
Innovations II Workshop, Dec 2 – 3

Air pollution exposure: measurement,
modelling and assessment

ABSTRACTS

DAY ONE – THURSDAY 2nd DECEMBER

Issues in air pollution and health research

Tord Kjellstrom – NCEPH

Research on the health effects of air pollution in Australia and other countries has built up a substantial evidence base for action to reduce the health risks. There are still a number of unanswered questions about the precise quantitative relation between air pollution exposure and the risk of health effects in specific exposure situations. This workshop provides a forum for discussion of methodological issues on exposure assessment with a focus on the Australian situation. The aim is to get a better understanding of the best approach to:

- estimate short term and long term exposures,
- the use of personal measurements, point measurements (monitoring) and exposure modeling,
- consider proxy measures of exposures,
- establish dose-response relationships,
- identify suitable environmental health indicators for air pollution,
- using exposure assessment to establish air quality guidelines, and
- estimating exposure in health impact assessment and health forecasting.

Health impact assessments of mortality due to air pollution in Australian cities have concluded that this environmental hazard may cause more than 1000 deaths each year. This health impact is influenced by local climate factors and other local environmental conditions. The aim of the workshop is to contribute to the building of Australian evidence on air pollution and health and to help in reducing the local health impact.

Spatial and temporal distribution of air pollution

Chris Eiser – NSW Dept of Environment & Conservation

Air pollutants vary in space and time according to factors such as emission source strength and location and changing meteorological and photochemical processes.

Ambient air quality monitoring networks have been established in response to community concerns about regional air quality and a region's performance against national air quality standards, but are being increasingly asked to satisfy many other objectives. These networks are normally the only source of reliable long term ambient air quality data available to researchers.

In NSW, for example, our 24 monitoring stations measure air pollutants and meteorological parameters continuously on a 2 min basis and consolidate these into hourly values which are then used as the basis for all statistical analyses. The configuration of the current network was developed to better understand photochemical smog events (meteorology and chemistry influences), requiring the expansion of the network into growth areas where earlier investigations had suggested higher pollutant levels than those previously measured would be found. However, the configuration also provided valuable information about particles and other pollutants and provided a sound basis for air quality reporting.

The recent introduction of the Ambient Air Quality National Environment Protection Measure (ANEPM) has driven networks to the concept of population exposure to pollutants. A further Air Toxics NEPM has now raised the concept of local "Hot Spot" monitoring. These new requirements are stretching the capacity and ability of the networks to satisfy new roles, bearing in mind all jurisdictional networks are "regional" in nature.

In terms of developing our understandings of airshed processes, there is a need to collect and analyse the data both in the temporal and spatial domain and to study the regional air pollution pattern throughout the region. This raises the network design issues such as:

- the adequacy of the number of stations to represent the region and to permit a reconstruction of the underlying concentration fields within a given limit of error;
- the identification of different sub-regions which have different pollution characteristics;
- the adequacy of the current stations within each sub-region to collect information to interpret, represent and infer (or predict) pollution concentrations at any nominated location within a sub-region
- the possibility of using data from a neighbouring station when only limited data is available from a monitoring station.

In health studies, the data needs are becoming increasingly complex as the exposure to ambient pollution is but one component of the population's total exposure. Nevertheless, the monitoring network generally provides the only data stream available. Also, for health studies, it may be more appropriate to evaluate the total population dose rather than the peak concentration to gauge the effect on human health, further stretching the existing data sets.

Health studies are beginning to look at smaller sub-regions and the use of modelling to interpolate between monitoring stations or to predict pollution concentrations from nearby roads, for example, is being pursued. In these cases, while these models are reasonably sophisticated and well developed, validation of the model outputs as part of the study protocol is essential for confidence in the final results..

As the needs of various data users become more sophisticated, the current spatial data sets will require augmentation with specific campaign studies. This has implications for network operators who operate in a climate of finite resources. The challenge is to ensure that our monitoring networks are managed in a manner that addresses the most pressing environmental and public health priorities, optimises efficiency, and accommodates future needs, all within existing funding. A challenge indeed!

Measurement: personal versus area based measurements.

