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**Indoor Air Quality in Australia:
A Strategy for Action**

by

Indoor Air Quality Special Interest Group

of the

Clean Air Society of Australia and New Zealand

\$20

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FASTS
PO Box 218
DEAKIN WEST ACT 2600

Phone: (02) 6257 2891
Fax: (02) 6257 2897
Email: fasts@anu.edu.au

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Clean Air Society of Australia and New Zealand

Web site: <http://www.casanz.org.au/>

Email: casanz@ozemail.com.au

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FOREWORD

The role of the FASTS Occasional Paper series is to bring significant issues to the attention of the community, the government and the bureaucracy.

In the case of the paper prepared by the Clean Air Society of Australia and New Zealand, the science is well established. Measurements have been done, evidence collected, and the implications emphasised. There is a clear and present danger. A significant proportion of our community is at risk, and will remain at risk until the governments of Australia tackle issues which affect the quality of air within the buildings where we work, live and study.

The paper makes a number of recommendations. These range from establishing a national body to take responsibility for the issue of indoor air quality and the setting up of programs offering practical solutions, to filling in gaps in the data. These recommendations deserve close scrutiny from all levels of government, and a coordinated response.

Often science-based issues demand a whole-of-government response, because the issues cross the administrative boundaries established by the allocation of portfolio responsibilities. Australia has been slowly improving its capacity to respond to matters that involve a number of ministers or require actions at all levels of government.

It is our belief that Australia requires a wider whole-of-government approach to coordinate the national research effort because of the pervasiveness of science to almost all policy areas, and because many issues involve federal, state and territory governments. COAG—the Council of Australian Governments—has a role here.

There have been promising signs in Australia in recent years as both major political parties have increased their commitment to science and technology. The commitment has been accompanied by some modest (but welcome) increases in funding, but the missing ingredient has been the absence of a long-term strategy that would allow science and technology to serve its rightful place as a driver of the economy and solution to our environmental problems.

The issues raised in this paper are an illustration of the fact that Australia still lacks a national commitment to making the best of its science.



Chris Fell

President

Federation of Australian Scientific and Technological Societies

October 2002

OVERVIEW

Indoor air quality is a most significant environmental issue that has not been seriously addressed in this country. Unhealthy indoor air is costing the Australian community an estimated \$12 billion a year. Australia is failing its responsibilities of a 'duty of care' to protect the community in the environment where we spend most of our time.

Resolution of the issue requires assessment of the problem, the setting of standards, formation of a central responsibility for indoor air, and initiation of actions to improve air quality.

Though further assessment will be needed to better define the problem, the facts before us already show:

- we spend up to 90 percent of our time indoors
- while on the one hand, national enforceable standards (NEPMs) are rarely exceeded outdoors, on many days every year millions of people inhale air in excess of air quality standards or goals while indoors
- the indoor air pollutants that often exceed acceptable levels include nitrogen dioxide, carbon monoxide, particles, formaldehyde, environmental tobacco smoke, and house dust mites
- in 2000 there were five fatalities from carbon monoxide poisoning in dwellings in Victoria alone (Office of Gas Safety 2002), and by calculation the health of millions of people is being impaired by indoor air pollution.

Australia has national enforceable standards for ambient air (NEPMs), where people spend only around 10 percent of their time, but it has only non-enforceable interim guidelines for some indoor air pollutants. There is a very much wider range of pollutants indoors that are of concern when compared to outdoors. Ott and Roberts stated in *Scientific American* (February 1998) that 'Of the hundreds of air pollutants covered by US laws, only ozone and sulfur dioxide remain more prevalent outdoors'. It is imperative that national standards are set for indoor air quality in the very near future so the extent of indoor air pollution can be fully established.

A critical factor that has permitted the poor condition of indoor air to deteriorate to its present state is the lack of government ownership of this environment. In the case of outdoor air, the state governments have passed legislation that is enforced by regulation. Fines of up to \$1 million can be imposed for infringements that result in unhealthy air. The environment ministers in the states and the Commonwealth have formed a partnership to ensure everyone in the community has access to clean air in the ambient environment. However, in the indoor environment there is only a fragmented interest spread amongst departments of public health, environment, building, work safety, and so on. This has resulted in sporadic involvement, usually by issuing information brochures on isolated issues such as unflued gas heaters or passive smoking. Environment Australia has funded some research studies on indoor air. Although well over 15 years have passed since the first major study revealed very serious air pollution levels in homes, hospitals, schools and caravans, the community remains uneducated and the government largely unmoved.

It seems astonishing that certain environmental programs are being put in place without full consideration of the total exposure of the population to air pollutants. This is exemplified in the strong government program associated with the construction of new dwellings and commercial buildings to conserve energy, and thereby reduce greenhouse gas emissions. Unfortunately, without due consideration of the effects on the indoor environment, this can result in modern building designs that are reducing ventilation and thus potentially causing a very serious decline in the quality of indoor air and the health of the occupants.

The immediate steps required to address the issue of indoor air pollution are to:

- establish a national body (linked or similar to the National Environment Protection Council—NEPC) responsible for indoor air
- establish indoor standards of air quality for the most common and serious pollutants

- collate existing measured indoor air pollution levels into a national database
- commence studies in areas where insufficient data are available
- establish programs that will address the most serious problems
- commence a wide-ranging and comprehensive public education program.

The sooner these steps are taken the sooner the health and economic benefits will accrue.

Len Ferrari

President

Clean Air Society of Australia and New Zealand

1 INTRODUCTION

It has long been known that substances in the air can have adverse effects on human health. Air pollution (of ambient air) came into focus with London's 'killer smogs' in the early 1950s, when it is estimated that some 4000 people lost their lives in one incident alone that lasted several days. The smogs brought swift government action to improve the situation. However, it was another two decades before a similar level of concern was first expressed about the quality of air within non-industrial buildings—indoor air quality.

The slow rise of concern about indoor air quality was addressed by a rapid rise in overseas interest and research into the subject. In Australia the first major investigations took place in the 1980s. However, in contrast to the overseas experience, the response to the research findings in Australia has been less comprehensive. There has been concerted action to address only a few of the pollutants that have been the source of concern in research findings.

This paper focuses on concrete and immediate steps to improve indoor air quality in Australia, based on the current state of knowledge. As a means to that end it also looks at the most significant indoor air pollutants in the Australian context and attempts, briefly:

- to review what is known about them
- to indicate their possible impact on health
- to estimate the population that may be at risk
- to outline any significant actions that have already been taken to improve the situation
- to recommend ways to remedy identified problems.

A summary of the 21 pollutants discussed in this paper and recommended actions is included as section 2.

What is indoor air?

The term 'indoor air' has a wide range of meanings and the community can interpret it in many ways. This paper uses the term in accordance with the NHMRC definition: a non-industrial indoor space where a person spends a period of an hour or more in any day. Thus indoor air includes the air inside homes, offices, commercial premises (such as shops, restaurants), schools, and automobiles including cars and buses. A distinction is made here between occupational exposures where the pollutant of concern is directly associated with the work undertaken and is thus covered under industrial worker safety legislation, and exposures to pollutants that are incidental to the occupation. For example, perchlorethylene is a commonly used dry-cleaning solvent. If someone were exposed to it while working at a dry-cleaners it would be an occupational exposure. In contrast, perchlorethylene is not usually found in office environments, where this paper would treat it as an indoor pollutant. The distinction is somewhat arbitrary. However, the functional difference is that industrial legislation protects workers from air pollutants likely to be found in certain industries. Further, they have the choice of changing employment if they find that they are sensitive to the air pollutants found in the workplace and their health is affected even when work safety standards are met. On the other hand, someone whose health is affected by indoor air pollution is not protected by legislated limits, may be unaware of the cause of their ill health, or may have no option but to continue their exposure.

This paper also does not treat those pollutants found indoors where the only (or overwhelmingly dominant) source is from the ambient environment. In that situation the pollution sources are regulated and controlled as a means of maintaining the 'common good' under legislation often called or derived from 'Clean Air Acts'.

Thus, effectively, 'indoor air pollution' becomes all those air pollutants indoors that are not controlled by occupational or ambient legislation in the environment in which they are encountered.

Emphasis on ‘what can be’

This paper has been prepared in the full knowledge that several significant papers and monographs have already been published on the topic. Worthy of specific mention are:

- Brown’s seminal paper *Indoor Air Quality—Australian State of the Environment Technical Paper Series (Atmosphere)* (1997)
- Environment Australia’s *State of Knowledge Report: Air Toxics and Indoor Air Quality in Australia* (2001)
- Department of Health and Aged Care’s *Indoor Air Quality—A Report on Health Impacts and Management Options* (2000).

Little has changed since these papers were written, although this paper refers to new research that post-dates them. Rather than replicate them in terms of describing the current situation, this paper seeks to build on their analysis of ‘what is’ by emphasising the way forward—the ‘what can be’. It refers briefly to the ‘what is’, partly to make this a complete document in itself; primarily to support the compelling arguments for immediately addressing the currently degraded state of indoor air in key areas. For more details about the ‘what is’ refer to the above works (and/or references in the text).

It should be noted that the section on potential health effects for each pollutant contains only limited references. Unless otherwise indicated, the information in these sections has been drawn from the above references and the *Final Impact Statement for the National Environment Protection Measure for Ambient Air* (1998). Again, these sections should be viewed as indicative rather than as an exhaustive treatment of what is known about the health effects of the pollutants. They are included to indicate some of the salient, known adverse effects.

National Environment Protection Council / National Environment Protection Measures

Mention is made throughout of the National Environment Protection Council (NEPC) and National Environment Protection Measures (NEPMs).

The NEPC was established to set national environmental goals and standards for Australia, through NEPMs. It is a statutory body with law-making powers established under the *National Environment Protection Council Act 1994* (Commonwealth), and corresponding legislation in the other jurisdictions. The objectives of NEPC are to ensure that:

1. the people of Australia enjoy the benefit of equivalent protection from air, water or soil pollution and from noise, wherever they live
2. decisions of the business community are not distorted, and markets not fragmented, by variations between member governments in relation to the adoption or implementation of major environment protection measures.

Members of Council are ministers (not necessarily environment ministers) appointed by first ministers from the participating jurisdictions—the Commonwealth, state and territory governments. The NEPC Committee, the principal advisory body to the Council, comprises the NEPC Executive Officer and one nominee of each Council member. A non-voting observer has been appointed by the President of the Australian Local Government Association.

NEPMs are ‘framework’ documents outlining agreed national objectives for protecting or managing particular aspects of the environment. They may consist of goals, standards, protocols, and/or guidelines. NEPMs must be agreed by a two-thirds majority of ministers of the NEPC and are binding on each participating jurisdiction. Progress is reported annually through state/territory parliaments and through the NEPC to the Commonwealth Parliament. In the past four years, the NEPC has made six NEPMs, including one on ambient air quality (July 1998).

This paper uses acronyms and abbreviations throughout. A glossary of these and other terms is provided at section 10.

2 SUMMARY OF 21 INDOOR AIR POLLUTANTS & RECOMMENDATIONS

The following is an overview the 21 indoor air pollutants discussed in sections 4–7.

POLLUTANT	MAJOR SOURCES	PRIORITY	IMMEDIATE ACTION	FOLLOW-UP ACTION
Carbon monoxide	Combustion appliances, ETS, vehicle exhaust	High	Education; replace old unflued heaters	Improve ventilation when source active
Nitrogen dioxide	Combustion appliances, ETS	High	Establish goal; education; replace old unflued heaters	Improve ventilation when source active
Environmental tobacco smoke (ETS)	Smoking cigarettes, etc.	High	Urgent education	Urgent education
Formaldehyde	Wood products, furnishings, combustion appliances, ETS	High	Emission standard; education; statistical study	Control of major emitters
House dust mite (HDM)	Discarded skin cells and high temperature/humidity	High	Education; reduce incidence	Education, reduce incidence
Moulds and fungi	Damp areas, air conditioning ducts	High	Establish benchmarks; survey of targeted areas including hospitals; education	Establish standards for maintenance of air conditioning systems
Particulate matter (PM ₁₀)	Wood combustion appliances, cooking, vacuuming	Medium–high	Statistical study on exposure	Education
Lead	Leaded paint removal, ceiling dust	Medium–high	Education	Further education
Particulate matter of other sizes	Wood combustion appliances, cooking, vacuuming	Medium– high	Education	Further education
Benzene	Petrol vapour and combustion products	Medium–high	Statistical study	Further control if necessary
Bacterial and viral pollutants	Human breathing, sneezing	Medium–high	Establish standards for maintenance of air conditioning systems	Education
Carbon dioxide	Combustion appliances	Uncertain	Statistical study on exposure	Education
Pesticides	Terminicides, insecticides	Medium	Guidelines; statistical study	Action if warranted
Total volatile organic compounds (TVOCs)	Paints, solvents, adhesives, aerosol products	Medium	Statistical study	Reduce levels in major sources
Chlorinated hydrocarbons	Solvents, chlorinated town water	Medium	Statistical study	Further control if necessary
Other allergens	Cats, dogs, cockroaches	Medium	Education, statistical study	Further education if necessary
Ozone	Ionisers, photocopiers	Low	No action	No action
Radon	Natural rock and earth	Low	Education in certain areas	Watching brief on geology of new housing development sites
Asbestos	Asbestos cement, lagging	Low	Education	Education
Sulfur dioxide	Few	No	No action	No action
Metals	Few	No	No action	No action

3 REASONS FOR CONCERN ABOUT INDOOR AIR QUALITY

While it can be claimed that ambient air pollution in Australia is well understood and is being successfully controlled (if not yet completely within acceptable limits), the situation for indoor air pollution is not nearly as positive. The state of knowledge is paradoxical. Compared to ambient air quality, relatively little is known about indoor air quality, but what is known generally shows that the situation is much worse than outdoors. Furthermore, with limited exceptions, the quality of indoor air is not improving. The following features of indoor air pollution should increase the level of concern of both citizens and all spheres of government.

