National Environment Protection (Ambient Air Quality) Measure

Report of the Risk Assessment Taskforce

Appendix 3

Epidemiological Study Design and Data Requirements

CONTENTS

GLOSSARY OF TERMS

Association	Non-random occurrence of disease in relation to exposure
Bias	Error in the measurement of an exposure's effect
Case-control study	An analytical design involving selection of diseased cases and non-diseased controls followed by assessment of prior exposures
Cohort Study	An analytical design involving selection of exposed and non-exposed subjects with subsequent follow up for development of disease.
Confounding	Bias resulting from the contamination of an exposure's effect by that of another risk factor
Cross-sectional study	Subjects are identified and exposure and disease status determined at one point in time
Incidence rate	Ratio of number of new cases to population at risk during a specified time period
Misclassification	Bias from error in determining disease or exposure status
Mortality rate	Ratio of number of deaths to population at risk during specified time period
Prevalence	Proportion of population with disease at a particular time
Selection Bias	Bias resulting from the technique used to select a study's subjects

Source: Samet JM, Jaakkola JJ. The epidemiologic approach to investigating outdoor air pollution. In: Air Pollution and Health, Ed: Holgate ST, Samet JM, Koren HS, Maynard RL. Academic Press, London 1999

1. AIR POLLUTION AND HEALTH RESEARCH METHODS

The investigation of the effects of inhaled air pollutants on human health has followed a multi disciplinary approach using animal toxicology, molecular and cellular biology, controlled human exposure studies, and epidemiology. Each approach has specific strengths and weaknesses in evaluating the human health effects of air pollution.

1.1 Animal Studies

Laboratory studies of animals *in vitro* and *in vivo* provide the opportunity to evaluate pathogenic mechanisms of injury by pollutants and to use methods that would not be ethical or practical to apply to human subjects. Closely controlled exposure-response data can be collected using a wide variety of biological outcome measures in multiple species. However, regardless of the scope and quality of the data, uncertainty may be introduced by extrapolating from animal models to humans. Differences in respiratory tract morphology, regional deposition of pollutants in the lung, and inter-species differences in biologic and physiologic sensitivity to given concentrations of pollutants contribute to the uncertainty of such extrapolations[1].

1.2 Human Exposure Studies

Controlled human exposure studies (or chamber studies) generally investigate mechanisms of injury and permit strict control of the exposures and the characteristics of the exposed persons. These studies typically involve small and homogeneous groups of subjects who inhale air pollutants through a mouthpiece, mask or chamber air. In addition to enabling control of exposure the outcome measures can be carefully characterised, even with relatively invasive tests (eg bronchoalveolar lavage or lung histopathology). Ethical and practical considerations limit the use of laboratory studies. Exposures must be at concentrations below the levels that are likely to produce unacceptable short term or long term effects. Feasibility usually limits exposure to a few hours, and chronic effects cannot be readily addressed. Despite these constraints, controlled clinical testing has been used extensively, for example, in the investigation of the acute effects of exposure to NO_2, SO_2 and O_3 in persons with asthma.

1.3 Epidemiological Studies

Epidemiological studies of air pollutants have largely focussed on the relationship between exposure and health effects in the community setting. Accurate estimation of exposure to a pollutant is usually difficult, as many pollutants occur as components of complex mixtures and exposure is often estimated from fixed monitoring sites.

Epidemiological studies of the health effects of air pollution can be classified as investigating acute or chronic effects. Studies of acute effects, for example, assess relationships between day to day changes in mortality and morbidity and same day or previous day air pollution levels.

Such studies have found associations between air pollution and acute health effects ranging in severity from death, hospital usage, restricted activity days, exacerbations of asthma, to occurrence of respiratory and other symptoms and minor changes in lung function. Acute effects should be distinguished from the way in which long term exposure to ambient levels of air pollution may help initiate or promote development of chronic disease. Such chronic effects may eventually lead to increased or earlier hospital usage or to premature death, irrespective of whether higher air pollution levels on preceding days had a role in triggering these acute health effects.
The fundamental strength of epidemiology is its ability to evaluate health outcomes with real

people, living in normal environments, exposed to typical air pollution. However, limitations are also inherent in the use of such observational studies including:

- linkages between biological mechanisms which produce both acute and chronic effects;
- determining independent effects or potential interactions between highly correlated risk factors;
- potential confounding by correlated co-pollutants; and
- comparability of ambient and personal exposures.[18]

STUDY TYPES

The widespread exposure of populations to air pollution have lead to epidemiological studies to use aggregated data. Such study designs are termed ecological studies, that is those, which have no information at the individual level. Ecological studies are usually descriptive studies subject to substantial confounding and other biases. However, confounding can be reduced by use of improved study designs and analytical techniques.

