National Environment Protection (Ambient Air Quality) Measure

Report of the Risk Assessment Working Group

Prepared for the Environment Protection & Heritage Standing Committee

March 2002

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REPORT OF THE RISK ASSESSMENT WORKING GROUP

The report of the Risk Assessment Taskforce (RATF) was tabled at the November 2000 NEPC Committee meeting and was accepted at the December 2000 meeting of Council. The RATF report contained a range of recommendations relating to the use of risk assessment in the setting of air quality standards in Australia. NEPC Committee requested that a supplementary report be prepared on a number of these recommendations and a set of five issues requiring further consideration was endorsed at the May 2001 NEPC Committee meeting. It was agreed at that time that an unfunded working group be established to address the issues and to report to Committee in March 2002 on the findings of the working group.

The issues that the Risk Assessment Working Group (RAWG) was asked to address are:

1. With regard to the proposed reviews to examine the practicability of additional standards for ozone and sulfur dioxide in 2003, indicate whether a health risk assessment (HRA) approach is likely to be needed or not, so that decisions on the collection of relevant data (eg time activity data) required for any HRA process can be made in sufficient time for that data to be available.
2. Undertake an assessment of existing air monitoring data and advise NEPC Committee on whether or not existing monitoring networks provide an adequate data set of pollutant levels for population exposure estimation for all criteria pollutants. In order to make such an assessment a set of assessment criteria would need to be established.
3. Assess the need for the development of Australian exposure assessment models for the criteria pollutants, assess which Australian cities have data suitable for conducting exposure assessments pollutant by pollutant (based on information and advice from jurisdictions), and whether or not those cities are sufficiently representative to enable national air quality standards to be set.
4. Invite health agencies to assist in the identification of targeted epidemiological studies that may be required in Australia to assist in the NEPM reviews. Particular emphasis should be placed on children's health in identifying these studies.
5. Prepare an HRA reporting protocol to facilitate a clear understanding of the health risk assessment process as used in deriving air quality standards under the NEPM. This should be based on the criteria outlined in the RATF report.

The Risk Assessment Working Group report addresses the above and makes recommendations to EPH Standing Committee on these issues. The report has a number of appendices containing detailed information that supports the main findings in the report. The composition of the RAWG is found in Attachment 1.

<u>Background on Health Risk Assessment</u>

As discussed in the RATF report, risk assessment is usually comprised of five stages:

- Issues identification
- Hazard identification

- Dose-response assessment
- Exposure assessment
- Risk characterisation.

In conducting a quantitative risk assessment, all of the stages outlined above would be undertaken to provide a numerical estimate of risk. A qualitative assessment does not involve quantification of the risk to the population in the risk characterisation stage, but rather a narrative description of the level of risk is given. In the process of setting air quality standards either approach can be taken.

For pollutants where a threshold can be identified below which no adverse effects are observed, uncertainty or 'safety' factors are applied to the No Observed Adverse Effects Level (NOAEL) or Lowest Observed Adverse Effects Level (LOAEL) to derive a standard protective of sensitive members of the population.

For non-threshold pollutants, such as ozone, particles and carcinogens, there is assumed to be no 'safe' level of exposure and therefore no NOAEL or LOAEL can be identified. In this case a quantitative risk assessment approach may need to be undertaken to estimate the risk at the level of the proposed standard.

Whichever approach is taken, the critical part of the risk assessment process in deciding where the standard should be set is the exposure assessment. The quality of the exposure assessment is dependent on the available air quality data and the approach taken to assess population exposure. A number of approaches can be used for an exposure assessment which range from simply averaging the pollutant levels monitored at air monitoring stations through to complex models that require significant monitoring data and modelling approaches to enable the estimation of the size and distribution of population groups exposed to the different levels of exposure occurring across a region or city. The RATF concluded, and the RAWG agree, that the decision on any exposure assessment model needs to be done on a pollutant-by-pollutant basis taking into account the types of epidemiological studies used as a basis for the dose-response relationships and available air monitoring data.

The responses to the issues 1-3 in this report relate to data availability for conducting exposure assessment and subsequent risk assessment. Issue 4 identifies priority areas of research that health agencies suggest environment agencies consider when recommending, conducting or funding research to be undertaken to address gaps in the knowledge on the health effects of air pollution in Australia. These priority areas have been identified by enHealth Council. Issue 5 sets out a reporting protocol for risk assessment conducted through NEPC processes.

Summary of Findings

The RAWG has concluded that HRA could be used in the reviews of the ozone and sulfur dioxide standards due to commence in 2003 (Issue 1).

For ozone, the purpose of HRA would be to assess the exposure of the population to an ozone level of 0.08 ppm and the health risk resulting from such exposure. This would provide information for the cost-effectiveness analysis required to justify the setting of such a standard.

For sulfur dioxide, HRA would enable an estimation of population exposure and the subsequent risk at any proposed standard. This would allow an appropriate standard to be set and would again inform the cost-effectiveness analysis.

For both ozone and sulfur dioxide, the RAWG believes that there are sufficient air monitoring data available in the larger jurisdictions to support the reviews. The only data that should be collected are time-activity data for the Australian population.

Issues 2 and 3 relate to the review of the Ambient Air Quality NEPM due to commence in 2005. Issue 2 relates to individual cities and the assessment in the report relates to whether there are sufficient data to conduct exposure assessments in all major Australian cities. Issue 3 relates to the availability of data nationally to conduct an exposure assessment representative of the Australian population. Although there are not sufficient data available for all pollutants to conduct exposure assessments in all major cities (Issue 2), the RAWG has concluded that it is not necessary, in developing a national air quality standard, to conduct exposure assessments in all cities. The air monitoring data that is available is sufficient to conduct exposure assessments on which the development of air quality standards in Australia can be based (Issue 3).

In addition the RAWG has concluded that it is not necessary to develop an exposure assessment model specifically for Australia, but that time-activity data should be collected for the Australian population to validate the applicability of overseas models in Australia.

Responding to an invitation from the RAWG to provide advice on priority areas of research needed to support the development of air quality standards (Issue 4), enHealth Council has identified a number of studies that should be considered by Environment agencies. The RAWG recommends, if funding were to become available, that consideration should be given to the first four priority areas identified by enHealth Council.

A reporting protocol (Issue 5), based on the criteria recommended by the RATF, has been developed. The RAWG recommends that NEPC utilise this protocol to report the findings of any risk assessment used in the setting of air quality standards in Australia.

Issue 1: With regard to the proposed reviews to examine the practicability of additional standards for ozone and sulfur dioxide in 2003, indicate whether an HRA approach is likely to be needed or not, so that decisions on the collection of relevant data (eg time activity data) required for any HRA process can be made in sufficient time for that data to be available.

The future actions arising from the Ambient Air Quality NEPM include a review of the O_3 and SO_2 standards commencing in 2003. The scope of these reviews is quite specific:

- To review the practicability of setting a long-term goal of achieving a 1-hour O_3 standard of 0.08 ppm; and
- To review the practicability of setting a short-term 10-minute standard for SO_2.

The application of health risk assessment to these reviews is discussed separately below.

Ozone

The main issue regarding the practicability of setting a long-term 1-hour standard for ozone centres around whether such a standard can be achieved given the background levels of ozone currently existing in Australia. However, if NEPC did proceed with the development of such a standard then a risk assessment approach could be used. The HRA would provide an estimation of population exposure at the proposed level of 0.08ppm and the risk to the population resulting from exposure at that level. The results of the HRA process would provide valuable information for the cost-effectiveness analysis.