1. ***A much wider range of possible air pollutants can be found at elevated levels indoors than occur at levels of concern outdoors*** (see, for example, Wadden and Scheff 1983; Newton *et al.* 2001). This is because many of the sources of indoor air pollution are only found indoors. Pollutants such as some solvents, formaldehyde, environmental tobacco smoke and house dust mite allergen, to name just a few, are rarely, if ever, found outdoors at levels of concern. But in common indoor environments they may frequently be present at levels which are injurious to health, particularly for susceptible sub-populations of the community.
2. ***The health effects from constant exposure to mixtures of indoor air pollutants are poorly understood*** (Pollak 1993).
3. ***Levels of indoor air pollutants may be as varied as the situations in which they occur.*** Every home has a different mix of possible sources—new furnishings, a cat, a flueless gas heater, or particle board floors, to name but a few. The owners may like to keep the windows open even in the depths of winter or prefer to close up tight and save on energy bills. The range of situations makes it difficult to predict with any certainty the levels of even common pollutants that will be found indoors. There are none of the increasingly sophisticated computer models that are used to predict, accurately, ambient levels of pollution with almost street-by-street resolution. In contrast, there have only been a relatively small number of studies to define levels of indoor air pollutants in Australia. Thus it is a much greater challenge to monitor indoor air quality than it is to monitor the ambient environment—there are many more pollutants indoors and there are, literally, millions of environments (individual houses and other structures) about which we need information. Such information cannot be gathered by fixed ambient monitoring networks as are operated by the various state and territory environmental agencies.
4. ***There is no national framework, such as the ambient air quality NEPM, to ensure a systematic examination of the situation.*** Studies undertaken to date are of a research nature. They have not been coordinated nationally with a view to developing a cogent overview of the current situation. There are few protocols for monitoring indoor air or for the methods to be used. Thus the results are not easily comparable; nor do they necessarily complement one another.

Thus the situations where harmful indoor levels occur and their distributions, while indicated by the research to date, have yet to be adequately documented. Yet the available evidence consistently points to much higher indoor levels of a much wider range of pollutants that are potentially affecting many more people than those outdoors. In addition, Australians spend most (up to 96 per cent) of their time indoors (Newton *et al.* 2001). However, what is clear is community exposure to unacceptable levels of air pollution occurs overwhelmingly indoors.

5. ***Even on the limited available data, the adverse health implications of indoor air quality have very significant economic effects. A CSIRO estimate (CSIRO 1998) is that poor indoor air quality costs Australia \$12 billion per annum.*** What is more, people who are the most vulnerable in terms of their health spend almost all of their time indoors, possibly greatly increasing their exposure to a wide range of harmful pollutants. They include children, the elderly and the infirm. Particularly in the case of children, these sections of the community are often the least able to either find out about the impact of their indoor environments or

if they did, to improve the situation. Thus, there is an issue of ‘duty of care’ regarding the quality of indoor air, especially for government.

6. ***There is serious cause for concern—the appropriate response is immediate action to improve the situation.*** The pollution levels found, the extent of the potentially exposed population and the presence of vulnerable sub-populations all demonstrate that there is cause for concern about the quality of Australia’s indoor air.
7. However, so far in Australia the emphasis has been on ambient air, which is now well monitored, controlled and regulated. In comparison, ***indoor air quality has no coordinated system of control or even a single area of government (local, state or federal) taking responsibility for it.*** Areas of responsibility are often found within health departments, work safety departments, building departments and sometimes environment agencies, often in both local and state government. This means that circumstances can easily arise where no organ of government is prepared to take responsibility or for which there is more than one responsible area in government. In a school, for example, teachers may be covered under work safety regulations while the children may be seen as the responsibility of the department of health or not be covered by any specific regulations at all, except as part of the education department’s duty of care. This means that the same air may need to meet different standards or goals measured under different criteria.
8. ***Citizens have little idea about the effect indoor air quality may be having on their health, or its potential impact on their economic wellbeing.*** In these circumstances, they are inadvertently doing things such as using appliances or products that are actually harming them and those around them, including dependant children.

We know from experience that substantial change is possible when citizens have become aware of possible dangers. The community cooperates in making the changes; sometimes it is the driving force behind them. The best example is the measures to reduce exposure to environmental tobacco smoke in public areas. However, ***in too many areas, citizens simply do not have access to the information that would enable them to make informed choices or to improve the situation.*** Sometimes the information is not available or is not in a readily accessible form. Regrettably, there are occasions where available information may not be promulgated in a readily accessible way or is suppressed because it is convenient to do so.

While progress has been made, in many areas citizens are poorly informed and in the absence of public information, government has failed in its duty of care to protect people from the adverse effects of indoor air pollution. This is in stark contrast to the situation in the ambient environment, where concerted action over several decades has brought substantial and sustained improvements. Any changes regarding indoor air have been mostly incremental and largely uncoordinated.

In all, we need to be much more concerned about indoor air quality in Australia.

The following discussion of indoor air pollution provides information on the pollutants found indoors, their source, possible health effects and the size of the exposed population. In the discussion of exposures, an estimate has been made of the number of times in a year that the level of a pollutant indoors will exceed the relevant standard. An estimate has also been made of the number of people exposed to these high levels.

An occasion when the level of the pollutant indoors exceeds the relevant standard is referred to as an event. An occasion when a person is exposed to an event is called a person-event. For example, if three people are exposed to an event, there are three person-events; if three people are exposed to two events, there are six person events.

4 NEPM AIR POLLUTANTS INDOORS

4.1 Carbon monoxide

4.1.1 Sources

Carbon monoxide is formed by the combustion of carbon-containing substances (often in the form of fossil fuels). Important potential indoor sources include:

- flueless or poorly flued gas heaters or cooking appliances, poorly flued wood heaters, kerosene heaters
- motor vehicle exhaust in underground or enclosed car parks, or where fumes from the car park may enter the rest of the building, possibly through the ventilation system
- motor vehicle exhaust in domestic situations where the garage and the dwelling are connected by an internal door
- environmental tobacco smoke.

4.1.2 Possible health effects

Carbon monoxide binds with haemoglobin to reduce the blood's oxygen-carrying capacity. At high concentrations this can be fatal; at lower concentrations symptoms include headache or loss of concentration. There is now consistent evidence that people with heart disease are a susceptible sub-population and are at risk at relatively low levels. The NEPM ambient standard is 9 parts per million averaged over 8 hours, which is the same as the NHMRC interim indoor goal. The WHO has also established goal levels for other averaging times, including a one-hour goal of 25 parts per million.

4.1.3 What is known about it and its levels in Australia?

Some studies have been undertaken to determine carbon monoxide levels where there are combustion sources indoors. While none of the published results has provided sufficient detail to enable precise estimates to be made of the percentage of situations in which standards or goals are not met, it is possible to estimate the magnitude of the potential exposed population. Lyall (1993) reported carbon monoxide levels from flueless gas heaters that exceeded the WHO one-hour ambient goal in both NSW and South Australia (but not Western Australia where there are mandatory ventilation requirements). McPhail *et al.* (1988) also reported levels exceeding the WHO one-hour goal from flueless gas heaters in NSW, while Steer *et al.* (1990) reported similar exceedences for gas cooking appliances in South Australia. Obviously the situation is not isolated to one state; nor are situations where the goal is exceeded so infrequent that they were not detected by the relatively small surveys reported.

In Victoria in 2000, there were five deaths caused by carbon monoxide poisoning associated with gas heaters. Three people died in a caravan where a flueless gas heater was in use and two people died in a room where a leaking flued gas heater was operating (Office of Gas Safety 2002).

Ambient air quality measurements suggest that the NEPM carbon monoxide standard is now rarely exceeded except in circumstances directly adjacent to heavily trafficked roads (eg Manins *et al.* 2001). Certainly, the WHO one-hour goal would not be approached at any of the Australian ambient NEPM monitoring stations. Clearly, indoor exposures can be significantly higher.

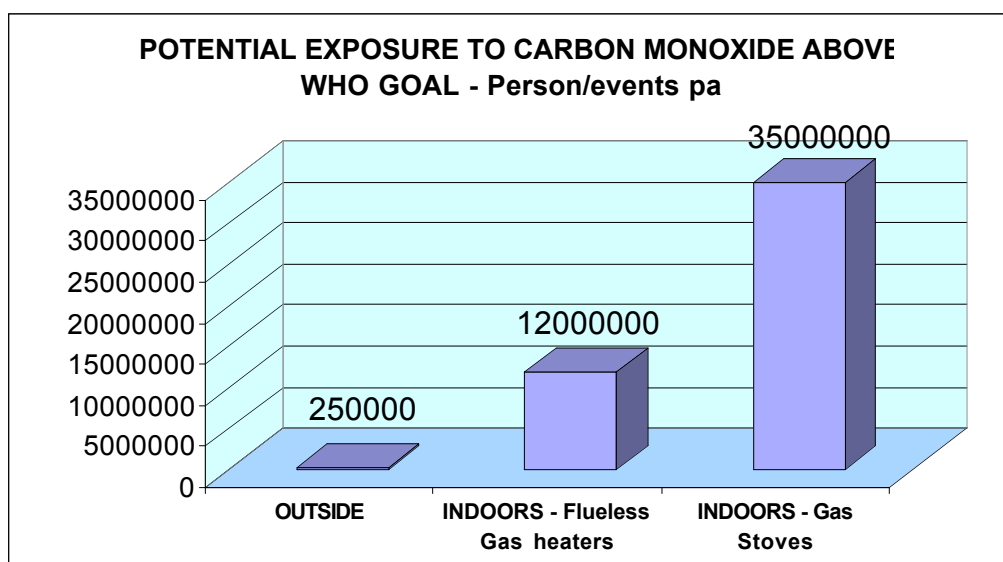
There appear to be few data available about levels of carbon monoxide in enclosed car parks or in buildings attached to them.

4.1.4 Potential exposed population

The ABS has estimated that 23.1 per cent of Australian homes are heated by non-ducted gas heating (ABS 2000a). 50 percent of these can be assumed as unflued. Further, 40.5 per cent use

gas for cooking (ABS 2000a). Additionally, in 1996 there were about 6.6 million homes in Australia with an average occupancy of 2.7 people (ABS 1996). Thus, some 2 million people live in a flueless gas-heated home, while some 7 million have a gas cooking appliance. Published study findings do not contain sufficient detail to allow reliable estimates of the percentage of homes that may experience levels exceeding the WHO one-hour goal. However, it would be consistent with the published data to estimate that 2–4 per cent of flueless gas heaters produce levels in excess of the WHO one-hour goal, as do maybe as many as 5 per cent of gas cooking appliances. This means that possibly some 80,000 people may experience unacceptable levels of carbon monoxide due to gas heating. The equivalent number for gas cooking appliances may be as many as 350,000 people.

Further, it should be noted that these exposures are likely to occur regularly—often whenever the appliance is used or is used for more than a certain period of time. Thus, in the case of flueless gas heaters, if, unacceptable levels were to occur for say 3 hours a day for 50 days a year, this represents 150 events per year with 80,000 people exposed to each event. This potentially represents some 12 million person-events. Similarly, for gas cooking appliances, the level may be exceeded on, say, 100 days a year, representing some 35 million person-events.



[Note that for display purposes in the above diagram, the number of ambient person-events has been set at an upper limit of 250,000. It is highly improbable that this limit would be exceeded.]

4.1.5 Controls or other responses by government, etc.

There have been few initiatives aimed directly at reducing exposure to carbon monoxide indoors. Modern gas heaters are now fitted with an oxygen-deficit sensor, which should shut off before oxygen levels fall below a certain level. In Victoria, education brochures have been published on flueless gas heaters. Carbon monoxide detectors are used to detect raised CO levels in several countries overseas.

4.1.6 Summary

• Is it of concern?

Given that there have been recent deaths from exposure to carbon monoxide indoors, and the very significant number of people potentially exposed to it, carbon monoxide clearly remains a pollutant of concern.

4.1.7 Possible actions

Few people appear to be aware of the risks posed by carbon monoxide emitted from poorly maintained or poorly operating flueless combustion appliances such as gas heaters and gas stoves. *A first step would be a national education campaign focusing on the need for regular maintenance and describing early symptoms of an incorrectly operating appliance.* This could be conducted as part of wider education campaign on indoor air pollution. *A program to replace older flueless gas heaters with flued gas heaters or reverse-cycle air conditioning would reduce exposures to unacceptable levels of carbon monoxide. A building code that mechanically or electronically linked gas stove use to exhaust fan operation would reduce exposure.*

4.2 Nitrogen dioxide

4.2.1 Sources

Nitrogen dioxide is formed as a by-product of combustion through the fixing of atmospheric nitrogen. Important potential indoor sources include:

- flueless gas heating and cooking appliances
- kerosene heaters
- environmental tobacco smoke.