Time Series Studies of acute mortality or hospital usage require large populations, studied over several years, to investigate relationships and are essentially ecological studies. Large populations are required because the rate of daily occurrence of the events studied is low and air pollution explains, at most, a small proportion of the day to day variations in these events. In these large population studies, subjects are not tracked at the individual level. Instead, information about deaths, hospital admissions or hospital emergency room visits in a well defined geographical area is obtained from routine health records, giving a time series of daily number of occurrences.[3]

Temporal or *Time Series Studies* of populations using a short time period as the aggregation unit (usually one day) have an important role in the detection of effects of short term exposure to air pollution. The use of long series of daily data provides sufficient power to detect weak effects if they exist. [6,7,8,9,10,11] Because most *Time Series Studies* are done within a single population the problem of confounding is greatly reduced. These studies are unlikely to be confounded by such personal risk factors like smoking, blood pressure, diet, socioeconomic factors and genetic predisposition since these factors do not vary from day to day and are not correlated with air pollution. Confounding variables include meteorological and chronological (season, day of week, etc) variables which are generally easily measured and recorded. Other problems specific to this design (eg autocorrelation) are addressed by the use of complex time-series statistical analysis methods. Robust analytical techniques, the availability of high powered affordable computer hardware, and the availability of the health outcome data (eg daily mortality and daily hospital admissions) has improved the reliability of results from this type of sudy enormously.

Time Series Studies are relatively inexpensive as they use routinely collected data on both health outcome (eg total or cause specific mortality counts, number of hospital admissions) and the exposure.

By contrast with these population-based studies, acute effects of air pollution on less severe end points such as asthma attacks, symptoms and lung function changes are typically based on groups or panels of identified individuals. A panel study takes a group of subjects, either with out without pre existing lung disease, and follows them prospectively for several weeks or months. The subjects record daily symptoms and/or lung function, hence they are also called *Diary Studies*.[3]

Panel or *Diary Studies* following a cohort of individuals (generally sensitive, eg asthmatics) for a relatively short time period investigate the acute effects of air pollution.[13,14] The health outcomes measured include self-reporting of symptoms, medication use and indices of respiratory function (hence they are also referred to as *Diary Studies*). *Diary Studies* usually follow groups of sensitive subjects such as asthmatics. The time unit of observation is usually the day. Individual experiences may be compared separately. Data may also be pooled and averages formed for each time period of follow-up, thus treating the *Diary Study* as a *Time Series Study* using aggregated data. *Diary Studies* are complicated to analyse statistically and auto-correlation is an important issue. Medication use is a significant confounder which may mask or complicate the analysis. A large number of *Diary Studies* on individual respiratory symptoms and/or lung function have been conducted, predominately in North America and Europe. These studies are relatively expensive to conduct as all the data on individual respiratory symptoms and lung function must be collected.

Geographical Studies of populations assess long term (or chronic) air pollution health effects by comparing the frequency of a health outcome across different locations with varying levels of exposure. More recent studies of this type combine other design approaches such as *Prevalence Studies*[15] or *Cohort Studies*[16] within each area to improve the assessment of confounding variables.

Few *Cohort Studies* have been conducted to evaluate the long-term health effects of air pollution.[17] Cohorts have been chosen from different areas known to have different air pollution levels.

Geographical Studies of populations have been used to assess long term (or chronic) air pollution health effects by comparing the frequency of a health outcome across different locations with varying levels of exposure. The main advantages of this design are the possibility of using routinely collected data on health outcome(s), and the greater exposure contrast that exists between, rather than within areas.[2] Some of the older studies of this type were unable to measure adequately the potential confounding variables, but more recent studies combine other design approaches such as prevalence studies or prospective studies within each area to improve the assessment of confounding variables.

Cross Sectional Studies are sometimes used to study air pollution have also been used to collect data on the prevalence of a health outcome and improve information on confounding in *Geographical Studies* using aggregated health and exposure data.