The health effects of ozone range from irritation of the airways through to more serious effects that may result in hospitalisation or in some cases premature death in susceptible groups. These groups include the elderly, children, asthmatics and people with existing cardiovascular and respiratory disease. There has been no identified threshold for the adverse effects of ozone. Much of the evidence of the health effects of ozone has been derived from controlled exposure studies and population-based epidemiological studies. In these epidemiological studies the populations examined have primarily involved people in outdoor environments as exposure to ozone essentially only occurs outdoors, or in controlled exposure studies where the exact concentration of ozone and duration of exposure is known. In addition, the level of activity that these populations were undertaking at the time of exposure was also known.

In conducting any risk assessment it is critical that the exposure assessment mirrors that used in the epidemiological studies used to derive the health endpoints and dose-response relationships. For ozone this would require collection of time activity data for the Australian population. The data would relate to parameters such as the duration of time spent outdoors, the level of exertion when outdoors and the time of day when outdoors. Data from other countries that have a similar climate and geography to Australia, eg California, could be used, but some data for Australia should be collected to validate the transferability of the overseas data to Australia.

State and Territory environment agencies have been monitoring ozone for many years and, in the major cities, extensive air monitoring networks exist. This is not the case for the smaller jurisdictions. An analysis of population distributions and the existing air monitoring networks in Australia has shown that in the larger jurisdictions the existing network is sufficient to conduct an exposure assessment for ozone. However the case is different in the smaller jurisdictions where ozone monitoring is limited or non-existent. It is normal practice internationally to assess exposure to air pollutants using a small number of representative cities. For example, when the US determined their ozone standard they assessed population exposure in nine cities. In the 2003 review of the ozone standards, a decision will need to be made as to whether an assessment based on the larger jurisdictions is a sufficient base from which to develop national air quality standards.

Conclusion:

- An HRA approach could be used in the 2003 review of the ozone standards
- Existing air monitoring data is sufficient in larger jurisdictions to conduct a risk assessment for the 2003 review of the ozone standards
- Time activity data should be collected to validate overseas exposure assessment models

Sulfur dioxide

The proposed review of the SO_2 standard is to assess the practicability of setting a short-term 10-minute standard. The RAWG believes, on advice obtained from the jurisdictions, that short-term peaks are related to point source emissions and would not occur in the broader ambient environment. However, if NEPC decided to proceed with the development of a short-term standard then a risk assessment approach could be used. In this case, HRA would be used to develop an appropriate standard. The HRA would provide an estimation of population exposure to short-term peaks of SO_2 and the resultant risk to both local communities and the wider population. This information could be used in the cost-effectiveness analysis and help inform the final selection of a standard.

As discussed further under Issue 3, as SO_2 is predominantly a point source issue, current monitoring is designed to monitor the impact of those point sources on local air quality. The existing data is sufficient to characterise risk for these more highly exposed groups but may not be sufficient to characterise the risks from lower exposures to the broader population. The data from point source monitoring is likely to lead to an overestimate of exposures, and hence risks, if extrapolated to the broader population.

The health effects of SO_2 are derived from studies similar to those conducted for ozone. Therefore to accurately assess the risk to the population, time activity data would be required. This is probably more critical for SO_2 as the short-term peaks are likely to be localised in nature and not broadly distributed across the airshed.

Conclusion:
- An HRA approach could be used in the 2003 review of the sulfur dioxide standard
- Existing air monitoring data relating to short-term peaks of SO_2 will not be adequate to assess the risk to the general population, but would provide the basis for a risk assessment of exposed populations near point sources.
- Time activity data should be used in the exposure assessment process, however any data collected for the ozone review could be used for this purpose.

Issue 2: Undertake an assessment of existing air monitoring data and advise NEPC Committee on whether or not existing monitoring networks provide an adequate data set of pollutant levels for population exposure estimation for all criteria pollutants. In order to make such an assessment a set of assessment criteria would need to be established.

This issue relates to the ability to conduct exposure assessments in all Australian cities. It should be noted that the RAWG do not believe it is necessary to conduct exposure assessments in all Australian cities as a basis for the development of national air quality standards (see response to Issue 3).

The RAWG has consulted widely with jurisdictions about the extent of monitoring that is being conducted for each of the criteria pollutants to determine if it is sufficient to provide an estimate of population exposure. In addition, the RAWG reviewed the Ambient Air Quality NEPM monitoring plans that have been approved by Council. The data provided by jurisdictions and obtained from the individual monitoring plans is presented in Attachment 2.

To assess the adequacy of the existing monitoring data for population exposure assessment the following criteria were used:
- Air monitoring should be conducted to comply with clause 14 of the Ambient Air Quality NEPM regarding the number of performance monitoring stations for a region
- Data should also provide a cross section of exposures from high to low to appropriately reflect the distribution of exposures across the community
- Consideration was given to distribution of sources for SO_2 and lead, and whether exposure arises mainly from point sources
- Consideration was only given to stations where at least 12 months continuous data was available.

The RAWG considered each pollutant separately to make an assessment of the suitability of the data according to the above criteria.

Recommendations specific to the 2003 reviews (SO_2, ozone) have been addressed under Issue 1. The recommendations in this section relate to broader issues that may arise in future reviews of the NEPM including the review due to commence in 2005.

On the basis of the information provided by jurisdictions and review of the NEPM monitoring plans, the RAWG concluded that exposure assessments and subsequent quantitative risk assessments will not be possible for smaller jurisdictions because of the limited data available. In setting or reviewing national air quality standards under the NEPM, extrapolation of the results of any risk assessment process from the larger jurisdictions to estimate the risk in the smaller jurisdictions would be necessary. In some instances extrapolation of data from some larger jurisdictions to other larger jurisdictions would also be necessary. This is addressed in detail in the response to Issue 3.

The RAWG assessment for each pollutant is detailed below.

Sulfur dioxide

SO_2 is predominantly a point source issue and current monitoring is designed to monitor the impact of those point sources on local air quality. The data is sufficient to characterise risk for these more highly exposed groups but may not be sufficient to characterise the risks to the broader population. The data from point source monitoring is likely to lead to an overestimate of risks if applied to the broader population. Jurisdictions should give consideration to evaluating the need to include monitors that will represent the broader population.

Carbon monoxide

In all but two jurisdictions the number of monitoring stations measuring CO was considered to be insufficient to characterise population exposure. This was considered to be an important issue that should be addressed given that there is increasing evidence from epidemiological studies conducted in Australia and overseas indicating that significant health effects are observed at CO levels below the current standard. Jurisdictions should give consideration to evaluating the need to include monitors that will represent broader population exposure, as CO exposure at current ambient levels is likely to emerge as a significant health issue in the near future.

Ozone

Although existing air monitoring networks contain a significant number of ozone monitors in the larger jurisdictions, monitoring is biased towards high-end exposures and this data, used alone, could lead to an overestimate of whole-of-population exposures and subsequent risk. The RAWG considers that the current networks are adequate to provide data for exposure assessments if the bias of the data is sufficiently taken into account in estimating and reporting the resultant risk.

Nitrogen dioxide

Current monitoring networks often co-locate NO_2 monitors at peak ozone sites as NO_2 is a precursor to ozone formation. Although this provides a good estimate of peak ozone levels, it may not provide an accurate representation of the distribution of NO_2 levels across an airshed and therefore population exposures. This could lead to a tendency to underestimate NO_2 levels and therefore any risk estimate derived from exposure assessments using this data. Epidemiological studies conducted in Australia have found that current monitored levels of NO_2 in Australia are strongly associated with adverse health effects. The RAWG recommends that jurisdictions should give consideration to evaluating the need to include monitors that will represent a broad range of NO_2 concentrations and therefore a more accurate assessment of population exposure.

PM_{10}
The existing monitoring network is considered to be a good basis for assessing exposures for the Australian population.