J.L. Gras – CSIRO

While air pollutants are measured for a variety of reasons, the main reason considered for this presentation is the relationship between pollution and human health. This general area can be divided into two categories. These involve pollutant measurements as a tool for air shed management to reduce risk and pollutant measurements aimed at improved knowledge or understanding. Other factors considered are the distribution of sources, the idea of personal and shared public air space and a range of possible intermediate air spaces, independence of sources and sinks in different air spaces, population activity, exposure to pollutants and a succession of steps through to the different health end points. Differing perspectives on the need or type of measurement are expected, and these depend on the purpose of the measurements and the scope or ability of the body with authority to respond to the measurements. For example an air quality manager, or materials standards panel may have different views, and both may differ from those of a researcher undertaking an epidemiological study, although in all cases the information content in the measurements should be maximized and obtained in the most cost effective manner. The cost of personal monitoring can be a significant disincentive for large-scale measurement series; an alternative approach involves modeling to provide improved spatial resolution and this may prove beneficial.

Modelling short-term and long-term exposure

Bill Physick - CSIRO Atmospheric Research

This talk begins with a description of a typical 24 hours in the lives of Joe and Jemima Epidemiologist, in terms of their exposure to pollutants, and discusses the feasibility of modelling their actual exposure over that period. The Epidemiologists are aspirational and live in the outer suburbs, with Joe travelling to the city each day, while Jemima, a recent mother, stays at home. We conclude that while much is known about the various environments encountered in their daily lives, our quantitative knowledge of representative trip profiles within a population is lagging. Modelling results are given to illustrate the sensitivity of total exposure over 24 hours to the inclusion of various environments.

In case the Epidemiologists encounter hazardous plumes in their peregrinations, we discuss the advantages of a stochastic modelling approach to very short-term exposure.

Validation of modelled outputs with monitoring site data

Martin Cope - CSIRO Atmospheric Research

Air quality chemical transport models have the ability to generate fields of trace gas and aerosol concentrations over populated regions at high spatial (1 km grid spacing) and temporal (1 h) resolution. Modern computing resources enable the models to be integrated for periods of days to years. The computed concentration fields provide a powerful resource for augmenting spatially sparse air quality observational data, for convoluting with population data and for calculating population exposure metrics for epidemiological studies.

As will be discussed in this presentation, an important component of air quality modelling is verification of the modelled concentration fields. Examples will be given of the techniques which are commonly used for verifying model performance using monitoring station data. In particular, consideration will be given to the use of time series plots, frequency distributions and spatial plots. A process analysis example will be used to highlight the issue of compensating errors.

Meteorological factors for air pollution exposure

M.J. Manton – Bureau of Meteorology Research Centre, Melbourne

In many airsheds, the emission of air pollutants does not vary substantially and so the concentration of these pollutants is determined largely by the prevailing meteorological conditions. In other circumstances, the nature of emissions is influenced by the meteorology; for example, woodsmoke may be emitted in cold conditions. The meteorological factors affecting human exposure to air pollutants can occur at local, regional and global scales. Local factors, such as the interaction of the wind field with the orography, tend to determine the detailed concentration levels. Regional factors, such as the prevailing synoptic conditions, provide the large-scale meteorological forcing that determines whether a pollution event is likely to occur. Global scale factors can lead to sustained conditions in which high pollution levels may persist; for example, hot dry drought conditions can commonly occur during an El Nino event.

Examples of meteorological conditions influencing air pollution levels are given. In general, air pollution tends to be a problem when the atmospheric conditions are stable, with light winds and a relatively shallow boundary layer so that both horizontal and vertical dispersion are suppressed. On the other hand, local fumigation can occur from chimney stacks in very unstable atmospheric conditions when strong downdrafts can force pollutants down to the surface intermittently.

The potential impacts of climate variability and change are considered for Australia. For example, the current trend towards warmer temperatures could lead to more frequent conditions for photochemical smog in some airsheds.

Air pollution exposure assessment –

How do epidemiological studies use exposure data
Geoff Morgan – Northern Rivers University Department of Rural Health – University of Sydney,
gmorg@nrhs.health.nsw.gov.au

This presentation draws largely on a recent publication by the European Union funded AIRNET project: Air pollution exposure assessment. Ed: Janssen N, Sanderson E. AIRNET 2004.
http://airnet.iras.uu.nl/products/pdf/airnet_wg1_exposure_report.pdf

Exposure assessment is the science of identifying and estimating exposure (previous and / or current), or future exposure under different conditions. Epidemiology can investigate environmental risk factors for health by studying the occurrence of disease in a population. Epidemiology and exposure assessment are closely linked and recent epidemiological research has driven much of the increasingly strict air quality policy and standards implemented in Australian and overseas. Estimating human exposure to air pollutants is challenging. Valid exposure assessment must consider many factors including the size and make up of the population as well as various factors affecting exposure (frequency, duration, magnitude, spatio-temporal distribution, etc.). Exposure assessments would ideally measure exposure in every individual. In reality that is usually impractical or too costly. Exposure assessment generally relies on indirect measures of exposure, such as surrogates and modelling. Substantial advances in exposure assessment have occurred over the last decade due to the growing use of sophisticated models, and Geographic Information Systems. Reliable exposure assessment still requires the combination of actual measurements with models. Some of issues covered in this presentation are illustrated by an example of an exposure assessment for an epidemiological study in the Sydney metropolitan region.