Case-Control Studies have rarely been used in air pollution epidemiology, other than to investigate the long-term effects of air pollution on the development of lung cancer and chronic obstructive pulmonary disease.

Potential confounding factors generally include environmental agents other than the pollutant of concern (eg cigarette smoking) and factors that influence the susceptibility of subjects (eg health status, medication).

Semi-experimental epidemiological studies (or *Episode Studies*) have been prominent in air pollution epidemiology. Air pollution episodes may be considered as 'natural' (ie outside human control) semi-experiments.

1.4 Dose and Exposure

The concept of dose is essential to understanding relationships between exposures to air pollution and adverse health effects. Dose can be defined as the amount of the air pollutant reaching the critical target site. However, the most appropriate dose term differs for different pollutants, different effects, and different types of studies. The concept of dose is evolving, however, the most relevant dose term must practically be that quantity of pollutant which can be measured and which has the most direct relationship to the response of concern. Most often, dose cannot be estimated and human exposure is linked to the effect of interest.

1.5 Exposure Assessment in Epidemiological Studies

The most important and pervasive problem in air pollution epidemiology is exposure assessment. The broadest characterisation of dose, often employed in air pollution epidemiology, is the estimate of population exposure developed from fixed air quality monitoring sites located outdoors. Although there is continuous improvement towards more accurate exposure measurements, the problem of exposure assessment is to some extent inherent in air pollution epidemiology.

Estimating exposure using a limited number of air pollution monitors overlooks the spatial variations in pollution levels in urban areas. The vast majority of epidemiological studies of air pollution conducted to date have used data from a limited number of outdoor monitoring sites to estimate exposure. This is primarily due to the fact that actual (personal) exposures to air pollution are impractical to measure directly in populations large enough to have adequate statistical power in epidemiological studies. The relationship between air monitoring data and the actual exposures of subjects constitute potential sources of bias and errors in the assessment of exposure. Strategies to assess exposure to outdoor pollution are becoming increasingly sophisticated.

1.6 Exposure to Mixtures of Pollutants

Because pollutant concentrations can vary together it is often difficult to determine whether any observed health effects are related to one or more pollutants, or whether they represent additive or synergistic effects of components of the mixture. Urban air pollution is a complex mixture of numerous air pollutants. There is little information available to determine if the biological effects of mixtures of air pollutants differ from those of the individual pollutants in isolation. The results of controlled human exposure studies to combinations of air pollutants have been variable. There has been no clear evidence of synergism between pollutants at the concentrations studied, although interactions between air pollutants may have been underestimated in such studies due to the small size of many studies, limited duration of exposures and the confounding effects of prior exposure to ambient pollutants.

Health effects have been associated with primary pollutants as well as secondary acid aerosols. A limited number of laboratory studies have demonstrated enhanced reaction to aeroallergens in human subjects exposed to relatively high concentrations of air pollutants. The results of laboratory studies of humans exposed to combinations of air pollutants have been variable.

Pollutants may interact in a number of ways. Chemical reactions occurring in the air or in the course of inhalation may enhance or reduce the effects of individual pollutants. Different components of the air pollution mixture may deposit in different parts of the respiratory tract, producing separate types of effects. The effects of one pollutant may affect the effects of

another. Aeroallergens in the atmosphere can provoke an attack of asthma in a sensitive person and there is evidence that effects can be enhanced in the presence of urban pollutants.[30]

The temporal and spatial collinearity of air pollution exposures tends to make the evaluation of independent health effects very difficult and there will continue to be uncertainty regarding possible interactions between air pollutants, and the interaction of air pollutants with aeroallergens. However, until the independent effects of individual air pollutants are understood, it will not be possible to quantify their combined effects.

1.7 Causality in Epidemiological Studies

Causal inference in epidemiology is an informal process, and criteria have been proposed to allow judgments as to the causal nature of observed associations, the best known being the Bradford Hill criteria. Such criteria include a requirement that the association:

- be strong;
- exhibit consistency across studies;
- be specific for a few diseases or illnesses;
- exhibit the appropriate temporal relationship;
- exhibit an exposure response relationship;
- be biologically plausible; and
- be coherent with other observations.

Expert panels have emphasised that no one criterion is definitive by itself nor is it necessary that all be fulfilled in order for a determination of causality. These criteria are helpful, as action to protect the public health is often deemed necessary in the absence of certainty as to the causal nature of an association.

Attachment 1 outlines in more detail causal inference in epidemiological evidence as part of assessing epidemiological evidence.