$PM_{2.5}$
Monitoring requirements will be considered as part of any variation of the Ambient Air Quality NEPM to extend its coverage to $PM_{2.5}$. The existing air monitoring networks are not sufficient in most jurisdictions to assess population exposure.

Lead
With the phase-out of leaded petrol, lead is now considered to be essentially a point source issue. It is the view of the RAWG that changes are not required to the existing monitoring networks.

Conclusion:

- It will not be possible to conduct exposure assessments in the smaller jurisdictions due to lack of air monitoring data
- In the larger jurisdictions, the extent to which existing air monitoring networks provide data for population exposure assessments varies from pollutant to pollutant
- For PM_{10} and ozone existing air monitoring networks provide adequate data for exposure assessment
- There is a significant lack of data being collected for CO with only two jurisdictions having adequate data for exposure assessment. Jurisdictions need to give consideration to increasing the capacity for monitoring of CO to enable exposure assessments to be conducted
- For NO_2 sufficient data exists however it may not adequately represent the distribution of NO_2 across an airshed as in many instances the monitors are co-located at peak ozone sites
- The monitoring requirements for $PM_{2.5}$ will be addressed as part of the variation to the Ambient Air Quality NEPM to extend its coverage to $PM_{2.5}$

Issue 3: Assess the need for the development of Australian exposure assessment models for the criteria pollutants, assess which Australian cities have data suitable for conducting exposure assessments pollutant by pollutant (based on information and advice from jurisdictions), and whether or not those cities are sufficiently representative to enable national air quality standards to be set.

Development of Australian exposure assessment models for the criteria pollutants
Exposure to air pollution at an individual level depends on many different factors including the degree of activity that an individual undertakes, the time spent outdoors, the time of day when outdoors and indoor sources.

The highest exposures will be for those who are exercising or working outdoors, and children who have a higher breathing rate per kilogram body weight than adults. People with pre-existing disease and the elderly are also at increased risk from their exposures to air pollution. As a result, these three groups are considered to be susceptible sub-groups to air pollution and usually drive the setting of air quality standards. In setting air quality standards, however, risk is assessed at a broad population level or for susceptible sub-groups, not at an individual level.

Virtually all epidemiological studies on the health effects of air pollution have used pollutant measures obtained from fixed-site monitors. The RAWG have taken the view, consistent with overseas approaches, that, as health effects have been demonstrated in epidemiological studies using fixed-site outdoor monitors, such monitoring data should be used in any exposure assessment. It can be argued that using data from fixed-site monitors introduces uncertainty into the estimates of exposure and subsequent estimates of risk. The RAWG acknowledge that information about personal exposures may improve (ie reduce the uncertainty of) the estimates of risk produced through any risk assessment process, however the costs and limitations of available personal monitors limit the gains achieved through the use of such personal monitors. In addition, policy relating to ambient air pollution is developed and implemented on the basis of measurements made at fixed-site monitors not personal exposure.

Several exposure assessment models exist overseas and the approach to exposure assessment and choice of model is dependent on the pollutant under consideration. A review of overseas exposure models is presented in Attachment 3. No one model will be adequate to address all pollutants.

A range of computer models has been developed to estimate exposure. Models can be used to:

- Estimate local ambient concentrations based on estimates of emissions from various point sources
- Estimate regional ambient concentrations based on estimates of emissions, ambient monitoring data, the impacts of meteorology and interactions with other pollutants in the atmosphere
- Estimate likely exposures of the population using estimated ambient concentrations and an understanding of people's behavioral patterns that affect their exposure.

Models of varying complexity are available from international sources. The RAWG do not believe that an exposure assessment model (or models) needs to be developed specifically for Australia. However time activity data for Australia should be collected to validate the transferability of overseas models to the Australian situation.

Conclusion:

- An exposure assessment model does not need to be developed specifically for Australia
- Time activity data should be collected for the Australian population to validate the transferability of overseas models to Australia

Australian cities that have data suitable for conducting exposure assessments

On the basis of information provided by jurisdictions and contained in the NEPM monitoring plans for individual jurisdictions, the RAWG has formed the following views on which Australian cities have adequate data for conducting exposure assessments relevant to standard setting at a national level.

Sulfur dioxide

Sufficient ambient monitoring data is available for Sydney, Melbourne and Brisbane to provide an adequate assessment of population exposure for the purpose of setting air quality standards protective of the general population. Assessments conducted in these locations are likely to be representative of the exposure of the population residing in most urban areas of Australia. Further analysis regarding the applicability of these assessments to Perth should be conducted given that the sources located within this airshed differ from those in other urban areas of Australia.

Nitrogen dioxide

Sufficient ambient monitoring data is available for Sydney, Melbourne, Brisbane, Perth and Adelaide to provide an adequate assessment of population exposure for the purpose of standard setting. However it should be noted, as discussed under Issue 2, that this data is often obtained at locations chosen to reflect peak ozone levels and may not be an accurate estimate of the distribution NO_2 within an airshed. However, noting this limitation, and given that these five cities cover most of the population of Australia, this data should be sufficient to estimate population exposure for setting air quality standards.

Ozone

Sufficient ambient monitoring data is available for Sydney, Melbourne, Brisbane, Perth and Adelaide to provide an adequate assessment of population exposure for the purpose of standard setting. Given that these five cities cover most of the population of Australia, this should be sufficient. It should be noted however, as discussed under Issue 2, that this data may reflect high-end exposure.

Carbon monoxide

Sufficient ambient monitoring data is available for Melbourne and Perth to provide an adequate assessment of population exposure for the purpose of standard setting. Given that motor vehicles are the primary source of CO in urban areas, the Melbourne and Perth data should be sufficient to provide an estimate of population exposure for the Australian population.

PM_{10}

Sufficient ambient monitoring data is available for Melbourne, Sydney, Brisbane, Perth and Adelaide to provide an adequate assessment of population exposure. Given that these five cities cover most of the population of Australia, this should be sufficient to estimate population exposure for the purpose of standard setting.

$PM_{2.5}$

Although ambient monitoring data for $PM_{2.5}$ is limited, there is sufficient available data for Melbourne, Sydney, Brisbane and Perth to provide a limited assessment of population exposure. Given that these four cities cover a significant proportion of the population of Australia this should be sufficient to estimate population exposure for the purpose of standard setting.

Lead
With the phase-out of leaded petrol, lead is considered to be essentially a point source issue. It is not likely that an assessment of the exposure of the Australian population will be required.

Conclusion:
- Sufficient ambient air monitoring data is available in most larger cities to conduct exposure assessments for the criteria pollutants
- For some pollutants data is only available in a limited number of cities (2-4) and this data would need to be used to assess exposure of the Australian population

Are the larger cities sufficiently representative to enable national air quality standards to be set
The larger jurisdictions in Australia have extensive ambient air monitoring databases for the criteria pollutants. This is not the case however in the smaller jurisdictions. If data from the larger cities is used to estimate exposure in the smaller jurisdictions this may overestimate exposure for many of the pollutants, especially those arising from motor vehicles and large industry. For those pollutants resulting from wood heaters, the data collected in major urban areas may underestimate the risk due to these sources in smaller cities such as Launceston and Armidale where wood smoke is known to contribute significantly to elevated levels of particles in the cooler months.

As the available ambient monitoring data from the major urban areas represents approximately three-quarters of the Australian population, the RAWG believes, acknowledging the issues outlined above, that the data available in these cities could be used as the basis for assessing the risk posed to the Australian population and setting national air quality standards. To characterise exposures for the entire Australian population would require a considerable increase in resourcing for ambient air monitoring. The RAWG does not consider that the marginal benefits to standard setting justify such expenditure and consider that it would be extremely unlikely to change the outcome of the standard setting process. The use of a limited number of cities to represent an entire national population is consistent with world's best practice.