Managing air quality -

The use of exposure standards in policy development

Marilyn Olliff EPA Victoria www.epa.vic.gov.au

Clean air is fundamentally important to our social, economic and environmental health.

Government policies that set the framework for managing air quality need to protect a range of beneficial uses of the environment including:

- Health and well-being;
- Amenity and aesthetic enjoyment;
- Visibility; and
- Climate systems.

In addition to setting the framework for managing air quality, policies may identify tools for assessing air quality and set criteria to ensure that the beneficial uses of the environment are protected. Policy developers need to consider recent developments in environmental management at State, national and international levels to ensure that any changes to policy are consistent with current thinking on environmental protection. For example, consideration must be given to significant developments in operational management and technologies such as cleaner production in industry and new scientific information on the potential impacts of hazardous air pollutants.

Exposure standards may be used to develop policy objectives and criteria. In Victoria there are two major State environment protection policies (SEPPs): SEPP (Ambient Air Quality) to set environmental quality objectives and goals for ambient air and SEPP (Air Quality Management) to set the framework for the management air quality. EPA Victoria uses the following criteria:

- To assess air monitoring results –
 - Ambient air standards – NEPM standards to be met in residential areas eg SEPP(AAQ) air quality objectives and goals.
 - Investigation levels for potential 'hot spots' – trigger levels for further investigation eg SEPP(AQM) intervention levels.
 - Incidents of high pollution – levels at which there may be some harm eg SEPP(AQM) alert levels.
- To assess modelling predictions –
 - Design ground level concentrations – conservative values for new proposals eg SEPP(AQM) Schedule A design criteria.
 - Health risk assessment standards – criteria to determine whether there are adverse health impacts in targeted areas. (These are generally provided on a case by case basis).

DAY ONE – THURSDAY 2nd DECEMBER – Participant Presentations

Sydney studies of the health effects of air pollution.

Geoffrey Morgan – Northern Rivers University Department of Rural Health – University of Sydney

An overview of three current studies of the health effects of air pollution in Sydney will be presented:

- **The effects of low level air pollution on daily mortality and hospital admissions in Sydney, Australia, 1994 to 2000.**
PM levels in Sydney are low compared with most cities where time series studies of the acute effects of air pollution have been conducted. Daily PM_{2.5} data (measured by TEOM) in Sydney is available from 1997. We investigate associations between the three ambient particulate measures (BSP, PM_{2.5} and PM₁₀) and the gaseous pollutants (nitrogen dioxide and ozone) with daily mortality and hospital admissions for all ages and the elderly (65+years) in the Sydney metropolitan area from 1994 to 2000 using time series analysis controlling for a range of confounders. We conducted sensitivity analyses to investigate the effect of different modelling approaches including the use of various methods for smoothing long term and seasonal trends, and weather parameters (penalized splines compared with loess and natural splines). The relatively low levels of particulate air pollution in Sydney were consistently associated with both daily mortality and hospital admissions. These particulate associations were generally strongest for fine particles (ie: PM_{2.5} and BSP) compared with PM₁₀, and persist even at the relatively low particulate levels seen in Sydney, indicating no threshold concentrations are present. These results are consistent with the international literature.
 - **Time scale effects of particulate air pollution and mortality in Sydney, Australia, 1994 to 2000.**
There is uncertainty about the extent of life-shortening due to the effects of air pollution on mortality demonstrated in time series studies. We implemented a methodology recently developed by Dominic F et al 2003 (Am. J. Epidemiol, in press) to investigate the extent of life shortening due to air pollution in Sydney. We decomposed the daily time series for particulate pollution into a set of distinct independent component series representing six specific time scales of particulate variation, ie: greater than 2 months, 2-1 month, 1 month-1week, 2-1 week, 1 week-3.5 days, less than 3.5 days. We then used this set of particulate exposure measures as predictors in a Poisson regression model to estimate the effects of particulates on mortality at each time scale. Our results indicate that the effects of particulate air pollution on mortality are larger at longer time scales (greater than one month) than at short time scales (1 to 4 days). The shape of the response curve for the effects of particulates on mortality across all time scales in Sydney is similar to that found by Dominici et al in US cities. The Sydney results support previous studies indicating that the effects of particulates on mortality are not only due to advances in the timing of death by a few days.
 - **The Health Effects of Bushfire Smoke in Sydney, Australia, 1994 to 2001**
The Sydney metropolitan area is surrounded by bush land and is subject to occasional short episodes of extreme particulate air pollution due to bushfires and controlled burning. This presentation will discuss the time series methods being used to investigate the effects of these bushfire episodes on daily mortality and daily hospital admissions.
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Dose response of nitrogen dioxide and house dust mite exposure: two environmental indoor asthma triggers and their health effects on asthmatic children