1.8 Coherence in Epidemiological Studies

Epidemiological studies of air pollution have used various health indices as the health outcome measure. The observation of increased mortality associated with air pollution exposures implies that measures of morbidity also must necessarily be increased, for example, hospital admissions, hospital emergency department visits, or doctor visits. Among potentially responsive subjects such as asthmatics, it would be expected to observe increased symptoms, lower lung function, increased medication use, and, ultimately, higher use of hospital services. A similar cascade of associations may also be detected among the general population. This has been described as a coherence of effects, ie the adverse effects of air pollution should be observable across a range of related health outcomes. Adverse effects of air pollution should also be reproducible observed by different investigators in different settings, ie there should be a consistency of effects across independent analytic studies.

2. DATA REQUIREMENTS FOR EPIDEMIOLOGICAL STUDIES OF AIR POLLUTION AND HEALTH

The data requirements for epidemiological studies of the health effects of air pollution depend on the study design and the health outcome being assessed. Health outcomes used to investigate the effects of air pollution range from less sensitive indicators like daily mortality to more sensitive indicators such as lung function.

The magnitude of the anticipated effect on the health outcome studied is of primary importance if the study design is to have adequate statistical power to find an effect (if one is present). Therefore, epidemiological studies using the less sensitive health effect indicators such as daily mortality must have data on large population (ie major cities) for long time periods (ie typically for several years). Studies using more sensitive indicators such as daily lung function can be of much smaller populations for shorter time periods.

Section 1.3 classified epidemiological studies of the health effects of air pollution as investigating either *acute effects* or *chronic effects.*

The health outcome data used in epidemiological studies of air pollution can be classified as:

- routinely collected health outcome data (for population studies such as *Time Series Studies* of daily mortality); and
- individual health outcome data (for studies with data on individuals such as *Diary Studies* of lung function).

The air pollutant data used in epidemiological studies is usually routinely collected at fixed monitoring sites on a continuous basis by government air pollution monitoring agencies. The need to improve exposure assessment in epidemiological studies will increasingly require future studies to collect additional air pollution data (eg personal air pollution monitoring, time-activity pattern data) and/or perform spatial air pollution modelling.

Epidemiological studies also need to control for a range of factors and therefore collect data which may confound any association between the health outcome and air pollution such as weather, influenza, and pollens.

2.1 Health Outcome Data

The routinely collected health outcome data for daily *Time Series Studies* must include at least the following data on residents of the study area (usually a city) for the study period (usually several years):

- health outcome – usually defined by the World Health Organisations International Classification of Diseases (ICD) code;
- date of health outcome; and
- place of usual residence.

The (individual) data is then aggregated to get a daily count of the selected health outcome for the population in the study area (hence they are known as population studies). Due to the availability of appropriate data in electronic format numerous *Time Series Studies* of the effects of air pollution on daily mortality and a large number of *Time Series Studies* of daily hospital emergency department (ED) admissions and air pollution have been conducted around the world. Such data cannot assess the role of air pollution in developing chronic disease or in increasing annual death rates

Daily hospital ED attendance is a more sensitive health end point than daily mortality or daily hospital admissions. Until recently hospital ED attendance data was not routinely collected in electronic format in the same way as daily mortality and hospital admissions data. Increasingly, hospitals are developing electronic databases of hospital ED attendances and more studies are being conducted using these data.

In some areas networks of local GPs have been established, primarily to monitor infectious diseases (eg influenza). The GP Surveillance network offers the potential to obtain data on a

sensitive indicator of health for use in epidemiological studies of air pollution (eg asthma GP attendance).[31] However, the data has a number of limitations and such studies need to be evaluated carefully.

A small number of studies have been conducted using data from health surveys that include information on the prevalence of health outcomes which may be associated with ambient air pollution such as restricted activity days.[32] Such *Cross-Sectional Studies* have a number of limitations including confounder control and reporting bias.

2.2 Health Data for Studies of Individuals

Diary Studies of respiratory symptoms and lung function have been important in the understanding of the health effects of air pollution. Data on respiratory symptoms and/or lung function is collected on each individual participating in the *Diary Studies* and data on a range of other potential confounders is also obtained, such as medication usage.