4.2.2 Possible health effects

Nitrogen dioxide is an oxidising gas that irritates the lungs. There is evidence that it suppresses the body's immune system.

At very high levels, nitrogen dioxide can cause fatal swelling of the lungs. At lower levels, symptoms include exacerbated asthma and more frequent and more severe respiratory illness. Australian epidemiological research confirms overseas findings that there is a significant correlation between exposure to nitrogen dioxide and adverse health outcomes, including increased hospital admissions for sufferers of childhood asthma and heart disease.

The NEPM ambient standard is 0.12 parts per million (one-hour average). There is no NHMRC indoor goal; the previous 'level of concern' of 0.3 ppm has been under review for a very long time.

4.2.3 What is known about it and its levels in Australia?

Studies of nitrogen dioxide levels have been undertaken in a variety of indoor environments, including homes and schools (see for example Ferrari *et al.* 1988; Steer *et al.* 1990; McPhail & Betts 1992; Lyall 1993; Nitscheke *et al.* 1998; Farrar *et al.* 2000; Sheppard *et al.* 2002). All studies have consistently found elevated levels in the presence of indoor sources, frequently in substantial percentages, of environments tested, that often exceed ambient standards by significant amounts.

In 1989, monitoring in NSW government schools, where flueless gas heaters are common, found levels of up to 2.9 parts per million nitrogen dioxide. Seven per cent of heaters exceeded the then NHMRC 'level of concern' of 0.3 parts per million (McPhail *et al.* 1989; McPhail & Betts 1992). After an extensive program of servicing heaters and rectification, which included the installation of new 'low-NOx' heaters in some cases, heaters exceeding the level of concern dropped to 2.9 per cent (NSW Department of Public Works 1992) but returned to 6.1 per cent in 1993. Indeed, in 1993 some of the new 'low-NOx' heaters were found to exceed the level of concern (Department of School Education 1993). Given that there were, at this time, some 44,000 flueless gas heaters in use in NSW government schools, it could be estimated that more than 2,000 of them were not performing adequately. It is difficult to estimate how many students this may have affected given that students move between rooms for some lessons, for example, but it would be expected to exceed 50,000. The number exposed to levels exceeding the NEPM ambient standard

would be significantly greater since the then 'level of concern' was over 2 times higher than the NEPM standard.

Monitoring in NSW homes made it possible to estimate percentages of homes exceeding specific levels (Ferrari *et al.* 1988; McPhail *et al.* 1988). It appeared that around 80 per cent of gas-heated homes in NSW had levels that would exceed the NEPM ambient standard (0.12 ppm). While new heaters designed to meet the AGA emission limit of 0.3ppm (see section 4.2.5) would perform better than the older heaters, it should be noted that many, if not most, older heaters would still be in use.

(While this study is now over 10 years old, there appear to have been few published studies making measurements over suitable averaging times with which to update its findings. Most recently, Sheppard *et al.* (2002a) measured weekly average nitrogen dioxide levels, from which they used a method to estimate that about half the homes tested had nitrogen dioxide levels exceeding the NEPM standard. Given the substantial difficulties in estimating one-hour levels from weekly average results, it could be argued that this estimate is consistent with that of the late 1980s.)

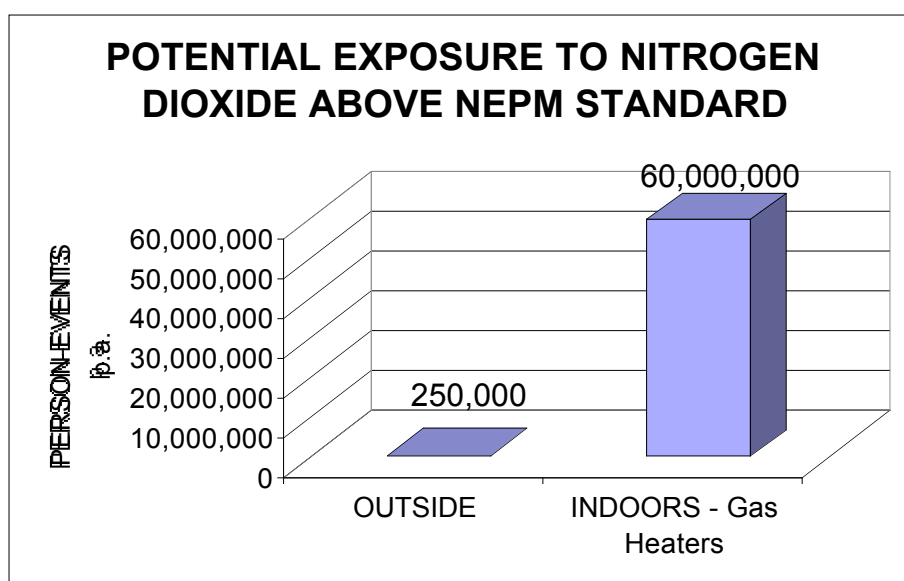
Steer *et al.* (1990) reported levels which suggest that 40 per cent of those kitchens in South Australia with gas cooking appliances would exceed the NEPM ambient standard. Nitscheke *et al.* (1998) reported that 36 per cent of dwellings tested in Port Adelaide had one or more readings (usually of averaging period greater than one hour) exceeding 0.1ppm.

In contrast, ambient levels of nitrogen dioxide now rarely, if every, exceed the standard anywhere in Australia (see, for example, Manins *et al.* 2001)

4.2.4 Potential exposed population

As described in 4.1.4, some 2 million people live in a flueless gas-heated home, while some 7 million have a gas cooking appliance. Using the 1988 study findings (McPhail *et al.* 1988), some 400,000 people in NSW alone could be exposed to levels of nitrogen dioxide from flueless gas heaters that exceed the NEPM (ambient) level.

Further, it needs to be borne in mind that these exposures may take place repeatedly throughout the heating season, possibly over several months. At most there may be one exceedence of the NEPM standard for nitrogen dioxide in ambient air each year in NSW (EPA NSW 2000) affecting an area where no more than 250,000 people live, giving an upper limit of 250,000 person events. However, in the indoor environment, 400,000 people may experience 150 events per year, giving an estimate of 60,000,000 person events. On this estimate, the indoor exposure in NSW is of the order of 200 times greater than the ambient exposure.



[Note that this diagram is for exposures in NSW domestic residences only and from flueless gas heaters alone. Exposures in schools, hospitals, etc. would be additional. Exposures from gas cooking appliances would be expected to be of a similar magnitude in residential dwellings.]

The above estimates are based on NSW alone. The exposure of the whole Australian population would be significantly greater, possibly reaching well over 100 million person-events/year.

4.2.5 Controls or other responses by government, etc.

In response to the unacceptable levels of nitrogen dioxide found in these studies, in 1991 the AGA introduced appliance emission limits for nitrogen dioxide from new flueless gas space heaters with a view to meeting the then NHMRC level of concern of 0.30ppm. A limit three times higher was set for new (flueless) cooking appliances.

As a result of testing in government schools, in 1990 the then NSW Department of Education undertook an extensive heater testing and rectification program. A second component of the program was intended to replace heaters with new heaters designed to meet the 1991 AGA requirements, starting with those in the coldest parts of the state. A time frame of about ten years was envisaged. Over 10 years later, it is understood this program is only now coming to the Sydney region (where the majority of heaters are). In addition to the replacement program, a directive was issued to schools requiring open window and door ventilation when the heaters were used in classrooms.

In NSW, the state with the greatest number of flueless gas heaters, AGL also undertook a heater testing and rectification scheme in private homes in the early 1990s. Potential participants were sought by means of information included in accounts sent to its customers.

4.2.6 Summary

- **Is it of concern?**

Yes. Many thousands of tests have shown a widespread problem. When many of the studies were undertaken, the ambient NHMRC goal for nitrogen dioxide was set at 0.16 parts per million, with a 'level of concern' for indoor air of 0.30 parts per million. Since then, the NEPM process has established a national ambient standard of 0.12 parts per million. This tightening of the ambient benchmark reflects increased concerns about the potential harm caused by nitrogen dioxide. Clearly, this concern transfers to the indoor environment, particularly in view of the large number of people exposed to levels near or above the standard.

- **Possible actions**

Decisive action to reduce exposure to nitrogen dioxide indoors is hampered by the lack of a standard against which to evaluate measurements. *The NEPM standard for ambient air must surely be adopted immediately as an interim benchmark for indoor air unless overwhelming evidence can be produced that the effects of this pollutant indoors are different to those outdoors.* (In fact, based on length of exposure, it appears that an indoor standard could be more stringent.) A mechanism for setting benchmarks is included in section 9.

The emissions performance of flueless gas heaters deteriorates with time. This fact needs to be incorporated into the AGA compliance standard in much the same way that motor vehicle exhaust catalyst performance over time is incorporated in Australian Design Rules. Thus, *the current AGA regulation on the rate of emission of nitrogen dioxide needs to be amended to require that any heater will demonstrate continued compliance with a much lower emission limit over a substantial period of operation.* This period needs to be linked to the average replacement age of heaters to ensure satisfactory performance throughout their often-extended life. For example, it would be appropriate to expect continuing compliance over, say, the equivalent of at least ten to twenty years of normal use.

Furthermore, given that a very substantial proportion of the flueless gas heaters now in service were purchased before the 1991 AGA emission limit was implemented, *there needs to be an immediate program to alert users of older heaters of the potential risk.* These heaters could be part

of concerted government action to encourage users to shift to flued heating or to other forms of heating with less impact on indoor air quality. Such a program may also have benefits in reducing exposure to unacceptable levels of carbon monoxide. ***All governments need to consider funding a heater replacement program similar to that currently being operated in some parts of NSW and Tasmania for solid fuel heaters.***

Study data consistently show that nitrogen dioxide levels resulting from the use of gas cooking appliances are of as much concern as are those from the use of flueless gas space heaters, despite differences in the duration of use. Thus, ***the emission requirements for flueless gas space heaters needs to be extended to all flueless appliances***, taking into account the volume of the room in which they are used. Indeed, ***the AGA limit for all such appliances needs to be substantially reduced*** to reflect reduced ventilation rates in Australia's housing stock and in addition with a requirement to meet the NEPM ambient standard for nitrogen dioxide. Additionally, ***stricter controls would be needed to ensure the emissions standards were met for the life of the appliance. A building code that mechanically or electronically linked gas stove use to exhaust fan operation would reduce exposure.***

4.3 Particulate matter (PM₁₀)

4.3.1 Sources

This section considers PM₁₀—particulate matter less than 10 micrometres in size—arising from sources other than environmental tobacco smoke and biological origins such as house dust mite, which are addressed in sections 6.1 and 7.1 respectively. Indoor PM₁₀ is usually generated by combustion, cooking or from the ingress of PM₁₀ from outdoors.

Wood combustion for domestic heating can be a significant source for two reasons. First, smoke can easily enter indoor air from the burning wood in an open fireplace. Even with a sealed slow combustion heater, smoke can escape indoors during lighting and reloading. Second, where the external flue is poorly sited or there are adverse wind conditions, significant quantities of smoke emitted outdoors can be re-entrained into the indoor environment.

Cooking activities can also produce particles indoors. These can originate from both the fuel and from the food itself, particularly during processes such as grilling, toasting or deep-frying.

The use of vacuum cleaners on carpet and other surfaces is another potential source of particles indoors (Na *et al.* 2000).

4.3.2 Possible health effects

There is a substantial body of work linking episodes of elevated (ambient) particulate pollution to measurable adverse health effects. These effects range from increased prevalence of respiratory symptoms; to increased hospital admissions for cardiovascular or respiratory conditions; to increased death rates from all causes, but particularly from respiratory and cardiovascular disease. At these times there are also increases in the number of visits to medical surgeries or hospitals for asthma and other respiratory conditions and an increase in absences from school.

There would appear to be no threshold below which health effects cannot be demonstrated. (NEPC 1998).

4.3.3 What is known about it and its levels in Australia?

There has been only limited work to examine the levels of PM₁₀ indoors in Australia.

Recently, Sheppard *et al.* (2002a) have reported PM₁₀ levels in more than 130 homes in NSW, using a device that accurately size selects for PM₁₀. The results show levels are significantly correlated with the presence of smokers and the use of wood as a heating medium. While averaging times were longer than for the NEPM standard, the majority of the homes with smokers and a significant number using wood heating could be inferred to have PM₁₀ levels that would exceed the ambient standard.

Ferrari *et al.* (1988) found the average level of particles in eight homes with wood heating was $86 \mu\text{g}/\text{m}^3$. This was much higher than in homes without wood heating. However, there was no appropriate standard against which to compare this level at that time; the methodology did not provide samples that were effectively size-selected to enable them to be categorised as PM_{10} ; nor were they collected over a 24-hour period. However, this work strongly suggests that many homes with solid fuel heaters experience levels of PM_{10} that exceed the current NEPM ambient standard.

The same study also found much higher levels of particles during some types of cooking. However, the duration of domestic cooking events is usually relatively short, so there is little likelihood of producing levels that would exceed a 24-hour average standard though they would exacerbate levels produced from other sources.