Monika Nitschke – Environmental Health Service, Department of Health, South Australia

Background

The purpose of this study was to investigate dose response relationships between respiratory outcomes and indoor nitrogen dioxide (NO₂) and house dust mite (HDM) allergen (DerP1) levels in asthmatic children using regression methods.

Methods

Children with asthma were recruited from 18 primary schools. NO₂ levels were measured repeatedly during winter 2000 in homes and classrooms. DerP1 levels were based on the children's bed exposure. A skin prick test established DerP1 sensitivity. Children kept a daily symptom and medications diary over 12 weeks and data were gathered fortnightly via a telephone interview. Lung function tests were performed before and after the study period.

Results

Data on exposure and respiratory outcomes were gathered for 174 children. Six-hourly time averaged mean classroom NO₂ levels ranged from 7 to 117 ppb. Over one quarter of the children was exposed to in excess of 10 µg/g of DerP1 and 56% of children were mite sensitive. Sensitised children were exposed to significantly higher levels of DerP1 (12.1 µg/g versus 7.5 µg/g) than the non-sensitised children. Increasing dose response relationships were established for symptom rates and NO₂. Statistically significant results were observed for difficulty breathing during the day, with a relative risk (RR) per 10 ppb NO₂ of 1.12 (95% Confidence Interval (CI) 1.02-1.23), during the night 1.19 (95% CI 1.11-1.27) and for chest tightness at night 1.12 (95% CI: 1.02-1.22). This was supported by a marginally significant decreasing dose response relationship between FEV1 %predicted and NO₂. No consistent increasing dose response relationships were observed for symptom rates and HDM levels, but some threshold effects were established using a 10 µg/g cut off point. The effects were strongest within the subset of DerP1 sensitised children. Statistically significant RR for high vs low HDM exposure were observed for daytime wheeze (RR = 2.38 95% CI 1.18-4.79), night time wheeze (RR = 3.72 95%CI 1.61-8.59), daytime cough (RR = 1.54 95% CI 1.10-2.17) and daytime asthma attack (RR=1.94 95% CI 1.10-3.43). No corresponding effects were seen between HDM exposure and lung function. There was no evidence of a synergistic effect on respiratory outcomes by simultaneously high NO₂ and DerP1 exposure.

Conclusion

The levels of indoor NO₂ exposure have been shown to be related to the frequency of respiratory symptoms in asthmatic children and provide reliable estimates for risk identification in the indoor environment. There is also clear evidence that higher symptom rates are associated with high HDM levels, especially in mite sensitive children.

Visualising and modelling individual population mobility exposure opportunities

Clive Sabel - Department of Geography, University of Canterbury, Te Whare Wananga O Waitaha, Christchurch, New Zealand.

A major problem with current geographical epidemiological modelling is the naivety of assumptions concerning exposure (Gatrell, 1995). Many studies examining associations between geographical patterns of disease and causal factors adopt the key underlying assumption that current residence in an area can be equated with exposure to conditions that currently (and historically) pertain there (Bentham, 1988). This is important since the residential address at the time of diagnosis or death is often adopted as the 'site' for further analysis of the disease in question. This of course is often spurious, as Picheral (1982) has highlighted, since we know full well that people do not stay rooted to their home; they might have quite complicated 'activity spaces' based on journeys to work, school, shops, recreational destinations and so on.

A second issue concerns the effects of latency periods. There is a need to allow for a time lag or period between first exposure to a potential pathogen and the initial manifestation of the disease. For example, if a disease has a known lag period of 10 years, then only those cases registered at least 10 years after a suspected pollution 'event' should be included in the analysis. What length lag period to adopt is not straightforward, particularly for diseases that have an unknown, but suspected long lag or latency period.