Cohort Studies that follow groups of individuals (sometimes tens of thousands) for long time periods (sometimes several years) can investigate the chronic effects of air pollution. The data collected is specific to health effects being investigated. Health outcomes for such cohorts are determined from a range of sources including cancer registers, hospital records and standardised questionnaires of respiratory symptoms. Data is usually collected on information relating to exposure, sometimes historical data. Information is also collected on confounders such as socio-economic status and smoking.
Only a few *Cohort Studies* have been conducted, largely due to the complexity and cost of such studies. Two *Cohort Studies* (or *Geographical Studies*) of the adverse effects of long term exposure to air pollution on death rates have been conducted. Both studies obtained information on the vital status and confounders of each member of the cohort by questionnaires and/or national mortality data bases. *Cohort Studies* investigating the incidence of lung cancer and the development of other chronic diseases including chronic respiratory symptoms have been conducted.[33,34,35]

Evidence of chronic health effects of air pollution has also come from *Cross Sectional Studies* of the prevalence of respiratory symptoms and/or lung function in populations living in areas of contrasting levels of air pollution. The information on respiratory symptoms is generally obtained using standardised questionnaires and data on a range of potential confounders is also collected.[36, 37, 38] As with the *Cohort Studies* one of the main problems in establishing exposure-response relationships is controlling for the changing concentration and composition of air pollution over time.

2.3 Air Pollution Data for Epidemiological Studies

The air pollution data used in epidemiological studies is usually routinely collected on a continuous basis by government air pollution monitoring agencies (see Appendix 5). Some studies collect additional air pollution data to improve exposure assessment. The need to improve exposure assessment in epidemiological studies will increasingly require future studies to collect additional air pollution data or perform spatial air pollution modelling.

When exposure is measured by fixed monitors there can be no estimate of the individual variation in exposure, or any assurance that these measurements are representative of the mean population or personal exposure. Total personal exposure to an air pollutant, which determines the likelihood of development of disease, represents the summation across all micro environments of the time spent in the micro environment and the concentration of the

pollutant.

The simplest method to estimate the population exposure is to average the data at the monitoring sites where the study population live (eg the city). This one value (per time unit of the study) is then assigned to the entire study population. The accuracy of the estimate will depend on the topography and meteorology of the study region and overlooks the spatial variations in pollution levels in urban areas. This method has been used in most epidemiological studies where exposure-response relationships have been calculated and this enables comparison of such relationships between studies.

There is currently no database on personal exposure measures and methods of inpterpolating data from fixed networks to personal exposure are in their infancy in Australia.

Monitoring personal exposure is clearly impossible for the large scale population based studies of daily mortality and hospital admissions. While it has been recommended that personal monitoring always be used for Diary Studies[41], practical difficulties of the sampling instruments, logistics and resources make this difficult to achieve in practice.

The paucity of information on personal exposure is largely due to the high cost of instrumentation and the labour required to maintain the monitors.[39] Indoor and personal monitoring have occasionally been used to assess personal exposure.[40]
A large number of metrics have been developed to assess the health effect of a particular air pollutant. The metrics may vary by the property of the pollutant (eg PM_{10}, $PM_{2.5}$) and/or the averaging time used (eg 1 hour ozone, 4 hour ozone). As much as possible metrics should be consistent between studies and at least include the same metric by which the pollutant standard is defined. Where different pollutant properties are measured (eg PM_{10}, $PM_{2.5}$) conversion factors should be supplied.

The *minimum* exposure data requirements for *Time Series Studies* are:

- sufficient fixed monitoring sites in the monitoring network to characterise the spatial distribution of air pollutants in the study region, ie sub regions within the airshed contain at least one monitoring site;
- sub-regional monitoring sites are located to measure air quality representative of the sub-region;
- each sub-regional monitoring site in the network has been operating at the same location throughout the study period (ie at least 5 years); and
- daily data from each sub-regional monitoring site is available for at least 90% of days (non random variations in the number of monitoring sites contributing daily data to calculate MDPEP could bias the exposure assessment).

Studies of the chronic effects of air pollution require data on the historical concentrations and composition of air pollution for long time periods. While studies of the chronic effects of air pollution may not require data to the same degree of spatial resolution as acute studies, they require consistent data for even longer time periods (ie at least several years). Validated data bases of detailed historical daily air pollution data are required for future studies of the chronic effects of air pollution.