Conclusion:
- As the ambient air monitoring data from the larger Australian cities represents approximately three-quarters of the Australian population, the available data is adequate to represent the Australian population as a whole as long as the uncertainties associated with this approach are clearly articulated
- This approach is consistent with approaches used internationally in the setting of air quality standards

Issue 4: Invite health agencies to assist in the identification of targeted epidemiological studies that may be required in Australia to assist in the NEPM reviews. Particular emphasis should be placed on children's health in identifying these studies

A number of epidemiological studies investigating the effects of air pollution on health have been conducted in Australia. Epidemiological studies have been conducted in Melbourne, Brisbane and Sydney to investigate the association between air pollution levels in these cities and increases in daily mortality and hospital admissions for respiratory and cardiovascular disease. Other studies have been conducted in Newcastle and Adelaide using cohorts of children to investigate the effects of air pollution on respiratory symptoms such as cough and wheeze.

There are a number of studies currently underway. A large study is being conducted under a SPIRT (Strategic Partnerships with Industry – Research and Training) grant to investigate the effects of air pollution in Melbourne, Sydney, Brisbane and Perth on mortality and hospital admissions for respiratory and cardiovascular disease. This study is using a standardised statistical approach consistent with large multi-city studies conducted in the US and Europe. This will ensure national and international consistency in the data generated. Studies using a different statistical approach are also underway in Perth to investigate the association between air pollution and daily mortality and hospital admissions. In Melbourne studies are underway to investigate the effects of air pollution on emergency attendances for children with asthma and the elderly with cardiovascular disease.

The results of all these studies will contribute to the growing national database on the health effects of air pollution in Australia.

The RAWG invited the enHealth Council to provide advice on additional studies that could be conducted to contribute to the national understanding of the health effects of air pollution on the Australian population. Responding to this request, enHealth provided a list of targeted epidemiological studies that they consider would be useful in reviewing the NEPM standards. The prioritisation was based on feasibility, relevance to Australian circumstances, usefulness with regards to setting Australian guidelines, and cost.

EnHealth indicated that they were particularly interested in research about patterns of environmental factors that are unique to, or more pronounced in Australia, and research relevant to conditions that are particularly prevalent in Australia such as asthma.

Tentative budgets and times from initiation to reporting of findings were attached to the projects.

The suggested studies are:

1. A cohort study of children with personal monitoring of nitrogen dioxide, sulfur dioxide and ozone exposure and respiratory symptoms and function. In particular, the relationship between peak exposures to nitrogen dioxide and longer-term exposures (days, weeks) and respiratory symptoms in children would be investigated. ($250,000-$400,000 and up to 2 years)

2. The apparent effects of carbon monoxide at or close to the current goal are of concern, particularly for population sub-groups with pre-existing heart disease. The relationship between peak (eg roadside) and ambient carbon dioxide, as measured at stations should be investigated through personal exposure studies of patients with pacemakers, where minor indicators of cardiac ischaemia can be detected. ($90,000 and 12 months)
3. Time series studies using hospital attendances and admissions (eg for asthma) with ambient pollution data and improved (multi-site) allergen monitoring data. ($120,000 and 18 months)
4. Time series studies of the health effects of $PM_{2.5}$ assessed by impacts on mortality and morbidity. ($120,000 and 18 months)
5. Appraisal of health warnings. No Australian data exists on community needs regarding health warnings on high pollution days, or on the efficacy of different methods of delivering warnings. Qualitative studies of community opinion in this area are required. ($80,000 and 6 months)
6. Studies investigating air pollution from large point source environments and its impact on the health of surrounding populations. Such studies will provide data that will address contentious areas related to the setting of NEPMs. ($120,000 and 18 months per study).

The RAWG considers that recommendations 1-4 should be given consideration should funds become available, as these are most clearly relevant to setting NEPM standards. Recommendation 5 is related to communication and the implementation of the NEPM rather than to the setting of standards in the NEPM. Recommendation 6 is important but is more relevant for individual jurisdictions to consider where large point sources exist.

It should be noted that although it is important that local data is available to support the setting of air quality standards for Australia, there will always be a reliance on overseas data, given the extensive databases available, to provide the basis for the development of such standards. As discussed in detail in the RATF report, the importance of developing and maintaining Australian databases is in validating the transferability of overseas data to the Australian situation. The results of studies to date indicate that the findings of Australian studies of health effects are consistent with those observed in studies overseas.

Conclusion:

- EnHealth have identified priority areas of research to support the development and review of air quality standards in Australia. Consideration should be given to how such studies should be progressed.

Issue 5: Prepare an HRA reporting protocol to facilitate a clear understanding of the health risk assessment process as used in deriving air quality standards under the NEPM. This should be based on the criteria outlined in the RATF report.

Any reporting protocol for risk assessment must provide information allowing all stakeholders to understand the inputs into the risk assessment process, the outputs of the assessment and how they are used in the risk management phase. The assumptions and uncertainties associated with each stage must be clearly documented and communicated.

The RATF recommended that any reporting protocol should include:

1. The criteria used to assess the health effects from exposure to air pollution
2. Identification of sensitive populations to be protected (eg asthmatics, children, people with diseases)
3. A clear statement of the health endpoint being assessed and justification for selecting that endpoint, as well as other health points considered and rejected and the reasons why
4. A clear description of how the exposure assessment was developed and the associated limitations
5. A description of how the dose-response relationships were derived and associated uncertainties
6. A description of all safety factors used and their derivation
7. Any default parameters used in the risk characterisation and the uncertainty associated with their use
8. An explanation of how the Precautionary Principle was applied
9. An explanation of any statistical methods used
10. How threshold and non-threshold pollutants are dealt with
11. Characterisation of the uncertainty in the risk estimates
12. Criteria for risk acceptability.

The RATF concluded that reporting against these criteria will increase transparency in the risk assessment process and help with stakeholder consultation throughout the standard setting process. Final reporting should acknowledge who was consulted, as is done in summary and response documents developed by NEPC in the NEPM development process. The above criteria should be used as a basis for a reporting protocol but could be further developed at the time of the review of the Ambient Air Quality NEPM.

Building on the recommendations of the RATF, the RAWG has developed the following reporting protocol for risk assessment that could be used in the NEPC context.

Purpose of the risk assessment

This section would outline the reason why the HRA is being undertaken, that is, to assess the risk to the Australian population from air pollution as a basis of setting ambient air quality standards. It would provide broad context to the scope of the risk assessment and an introduction to the process to be undertaken, including a description of what cities are to be assessed and the reasons why. All limitations to the risk assessment should be outlined in this section. An outline of the NEPM development process should also be included.

Methods

This section would provide information on the methods used in the risk analysis and the type of modelling to be undertaken for the exposure assessment and risk characterisation stages. This section would also provide information on the health endpoints selected as the basis for the standards and identify the dose-response relationships to be used in the assessment. It would also outline any sensitivity analyses to be conducted and their purpose.

Limitations and uncertainties in the risk assessment process

All assumptions made in the approach taken to the risk assessment and limitations and uncertainties involved in the output from the analyses should be clearly articulated at this stage. This should include an assessment of the accuracy of the dose-response relationships and the applicability of overseas data (if used) to the Australian situation. A discussion on the choice of health endpoints and other health indicators that may not have been included in the assessment should be undertaken. Issues such as confounding by other pollutants and how differences in air pollution between the major cities may impact on the results of the risk assessment should be discussed.

A discussion should be included as to the adequacy of the air quality data obtained from the air monitoring stations for the exposure assessment including an assessment of missing data for the period of analysis.

A discussion on baseline health incidence rates, such as baseline mortality data, should be included and an assessment of the uncertainty introduced by generalising this data across different population sub-groups should be reported. As many risk assessments do not address the most sensitive members of the population, an indication of the uncertainty consequently introduced should be included.