4.3.4 Potential exposed population

In 1999 the ABS estimated that 15.7 per cent of Australian homes used wood for heating (ABS 2000a), suggesting that some 2.8 million people live in homes with this type of heating. Clearly there is a substantial population that is potentially exposed to levels of PM_{10} from wood heating that exceed the ambient standard. Furthermore, many of these homes are likely to be in parts of the country where there are extended heating seasons as a result of the cooler climate. Thus, there are many occasions each year in these houses where the standard level is routinely exceeded—certainly more often than the five allowable exceedences each year under the ambient NEPM.

Wood heaters are not confined to the cooler climates of Australia. Wood-heater smoke is of growing concern in Brisbane and Alice Springs, where these heaters are being installed and used perhaps more for their decorative value than their utility. It follows that indoor pollution in these areas is also likely to be of concern.

(Section 6.1 discusses particles generated by environmental tobacco smoke.)

4.3.5 Controls or other responses by government, etc.

A number of governments have acted to reduce the use of solid fuel domestic heating. These initiatives have been introduced as a means to reduce unacceptable or elevated levels of PM_{10} in the ambient environment. Similarly, new solid-fuel heaters are now required to meet emission standards (AS 4013) in a number of jurisdictions, again as a means of improving ambient air quality. While reducing the number of wood-heated homes will improve indoor air quality, changes to product emission standards are unlikely to have a rapid or pronounced effect on average exposures since older heaters are unaffected by such actions. Furthermore, the new heaters just increase the number of people potentially exposed to unacceptable levels.

4.3.6 Summary

- **Is it of concern?**

It is clear that the community is very worried about (ambient) particle pollution (RTA NSW 2000). This, in concert with the substantially larger number of Australians who may be subject to unacceptable levels of particles indoors, shows that these levels are a very significant concern, although yet to be publicly appreciated.

- **Possible actions**

To date, almost all the attention on particles has been given to ambient levels and sources. *There is a clear need to determine levels of particles arising indoors by conducting a survey of a statistically valid cross-section of homes using solid-fuel heating.*

At present, the community, even if it knew where to search, has access to only very limited information about particle levels and sources indoors on which to base choices about heater type and usage. *Once a better database on actual levels is available, this information must be communicated to the community, thus improving people's ability to make informed choices.*

4.4 Lead

4.4.1 Sources

Lead can contaminate indoor air and dust. Principal sources include lead-based paint in older dwellings and, until recently, exhaust emissions from cars using leaded petrol. In some parts of Australia, emissions from major lead industries and mining are also a major concern.

Lead-based paints were used domestically until the mid-1970s. Before 1950, certain paints contained as much as 50 per cent lead. Lead-based paint can become a hazard in the home when the paint deteriorates by peeling and chalking, or when paint is disturbed during repainting or by renovating. Paint removal by burning volatilises lead; removal by blasting and dry sanding produces fine particles. While deterioration and disturbance of internal paint contaminates dust inside the home, deterioration and disturbance of external paint can spread lead-bearing particles throughout the neighbourhood, resulting in the contamination of soil, indoor dust and ceiling dust in other homes (Gulson 1995).

Until recently, the use of leaded petrol resulted in the contamination of soil and household dust close to major roads. However, as leaded petrol is no longer available in Australia, this source has ceased to be of direct concern, although many homes retain lead-bearing ceiling dust that accumulated over the years from this source.

Lead can enter the body by two major routes: ingestion and inhalation. The former is more significant for lead in the indoor environment, except during renovations where lead-based paint may be disturbed and fine particles may be inhaled.

A recent and unusual possible source of lead indoors has been from burning some imported candles. The lead can be a significant component of the wick. While such candles are not generally permitted for sale in Australia, some may find their way in.

4.4.2 Possible health effects

Lead is a toxin that affects enzymes. It often manifests as impairment of or damage to the central nervous system. High levels of exposure can result in coma, convulsions and death. Lower levels of exposure can cause chronic health effects. Lead is particularly harmful to the developing brain and nervous system of foetuses and young children.

Adults can experience lead poisoning, but this usually occurs in occupational and similar situations. For non-occupational exposures, lead is a pollutant of concern for young children. This is because they ingest more lead-bearing materials (such as dust and soil) from their hand-to-mouth activities; they also absorb more lead than adults and, as discussed previously, their brains and nervous systems are still developing. The transfer of lead from mother to unborn child via the placenta is also of concern. High exposure levels, such as eating flakes of lead-based paint, have caused overt lead poisoning. Lower exposure levels are associated with a decrease in intelligence scores, learning difficulties, hyperactivity, slow growth and defective hearing (EA 2001; CDC 1991.)

4.4.3 What is known about it and its levels in Australia?

To date, much of the work in Australia on indoor levels of lead has focused on situations where the lead source is from the outside environment, mainly from a large point source nearby, such as a primary metallurgical smelter.

Some studies have examined levels in homes resulting from other potential sources. Gulson *et al.* (1996) showed non-ore body sources are significant contributors even in a major lead mining community, Broken Hill. In a study of 58 children, some 60 per cent had blood levels of at least 15 micrograms per decilitre (the current level of 'personal exposure and source remediation/abatement'). Using high-precision lead isotope ratios, he found 34 per cent of those children also had significant contributions from paint and petrol.

4.4.4 Potential exposed population

Based on ABS data, over 3.5 million homes built before 1970 in Australia contain lead-based paint (Commonwealth of Australia 1994). While it is difficult to estimate the number undergoing renovation at any time, or in which the lead-based paint is peeling or chalking, clearly there is a very significant, potentially exposed population.

In 1994, the Australian Institute of Health and Welfare (AIHW) surveyed more than 2000 children in the 1 to 4 year age group (Donovan 1996). The study found that although levels were falling, more than 7 per cent still had a blood lead level greater than 10 micrograms per decilitre, the NHMRC target level. On the basis of estimates for Australian children aged four years or less (ABS 1997), this represents a possible affected population of the order of 100,000.

The AIHW study showed that three environmental factors were strongly related to blood lead levels in children. These were the cleanliness of the house, severely peeling interior paint, and year in which the home was constructed, (especially houses built before 1921). This is consistent with exposure to deteriorating lead-based paint being a major cause of raised blood lead levels in children. However, the study did not estimate the proportion of affected children that might be associated with this exposure (EPA Commonwealth 2001).

4.4.5 Controls or other responses by government, etc.

In 1969, the NHMRC amended the Uniform Paint Standard to reduce the amount of lead in domestic paint to 1 per cent (NHMRC 1993). During the early 1970s, the states and Commonwealth made regulatory changes to the permitted amount of lead in paint, in effect removing lead from paint used in domestic situations. As mentioned above (4.4.1) the government prohibits the sale of leaded petrol.

To assist householders in reducing lead levels in children, three major education campaigns have taken place on the dangers and safe use of lead-based products. The first campaign in 1994 was wide-ranging and addressing a range of sources. The second and third campaigns, in 1995 and 1999, focussed on the dangers from and correct management of lead-based paint.

4.4.6 Summary

- **Is it of concern?**

The exposure to lead-based paint is a known link for a significant number of children with elevated blood lead levels. With a possible affected population of 100,000 children of 4 years or less, this is certainly a matter of concern.

- **Possible actions**

Education campaigns were undertaken in 1994, 1995 and 1999 and this type of *education needs to be continued until the incidence of elevated blood levels in children is substantially reduced.*

4.5 Sulfur dioxide

There are no longer any sources of sulfur dioxide in indoor air in Australia. Indoor levels are thus determined by the levels in the ambient environment. Ambient levels around Australia are generally low, except near primary metallurgical works that smelt sulfide-based ores or similar. In these circumstances, sulfur dioxide is already the subject of government regulation intended to maintain ambient (and by implication indoor) levels below the ambient NEPM standard. Sulfur dioxide will not be considered further in this paper.

4.6 Ozone

Ozone has few sources in the indoor environment. Levels are thus largely determined by sources in the ambient environment. Photocopying machines and electrical equipment producing spark discharges may be potential sources but are unlikely to be encountered in the domestic

environment. Laser printers may be a source with a wider distribution. In some situations negative ion generators have been used to 'improve' indoor air quality but can produce ozone as a by-product, leading the NHMRC (1982) to advise against their use. Little is known of actual levels of ozone in offices, where a combination of sources and poor ventilation may see them elevated. However, what evidence there is suggests that levels are generally low (Brown 1997). Ozone is not considered further in this paper.

5 OTHER INORGANIC POLLUTANTS INDOORS

5.1 Carbon dioxide

5.1.1 Sources

Carbon dioxide has the same sources as carbon monoxide (section 4.1).

5.1.2 Possible health effects

Carbon dioxide at elevated levels can cause headaches and may cause changes in respiratory patterns. The ASHRAE guideline value is 1,000 ppm for public buildings to avoid staleness and body odour. The Worksafe Australia exposure standard for the occupational environment is 5,000 ppm as the 8-hour time weighted average limit for occupational exposures. Worksafe standards are developed for the fit, adult, working population and are generally much higher than ambient or indoor standards/guidelines.

5.1.3 What is known about it and its levels in Australia?

Very few levels have been reported in the literature in Australia. A recent comprehensive study by Tas (2001), carried out in a test room with two fixed vents and in several houses, showed levels ranging from 1,200ppm to 9,000ppm. In fact, in 50 per cent of tests, levels reached as high as 8,000ppm or above. The background level in air throughout the world is below 400ppm. It would be unusual to reach much above 400ppm in the ambient environment.

5.1.4 Potential exposed population

There has not been sufficient work to determine the exposure statistics, but wherever flueless combustion heaters and cookers are used in the home, carbon dioxide concentrations are expected to be very much higher than ambient levels.

5.1.5 Controls or other responses by government, etc.

There are no known initiatives aimed at reducing carbon dioxide levels. However, airtight houses, in line with energy efficiency requirements, will certainly increase levels where flueless combustion appliances are used.

5.1.6 Summary

- **Is it of concern?**

There is insufficient published information to determine if levels of carbon dioxide are of concern.

- **Possible actions**

The first step is to *design a statistical sampling program in houses using flueless combustion appliances*. Action after that will depend on the results of the study.

5.2 Radon

5.2.1 Sources

Radon (and thoron) are gases emitted as part of the radioactive decay chains of uranium and thorium. Radon itself decays rapidly, emitting an alpha particle and resulting in solid 'daughter' elements that in turn decay. Radon can be emitted from a wide range of naturally occurring materials found in and around buildings. In many instances the soil itself is the most significant source, with radon entering through the floor and being retained indoors. Bricks—especially earth or mud bricks—may be another source.

5.2.2 Possible health effects

Radon is of concern when its radioactive decay and those of its daughter take place in the lungs. Here the radiation is close to sensitive tissues and can potentially result in lung cancer.

The US EPA estimates that in the USA between 5,000 and 20,000 lung cancers per year are associated with radon exposure in air, and the National Academy of Sciences has predicted that 13,300 deaths per year occur as a consequence of these lung cancers (DiNardi 1997).

5.2.3 What is known about it and its levels in Australia?

Radon is a very serious indoor pollutant in some countries as a consequence of the dominant geological formations and rock types. For example, in response to the estimates of lung cancers cited above, the US government has taken steps to determine and reduce levels on a nation-wide scale.

In contrast, an extensive Australia-wide survey undertaken by the ARL in 1987 (Langroo *et al.* 1990) found few homes that were above the action level of 200Bq set by the NHMRC. This survey used a random sampling protocol based upon population, resulting in a preponderance of sampled homes from more densely populated areas in southern and eastern Australia. Subsequent limited work has indicated that elevated levels may be recorded in homes from locations with granite country rock (Basden 1993).

There is some evidence that homes constructed from mud bricks or similar earth-based construction methods may have higher levels than more traditional houses. However, levels generally would not appear to be of wide concern (Brown 1997).

5.2.4 Potential exposed population

On the basis of the ARL survey, only 0.06 per cent of houses in Australia are likely to be subject to levels exceeding the NHMRC goal. This represents something in the order of a few thousand homes. Such an exposure is small compared with that of some other indoor pollutants. However, should substantial growth occur in previously lightly populated areas with significant granitic geology, the extent of radon exposure indoors should be re-examined.

5.2.5 Controls or other responses by government, etc.

The survey by ARL was an important step in that it quantified the situation. There appears to have been no control action taken for radon.

5.2.6 Summary

• Is it of concern?

Radon is not an indoor pollutant of significant concern in Australia. While there are locations where levels may be elevated above the NHMRC action level, these are not widespread and can easily be anticipated from the local geology. Action to quantify and if necessary reduce radon exposure at the local level would appear to be the most appropriate response to these relatively rare situations. *Information for people considering the construction of earth or mud brick houses is needed.*

5.3 Asbestos

5.3.1 Sources

Asbestos can occur in the indoor environment in one of three ways. They are: from the use of fibre-cement building products that contained asbestos until the mid-1980s; from a small number of cases where it was used in its free form, and more numerous cases where it was bound as an insulating or texturing material; and from its (now discontinued) use in some vinyl floor tiles.

Further, there are a small number of townships around Australia where asbestos material was mined and processed or where it is a significant component of the country rock. Here, entrained asbestos may find its way into indoor air or enter the indoor environment on clothing, etc.

5.3.2 Possible health effects

Asbestos is an established human carcinogen. Exposure to it can lead to various diseases, including asbestosis, lung cancer and mesothelioma. It should be noted, however, that exposure to asbestos-containing products does not automatically lead to these diseases. Concentration of fibres in air and length of exposure are critical factors. Thus most cases of mesothelioma in Australia, for example, have resulted from industrial/mining exposure. Diseases related to asbestos may not be apparent for many years after the exposure occurred.