In both infectious epidemiological and atmospheric pollution contexts, determining accurate individual exposure assessments is confounded by population mobility. People move: typically travelling from home to work on a daily basis. Capturing these individual trajectories is essential in understanding an individual's exposure, if we are not to rely on aggregated analyses. We will present a framework for visualising these trajectories, and then demonstrate our GIS based modelling environment to illustrate spatio-temporal trends.

A paradox involving long-term effects of PM10 from motor-vehicles on mortality

Bill Physick - CSIRO Atmospheric Research

Using a numerical air quality model with separate emission files for each source is one way of quantifying the population (or personal) exposure to the one pollutant from different sources (source attribution). Application of a dose-response function can then lead to a ranking of relative health outcomes according to source.

However when there are both natural and anthropogenic sources of a particular exposure pollutant, and when there is a threshold below which there is no adverse health effect, the health outcome for the individual sources is highly dependent on how the numerical experiment is designed.

An example is given for the case of mortality due to long-term effects of PM10 emissions from motor vehicles in Melbourne

Air pollution and childhood asthma emergency hospital admissions: estimating intra-city regional variations

B Erbas¹, A-M Kelly², B Physick³, C Code¹, M Edwards³ - ¹ University of Melbourne, Melbourne, Australia, ² Joseph Epstein Centre for Emergency Medicine Research, Melbourne, Australia, ³ CSIRO, Melbourne, Australia

In recent years childhood asthma has increased. Although the precipitants of childhood asthma are yet to be established possible contributing factors are local ambient air pollutants. This study aims to assess associations of regional ambient air pollutants on emergency department childhood asthma presentations across four regions of the city of Melbourne, Australia.

Daily ED presentations for asthma in children were studied for the years 2000 and 2001. Estimates of local air pollutant levels were obtained using simulation modelling techniques. We used Generalized Additive Models to examine associations between combined local levels of air pollutants and childhood asthma ED presentations adjusting for seasonal variation, day of week effects, and meteorological variables.

There was consistent associations between childhood ED asthma presentations and regional concentration of PM₁₀, with a strongest association of RR = 1.17 (95% CI 1.05 to 1.31) in the central district of Melbourne. NO₂ and Ozone was associated with increased childhood asthma ED presentations in the Western districts.

This study suggests that regional concentrations of PM₁₀ may have a significant effect on childhood asthma morbidity. In addition, ozone may play a role however its effect may vary by geographical region.

A model for dealing with every-six-day PM data

Steven Roberts - Research Fellow, ANU .

In many cities of the United States measurements of ambient particulate matter air pollution (PM) are available only once every-six-days. Time series studies conducted in these cities which investigate the relationship between mortality and PM are restricted to using a single-day's PM as the measure of PM exposure. This is undesirable because current evidence suggests that the effects of PM on mortality are spread over multiple days. And, studies have shown that using a single-day's PM as the measure of PM exposure can result in estimates that have a large negative bias. In this paper we introduce a new model for estimating the mortality effects of PM when only every-six-day PM data is available. It will be shown that this new model typically offers an increase in statistical estimation precision and a reduction in estimation bias compared to existing models.

SCIAMACHY tropospheric NO₂: a new dataset for exposure assessment?

Simon Hales - National Centre for Epidemiology and Population Health, ANU, Canberra.

Existing estimates of spatial patterns of air pollution Either derived from surface monitoring, (which is logistically demanding) and/or from airshed modelling, (which is time consuming and depends upon emissions inventories). I compare spatial patterns of NO₂ in Sydney estimated using surface monitoring and SCIA satellite data. This is likely to be a useful new source of exposure data for epidemiology and health impact assessment.

UNSW School of Safety Science – current research to improve the risk assessment of benzene in the atmosphere

Dr Daniela Leonte - UNSW, School of Safety Science, Ph: (02) 9385 4744, Email: d.leonte@unsw.edu.au

Benzene exposure in humans occurs mainly through inhalation, with ambient air pollution being recognised as a major contributor. However, intake of benzene is highly variable, influenced by:

1. The presence of fixed sources of benzene such as oil refineries, chemical plants and/or major highways.
2. The atmospheric conditions, especially wind speed.
3. Various activity patterns, such as in-vehicle time spent in traffic, and spending time in houses where indoors smoking is permitted and/or which have an attached or integral garage.