Report on the findings on the risk assessment

The section would report on the findings of the risk analyses including an estimate of the uncertainty associated with the outcomes and the results of the sensitivity analyses if undertaken. A tabulation of all health data used in the assessment should be included and summary tables of the air quality data.

Interpretation of the results of the risk assessment

The acceptance of the findings of risk analyses is dependent on the understanding by stakeholders of the process undertaken and what the outcome of the process means. This section should include a 'plain English' interpretation of the results of the risk analyses written so that all stakeholders can easily understand:

- the process undertaken
- the uncertainty associated with the risk estimates
- how the outcomes of the risk assessment may be used in the selection of an air quality standard.

Attachment 1

Membership of the Risk Assessment Working Group

Chair

Dr Lyn Denison	Environment Protection Authority, Victoria

Members

Mr Paul Dworjanyn	Environment Australia
Mr David Wainwright	Queensland Environmental Protection Agency
Mr Sean Lane	Environment Australia
Ms Therese Manning	New South Wales Environment Protection Authority
Dr Andrew Langley	Sunshine Coast Public Health Unit, Queensland Government

Project Manager

Mr Ian Newbery	NEPC Service Corporation

Attachment 2

Current Monitoring of Air Pollutants by Jurisdiction

Summary

The first table summarises the total number of current monitoring stations per pollutant per jurisdiction, and of these how many are identified as Air NEPM Performance Monitoring Stations or Trend Stations (as defined by jurisdictional air quality monitoring plans). Totals are also given for the number of $PM_{2.5}$ monitors and nephelometers.

The tables following identify monitoring station locations and pollutants monitored for each jurisdiction.

The information has been gathered from information presented in jurisdictional AAQ NEPM monitoring plans, web sites and directly from jurisdictions, and is correct as at March 2002.

Jurisdiction	**CO**		**O_3**		**NO_2**		**SO_2**		**Lead**		**PM_{10}**		**$PM_{2.5}$**	**Neph.**
	Total Stations	NEPM PMS/Trend	Total Stations	NEPM PMS/Trend	Total Stations	NEPM PMS/Trend	Total Stations	NEPM PMS/Trend	Total Stations	NEPM PMS/Trend	Total Stations	NEPM PMS/Trend	Total Stations	Total Stations
ACT	2	1	2	1	2	1	0	-	3	1	3	1	0	2
South Australia	2	2	6	6	6	6	5	5	8	8	7	2	1	3
Northern Territory	0	-	0	-	0	-	0	-	0	-	0	-	0	0
Queensland	2	1	13	6	16	6	21	5	8	1	23	7	3	8
New South Wales	7	6	26	15	26	11	14	7	7	3	27	14	10	20
Tasmania	1	1	0	-	0	-	0	-	0	-	2	1	0	0
Victoria	6	4	15	9	14	8	11	6	4	1	14	9	4	12
Western Australia	5	4	6	3	9	3	14	1	1	1	6	3	3	9

ACT

Site	Loc.	CO	O_3	NO_2	SO_2	Lead	PM_{10}	$PM_{2.5}$	Neph.
Monash	Res	P/T	P/T	P/T		P	P/T[1, 3]		✓
Civic	CBD	✓	✓	✓		✓	✓[3]		✓
Woden	Res					✓	✓[3]		

Key –

Res	Residential	C	Campaign Monitoring *
Rur	Rural	✓	Other Monitoring
Ind	Industrial	1	TEOM
Com	Commercial	4	ANSTO Sampler
RS	Roadside	3	Hi Vol Sampler
P	NEPM Performance Monitoring Station *	4	Partisol Sampler
T	Trend Performance Monitoring Station *	*	(as described in the Air NEPM Monitoring Plan)

SA

Site	Loc.	CO	O_3	NO_2	SO_2	Lead	PM_{10}	$PM_{2.5}$	Neph.
Adelaide Metro									
Adelaide Hindley St	CBD	T							
Elizabeth	Res	T	P	P	C				
Gawler	Res		C	C	C				✓
Gilles Plains	RS					P	✓[3]		
Kensington	Res		T	T	C	T	T[1]		
Netley	Ind		T	T			P[1]	✓[1]	✓
Northfield	Res		T	T		T	✓[3]		✓
Parkside	RS					T			
Penrice, Pt Adelaide	Ind						✓[3]		
St John's Christies B	Ind				T				
Thebarton	RS					✓	✓[3]		
Regional									
Mt Gambier	Res		C	C	C		✓[1,3]		
Pt Pirie (W Primary)	Res					✓			
Pt Pirie (Oliver St)	Res					P	✓[3]		
Pt Pirie (Frank Grn)	Res					P			

Key –

Res Residential
Rur Rural
Ind Industrial
Com Commercial
RS Roadside
P NEPM Performance Monitoring Station *
T Trend Performance Monitoring Station *

C Campaign Monitoring *
✓ Other Monitoring
1 TEOM
4 ANSTO Sampler
3 Hi Vol Sampler
4 Partisol Sampler
* (as described in the Air NEPM Monitoring Plan)

NSW

Site	Loc.	CO	O3	NO2	SO2	Lead	PM10	PM2.5	Neph
Sydney									
Bargo	Rur		✓	✓	✓				✓
Blacktown	Res	T	T	T	T		T[1,3]		✓
Bringelly	Res		T	T	T		T[1]		✓
Camden	Res/Rur		✓	✓					
Campbelltown	Res		✓	✓			✓[1]		
Earlwood	Res		✓	✓		✓	✓[1,3]	✓[1]	✓
Kurrajong Hgts	Res/Rur		✓	✓	✓				
Lidcombe	Res		T	T			T[1]	✓[1]	✓
Lindfield	Res		✓	✓	✓		✓[1,3]		
Liverpool	ResCom	P	P	P			P[1]	✓[1]	✓
Oakdale	Rur		P	✓					✓
Randwick	Res		✓	✓	✓		✓[1]		✓
Richmond	Res		T	T	T		T[1,3]	✓[1]	✓
Rozelle	Res	T	T	T		T	✓[3]		✓
St Marys	Res/Rur		P	✓			✓[1]		✓
Sydney CBD	CBD	P		✓		P	✓[3]		
Vineyard	Res/Rur		✓	✓	✓		✓[1]		
Westmead	Res	✓	✓	✓			✓[1]	✓[1]	✓
Woolooware	Res		T	T	T		T[1]	✓[1]	✓
Lower Hunter									
Beresfield	Res/Rur		✓	✓	✓		T[1,3]	✓[1]	✓
Newcastle	CBD	T	T	T			✓[3]		✓
Wallsend	Res		T	T	T	C	T[1,3]	✓[1]	✓
Illawarra									
Albion Park	Rur/Res		P	P	P		P[1,3]		✓
Kembla Grange	Res		P	✓			✓[3]		✓
Port Kembla 1	Res/Ind					✓			
Port Kembla 2	Res/Ind					✓			
Port Kembla 3	Res/Ind					✓			
Warrawong	Res/Ind		✓	✓	✓		✓[1,3]	✓[1]	
Wollongong	CBD	T	T	T	T		T[1,3]	✓[1]	✓
Other Regional									
Albury	Rur						C[1]		
Bathurst	Rur		C				C[1]		✓
Nowra	Rur						✓[3]		
Tamworth	Rur						C[1]		
Wagga Wagga	Rur						C[1]		

Key –

Res	Residential	C	Campaign Monitoring *
Rur	Rural	✓	Other Monitoring
Ind	Industrial	1	TEOM
Com	Commercial	4	ANSTO Sampler
RS	Roadside	3	Hi Vol Sampler
P	NEPM Performance Monitoring Station *	4	Partisol Sampler
T	Trend Performance Monitoring Station *	*	(as described in the Air NEPM Monitoring Plan)

NT

The Northern Territory does not currently undertake any routine air quality monitoring.

