.149

Table 6. Vehicle benzene emissions according to year of manufacture.

deterioration factor of 0.04 - 0.06). Therefore the actual reduction in benzene emissions may be less than estimated unless regulatory action is taken to ensure the long term performance of pollution control equipment fitted to the Australian vehicle fleet.

In EPA 1990 emissions inventory, it was estimated that hydrocarbon emissions from motor vehicles had decreased by approximately 20% since 1985. If all cars manufactured after 1990 are fitted with 3-way catalytic converters whose exhaust deterioration factors are similar to those determined by the US EPA for the US motor vehicle fleet then the trend in motor vehicle hydrocarbon emissions predicted by the 1990 Emissions Inventory can be used to estimate future benzene emissions. Benzene emissions from motor vehicles in the Port Phillip control region are expected to decrease by 30% by the year 2000 (Table 7.). Ambient concentrations in urban areas not influenced by point source emissions are expected to decrease by approximately the same extent during this period.

RECOMMENDATIONS

The design ground level concentration for benzene should be reviewed as part of an overall review of the SEPP (The Air Environment)

Estimates of benzene from wood burning in the Port Phillip Control Region are impossible to predict accurately due to the lack of reliable Australian emission factors for stoves and fireplaces. Emission factors for these sources as well as the quantity and distribution of wood fuel use should be established for the region.

Future benzene trends have been predicted assuming catalyst deterioration rates are similar to those in the US motor vehicle fleet. Deterioration factors should be ascertained for the present Australian fleet and if necessary regulations should be enforced to ensure that catalytic converter deterioration is not excessive.

Motor vehicle emission factors for air toxics other than benzene should be established so that the results from this study can be extended to estimate ambient concentrations of these pollutants.

Year	Exhaust t/yr	Evap+running t/yr	Total t/yr
1990	3200	940	4140
2000	2380	480	2860

Table 7. Benzene emissions into the Port Phillip Control Region due to the exhaust, evaporative and running loss emissions from motor vehicles.

AML incidence was investigated using the available data from the Anti Cancer Council of Victoria for the years 1982-1986. The data should be reviewed with a larger data set as information for more recent years becomes available.

Benzene emissions from the Altona refinery and petrochemical Complex should be modelled as a single group of sources using data from this study to estimate the additional benzene background concentrations. In order to estimate benzene levels in the vicinity of the Complex, emissions from both known discharge points and fugitive benzene emissions estimated to arise from valves, glands, tanks etc. should be used in the model.

Benzene levels adjacent to major roads during stable meteorological conditions should be established by direct measurement.

SUMMARY

Aromatic hydrocarbons such as benzene are released into the atmosphere during all of the phases of production, handling, transport and end use. While locally elevated benzene levels may be due to emissions from nearby industrial sources, vehicle refuelling operations or accidental spills, the major contributor of benzene to the ambient air in Melbourne is vehicle emissions. Other human carcinogens such as 1-3 butadiene, which is also present in vehicle exhausts may also pose a health risk since this air toxic has a significantly greater risk factor than that for benzene even though the estimated concentration is probably less than a quarter of the predicted benzene concentration.

Benzene concentrations in Melbourne due to motor vehicle emissions are predicted to exceed the SEPP benzene design ground level

concentration of 100 $\mu\text{g}/\text{m}^3$ (3 min. average) and concentrations are expected to approach 100 $\mu\text{g}/\text{m}^3$ as a one hour average concentration. Concentrations on and adjacent to major roads during peak traffic periods are predicted to exceed 100 $\mu\text{g}/\text{m}^3$ under light wind, stable meteorological conditions.

Benzene emissions from motor vehicles are expected to decrease by 30% by the year 2000. This continues the downward trend in motor vehicle hydrocarbon emissions as a result of increasing numbers of cars fitted with catalytic converters. Benzene concentrations in areas in which the major source of benzene is due to motor vehicle emissions are also expected to decrease by about the same extent.

Although benzene measurements in Melbourne are limited, concentrations from industrial sources as high as 55 $\mu\text{g}/\text{m}^3$ have been recorded. Estimates from routinely measured nitrogen oxides and NMHC concentrations and measured benzene NO_x and benzene NMHC ratios suggest that the benzene design ground level concentration has been occasionally approached or exceeded in Melbourne's CBD and suburban areas.

Annual average concentrations in areas close to the CBD are estimated to be 11 $\mu\text{g}/\text{m}^3$. The predicted annual average benzene concentrations, together with the WHO' benzene risk factor were used to predict the incidence of acute myeloid leukaemia in the Port Phillip region. The predicted average incidence approximated the actual incidence rate of AML in the Melbourne region. However the spatial distribution of AML incidence levels correlated poorly with the age-standardized incidence of AML in Melbourne for the period 1982-1986.

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(Continued from page 22).

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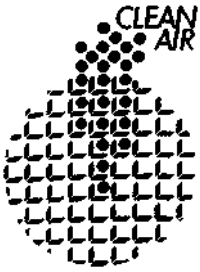
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