As industrial/mining exposures have been reduced or eliminated, the proportion of mesothelioma cases that can be attributed to the use and manipulation of asbestos-containing products by, for example, builders, painters and members of the general public has increased.

Standards for the various types of asbestos have been established for occupational exposures.

5.3.3 What is known about it and its levels in Australia?

There has been little work undertaken in Australia to measure levels of asbestos indoors although the work to date suggests that levels are generally low (Altree-Williams & Preston 1985). Higher levels are to be expected in those very few situations where loose asbestos was used as ceiling insulation in the ACT and nearby NSW towns. There has been a government program to remove such asbestos in the ACT.

5.3.4 Potential exposed population

Australia has a high rate of the use of building products that, until the mid-1980s, would have contained asbestos. ABS in 1999 (ABS 2000a) estimated that 8.3 per cent or more than half a million Australian homes were of 'fibro cement' construction. Thus there is an ongoing risk when these homes are subject to renovation or building work that disturbs the material. However the risk to occupants has been estimated as low (EA 2001).

5.3.5 Controls or other responses by government, etc.

Since the mid-1980s, government requirements for the removal of asbestos from building and associated materials have seen substantially less asbestos in the community. From 2003 it will no longer be legal to import asbestos into Australia for any purpose.

5.3.6 Summary

• Is it of concern?

In comparison with other indoor pollutants, there is relatively wide community understanding about the dangers posed by asbestos (if not a real appreciation of the small size of the actual risk for ordinary citizens). Thorough government and industry action has substantially lowered future exposure. However, a continuing health risk does exist from asbestos-containing material already in the community. Worksafe Australia (1996, 1997) estimates that a further 10,000 cases of mesothelioma and 30,000 cases of asbestos-related lung cancer are to be expected before 2020. Since there may be a protracted period before the diseases manifest themselves, it is difficult to determine the relative significance of industrial/mining exposures from years ago in comparison with other more recent exposures in these cases.

5.4 Particulate matter of other sizes, etc.

5.4.1 Sources

The most common particle sources indoors are from the combustion of materials (tobacco smoke, wood smoke from open fires or from poorly flued or operated slow combustion heaters) or

particles generated from cooking food. Most of these particles are likely to be less than 2.5 micrometres in size (called PM_{2.5}). Other particles found indoors are the result of infiltration from the ambient environment or from the re-entrainment of dust. While about half of ambient PM₁₀ particulate pollution is PM_{2.5}, re-entrained dust and particles arising from mechanical processes (such as crushing and grinding) are likely to be relatively larger in size.

(Environmental tobacco smoke and particles of a biological origin are dealt with elsewhere—see sections 6.1 and 7, respectively.)

5.4.2 Possible health effects

Epidemiological health research has found consistent associations between particle mass and adverse health effects. While much of this research has been based on existing particle measurements that are often of PM₁₀ or even coarser particles (for example, see part of the work of the ‘Six Cities Study’ by Dockery *et al.* 1993), it appears that the correlations are stronger for particles of smaller size. While there are plausible biological mechanisms by which particles, particularly smaller particles, could affect health, there is currently no consensus within the health community about actual causality. There have been suggestions that particle composition, surface characteristics, acidity, number and several other properties are involved but studies to date are not compelling (see for example, NEPC 1998; NEPC 2002).

It would seem that mass of PM_{2.5} remains the one parameter for which there is good epidemiological evidence. Consequently, the NEPC recently released a discussion paper with a view to adopting a standard for this pollutant (NEPC 2002).

(See section 4.3.2 on PM₁₀ for discussion about health effects of particles in general.)

5.4.3 What is known about it and its levels in Australia?

There do not appear to have been any studies that have directly measured indoor levels of PM_{2.5} in Australia. However, since the sources of particles indoors are related mainly to combustion (as opposed to mechanical) processes, the fraction of reported particle levels that are actually PM_{2.5} would be high. For ETS it may be close to unity.

Morawska (2000) reported on a number of measurements that have been made of particle numbers indoors in Queensland (Lyons & Morawska 1996; Morawska *et al.* 1998, 2001). However, it is difficult to be able to interpret the significance of these findings in the absence of allied health research.

5.4.4 Potential exposed population

Standards and goals for PM_{2.5} mass tend to be established at levels approximately half those for PM₁₀, reflecting the relative contribution of PM_{2.5} to PM₁₀ in the ambient environment. Since, in indoor air in Australia, sources producing PM_{2.5} tend to dominate, the ratio of PM_{2.5} to PM₁₀ would be expected to be more than a half. Thus, more people would potentially be exposed indoors to levels of PM_{2.5} greater than a notional standard (of half the ambient NEPM PM₁₀ standard) than are exposed to levels of PM₁₀ greater than the ambient NEPM standard (see section 4.3 on PM₁₀).

Until health metrics other than size are developed for particle parameters, it is not meaningful to use the term ‘exposed population’ for them.

5.4.5 Controls or other responses by government, etc.

The discussion paper on PM_{2.5} (NEPC 2002) has been an important first step. However, there appears to have been no control action directed specifically to this emerging area.

5.4.6 Summary

- **Is it of concern?**

It is clear that particle pollution indoors is of concern. $PM_{2.5}$ may well be of greater concern than PM_{10} simply because it is the major form found indoors. However, in terms of reduction strategies, it would seem less important to make a distinction on the basis of size: reducing indoor sources of particles will have beneficial effects for all size fractions.

- **Possible actions**

See under PM_{10} (section 4.3).

5.5 Metals

A wide range of metals (other than lead) could be considered potential indoor pollutants. However, in the Australian context it is expected that there are few sources that are not simply the result of infiltration of ambient air. These metals are not considered further.

6 ORGANIC POLLUTANTS INDOORS

6.1 Environmental Tobacco Smoke (ETS)

6.1.1 Sources

ETS is the complex mixture of chemicals and particles released into the air whenever someone smokes a cigarette, cigar or pipe. It is a combination of sidestream smoke (smoke from the burning tobacco product emitted directly into the air) and exhaled mainstream smoke (the smoke inhaled by the smoker and subsequently exhaled).

6.1.2 Possible health effects

ETS poses the same types of threats to the health of involuntary smokers as does active smoking. These include acute and chronic respiratory diseases, lung cancer, and increased incidence of heart and coronary disease.

Significantly, children exposed to ETS have increased risk of developing asthma and of developing respiratory diseases (NHMRC 1997).

6.1.3 What is known about it and its levels in Australia?

Much of the work to determine levels of ETS in indoor public places in Australia was carried out before the relatively recent practice of progressively banned smoking from many of these areas. In many instances, smoking has been banned following successful litigation by people harmed by ETS rather than on the basis of extensive scientific research into actual levels. However, Sheppard *et al.* (2002b) have recently reported on levels in hospitality industry premises in Sydney. Their findings show that all but one venue where smoking was permitted had levels of PM₁₀ that would have exceeded the ambient air quality standard. They concluded that these levels were 'likely to be associated with significantly increased risk for respiratory and cardiovascular disease, particularly in employees'.

Sheppard *et al.* (2002a) also measured PM₁₀ levels in the homes of smokers, finding a positive correlation with the number of smokers. (See section 5.3.3 for additional discussion.)

6.1.4 Potential exposed population

While the past decade has seen marked gains in reducing the risk of people being exposed to ETS in public places across Australia, there have been few coordinated efforts to change the situation in homes. Smoking indoors in homes may have declined in view of reduced acceptance of this practice.

The ABS estimated in 1990 that 43 per cent of children aged less than 5 years live with one or more smokers. This represented a population of some 1.6 million children (Mitchell 2000). There has been a slight reduction in levels of active smoking since that time. However, the expected reduction in exposure of children this would suggest may not be as great since there is some evidence that the rate of decline in smoking has slowed amongst younger women—women of prime child-bearing age (Quit Victoria 1995; NSW Cancer Council 2002a, 2002b). As mentioned above (Sheppard *et al.* 2002a) the majority of these 1.6 million children may be exposed to PM₁₀ levels above the NEPM standard.

6.1.5 Controls or other responses by government, etc.

Most state and territory governments have now introduced legislation that restricts or bans smoking in a variety of public places. Additionally, voluntary actions by owners/operators of other public places such as shopping centres have either discouraged or banned smoking, largely to protect themselves from potential litigation.

Little has been done to reduce exposure to ETS in private dwellings other than by reducing the incidence of active smoking.

As this paper goes to press, NSW has launched an education program aimed at reducing smoking in homes and cars.

6.1.6 Summary

• **Is it of concern?**

Australia has one of the highest incidences of asthma in the world. Given the high number of children (estimated to be 1.6 million) exposed to ETS during the time of their lives when they potentially develop asthma, such exposure is of grave concern in regard to public health.

• **Possible actions**

There is growing evidence that traditional mechanisms to cut the rate of smoking in the community are becoming less effective as the number of smokers is reduced to a 'hard core'. Neither education campaigns nor economic mechanisms such as increasing excise are likely to have a real impact on this group (Mitchell 2000). This is confirmed by the number of pregnant women who decline to cease smoking during their gestation even after being personally warned of the adverse effects continued smoking has on the foetus.

There is now an urgent need for action to reduce the exposure of children to ETS. Whereas adults have the ability to remove themselves from environments polluted by ETS, children, particularly young children, may not. In such circumstances, it is surely a fundamental role of government to protect these children. While it may be argued that an adult is free to decide to smoke, where that choice impinges on the well-being of others it needs to be controlled, just as decisions to drink alcohol are curtailed by drink-driving laws. Otherwise the health of a very large number of children will continue to be at risk. ***Only government action can bring about this change. New and more direct mechanisms to achieve the result are needed.***

6.2 Formaldehyde

6.2.1 Sources

Formaldehyde is emitted from a wide range of building and furnishing materials as a result of its use in their construction or post-manufacture treatment. The most common Australian sources are compressed wood products such as particle board, where formaldehyde is a common constituent of the binding agent.

Overseas, formaldehyde is also associated with one particular type of home insulation. This is rarely used in Australia.

It can also be emitted from flueless gas appliances. A recent preliminary study indicated excessive levels of formaldehyde can be emitted from a 'low NOx' flueless gas heater under some conditions.

6.2.2 Possible health effects

Formaldehyde is an irritant gas that potentially affects the skin, eyes and lungs. Some people can become hypersensitive to its effects, resulting in symptoms at very low concentrations. There is evidence that it is a nasal carcinogen.

The NHMRC indoor goal is 100 parts per billion.

6.2.3 What is known about it and its levels in Australia?

There have been a number of studies across Australia focusing on formaldehyde in situations where compressed wood products are used extensively (McPhail 1991; Dingle *et al.* 1992; Hooper *et al.* 1994; Brown 2000; Sheppard *et al.* 2002a). Levels in conventional homes have been found to meet the NHMRC goal soon after renovation or extensive building works, although levels were

sometimes close to the goal (Dingle *et al.* 1992; Brown 2000). However, the recent large study in NSW by Sheppard *et al.* (2002a) found no levels close to the goal, suggesting that levels in conventional homes may be reducing.

In contrast, levels in some conventional offices were found to exceed the goal (Brown 1997) and levels in new caravans and mobile homes have been shown to exceed the goal often by considerable margins and for many years after manufacture. Dingle *et al.* (1992) reported levels more than 8 times the goal and McPhail (1991) reported levels up to 12 times the goal.

Sparse data are available on formaldehyde levels resulting from gas heaters. However in a recent study by Brown *et al.* (2002) examining three low NO_x flueless heaters, in a steel emissions chamber, levels from one heater reached concentrations that were more than 15 times the NHMRC goal under some conditions.

Formaldehyde is not found at other than background levels in the ambient environment except in very limited areas around certain wood product manufacturing plants. (Increased use of ethanol as a motor vehicle fuel may see increased levels of formaldehyde in ambient air.) Thus indoor exposures are many times more significant in terms of health.

6.2.4 Potential exposed population

Mobile homes and caravans are an important part of the housing stock in Australia, with more than 68,000 Australians living permanently in caravan parks in 1996 (ABS 2000b). This number is increased by those using them as holiday accommodation, with the ABS reporting that over 250,000 caravans were registered in Australia in 1999 (ABS 2001). Further, it has been estimated that more than 160,000 Australians were living in caravans or mobile homes either permanently or while on holiday in 1996 (EA 2001). Added to this are people in new relocatable offices and children in new relocatable classrooms, who would also be exposed to elevated levels of formaldehyde. As already noted, it would appear unlikely that exposures in conventional housing stock are likely to exceed the NHMRC goal.

Further testing of low NO_x flueless gas appliances is required to examine their potential emissions.

6.2.5 Controls or other responses by government, etc.

Following early findings of unacceptable levels of formaldehyde resulting from emissions from compressed wood products, especially in caravans and relocatable offices, the industry undertook a voluntary program to reduce these emissions. The intent was to ensure that emission rates meet the European standard. Recent work by Brown (1998a) shows that considerable improvements have been made to emissions of formaldehyde from these products. On the basis of emissions data, the NHMRC indoor air standard would still be exceeded for some months after manufacture, but this is a significant improvement on the earlier years of exceedence. Australian compressed wood products do not yet meet the European standard.