2.4 Meteorological Data

The association between temperature, and more generally weather, and various health outcomes including daily mortality and daily hospital admissions has long been recognised (eg extremes of temperature, both hot and cold, cause increased deaths). Because of the

potential for weather to confound the air pollution-health outcome relationship, its effects must be controlled in the analysis so that the independent effects of air pollution on the chosen health outcome can be determined.

Analytical approaches to control for weather can be categoriesed as "empirical" or "synoptic". These two approaches contrast sharply. Comparisons between the empiric and synoptic approach to controlling for weather in models investigating the association been daily morality and air pollution have been conducted. The results found no meaningful differences in the daily mortality-air pollution association regardless of the approach used to characterise weather.[45]

Confounding by weather appears to be much less serious an issue for the less severe health outcomes examined in *Diary Studies* compared with population based *Time Series Studies* of daily mortality and hospital usage, ie respiratory symptoms and lung function are less affected by weather. The effect of temperature may also be greater where climatic variation is larger.

3. ROUTINELY COLLECTED AUSTRALIAN DATA FOR EPIDEMIOLOGICAL STUDIES OF THE HEALTH EFFECTS OF AIR POLLUTION

This section applies to those epidemiological studies which use routinely collected data on populations, specifically *Time Series Studies* of daily mortality, daily hospital admissions and daily hospital ED attendances. These studies are typically conducted in large cities over several years and have fairly generic data requirements. The aim of the following assessment is to establish if such *Time Series Studies* can be conducted in Australia's major capital cities with the currently available routinely collected Health data and confounder data.

It should be stressed that the appropriateness of data for a *Time Series Study* in a specific location over a specific time period can only be assessed by evaluation of the actual data in detail. Therefore, this assessment is only indicative of the availability and nature of the Australian data.
Appendix 5 covers in detail the status of network collected air quality data across Australia.

3.1 Daily Mortality Data

All deaths in Australia must be certified as to cause and date by a registered medical practitioner and the certificate registered by the Registrar of Births, Deaths and Marriages in each State and Territory. Death certificate data on all deaths of Australian residents is collected by the Australian Bureau of Statistics (ABS). De-identified unit record data in electronic format can be purchased from the ABS and is available from 1964. Standard data definitions apply and the data is coded by trained coders. These data are comperable to data used in overseas *Time Series Studies* of acute daily mortality and air pollution and are adequate for Australian epidemiological. Such studies have been conducted in Australia.

The records on mortality includes data on:
- principal (or underlying) cause of death coded as ICD;
- date of death;
- age (or date of birth);
- sex;
- place of usual residence (eg Statistical Local Area or Postcode);
- place of death (approximately 80% of deaths are in hospital); and

- occupation (not very useful as most are retired - occupational history would be more useful).

These data are adequate for Australian studies of daily mortality and air pollution.

3.2 Daily Hospital Admissions Data

All States and Territories collect electronic data on patient separations in public and private hospitals in Australia. These data are generally referred to as hospital Inpatient data. The Australian Institute of Health and Welfare (AIHW) compiles a minimum data set of inpatient data from all State and Territory health authorities for public and private hospitals since 1993/94 in the National Hospital Morbidity Database (NHMD). These data are available from AIHW for a range of epidemiological and health service research. Attachment 2 presents the status of this data.
Standardised data definitions are used and trained coders code the data. The actual definitions used by the State and Territory data providers may vary from year to year. In addition, the scope of the data collection may vary from one jurisdiction to another. Therefore, studies using this data must pay particular attention to changes in data definitions and data quality over time, between States and Territories and hospital sectors.

While access to hospital services varies between countries these data are comparable to data used in overseas *Time Series Studies* of the acute effects of air pollution on daily hospital admissions and are adequate for Australian epidemiological studies. Such studies have been conducted in Australia.

Inpatient data is also available from all State and Territory health authorities. Some jurisdictions have inpatient data in electronic format in the years prior to 1992/93 and a summary of the available data is shown in Attachment 3. Data prior to 1992/93 may be adequate for Australian *Time Series Studies* of the acute effects of air pollution on daily hospital admissions. However, studies using these data should evaluate the comparability of data definitions and data quality with more recent data prior to use.
Inpatient data includes the following data in standard formats:

- Hospital where admissions occurred;
- Date of hospital admission;
- Age (or date of birth);
- Sex;
- Principal discharge diagnosis coded as ICD:
    - the diagnosis chiefly responsible for the admission;
    - some data may also be available on the additional diagnoses affecting treatment or length of stay such as comorbidities and complications;
- Place of residence:
    - Statistical Local Area, postcode, other;
- Mode of hospital admission (ie source of referral):
    - this enables identification of admissions via the Casualty or A and E Department, as opposed to a scheduled admission to hospital for a previously planned procedure.