The current approach used to estimate daily intake of benzene among the general population relies on the collection of time activity information, benzene concentration measurements in various microenvironments, and personal exposure. These data are statistically analysed, either collectively or separately, to obtain daily benzene intake estimates. An important drawback of the approach is that variable groups 1 and 2 above are not explicitly accounted for in these estimates, thereby significantly restricting their use for decision-making purposes. Furthermore, the estimates are only relevant for the sample on which data were collected, and any sampling size limitation (temporal or spatial) is directly reflected in the estimated intake values.

Research is currently conducted in the UNSW School of Safety Science, which proposes an alternative approach to estimate daily intake of benzene among the general population. The research uses data on all three variable types identified above, and is based on stochastically modelling the benzene concentration in various microenvironments as a function of the ambient concentrations at various points in space and time. Either direct measurements or modelled ambient atmosphere data may be used. Implementation of the approach is proposed for the Sydney region, where data are available through various studies conducted by the NSW Department of Environment and Conservation and the Department of the Environment and Heritage. For Sydney, ambient benzene concentrations are estimated from the CSIRO model, TAPM, which uses emission inventories and weather data to generate daily ambient benzene concentrations.

The research is expected to provide daily benzene intake estimates for a human receptor, given his/her specific activity pattern; provide information on the variability of intake estimates for the general population, as a function of geographical location and meteorological conditions; and enable the evaluation of various factors, among the three categories identified above, which influence daily intake estimates.

DAY TWO – FRIDAY 3rd DECEMBER

Status of National Environment Protection Measures (NEPMs) related to air quality

M.J. Manton – Bureau of Meteorological Research Centre, Melbourne

Over the last fifteen years, there has been significant progress towards the development of a national approach to environmental problems. A major milestone for this process was the decision of the Special Premier's Conference in October 1990 to establish the Intergovernmental Agreement on the Environment (IGAE), which became effective in May 1992. The objectives of the IGAE can be summarised as to ensure that all Australians enjoy equivalent protection from pollution and that markets and businesses are not impeded by variations in environmental measures between jurisdictions. The implementation of these objectives is effected through the establishment of the National Environment Protection Council (NEPC) in 1994, which has the power to create National Environment Protection Measures (NEPMs).

Currently there are three NEPMs related to air pollution. The National Pollutant Inventory (NPI) was made in February 1998 and extended in June 2000 to include more substances. Under the NPI, data on the emission of 90 substances is collected and made available to the community through the Internet. The Ambient Air Quality NEPM (AAQNEPM) was made in June 1998 with the goal of achieving specific standard levels for six key pollutants within 10 years. Nationally consistent monitoring of these pollutants is achieved through adherence to a monitoring protocol under the NEPM. In May 2003 the NEPM was extended to include data collection related to PM_{2.5} with the goal of collecting sufficient data to inform the review of the NEPM standards in 2005. The Air Toxics NEPM was made in April 2004 and it will lead to the collection of data on five air toxics. A formal review of the AAQNEPM will commence in 2005.

South East Queensland region air quality model of regional-, urban- and suburban-scale air pollution

Josef Ischtwan – Queensland Environmental Protection Agency
Environmental Sciences Division, Air Sciences Unit

The Environmental Protection Agency (EPA) is a department of the Queensland Government and is its lead agency to manage environmental protection. EPA's operations include: planning, licensing (monitoring, compliance, enforcement), consultation and education, encouraging eco-efficiency and eco-innovation. The development of an air quality model for South East Queensland (SEQ) focussed on regulatory (eg. licencing, environmental impact assessment) and strategic planning requirements for air quality modelling.

The prediction (modelling) of air pollution at a regional-scale (ie. in an area of approximately 30,000 km² hosting several urban centres including the Brisbane metropolitan area), urban-scale (ie. urban areas of 1,500 km² or so) and suburban-scale (ie. in areas of 400 km² with relevant industries and population) requires the accurate prediction of the meteorology relevant for pollution at those spatial scales: mesoscale meteorology arising from the regional-scale complexity of the terrain (eg. Moreton Bay, Great Dividing Range, Brisbane basin) and urban- and local scale meteorology arising from both the underlying mesoscale meteorology and urban- and local-scale land/water and landuse discontinuities (eg. mountains, Brisbane river mouth).