6.2.6 Summary

- **Is it of concern?**

Many Australians use mobile homes and caravans as permanent dwellings. Many are retirees who, as a result of their age, may be more susceptible to the effects of formaldehyde. Thus, this pollutant must remain of concern, even though the improved emissions performance of modern Australian compressed wood products has delivered a significant reduction. Further, imported products may well have higher emission rates.

- **Possible actions**

As suggested by Brown (1998a), the testing procedure used to assess compliance with emissions standards can have a significant effect on the results obtained. He proposed a regime of testing that is quick yet accurate and which allows comparison with the European standard. *It is imperative that an Australian Standard for testing emission of formaldehyde be established without delay.* This would give added focus and assurance to the voluntary industry process.

Furthermore, *it is imperative that any testing regime is extended to mandatory testing of imports of compressed wood products*. Otherwise the situation could arise where the testing and improvement initiatives for Australian manufactured materials are undermined by imported product. This situation would be even worse if the price of producing low-emission product placed Australian manufacturers at a cost disadvantage to imports.

A comprehensive study to examine the emissions from 'low NOx' flueless appliances is necessary to establish a sound basis for assessment.

Standards for flueless gas heaters should include an emission limit for formaldehyde as well as emission limits for nitrogen dioxide and carbon monoxide.

6.3 Benzene

6.3.1 Sources

Benzene is no longer used in commercial or domestic cleaning products in Australia as it once was. The only source of benzene now encountered by the general public is from petrol, where it currently constitutes around 2 per cent.

6.3.2 Possible health effects

Benzene is a human carcinogen linked to a number of leukemias, including acute myeloid leukemia.

There are no goals or standards for benzene in Australia. Internationally, the UK has established an ambient standard of 5ppb (annual average). The European Commission (1998) has proposed a much stricter annual air quality goal of 5µg/m³ (equivalent to 1.5ppb) for benzene. This goal is to be met by 1 January 2010 (see discussions in Manins *et al.* 2001).

In the US, risk assessment techniques are used with the acceptable (*de minimis*) risk being one excess cancer per million exposed population. On this basis benzene would have a standard of about 0.1 parts per billion (range 0.04 to 0.14 ppb, lifetime average exposure) (US EPA 2002).

6.3.3 What is known about it and its levels in Australia?

There has been some testing of benzene levels in cars while being driven and in cars and other forms of transport while commuting. Duffy and Nelson (1996) found that mean in-vehicle concentrations of benzene measured for new vehicles during peak-hour commuter trips were about 11 times higher than the average ambient air concentrations measured in residential areas. For older, poorly maintained vehicles without exhaust catalytic converters, concentrations inside the vehicle were as high as 27 times the ambient air concentrations. However, it is difficult to determine how much of the levels found in cars were generated by the vehicles themselves as opposed to entering the vehicles as a result of their proximity to the exhausts of surrounding vehicles.

Torre *et al.* (1998) found levels of benzene in cars and trams and levels for bike riders were significantly higher than for walkers and at a fixed roadside monitoring station. VOC levels were also higher for car users and bike riders than at the fixed monitoring station.

The federal government is currently funding a project to determine the significance of sources of benzene, toluene, ethyl-benzene and xylenes and the contribution those sources make to human exposure in four Australian cities (Sydney, Melbourne, Perth and Adelaide). It is expected to be completed in 2002.

6.3.4 Potential exposed population

All drivers and passengers of vehicles are potentially exposed. Thus, the number of people exposed, possibly on a daily basis, may be very large indeed. Clearly, duration of exposure is an important consideration, with urban motor vehicle congestion suggesting that more than two hour's exposure per day would not be uncommon in many cases in Sydney or Melbourne.

6.3.5 Controls or other responses by government, etc.

Until recently, the level of benzene in petrol was controlled by an industry agreement. This set an upper limit of 5 per cent. In reality, most petrol sold had levels substantially below this level, with only Premium Unleaded Petrol (PULP) approaching it. Now, the federal government has introduced the first mandatory standards for petrol under the *Fuel Quality Standards Act 2000*. From January 2006, benzene in petrol will be limited to 1 per cent. Further, the permitted aromatic content of petrol will also be controlled, lowering progressively to a maximum of 42 per cent by January 2005. (Aromatics are important as they can be converted to benzene in tail-pipe emissions.)

6.3.6 Summary

- **Is it of concern?**

Applying the risk assessment methodology of the US EPA to the benzene levels detected in vehicles would suggest that there is a need for action to reduce levels, even assuming that there was only in-vehicle exposure to benzene (no ambient exposure).

- **Possible actions**

The results of the human exposure study (referred to in section 6.3.3) will form a good basis from which to proceed. Given these findings, it will be possible to determine whether the new controls noted in section 6.3.5 would be sufficient to reduce exposures to satisfactory levels.

6.4 Pesticides

6.4.1 Sources

Pesticides in this context can be considered to be a group of chemicals including insecticides, herbicides, termatocides and fungicides. They range from organochlorine compounds, to organophosphorus compounds, to compounds based on metals such as copper, to natural pyrethrum derivatives. They are found in domestic products and products designed for professional application. They enter the indoor environment in various ways.

Termatocides are used to protect wooden-framed buildings from termite attack. They can be applied both before and after construction—often by repeated applications. The termatocide can then enter the indoor environment from the sub-floor area either as vapour or adsorbed on dust.

Insecticides are routinely used in a wide variety of applications around the home, such as proprietary fly and cockroach control sprays and baits. In areas near orchards or broad-acre farms, insecticides, fungicides and herbicides can enter the indoor environment as spray drift when they are being applied to crops. Home garden products containing pesticides can also be a source.

6.4.2 Possible health effects

As would be expected with a widely diversified group of chemicals, health effects from exposure to elevated levels of pesticides are not specific. They include headaches, dizziness, nausea, and eye and skin irritation (EPA Vic 1993). It should be noted, however, that some specific pesticides are highly toxic and some, in particular those based on chlorine compounds, may be carcinogens (see chlorinated hydrocarbons).

6.4.3 What is known about it and its levels in Australia?

There have been several studies to determine levels of pesticides in Australian homes (Dingle 1988; Dingle *et al.* 1994; Gunn *et al.* 1994) with a focus usually on organochlorine termatocides. These have shown that not surprisingly, levels of the pesticides found are associated with the types used in and around the home. There also appears to be some correlation with blood levels of pesticides. Miller (2000) has summarised available data, concluding that indoor levels are substantially higher than those found in the ambient environment.

However, the results are difficult to interpret since there are no goals or reference levels with which to compare them. Miller (2000) concludes on the basis of risk assessment that lifetime risks would seem low—1 in a million to 10 in a million—though this seems to be at odds with reported symptoms and the level of complaint.

Additionally, the studies to date have been of limited scope so that the likely exposure levels of the broader community are difficult to gauge.

6.4.4 Potential exposed population

ABS (1998) estimated that 79 per cent of Australian homes use fly sprays or baits. Thus the potentially exposed population is very large indeed.

6.4.5 Controls or other responses by government, etc.

Government action has banned some of the most toxic pesticides from production, importation or use in Australia. Further, public opinion has moved, so that less toxic preparations are now more favoured for use, particularly in the garden.

6.4.6 Summary

- **Is it of concern?**

Since such a large population is exposed to pesticides, even if only at relatively low levels, pesticides remain an area of potential public health concern.

- **Possible actions**

The true magnitude of the concern about pesticides will only be known when there are guidelines against which to measure levels. These *guidelines are the first priority*. Once guidelines are established, the *levels found in previous studies can be used to determine whether broader survey work needs to be conducted to ascertain the likely population exposure*.

6.5 Total Volatile Organic Compounds (TVOCs)

6.5.1 Sources

VOCs are a very diverse class of compounds that include alkanes, aromatics, aldehydes, ketones, alcohols and ethers. Pesticides are excluded. VOCs can be emitted from a wide variety of materials and consumer products used in homes and offices, including paints and adhesives. Individual VOCs are frequently used as solvents or dispersing agents and are sometimes added to products to give them a pleasant fragrance. While no one VOC may be found at particularly elevated levels, the total of them may be substantial. (Note, instances of elevated levels of an individual VOC are dealt with under separate headings; chlorinated VOCs are also dealt with separately.)

6.5.2 Possible health effects

There is evidence that individual VOCs may have an interactive effect on sensory irritation (Molhave & Nielsen 1992). Symptoms include irritation, dryness and low-level inflammatory reactions of the nose, eyes, airways and skin. Elevated levels of VOCs are sometimes found in buildings where occupants complain of non-specific adverse health outcomes associated with being in the building ('sick building syndrome').

The NHMRC has established a goal for TVOCs in indoor air of 500 $\mu\text{g}/\text{m}^3$, with no one VOC to represent more than 50 per cent of the total.

6.5.3 What is known about it and its levels in Australia?

There have been relatively few studies of levels of TVOCs in indoor air in Australia (EA 2000). Some of the situations that have been studied have been in response to occupant complaint (see, for example, Brown 1998b). Thus it is difficult to judge to what extent the data on levels are representative of the broader community. However, the results available point to numerous

instances where the NHMRC goal is exceeded, often significantly and for long periods. For example, the CSIRO (2000) reported that occupants of new Australian homes might be exposed to up to 20 times the maximum allowable NHMRC limit for at least ten weeks after completion of construction. Levels of VOCs were at their highest immediately after construction, showing many materials used in building homes were significant sources.

Brown and Cheng (2000) measured VOCs in the interior of new cars, finding substantially elevated levels—up to 64,000 $\mu\text{g}/\text{m}^3$. Further, levels took many months to decrease to below the NHMRC indoor goal.

Mesaros (1998) found levels in office buildings in Hobart up to 1934 $\mu\text{g}/\text{m}^3$ as a weekly average (nearly 4 times the NHMRC goal).

TVOCs in ambient air are of concern for very different reasons to those indoors. TVOCs (often referred to as Reactive Organic Compounds, or ROCs) are an integral part of the reaction system that leads to the formation of photochemical pollution. There are no national goals or standards for ambient ROCs, but there has been substantial government action to control their levels as a means of reducing photochemical pollution (EPA NSW 1997).

6.5.4 Potential exposed population

The CSIRO (2000) estimates that up to 500,000 Australians moving into around 120,000 new homes every year could be subjected to high levels of toxic VOCs for several months.

6.5.5 Controls or other responses by government, etc.

Sometimes, action to reduce ambient levels of TVOCs has also reduced indoor levels, such as the move toward using more water-based paints and away from the traditional oil-based paints. This has seen the average TVOC content of paint reduced and its make-up substantially changed. Other products have been reformulated where they had become prone to intentional abuse for their solvent (substance abuse).

6.5.6 Summary

• Is it of concern?

With the limited information on levels and hence exposure in the broad community, it is difficult to quantify the TVOCs risk to the community. The large number of people moving into new houses certainly raises the potential for high exposures. In addition, the suggestion by Smede *et al.* (1997) that indoor air pollution in schools is important and may exacerbate asthma and affect perception even at low levels, indicates an urgent need to identify the exposure levels of the population, particularly of sensitive sub-populations such as children.

• Possible actions

Funding is required to undertake a statistically significant survey of TVOC levels in a representative cross-section of situations. It is also highly desirable that a process be commenced to reduce the amounts of VOCs used in products that have been identified with unacceptable indoor levels.

6.6 Chlorinated hydrocarbons

6.6.1 Sources

There are many chlorinated hydrocarbons that are sometimes found in indoor air. These range from solvents like trichloroethylene and tetrachloroethylene to chloroform emitted, for example, from showers where chlorinated town water is heated. Tetrachloroethylene is the most commonly used commercial dry-cleaning solvent in Australia.

6.6.2 Possible health effects

Many of the acute symptoms of exposure to elevated levels of chlorinated hydrocarbons are similar to those of other hydrocarbons. However, a larger proportion of chlorinated hydrocarbons are recognised as or suspected of being carcinogens. Thus chloroform has been declared carcinogenic by the US EPA, while trichloroethylene is suspected of being so. In general, the chronic toxicity/carcinogenicity of chlorinated hydrocarbons is greater than that of their unsubstituted equivalents.

6.6.3 What is known about it and its levels in Australia?

Relatively little is known about levels of chlorinated hydrocarbons other than pesticides in Australian indoor environments. Some broad-sweep investigations of VOCs have detected chlorinated species. However, it is difficult to know whether other investigations that did not find such species used a technique capable of detecting them, or they simply were not present.

The NHMRC goal for TVOC would obviously include the contribution to the total of any chlorinated species present. However this goal was not established as a means of controlling long-term exposure to low levels of carcinogenic chlorine-containing compounds.

6.6.4 Potential exposed population

The present state of knowledge of chlorinated hydrocarbon levels precludes a realistic assessment of the exposed population. However, it is clear that use of hot water for personal hygiene and other washing activities indoors is a regular, daily activity for the vast majority of Australians. Thus the potential exposed population is large.

6.6.5 Controls or other responses by government, etc.

Many of the more toxic chlorinated hydrocarbons that were once used in consumer products have been removed in recent years, particularly in response to substance abuse.

6.6.6 Summary

• Is it of concern?

Given the substantial size of the potentially affected population and the carcinogenic nature of some chlorinated hydrocarbons, there is clear cause for concern about chlorinated hydrocarbons indoors.