Qld

Site	Loc.	CO	O_3	NO_2	SO_2	Lead	PM_{10}	$PM_{2.5}$	Neph.
Brisbane CBD	CBD	T	✓	✓	✓		✓[1]	✓[2]	✓
Deception Bay	Res		T	T					
Eagle Farm	Com		✓	✓	✓		✓[1,3]		✓
Flinders View	Res		T	T	T		T[1]		✓
Helensvale	Res		✓	✓			✓[1]		
Maroochydore	Res		P	P			P[1]		✓
Mt Warren Pk	Res		✓	✓					
Muttapilly	Rur		✓	✓					
North Maclean	Rur		✓	✓					
Rocklea	ResCom		T	T		✓	T[1,3]	✓[1,2]	✓
Springwood	Res		P	P	P		P[1]	✓[1]	
Woolloongabba	RS	✓				P	✓[1,3]		
Wynnum	Res/Ind		✓	✓	✓		✓[1]		
Gladstone									
Barney Point	Com			✓	✓		✓[3]		✓
Clinton	Res			✓x3	✓x3		✓[3]		
South Gladstone	Res/Ind			T	T		T[1]		
Targinie	Rur/Ind		P	✓	✓				✓
Rockhampton									
Parkhurst	Rur						✓[3]		
Mackay									
West Mackay	Com						P[1]		✓
Townsville									
Garbutt	Com						✓[3]		
South Townsville	Res				P		T[3]		
Townsville Port	Ind						✓[1]		
Mt Isa									
Menzies	Com				T				
Mt Isa (industry site)	Ind				✓ 10 sites	✓ 6 sites	✓[3] 6 sites		

Key –

Res	Residential
Rur	Rural
Ind	Industrial
Com	Commercial
RS	Roadside
P	NEPM Performance Monitoring Station *
T	Trend Performance Monitoring Station *
C	Campaign Monitoring *
✓	Other Monitoring
1	TEOM
4	ANSTO Sampler
3	Hi Vol Sampler
4	Partisol Sampler
*	(as described in the Air NEPM Monitoring Plan)

Tasmania

Site	Loc	CO	O_3	NO_2	SO_2	Lead	PM_{10}	$PM_{2.5}$	Neph.
Hobart	Res	P					✓[3]		
Launceston	Res						P[3]		

Key –

Res	Residential	✓	Other Monitoring
Rur	Rural	1	TEOM
Ind	Industrial	4	ANSTO Sampler
Com	Commercial	3	Hi Vol Sampler
RS	Roadside	4	Partisol Sampler
P	NEPM Performance Monitoring Station *	*	(as described in the Air NEPM Monitoring Plan)
T	Trend Performance Monitoring Station *		
C	Campaign Monitoring *		

Victoria

Site	Loc.	CO	O_3	NO_2	SO_2	Lead	PM_{10}	$PM_{2.5}$	Neph.
Alphington	Res	T	P	T	T	✓	T[1,3]	✓[1,4]	✓
Ballarat	Res						✓[1]		
Box Hill	Res	✓	✓	✓	✓		✓[1]		✓
Brighton	Res		T	P			P[1]	✓[1]	✓
CBD Collingwood	Res/Ind					T	✓[3]		
CBD Richmond	Res	P		✓			P[1,3]	✓[1]	
CBD RMIT	CBD	T	✓	T	P	✓	T[1]		✓
Dandenong	Ind		P	✓			P[1]		✓
Footscray	Ind	✓	T	T	✓		T[1]	✓[1]	✓
Geelong South	Res/Ind	T	T	T	T		T[1]		✓
Grovedale	Rur			✓					
Jeralang Hill (industry site)	Rur				✓				
Mount Cottrell	Rur		✓						
Paisley	Res/Ind		✓	✓	P	✓	✓[3]		✓
Point Cook	Rur/Res		T	T					✓
Pt Henry (industry site)	Ind		P		✓				
Rosedale Sth (industry site)	Rur		✓	✓	✓		✓[3]		✓
Latrobe Valley									
Darnum Nth (industry site)	Rur		✓						
Moe	Res		P	P	P		P[1]		✓
Traralgon	Res		T	T	T		T[1]		✓

Key –

Res	Residential	C	Campaign Monitoring *
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RS	Roadside	3	Hi Vol Sampler
P	NEPM Performance Monitoring Station *	4	Partisol Sampler
T	Trend Performance Monitoring Station *	*	(as described in the Air NEPM Monitoring Plan)

WA

Site	Loc.	CO	O_3	NO_2	SO_2	Lead	PM_{10}	$PM_{2.5}$	Neph.
Perth Region									
Caversham	Res/Rur	✓	P/T	P/T			✓[3]	✓[1]	✓
Duncraig	Res	P/T		✓			P/T[1,3]	✓[1]	✓
Hope Valley	Res/Ind			✓	✓				✓
Nth Rockingham	Res		✓	✓	✓				
Queens Building	CBD	P		✓		P	✓[3]		✓
Quinns Rocks	Res		✓	✓					✓
Rolling Green	Rur		✓	✓					
South Lake	Res	P	P	P	P/T		P[1]		✓
Swanbourne	Res		P	P			✓[3]		✓
Wattleup	Res/Ind				✓				
Regional									
Bunbury	Res	C					C[1]	✓[1]	✓
Busselton	Res								✓
Kalgoorlie (industry site)	Res/Ind				✓ 10 sites				

Key –

Res Residential
Rur Rural
Ind Industrial
Com Commercial
RS Roadside
P NEPM Performance Monitoring Station *
T Trend Performance Monitoring Station *

C Campaign Monitoring *
✓ Other Monitoring
1 TEOM
4 ANSTO Sampler
3 Hi Vol Sampler
4 Partisol Sampler
* (as described in the Air NEPM Monitoring Plan)

Attachment 3

Review of Overseas Exposure Assessment Models

Introduction

The accepted paradigm for health risk assessment (HRA) requires, after an initial issues identification stage, the sequential consideration of the following four elements: hazard characterisation, dose-response assessment, exposure assessment, and risk characterisation (National Research Council 1993[i], NEPC 2000[ii], enHealth 2000[iii]). The exposure assessment phase provides an estimate of how much (concentration), how long and how frequently human populations are exposed to a particular pollutant over a given period of time, including information on how many people are exposed. Exposure assessments are used to estimate past, present and future exposures.

Factors that need to be considered in an exposure assessment

In undertaking an exposure assessment the exposure assessment specialist needs to appraise[1] a wide range of factors, including:

- the source of the pollutant;
- how much is released from the source in a given period;
- how and where the pollutant is transported;
- population data (how many people in the area of concern);
- physiological factors (eg rate and significance of inhalation, ingestion and dermal absorption pathways, susceptible sub-groups);
- exposure factors (including demographics — age/gender/race/work status, location/activity of people, amount of pollutant in air, period of exposure, indoor vs outdoor levels);
- the presence and exposures of susceptible populations (eg children and people with pre-existing cardiovascular or respiratory disease).

The traditional approach to evaluating the risk to human health from the criteria pollutants is to focus on the inhalation exposure pathway. This approach is still relevant for most air pollutants but regulators will need to consider other exposure pathways (ingestion and dermal absorption) for the air toxics or in reviewing the Ambient Air Quality NEPM standard for lead[2]. In major urban areas in Australia the dominant exposure pathway for lead is ingestion given that the ban on leaded petrol has virtually eliminated atmospheric emissions of lead except near point sources.