To achieve this, a prognostic (ie. fluid dynamics simulations from first principles) modelling approach was adopted using CSIRO's prognostic mesoscale meteorology model, TAPM, at all

spatial scales, ie. regional-, urban- and suburban-scales and coupled with the validation against and analysis of an extended dataset of (near-surface and upper air) meteorology and air quality and use of best-available quality data on terrain, land-use and land/water. The resulting meteorology model system consists of the mesoscale meteorology model, TAPM, (i) for the entire SEQ region and which resolves terrain and land/water discontinuities on 3 km resolution grid, (ii) for the urban-scale area of Brisbane CBD and Brisbane Ports and which resolves terrain and land/water discontinuities on a 1 km resolution grid using a mesoscale meteorology model consistent with (i), and (iii) for the suburban-scale area of the industrial Brisbane Ports, which resolves terrain and land/water discontinuities on a 500 m resolution grid, and using mesoscale and urban-scale meteorology models consistent with (i) and (ii). The mesoscale meteorology model is combined with CSIRO's photochemical transport model, incorporating an explicit chemical kinetics mechanism, for the prediction of a statistically relevant series of photochemical smog episodes and concentrations of ozone, nitrogen dioxide and nitrates. The urban- and suburban-scale meteorology models are combined with the TAPM pollution dispersion and chemical transformation models to the prediction of year-long concentrations of other criteria pollutants, ie. nitrogen dioxide, fine particles, sulfur dioxide, and carbon monoxide. Emissions inventory estimates for the year 2000 are also used in this model.

The resulting model system of regional-scale photochemical smog and urban- and suburban-scale pollution from sulfur dioxide, fine particles and nitrogen dioxide emissions is self-consistent with respect to the prediction of meteorology at those scales. Results demonstrate the model's ability to predict both the significant spatial variability of regional-scale ozone concentrations and the influence of local geographical features on local-scale meteorology and near-source pollution. The model system has been applied to the evaluation of air quality impacts from industries located at the Brisbane river mouth. The model system is being applied to the evaluation of air quality impacts of the motor vehicle fleet's emissions resulting from the use of re-formulated (ethanol-blended) fuel. A future application of the model system is the evaluation of airshed capacities of two major industrial areas, the Swanbank airshed (located 40 km inland and containing the 900 MW Swanbank power station) in the SEQ and the Brisbane Ports airshed, with respect to their contributions to regional-scale, urban-scale and suburban-scale air pollution.

Improving air dispersion modelling for health risk assessments

Roger Drew, PhD, DABT -Toxikos Pty Ltd.,

Toxicology Consultants, PO Box 74, East Caulfield, Vic, 3145.

Health is defined by the World Health Organisation as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Well being is broadly described as an individual's self assessment of their state of happiness, healthiness and prosperity, it relates to the quality of life and ones ability to enjoy it. There are many social and economic factors that impinge upon well being. Air pollution may have direct (toxicological) or indirect health effects on health. The indirect effects of air pollution are heavily influenced by a wide range of social determinants. Included are the individual's reaction to stress and anxiety associated with odour and/or their beliefs regarding the source and nature of the air pollution. Health impact assessments should attempt to address all of these aspects. However because there are very different scientific disciplines involved, it is far more common for health risk assessments for direct toxic effects to be undertaken quite separately from social impacts. These are sometimes passed off as health impact assessments, but they are not.

In this presentation the role of air dispersion modelling in health risk assessment is discussed in relation to a hypothetical scenario for expansion of an industrial facility. There are four technical building blocks underpinning the assessment of health risks associated with

environmental hazards; these are hazard identification, dose response assessment, exposure estimation and risk characterisation. The risk characterisation cannot proceed without the other three segments being completed first. The whole process should inform decision making and risk management measures. With respect to air pollution the exposure assessment is very dependent upon chemical analysis of pollutants and air dispersion modelling. This is especially so if the assessment is being conducted to predict a potential future health impact and/or help design mitigation procedures to ensure health is not impacted if certain decisions are made.

Usually air modellers evaluate their outputs according to regulatory derived 'design' criteria and health risk assessors are not involved. If a health risk assessor becomes involved it is invariably near the end of the project, consequently the information flow is extremely linear from analytical chemist to dispersion modeller to risk assessor. Because risk assessors are interested in a different set of questions than are the air modellers, additional work by the chemists and modellers is usually required. Improvements to the air modelling could be made if a risk assessor was involved early in the project, the outputs would likely be more 'fit for purpose'.