• Possible actions

The first action is *to determine what levels of these substances are present in Australian indoor environments*. This would be an obvious adjunct to obtaining the same information for other TVOCs, but it is important that some expected chlorinates be targeted in any such work.

7 BIOLOGICAL POLLUTANTS INDOORS

7.1 House dust mite (HDM)

7.1.1 Sources

House dust mites are ubiquitous in all dwellings, no matter how clean they are. They live mainly on discarded skin cells. The allergen is present in the faeces and parts of the dead mite.

7.1.2 Possible health effects

The allergen is a potent asthma trigger in many sufferers from the disease. It has been estimated that some 85 per cent of young Australian adult asthmatics are sensitive to the allergen (Duffy 2000). Furthermore, more than 30 per cent of all children in a 1997 study showed allergic symptoms to HDM (Duffy 2000).

7.1.3 What is known about it and its levels in Australia?

House dust mites breed optimally when temperatures are between 17 and 25°C and relative humidity is greater than 60 per cent. Unfortunately, this describes the majority of Australian indoor environments, especially coastal environments, for most of the year. Therefore, it is not surprising that levels of HDM allergen have been classified as high in Australian coastal environments (Tovey 1993; Duffy 2000). Mahmic and Tovey (1998) reported that HDM are most prevalent in the home, where levels are between 20 and 40 times higher than in public buildings.

7.1.4 Potential exposed population

In 1995, the proportion of the Australian population who suffered from asthma was estimated to be 11 per cent, representing more than 2 million people (ABS 1999). The percentage for children under 15 years was around 15 per cent.

Although there have not been extensive surveys of HDM levels, there have been a number of statistically based surveys on which to base an estimate of potential exposures. Coupling high levels of asthma found in the Australian community, a large proportion of whom are sensitive to HDM allergen, with the high levels of this pollutant present in almost all houses in the temperate parts of Australia, there is clearly a very large population susceptible to exposure to HDM.

7.1.5 Controls or other responses by government, etc.

While governments have provided some educational material in this area, direct control actions have not been taken.

7.1.6 Summary

- **Is it of concern?**

The population at risk and social and economic costs of asthma in Australia indicate that HDM allergen is a very serious indoor pollutant.

- **Possible actions**

It is not clear what proportion of asthmatics is aware of the potential role HDM allergen may play in their illness, or what to do to reduce exposure to it. Clearly *a wider education program is needed to reduce the incidence of HDM levels and to alert those who are sensitive.*

7.2 Moulds and fungi

7.2.1 Sources

Moulds and fungi are able to grow anywhere there is sufficient moisture, making use of a wide range of materials, such as wood, paint and insulation, as sources of carbon. They release spores and/or mycelial particles into the air either as part of their reproductive process or on death. Both spores and mycelial particles contain mycotoxins that are believed to be a cause of ill health when inhaled. Species found indoors reflect those in the ambient environment, although relative abundances may change where the indoor environment is favourable to the growth of particular species. The most common genera are those living on leaves, including *Cladosporium*, *Alternaria*, *Epicoccum* and *Aureobasidium*, while soil-based species such as *Aspergillus* and *Penicillium* are relatively uncommon in outdoor air but are found at increased levels indoors (Hargreaves and Parappukkaran 2000). *Stachybotrys atra*, a species described as 'specifically harmful', has been found in some indoor environments, particularly in association with dwellings experiencing mould problems (Whillans 1995).

Air conditioning can be an important means by which levels of moulds and fungi are increased indoors. It provides both a means whereby spores are dispersed while providing areas, such as moist ventilating ducts, where the fungi can grow.

In houses where evaporative water coolers are used to reduce temperatures, cooling is brought about at the expense of increased relative humidity. This increased humidity can provide a climate for increased growth of moulds and fungi.

The operation of flueless gas heaters, especially those using natural gas, can significantly increase humidity in homes with limited ventilation.

7.2.2 Possible health effects

Whillans (1995), on the basis of an extensive literature review, concluded that there were 'strong associations between mould and various adverse effects on human health'.

Many of the genera listed above are known to cause allergies such as hayfever. *Alternaria* and *Aspergillus* are both known to be important triggers of asthma, particularly in drier, inland Australia (Duffy 2000).

Tests conducted on building occupants suffering allergic symptoms found responses to fungi found in air conditioning ducts, most commonly *Penicillium* and *Aspergillus* (Schata *et al.* 1989). Most significantly, Graveson (1994) found that repeated exposure to spores or other parts of fungi commonly found in indoor air could result a wide range of health impacts. These include Type I allergies such as asthma and rhinitis; Type III allergies such as extrinsic allergic alveolitis (a group of lung diseases) or hypersensitivity pneumonitis with flu-like symptoms; 'sick building syndrome' including symptoms such as headache, fatigue and mucosal complaints; or organic dust toxic syndrome recognised by tightness of the chest, bronchitis and asthma.

Those with impaired immune systems are most at risk.

7.2.3 What is known about it and its levels in Australia?

There have been only limited published studies of fungal levels in Australian indoor environments. However, the levels found have often substantially exceeded the guidelines proposed by the WHO (1990). Levels have been reported of up to 18,000CFU/m³ in comparison with the WHO guidelines of between none and 500CFU/m³, depending on the types present (Brown 1997).

Godish *et al.* (1993) reported levels in 80 Latrobe Valley homes. They found that one in every eight (12.5 per cent) had total spore counts in excess of 10,000CFU/m³, with 95 per cent having visible mould growth.

7.2.4 **Potential exposed population**

With the limited data available, it is difficult to assess the likely population exposed to levels that are above the WHO guidelines. However, it appears that there would be elevated levels in many houses and air-conditioned buildings, possibly affecting a substantial number of people. Of very great concern is the potential that some hospitals may have high levels of fungi present in their air conditioning ducts when the health of the exposed population is already compromised.

7.2.5 **Controls or other responses by government, etc.**

New building codes directed towards improving energy efficiency have unintentionally resulted in a worsening situation. Ventilation is sometimes being reduced to a level where increased humidity favours the development of moulds and fungi.

7.2.6 **Summary**

- **Is it of concern?**

Even in the absence of widespread survey information, the results of work conducted in homes and in hospitals and other air-conditioned buildings in Australia indicate fungi are an indoor pollutant of significant concern. Furthermore, it would appear that there is widespread lack of knowledge in the general community about their possible adverse health effects.

- **Possible actions**

The ramifications for hospital patients are such that ***urgent action needs to be taken to determine whether Australian hospitals have unacceptable levels of fungi so that immediate remedial action can be carried out in any that do.***

Unfortunately, airborne concentration goals do not exist at present. The proposed 1990 WHO guidelines based on CFUs have been withdrawn as a consequence of further work (Maroni *et al.* 1995; Rao *et al.* 1996; Marcher *ed.* 1999) that led to the realisation that frequently, only a very low (and variable) proportion of the total airborne spores are viable and hence able to grow into CFUs. However, all spores, alive or dead, are capable of producing symptoms. In the absence of agreement on better measurement techniques (such as direct microscopic examination) and new guidelines, it would seem justified, in specific cases, to use the previous WHO values as one means by which to inform the need for action.

Furthermore, ***the community needs to be made aware that moulds and fungi may have an important role in causing ill health and what they can do to improve air quality.***

7.3 **Other sources of allergens**

Pets provide another large source of allergens in indoor air. It is estimated that 64 per cent of Australian homes in 1998 were also home to a pet (Petnet 2002). Dogs were more popular than cats and birds. However, 26 per cent of pets owned were cats.

Cat allergy is a known trigger of severe asthma episodes. Cat allergens are present in both hair and saliva. Allergen in saliva is transferred to the hair during grooming, later to dry and possibly become airborne together with parts of the hair itself. Cat allergen is particularly pervasive indoors; even environments without a resident cat sometimes show significant levels of it (Rutherford and Eigeland 2000). This is possibly from the transfer of allergen on the clothes of cat owners.

Dog allergens are produced by the tongue. There appear to be no allergens associated with the hair. While the symptoms of dog allergy are similar to those of cat allergy, it seems that they are not as severe (Rutherford & Eigeland 2000).

Cockroaches are another pervasive element of homes in many parts of Australia. Relatively little is known about the extent of allergic responses to cockroach allergens, but it could be very significant if it were to follow results from the US, where a study found that more than one third of children in urban environments showed allergic responses to cockroach allergens.

There are currently too few data on Australian incidences of allergy to any of these allergens to enable cogent advice to be given on whether sensitive individuals should avoid them. However, it is clear that the potentially exposed population is large and that the public health consequences are potentially very great. ***Thus there is an urgent need for research to answer these basic questions in the Australian context.***

7.4 Bacterial and viral pollutants

7.4.1 Sources

Bacteria and viruses enter the indoor environment with ambient air and are also introduced directly through actions such as breathing and sneezing by people in those environments. They can be easily transported indoors, particularly by air conditioning systems. An air conditioning system can provide bacteria with the warm and wet conditions they use to multiply. Moisture is provided by condensation or the use of water sprays as part of the conditioning process. Thus an air conditioning system can become both the site of bacteria growth and the means of dispersal.

While viruses cannot reproduce outside their host, the air conditioning system can transport them about large buildings in a state where they can still cause disease.

However, *Legionella* from air conditioning is usually caught outside buildings by inhaling contaminated spray drift from cooling towers, where it is frequently found. Levels may be high, particularly if the system is poorly maintained or has been restarted recently after a period of lying idle. The bacteria leave the cooling tower in tiny droplets (in spray drift) and contaminate the outside air. They can enter indoors if an air intake for an air conditioning system is located too near the cooling tower. *Legionella* can also be caught from garden compost when the compost is in aerosol form, that is, when it is shaken from the bag or on opening the bag, but not from pot plants inside the home, unless it is disturbed and made into an aerosol inside the home.

7.4.2 Possible health effects

As noted above, air conditioning plant is implicated in infection by the well-known bacteria, the *Legionella* species, known to cause the sometimes fatal Legionnaires' disease and the less severe Pontiac fever.

7.4.3 What is known about levels in Australia?

While there have been some investigations into air quality in association with ducting in large buildings such as hospitals, little of this information is in the public arena.

7.4.4 Potential exposed population

It is estimated that some 30 per cent of Australians have been exposed to the *Legionella* bacterium (Brown 1997). It is not known whether this has been through indoor air exposure, from other anthropogenic sources such as potting mixes, or from natural contact in the general environment.

7.4.5 Summary

• Is it of concern?

Given the regular deaths from diseases caused by *Legionella* species in Australia, there is a clear need for ongoing action to address the possible public risk. Of greater concern is the poorly quantified risk posed by other bacteria and viruses, particularly in hospitals where there is the convergence of (i) a potentially exposed population, many with compromised health; and (ii) the air conditioning system, which provides an environment in which disease-causing organisms can breed and then be spread. Concerns exist about the air conditioning systems in other public buildings.

- **Possible actions**

It is simply not adequate to allow the status of air conditioning systems in hospitals and other public buildings to be assessed and addressed when found necessary on an *ad hoc* basis, often driven by complaint. There are standards or guidelines for maintenance of cooling towers but these differ from state to state in relation to their strictness and enforceability. ***There is an urgent priority to establish National Standards of maintenance and air quality outcomes*** in this important area

8 IMPEDIMENTS TO ACHIEVING BETTER INDOOR AIR QUALITY

Over the past two decades in Australia, there have been sufficient studies of a wide range of pollutants in indoor air to demonstrate that many represent serious risks to health at the levels found. Yet there has not been a corresponding level of action to address the situation. There are many reasons for this lack of action; some of the more salient are described below.

Ventilation versus energy efficiency

The simplest way of reducing levels of indoor air pollution in domestic situations is to increase ventilation so that emissions from sources and products in the home are diluted with (the generally much cleaner) ambient air. Since the 'oil shocks' of the 1970s, the trend has been to reduce ventilation in order to improve the energy efficiency of the home and reduce the use of fossil fuels for heating. In many instances this trend has become enshrined in building codes. Thus, the building code no longer requires fixed ventilation in rooms. Further, the move to 'energy-smart' housing, often driven by government, has emphasised better sealing of flooring, windows and doors and has even suggested moving to double glazing in colder areas. While these initiatives are excellent for their intended purpose—to reduce Australia's very large per capita energy consumption—they can have a substantial adverse impact on indoor air quality. If ventilation rates are halved but no change is made to an indoor source of a pollutant then the level obtained indoors would double (assuming no reactions or absorption).

Ventilation rates for rooms being heated in Sydney homes in the late 1980s showed the impact of changes to building practice to that time (Ferrari *et al.* 1988). While the average ventilation rate of these rooms during winter was measured to be around one air change per hour, that in homes less than five years old had reduced to only 0.37 air changes per hour.

While actions to improve energy efficiency are laudable, they must be coupled with actions to ensure that an unintended consequence is not substantially reduced air quality indoors for a significant proportion of the population. One facet of 'energy-smart' housing should be concomitant action to ensure that indoor sources of pollution are reduced or eliminated.

Global concerns versus indoor air quality

Worldwide concerns over the role of fossil fuel consumption in the enhanced greenhouse effect have led consumers to seek fuels that have the potential to lower global warming. Energy suppliers have tapped this trend as a way to increase their market share. Thus, natural gas advertises itself as a cleaner fuel than electricity (generated by coal combustion). While this is true at the global level, the impact on indoor air quality has often been the opposite. Use of electricity for home space heating produces no indoor air pollutants directly, whereas changing to natural gas heating by flueless gas heater (the cheapest option) will significantly increase indoor levels of nitrogen dioxide and other combustion gases.