As previously noted in the RATF report (NEPC 2000[iv]), the approach to exposure assessment in any risk assessment needs to parallel the exposure assessment in the

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[1] In the event that a quantitative exposure assessment is not required or practicable, qualitative evaluation of these factors should be undertaken.

[2] NEPC Ministers agreed that a review of all the Ambient Air Quality NEPM standards should commence in 2005, seven years after the decision to make the NEPM.

epidemiological studies used to derive the dose-response relationship (eg use of fixed point monitors for population based time-series studies). The complexity of the exposure assessment will depend on the nature of the exposure assessment used in the health studies chosen to derive the dose-response relationship.

In setting standards for the criteria pollutants, modelling has been largely related to outdoor exposures even though for most of the population this only accounts for approximately 10-20% of their time. Outdoor workers, children and people during leisure time may spend considerably more time outdoors.

Criteria pollutants may manifest health effects from short-term exposures (15 min - 24hr) or long-term cumulative exposures (several days to years). Different approaches to exposure assessment are required to take into account both these scenarios.

A person's total daily exposure to an air pollutant will be the sum of exposures experienced when interacting with a range of different microenvironments. Microenvironments are relatively homogeneous, easily characterised locations where human exposure to a pollutant can occur. They range from broad categories such as the home, office and commuting to more specific sub-categories such as home-outdoors, home-indoors, commuting-car, commuting-bus, commuting-bike etc.

Individual vs population exposure

Effectively there are two foundations for modelling exposure assessment (i) individual measurement using personal exposure monitoring (PEM), or (ii) population measurement from ambient monitoring stations. The personal exposure monitoring gives a direct measure of an individual's exposure to a pollutant while the ambient monitoring gives an indirect measure of a population's exposure.

Whilst, in principle, the use of direct measurement (PEM studies) would appear to be the preferred option, in practice this tends not to be the case. In addition to their high costs and requirement for relatively large population sizes to deliver statistical significance and epidemiological relevance, there are a number of other practical considerations that limit the broader applicability of PEM studies.

The more common approach to exposure assessment has been to use fixed ambient monitoring networks to assess the exposure of the population. Such networks are focused on locations covering the range of concentrations that are likely to be experienced in the environment. This data is then used as the basis for setting air quality standards.

It has been long recognised that fixed ambient air monitoring networks alone may not be adequate to provide all the data necessary to establish the levels of exposure to individuals and the population in a given area (WHO 1982[v]). Hence the need for exposure assessment models.

Exposure assessment models may be as simple as an averaging of ambient air monitoring data across the network that collected the data (eg USEPA approach for particles) through to a detailed modelling of personal exposure taking into account time activity patterns over a given population (eg USEPA approach for ozone).

The benefit of models is that they allow extrapolations from a relatively small number of measured values to yield estimates of exposures for populations, including the levels, frequency and numbers of people exposed to a given pollutant. The weaknesses are that they are better at estimating typical exposures for populations rather than for high-end exposures; they tend to smooth out the range of exposures (ie missing short-term peaks); and there may be excessive reliance on subjective default data.

Recognising that there will always be limitations in available data sets, the use of conservative assumptions will be necessary in conducting an exposure assessment. These assumptions are necessary to counter the absence of agreed scientific measurements and/or understanding and are inherently conservative in order to ensure protection of human health (ie they will lead to an overestimate of the potential exposures and risks to the population). Such assumptions should be open to challenge by the community (including industry) when supported by sound scientific argument. Further discussion on default assumptions in various models is provided in the RATF Report, Appendix 2.

A testament to the complexity of issues surrounding exposure assessment is the fact that the USEPA does not provide guidance on the application of emission estimate models in the risk assessment process, despite the fact that it has developed a number of emission models for stationary and mobile sources.

Models

The exposure assessment phase can be sub-divided into three parts:

(i) emission estimate - identify the source and level of release;

(ii) transport (dispersion modelling) – where and how are the pollutants moved;

(iii) human exposure – who and what nature and levels of exposure.

If sufficient ambient air monitoring data is available, estimating emissions and modelling dispersion will not be necessary and modelling will be limited to the final step of assessing human exposure.

Emission estimates

The larger Australian jurisdictions have compiled extensive emission inventories for their major cities that could be fed into exposure assessment models. In addition, at a national level, the National Pollutant Inventory (NPI) NEPM provides emission estimates (based on physical measurement and mathematical models) for a broad range of pollutants. The first NPI data was published in January 2000 and with each successive annual report, the NPI will become an increasingly useful tool to demonstrate trends in emissions to the environment.

Transport (Dispersion models)

Each jurisdiction has a monitoring network in place to measure ambient levels of the criteria pollutants. In determining the exposure of the population, this monitoring data could be supplemented by estimates generated from dispersion/transport models, such as the TAPM and, in the future, the *Australian Air Quality Forecasting System*[3]. These

[3] A Natural Heritage Trust funded collaborative initiative between Bureau of Meteorology, CSIRO Australia, Environment Protection Authority (Victoria) and NSW Environment Protection Authority.

models require detailed emissions inventories and extensive development and validation if they are to be applied to any new sites. These models are expensive to develop and run. Developed by CSIRO, TAPM is a model that can predict air pollution concentrations for regional airsheds for periods ranging from days to a year. TAPM can be used for PM_{10}, NO_x, SO_2 and ozone.

The *Australian Air Quality Forecasting System* (AAQFS) forecasts, to a suburb level, the daily variation in the ground-level concentrations of key air quality pollutants. These include both PM_{10} and $PM_{2.5}$, NO_x, SO_2, carbon monoxide, ozone and air toxics (benzene and formaldehyde). The forecasting system is currently limited to Sydney and Melbourne but consideration is being given to expanding it to other major metropolitan airsheds. The AAQFS will generate twice daily, 24-36 hour air quality forecasts at an effective resolution of a few kilometres.

Human exposure assessment

Ambient air monitoring network data can be used directly to model exposure by extrapolating between stations taking into consideration regional topography and overlaying census population data to estimate weighted population exposures. Internationally, the approach for national standard setting has been to conduct such modelling for a number of cities considered representative of the range of likely exposure scenarios. For example, the US has modelled exposures to particles in just two cities (Philadelphia and LA County) and for ozone they modelled exposure in New York, Chicago, Denver, Houston, Miami, Philadelphia, Washington DC, Los Angeles and St Louis. The USEPA consider these cities representative for the large US population (270 million). The RAWG considers modelling based on selected cities would also be an appropriate approach to use in Australia and that determining which Australian cities and how many should be used depends on the pollutant being evaluated.

Which model?

For atmospheric pollutants, the limiting factor in undertaking a quantitative HRA will typically be the exposure assessment phase because of its requirement for ambient monitoring data and the relatively limited availability of such data across Australia (extensive databases are only available for the major capital cities). The availability of adequate monitoring data will need to be assessed pollutant by pollutant (see Issue 2).

While the World Health Organisation (WHO 2000[vi]) does provide a sound source of information on the hazard identification and dose-response data for individual pollutants (the first two parts of the four-phase HRA approach), it does not provide guidelines on exposure assessment. Rather, WHO recommends that each country undertake its own exposure assessment and risk characterisation phases using local data where appropriate.

In 1992 the USEPA introduced new Guidelines for Exposure Assessment (USEPA 1992)[vii]. These guidelines standardise the terminology and approach followed by the USEPA for the exposure assessment phase of a risk assessment. In reviewing these guidelines, the National Research Council (1994)[viii] noted that the current guidelines improve the transparency and accuracy of assessing exposure by requiring all assumptions to be clearly outlined and documented.