Uncertainty and variability are issues which must be addressed in the risk assessment. These are usually tackled well in the analytical determination of pollution constituents and their concentrations, but they are issues rarely broached in air dispersion modelling reports. Variability in industrial emissions is usually dealt with by modelling 'maximum' emission rates/concentrations, which when coupled with an illusion of accuracy in prediction of ground level concentrations creates false impressions of exposure estimations. They assume an unjustified status of reality. Variability in prediction of ground level concentrations of chemical pollutants is addressed in dispersion modelling by linkage with variability in local meteorological conditions but not with variability of emission constituents and concentration. Air modellers articulate the variability as the maximum, and various percentile ground level concentrations. The language is often confusing, even to people who have technical training but are not air modellers. Uncertainty in the accuracy of the nominated ground level concentration is, in this risk assessor's experience, never addressed. But it should be.

In summary, air modelling outputs would be more useful to health risk assessors if the assessor was involved early in the overall project, air modellers should attempt to address all sources of variability and uncertainty in their predictions, hopefully in a quantitative manner. Finally they should have pity on the mere mortals who have to read their reports and use as little jargon as possible. However all scientific disciplines are guilty of this sin.

How can modelling of air pollution best be used for health forecasting

Bill Physick, CSIRO Atmospheric Research

Recent reviews such as those underpinning the Australian National Environmental Protection Measure (NEPM) for air quality have concluded that meteorology and air pollution are associated with a range of health effects including excess cardio-respiratory mortality and increased hospitalisation. Susceptible individuals experience a deterioration in their health within hours or days following exposure to an air pollutant (acute effects), as well as during excessively hot or cold spells and variations of other conditions such as relative humidity. Daily forecasting of meteorology and air quality with a numerical model (the Australian Air Quality Forecasting System) is already done for Sydney and Melbourne. Development and coupling of a health module with AAQFS would enable health forecasts to be delivered too.

Short-term effect relations between meteorological and air quality variables, and various diseases are being developed, primarily through time-series studies. A common assumption in most of these studies is that the exposure (pollutant concentration) is the same value across an entire city. However, monitoring data and air quality simulation models show large spatial

gradients in pollutant concentration over an urban area. By making use of air quality modeling, with the results modified by monitoring data where available, there exists information to determine exposure-response relationships that take into account the spatially varying nature of the air quality and weather between sub-units in a large city. Carrying out epidemiological statistical analyses on health data sets plus the gridded meteorological and air quality data sets, will produce exposure-response relationships for different weather parameters, pollutants (or combinations thereof), and morbidity measures that can then be used in developing a health-forecasting module. Such analyses should be carried out on data sets over periods as long as 5 years.

Since daily variations in weather extremes and air pollution can be forecast prognostically (up to 7 days ahead in the case of weather forecasts and 1 to 2 days for air quality) our proposition is that health consequences due to variations in weather and air quality should also be predictable over similar periods. Such a health-forecasting system would enable Australians in cities and rural areas to have access to daily risk forecasts for sufferers of diseases affected by environmental conditions, such as asthma, respiratory and cardiovascular ailments, enabling them to adopt mitigation strategies. In addition, such a system would contribute to improved efficiency in the scheduling of hospital resource allocations, allowing the health system to respond to predicted variations in demand resulting from variations in atmospheric environmental conditions.

Air pollution and air flow modeling epidemiology and public health

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Air Pollution Modeling has for some years been used by Environment and Planning Agencies to help shape regional and state level public policy on air pollution reduction. This modeling typically takes account of weather – the most important determinant of pollution on a given day – inventories of mobile and stationary pollution sources, antecedent pollution levels and an understanding of large scale air flow patterns in an air shed or a region.

These same models have the ability to forecast pollution levels in a region, or associated with emissions from a point source. When asked to conduct a health impact assessment of, for example, a new pollution source, the results of modeling are often the only basis upon which to make statements about the likely health effects of these erstwhile pollutants.

Understanding the characteristics and limitations and post hoc performance of these models is essential to the conduct of meaningful health impact assessment.

Air flow modeling or computational fluid dynamics is another tool which is finding increasing application in public health and epidemiology. Indoor and outdoor air flow modeling was used extensively in the investigation of the recent SARS outbreak in Hong Kong to track the trajectory of infective aerosol plumes in hospital wards and in the Amoy Gardens apartment complex. Air flow modeling has many potential applications both in the investigation of disease outbreaks and in the design of control systems for communicable disease outbreaks – in protection from terrorist attack, in airline cabins, schools and health care facilities.

Developing national capacity and approaches to the use of these important technologies should be a part of public health development in Australia over the next decade.