3.3 Daily Hospital Emergency Department Attendance Data

Some hospitals have collected electronic hospital Emergency Department (ED) attendance data in standard formats for a number of years. Centralised systems to collect standardised ED data are under development in most Australian States and Territories and moves are underway to consolidate these data in a national minimum data set (similar to the NHMD

database).

State and Territory data was obtained from each authority and is summarised in Attachment 4. As these data developed (or are still developing) from a mixture of hospital based systems and centralised systems the data definitions between hospitals and between States and Territorities can vary. Also the quality of the coding of the data can also vary between hospitals and between States and Territorities. The information provided indicate that several Australian capitol cities may already have adequate health data for appropriate time periods for *Time Series* studies of the acute effect on hospital ED attendance of air pollution. As centralised hospital ED attendance dateabases are still in the early stages of development studies using these data must pay particular attention to changes in data definitions and data quality over time, both within hospitals and between hospitals in the study region.

Unit record ED data suitable for epidemiological studies of air pollution and health would include similar fields to the Inpatient data:

- Hospital where ED attendance occurred;
- Date of ED attendance;
- Age (or date of birth);
- Sex;
- Principal ED diagnosis coded as ICD:
  - the diagnosis or condition established, after assessment, to be primarily responsible for the ED presentation;
  - some data may also be available on the additional diagnoses affecting the ED presentation such as comorbidities and complications;
- Place of residence:
  - Statistical Local Area, postcode, other.

While access to hospital services varies between countries these data appear comparable to data used in overseas *Time Series Studies* of the acute effects of air pollution on daily hospital ED attendances.

3.4 Other Routinely Collected Health Data

A number of local regions throughout Australia collect data on infectious diseases and other conditions (including asthma) from networks of local General Practitioners (GP). At the moment GP surveillance data in Australia is of limited use in air pollution epidemiology mainly due to the voluntary nature of such schemes and difficulties in defining the study population. However, there is the potential for studies to be undertaken in specific areas using established and cooperative GP surveillance networks. In the future GP Surveillance data may become more routinely collected and could become an important data source in air pollution epidemiology. Interested researchers should contact the local GP Surveillance coordinating body for further information.

Some State/Territory Health authorities conduct regular population based surveys (eg annual population health surveys). The surveys may include data on the prevalence of health outcomes that are associated with ambient air pollution. As yet it is unclear if this ecological data could be used for air pollution and health studies. Interested researchers should contact State/Territory health authorities for more information.

3.5 Meteorology Data

The Australian Bureau of Meteorology (ABM) monitors meteorological parameters and numerous sites throughout Australia. The ABM Three Hourly Surface Data contains data on a

large range of meteorological parameters that can be used for both synoptic and empirical approaches to control for confounding by weather.

Some Australian environment agencies have included continuous meteorological monitoring at air pollution monitoring sites. Environment agencies use this data to investigate the development and transport of air pollution throughout a region. In some areas this data may be used instead of, or in addition to, ABM data.

The currently available Australian meteorological data is adequate for epidemiological studies of the health effects of air pollution and comparable with that from overseas studies.

3.6 Influenza Data and Pollen Data

Studies of the acute effect of air pollution on health must control for the potential confounding effects of infectious disease epidemics (ie influenza). Aeroallergens are important environmental factors, which can confound associations between the effect of air pollution and acute respiratory health outcomes such as respiratory symptoms, lung function and asthma. If data on these factors are available it should be included in the analysis. Otherwise, this potential complication can be addressed by various modelling techniques.

The Communicable Disease Intelligence (CDI) Virology and Serology Laboratory Reporting Scheme (at the Commonwealth Department of Health and Family Services) collects monthly data on a range of respiratory viruses including influenza from participating virology and serology laboratories. Many laboratories in all states and territories contribute to the scheme. However, as the reporting scheme is voluntary and the number of reporting laboratories has varied over time the data is only indicative of influenza incidence in the community. Changes in diagnostic practices, particularly the introduction of new testing methodologies, may affect the number of laboratory reports received.[46]

Data on influenza hospital admissions, or where available hospital ED attendances, may be used as a measure of influenza incidence in the community. Some data may also be available from local GP surveillance networks of infectious diseases. The validity and availability of GP surveillance data is best assessed by investigators on a case by case basis.