Detailed information on USEPA models is available from the EPA's National Exposure Research Laboratory at http://www.epa.gov/asmdnerl/modelling.html

Currently there is no comprehensive exposure assessment model for air pollutants generally accepted by key parties across Australia[4]. The NEPC Risk Assessment Taskforce (RATF) has previously noted (NEPC 2000, Appendix 6, page 2) that the USEPA approaches to exposure assessment could be used and models are available. The assumptions and default values incorporated into the models have been derived for the US situation and may not be applicable in Australia. These would need to be assessed before use. The collection of Australian time-activity data would assist greatly in transferring these models for use in Australia. Collection of time-activity data is relatively straightforward, needs only a single collection of data as it is not pollutant specific and, as a result, is likely to be a time effective and cost effective way of applying overseas models for use in Australia. It will also avoid the need to develop models specific to Australia.

The RATF also explicitly noted that the exposure assessment approach previously commissioned by NEPC for use in the development of the Ambient Air Quality NEPM is not appropriate, as it does not take into account the differences between the pollutants and was not transparent in the assumptions used and the approach taken. The RAWG agrees with this conclusion.

The RAWG does not believe that there is justification in diverting already limited jurisdictional resources into developing an Australian exposure assessment model. Rather, the RAWG recommends that overseas models should be utilised, adding Australian specific data and assumptions as appropriate for each pollutant at the time of review.

For example, the NEPC project team undertaking the development of a $PM_{2.5}$ standard is currently giving consideration to conducting its exposure assessment following the USEPA exposure methodology used in the review of the US National Ambient Air Quality Standard (NAAQS) for particles. This methodology involves averaging the air quality monitoring data across an airshed to determine community-wide exposure levels. Personal exposure data will not be used, as personal exposure measurements were not used in deriving the dose-response data from epidemiological studies. The various epidemiological studies available in the scientific literature all use the same approach of averaging the air monitoring data to estimate exposure.

The USEPA National Centre for Environmental Assessment (NCEA) has already completed risk assessments for particles, ozone and lead. These assessments may be down-loaded from their website at http://www.epa.gov/ncea/healthri.htm.

US models – new developments

The USEPA dominates the field in terms of developing and propagating exposure models. Over the last decade there has been significant improvements in the utility and ease of use

[4] The Report of the Risk Assessment Taskforce (NEPC 2000) noted that "[d]ue to difficulties obtaining consistent air quality data across all jurisdictions, a low level of confidence in the exposure assessment led to the abandonment of the HRA in developing the NEPM [for Ambient Air Quality] and the utilisation of other methods."

of their models (although they still remain the domain of experienced professionals) and further improvements are expected. As evident by the new TRIM model (discussed below), in addition to expanding the efficiency and power of models, the USEPA is placing special focus on characterising the uncertainties, assumptions and limitations of the models.

As an example of the progress being made in modelling, the HAPEM exposure model (discussed below), now in its fourth release, has migrated from a system requiring an IBM mainframe to being able to run on a desktop workstation. The TRIM model is also utilising a more modular framework allowing greater flexibility with respect to data inputting rather than writing the inputs into the software code. Developments such as these serve to increase accessibility to models.

Total Risk Integrated Methodology (TRIM)

In 1996 the USEPA commenced development of a new modular risk model – '*Total Risk Integrated Methodology*' (TRIM), comprising (i) TRIM.FaTe, an environmental fate, transport and ecological exposure module; (ii) TRIM.Expo, a human exposure module; and (iii) TRIM.Risk, a risk characterisation module. The first two modules, TRIM.FaTe and TRIM.Expo, have been developed, tested and received positive reviews. The final component, TRIM.Risk, is still being validated. The USEPA is developing TRIM to address recognised limitations in their previous models, notably that distinctly different methodologies were being used to estimate risk from toxic and criteria air pollutants. The exposure assessment modules have been trialed on particles and ozone. The rest of the model is nearing completion but as yet the approach has not been used in the development of an air quality standard.

Hazardous Air Pollutant Exposure Model (HAPEM)

The USEPA Hazardous Air Pollutant Exposure Model (HAPEM) calculates exposures to carbon monoxide (CO), and air toxics. HAPEM uses four core data inputs (i) monitoring; (ii) time-activity; (iii) microenvironment; and (iv) population data. The following specific data is required as inputs to the exposure calculations: hourly ambient temperature data, US census population data, and duration of activity per microenvironment from the time-activity database. HAPEM sub-programs process these data into forms that are used in the exposure calculations.

In 1990 the USEPA used HAPEM (version HAPEM-MS3) to evaluate mobile source emissions of carbon monoxide, over a year, for all the people in a given metropolitan area. The HAPEM 3 time-activity database contains 3568 person-days of data, with information on the time spent in each of 37 microenvironments during each hour of the day. It further distinguishes between winter/summer, weekend/weekday, and warm/cool weather. HAPEM 4, the current version, uses a stand-alone time-activity database, the Consolidated Human Activities Database (CHAD). CHAD is an aggregation of separate time activity surveys and is updated as new studies become available. It currently includes in excess of 7000 person-days of data. This equates to a very small proportion of the annual person days of the US population. The US considers a database of this size to be sufficient for their exposure assessments.

Outputs from the HAPEM analysis of CO summarised the quarterly and annual exposure for each demographic group. However, the current version of the model, HAPEM 4, now allows hourly and microenvironmental exposure calculations. A further strength of

HAPEM 4 is that the analysis of monitoring data is done independently for each monitoring station input, so the inclusion or exclusion of other monitors in the study area does not affect the results.

pNEM model

The pNEM methodology has been used for setting standards for ozone in the US. It provides an aggregate estimate of exposure for a large population by combining individual exposure estimates to generate a distribution of exposures. The models simulate the movement of each person in a specified population group, through a series of microenvironments (eg indoors, outdoors, in a car), with each person exposed to routinely measured ambient concentrations adjusted for that microenvironment.

The pNEM model was used to set the Canadian ozone standard. They used time-activity data from Cinncinnati in the US as it most closely approximated what was expected for the relevant Canadian cities. They used this time-activity data and the ambient monitoring data available from Vancouver, Montreal and Toronto to evaluate Canadian exposure to ozone.

Future priorities

Time activity

The US National Human Activity Pattern Survey (NHAPS) was initiated to fill a need for updated activity information on a nationwide scale. The USEPA validated the need to conduct the NHAPS time-activity survey by noting that studies have shown that human activities play a critical role in explaining the variation in human exposure because of their impact on the frequency, duration, and intensity of exposure to pollutants. The NHAPS, was conducted over two years (1992-94) using a telephone interview survey of approximately 10,000 persons. The study was designed to establish the time, location, and other characteristics of those activities most relevant to estimating pollutant exposure.

In Australia, time-activity data could be collected by a computer-assisted telephone interview survey of activities and locations over the preceding 24 hours. The people (approximately 3000) who are interviewed would be chosen to adequately represent all States and Territories. This would only need to be a one-off exercise as this data is useful for all the pollutants and can be useful for an extended period of time (in the order of a decade).

Indoor - outdoor exposure considerations

In conducting an exposure assessment there is a need to address the spatial and temporal variations in ambient levels of pollutants. There is increasing pressure to also include consideration of the difference between indoor and outdoor pollution levels, for some of the criteria pollutants. It is generally accepted that the chemically reactive criteria pollutants, ozone and sulfur dioxide, will have lower concentration indoors compared to those outdoors. However, for other air pollutants such as CO and NO_x (gas appliances) or air toxics like formaldehyde (off-gassing from furnishings and building materials) and benzene (cigarette smoke), indoor sources can also be significant contributors to human exposure. Recent US evidence suggests that, although there are indoor sources of particles, the levels for particles are driven primarily by the concentrations found outdoors. Given that Australian homes are generally not as well sealed as those in the US, this is also likely to be the case here.

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