Civil liberties versus protecting the innocent

Some moves to improve indoor air quality are accompanied by a concern about impinging on civil liberties. Obviously some actions, such as improving product standards and improving ventilation, have no real implications for personal freedom. Others may. This has become one of the main planks in arguments against further reducing opportunities for people to smoke in public places.

By its very nature, the quality of indoor air is often a result of the choices of the owners or occupiers of that indoor environment. Thus it can be argued that moves to improve indoor air quality differ qualitatively from, say, regulation of industries to ensure that their activities do not impinge on the 'common good' in the form of acceptable ambient air quality. In the case of indoor air it can be said that, in some instances, there is a balance between maintaining personal freedom and protecting the health of citizens. While this is a moot point where the person responsible for the pollution is also the one to suffer any ill-effects, there are two circumstances in relation to indoor air pollution which transfer it from one of personal choice to one of the common good. These are that, firstly, in almost all indoor environments there are people subject

to the air quality who are not responsible for the sources that created it. Most importantly, these are often children.

Secondly, the so-called 'freedom of choice' is almost always exercised in a situation where the choice-makers have little information about the implications of their decisions for indoor air quality. Making choices can only be done effectively when they are based on adequate knowledge about the implications of the various options. Currently, there is no adequate government approach to providing education and guidance on such important issues.

Lack of standards

It is much more difficult to provide choice-makers with adequate information when there are no clear Australian standards, goals or guidelines for the pollutants that may be emitted by a product. While some people are willing to purchase a product with a lower emission rate on a 'safety first' basis, the argument for others is not compelling unless the choice is between a product that meets a standard and one that does not. Further, it is much more difficult to convince manufacturers to improve the performance of a product unless there is a standard of some type that needs to be met.

Lack of adequate information

At present, there is little community understanding about the health risks posed by a range of indoor pollutants, although occasionally an issue will arise that captures the attention of the media, the community, or both. Environmental tobacco smoke is one such issue. However, it is often difficult to judge the merits of spending scarce resources on addressing an issue where there is insufficient data to allow a rational decision to be made about relative risks and benefits and the real driver is community outrage. Much of the work to remove PCB-contaminated transformers from installed Australian fluorescent lights could be an example of this. The community can only be expected to respond on the basis of available information. When the information base is inadequate or the mechanism for delivering the information may have other objectives (for example, some may say, to sell newspapers or television advertising space), less than ideal outcomes are a real chance. Rational debate in a democracy requires that adequate information is available to all. This situation does not exist in Australia for many of the indoor pollutants considered in this paper.

Decisive and quick action to improve indoor air quality is sometimes less straightforward because it requires action by individuals. That is, there are areas where traditional regulation is not feasible; rather, the only way forward is by influencing behaviour and choices. This means that a substantial educational effort is required in much the same way that education has been used to reduce active smoking or drink driving in the community.

Lack of clear ownership

Since no one sphere of government or government department has obvious responsibility for ensuring acceptable indoor air quality, it is too easy for areas that need attention to 'slip through the cracks'. It is even more difficult when the skills and resources needed to make an impact are not available within one single area of government. For example, analytical skills could be in one government department, the responsibility for community education within another, and the regulatory role could be that of a self-regulating industry body. To date, no one area of government has sought to assume a leading or driving role. Thus it has been left for individual areas to make what progress they can, often without the benefit of a whole-of-government approach. It is urgent that one area of government takes a coordinating role to ensure that education, evaluation and/or regulation is carried out as necessary.

9 SIX STEPS TO BETTER INDOOR AIR QUALITY

It is clear that a number of indoor air pollutants pose a serious risk to the health of the Australian community. It is also clear that while the extent of this risk has been understood at least qualitatively or semi-quantitatively for some time, little progress has been made to improve the overall situation. While there has been no public outrage (largely the result of general ignorance) there has been, in some quarters, an attitude best described as ‘letting sleeping dogs lie’.

It is worth remembering that the major gains in reducing exposure to environmental tobacco smoke and reducing the extent of drink driving were the result of considerable community pressure. Leadership was provided by a few individuals who understood the ramifications and were able to inspire the community. Only then was there government action. The reluctance to lead a push to address the quality of indoor air must be overcome unless the community, who suffer from inaction, are to continue to bear significant cost and social burdens.

Below is a list of essential steps for implementing a process of general improvement, plus a concrete proposal for each step. These are indicative, not prescriptive. It would also be possible, though maybe more difficult, to take these essential steps within existing structures. While the detail of each step is open to discussion and modification, as a whole they are necessary conditions for providing acceptable indoor air quality for the majority of Australians. In fact, they parallel the work that has been undertaken in the ambient environment for decades. This work has resulted in a national approach under the Ambient Air Quality NEPM. A similar national approach is needed for indoor air.

A national working fund will need to be established to set up and fund the National Indoor Air Quality Council, fund research to fill in the knowledge gaps, and fund the jurisdictions to establish programs to improve indoor air quality. This would soon be self funded by the return on investment generated by lower health costs resulting from a cleaner indoor environment.

The ‘bottom line’ is that such action will substantially reduce the \$12 billion cost of unhealthy indoor air pollution.

1. **Establish Australian indoor standards of air quality for the most common and serious pollutants**

This is a trigger step. Until we have adequate Australian benchmarks we cannot establish the degree of concern about levels of many of the pollutants mentioned in this paper, and action for improving the situation in Australia will always be slow.

There will always be doubts about the level at which benchmarks should be set where, in the absence of extensive scientific research, there is uncertainty. The term ‘benchmark’ is used to indicate that for some pollutants there will be greater uncertainty than for the Ambient Air Quality NEPM pollutants.

Further, some will fear that establishing benchmarks will leave them open to either litigation, should it be found that the benchmarks have been exceeded, or lost business opportunities if products result in benchmarks not being met. These issues were addressed, directly or indirectly, with the establishment of the Ambient Air Quality NEPM. However, the commercial self-interest of a few cannot be allowed to stand in the way of the health of many.

The process of setting benchmarks can start without delay by adopting all Australian ambient standards and goals as interim indoor standards. The NEPM standards for ambient air quality have been through a recent and extensive process of establishment, review and community consultation. Therefore there should be no impediment to establishing them as indoor benchmarks. Unless decisive evidence can be presented that the health effects differ from those experienced in ambient air—and it is highly unlikely that such evidence exists—the precautionary principle must prevail and they should be adopted indoors.

The benchmarks would then be expanded to other pollutants by adopting international levels as working guidelines. This may require the use of ranges to reflect the various positions taken in

other jurisdictions or where the jurisdiction itself has selected a range to reflect less certainty. This should not be seen as an impediment: it is to be expected that there is still uncertainty about the effects of some pollutants. Ranges will demonstrate that the benchmark is not to be taken as a well-established, no-effect level or similar. However, the benchmark would indicate that for some measurements there was cause for concern and for others there was not. Measurements indicating levels that fell within the range of the benchmark would be evaluated on the basis of the at-risk community and its likely susceptible subgroups. This is what happens now when borderline results are obtained in comparisons with well-established standards. Indeed, in some cases it may be decided to await clarifying research. This, however, would be the outcome of a process that is far more transparent than is currently the case.

2. Collate existing information into a national database, establish knowledge gaps and fund research to fill them

Uncertainties as to the degree of concern about levels of some individual pollutants need to be reduced as soon as possible by:

- collating existing measured indoor air pollution levels into a national database
- commencing studies in areas where insufficient data are available

The Commonwealth is to be commended for funding the first work in Australia to attempt to bring together in a single, easily accessible source as many as possible of the Australian measurements on indoor air quality. This is the first component of work that needs to be undertaken to document existing study data, establish knowledge gaps, assign priorities to them on the basis of existing knowledge either in Australia or overseas, and then fund work to fill them.

The mechanism for guiding this work could follow the model of the Peer Review Committee of the Ambient Air Quality NEPM, but bearing in mind that indoor air quality is more diverse. Such a guiding body—referred to hereafter as the technical committee—would comprise experts in the various fields and jurisdictional representatives. It would have a technical/research focus. Its major activity would be to make proposals to a funding organisation (see step 3).

The technical committee would provide a focus for research on indoor air pollution, be it medical or technical. This would overcome the current situation where research is frequently conducted in a fragmented way, with funding provided by a range of bodies, but lacking a mechanism to ensure that the various components create a cogent whole that could lead to action where necessary. For example, there is little point in collecting more data on levels if there is no complementary medical research (be it actual or literature) to quantify the risks to human health posed by those levels. A focal body could overcome such issues.

3. Establish a national body (linked or similar to NEPC) responsible for indoor air

There is no coordinated focus for policy to improve indoor air quality, where necessary, within or between any spheres of government. By its nature, indoor air quality will cross the boundaries of responsibility set by governments to make the exercise of functions practical. However, in the case of indoor air quality, this compartmentalisation can be a significant hindrance to action. It can be overcome by establishing, under the auspices of the federal government, a high-level indoor air quality council to give direction to all aspects of indoor air quality.

Such a council would be linked to or similar to the NEPC, a statutory body with law making powers established under the Commonwealth *National Environment Protection Council Act 1994* (see page 5).

The Indoor Air Quality Council would include local government representation. To overcome the different ways in which areas of responsibility may be delineated in the separate jurisdictions, each Council member would be charged with bringing to each issue a whole-of-government response for their jurisdiction. The Motor Vehicles and Environment Council overcomes issues of responsibility in this way.

The role of the Indoor Air Quality Council would be to address issues brought before it by the technical committee (see step 2) or independently by members. Actions agreed to by Council would be binding on jurisdictions, as is the case with NEPC, and undertaken in each jurisdiction under the leadership/direction of the Council member in that jurisdiction.

From time to time the Council would need to establish working parties of experts, representatives of NGOs, etc. to advise on actions to address issues before it. The working parties would assess the current evidence and where necessary, make immediate recommendations to the Council. Such actions could include education, appliance or product control, or direct regulatory control. When uncertainty is greater, a working party could recommend 'no-regrets' actions or alternatively, the need to reduce uncertainty, possibly as a remit to the technical committee.

The Clean Air Society of Australia and New Zealand, with its wide range of experts and independent nature, should be represented at an appropriate level on this national body.

4. Establish an evaluation/monitoring mechanism

To close the loop an evaluation/monitoring mechanism is needed to assess the effectiveness of measures to reduce exposures to a particular pollutant indoors to acceptable levels and to determine whether further actions were necessary. The detail of this mechanism could be determined on a pollutant-by-pollutant basis at the same time the course of action was being considered. It is likely that such a mechanism would require continuing monitoring in somewhat the same way that ambient air is subject to a monitoring regime under the Ambient Air Quality NEPM. The technical committee would need to consider means of achieving this end in the light of research findings.

5. Create programs that will address the most serious problems

Action can be taken before a substantial structure is established and wide-ranging research is commissioned. This paper describes several pollutants that are present at unacceptable levels in either a substantial proportion or a well-defined subgroup of indoor environments. Large numbers of citizen are potentially affected. Urgent action is needed to address each of these situations. Pollutants in this category include: nitrogen dioxide, carbon monoxide, environmental tobacco smoke, formaldehyde, house dust mites, and moulds and fungi. While the action that needs to be taken in each of these cases may be different, for each, action is needed now.

6. Commence a wide-ranging and comprehensive public education program

In many cases, the poor state of indoor air quality has been known within government for decades without effective action being taken to address the problems. This situation cannot be allowed to continue. It breaches the governments' 'duty of care' to its citizens; it risks higher health and other economic costs; it results in social dislocation caused by preventable morbidity and mortality in the community.

Part of the solution is to institute a coordinated education program designed to equip people with the knowledge they need to make informed decisions about actions that could affect the quality of indoor air. This is particularly important in those instances where traditional regulation is not feasible and the only way forward is by influencing behaviour and decisions.

One immediate action to raise the community's awareness of indoor air quality would be to institute an annual National Indoor Air Quality Day. This would provide a focus for the issue together with a forum for announcing actions. The day would be an important anchor for education programs to lift community awareness about indoor pollution.

10 SHORT FORMS AND GLOSSARY OF TERMS

ABS	Australian Bureau of Statistics
AGA	Australian Gas Association
AGL	Australian Gas Light Company
ARL	Australian Radiation Laboratory
AS	Australian Standards
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
CEO	Chief Executive Officer
CFU	colony forming unit
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EA	Environment Australia
EPA	Environment Protection Authority
ETS	environmental tobacco smoke
HDM	house dust mite
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NGO	non-government organisation
NHMRC	National Health and Medical Research Council
NO _x	total oxides of nitrogen (a low-NO _x gas heater is designed to emit reduced quantities of NO _x)
PCB	polychlorinated biphenol
PM ₁₀	particulate matter with an aerodynamic diameter less than 10 micrometres
PM _{2.5}	particulate matter with an aerodynamic diameter less than 2.5 micrometres
ppb	parts per billion
ppm	parts per million
PULP	premium unleaded petrol
ROC	reactive organic compound, that is, an organic compound capable of participating in the reactions that lead to ozone being formed at ground-level
RTA	Roads and Traffic Authority
TVOCs	total volatile organic compounds
US EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WHO	World Health Organization

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