Aeroallergens such as tree, grass and weed pollens, as well as fungal spores such as alternaria, are known causes of asthma. Aeroallergen data is not routinely collected by government authorities. However, a number of researchers around Australia monitor daily aeroallergen counts at various locations for various periods. The availability of this data for specific studies is best investigated by individual researchers on a case by case basis.

4. AVAILABILITY OF AUSTRALIAN EPIDEMIOLOGICAL DATA

The results from studies of the health effects of air pollution in North America and Europe in the late 1980's and early 1990's prompted concern that current levels of air pollution in Australian cities are capable of producing both acute and chronic health effects. Some commentators argued that the generally lower levels of air pollution in Australian cities compared to the overseas cities studied were too low to cause health effects. The relatively low levels of sulphur dioxide and acid aerosols in Australian cities produces a mix of air pollutants that is very different to the overseas cities and the generalisability of the international results to Australian conditions was questioned. These factors prompted calls for local Australian studies to attempt to replicate the overseas results. Australia's climate and

air pollution mix offer the opportunity to study the health effects of air pollution under different conditions to North America and Europe, where most studies have so far been conducted

Overseas studies indicate that current levels of air pollution in some Australian cities are detrimental to health. Australian epidemiological studies on the health effects of air pollution must be seen in the context of the large and growing body of international studies. Appendix 4 describes the results of these studies.

A number of Australian studies have used routinely collected health outcome data (ie population data), while others have used health outcome data collected specifically for the study (ie data on individuals). Attachment 1 lists Australian epidemiological studies on the health effects of the common air pollutants. The studies have been categorised by health outcome. The list includes studies published in the peer reviewed scientific literature as well as a range of other reports. This list is far from complete and any inclusions/corrections will be appreciated.

Studies with data on individuals (eg *Diary Studies, Cohort Studies*) require far more detailed data on health outcomes and confounders than those using routinely collected data on populations. Accordingly, such studies are far more expensive to conduct than those using routinely collected data. Well established study designs are available for such studies and a number of these types of studies could be conducted in Australia with appropriate funding. Australian epidemiological studies on the health effects of air pollution must be seen in the context of the large and growing body of international studies. The current body of Australian literature suggests that much of the international work is generalisable to Australian conditions.

Epidemiological studies of Pb are somewhat different to the epidemiological studies of the other criteria pollutants. The health outcome generally examined in epidemiological studies of the health effects of Pb exposure is blood Pb (Pbb) concentration. Blood Pb concentration is a specific biological indicator of Pb exposure. Increased concentrations of Blood Pb have been associated with a range of health outcomes including neurological and behavioral effects. Pb exposure control strategies aim to ensure blood Pb concentrations are below particular levels. In this way Pb is similar to CO control strategies which aim to ensure carboxyhaemoglibin levels in the blood are below particular concentrations. The situation with CO is changing with the recent finding of epidemiological studies which have demonstrated relationships between CO and heart disease at levels previously thought to be "safe" with respect to carboxyhaemoglobin levels. A number of Pb surveillance studies have been conducted to identify individuals or sub populations at risk from Pb exposure.

Studies linking Pb exposure with health effects generally use health outcome data collected specifically for the study (ie blood lead concentration), rather than routinely collected (population) health outcome data used by studies of the other criteria pollutants.

Attachment 4 outlines the studies in progress and those planned as well as a list of areas that are considered gaps in the epidemiological study data base in Australia.

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ATTACHMENT 1 -
AUSTRALIAN EPIDEMIOLOGICAL STUDIES OF AIR POLLUTION AND HEALTH

While every attempt has been made to compile a comprehensive list, it is acknowledged that some studies may not be included below.

1.1 Australian Air Pollution and Daily Mortality Studies

Simpson R, Williams G, Petroeschevsky A, Morgan G, Rutherford S. The Association Between Outdoor Air Pollution and Daily Mortality in Brisbane, Australia. Arch Environ Health 1997; 52: 442-454

Morgan G, Corbett S, Wlodarczyk J. Air pollution and daily mortality in Sydney, Australia, 1989 - 1993. Am j Public Health. 1998; 88: 759-764

1.2 Australian Daily Hospital Admissions Studies

Morgan G, Corbett S, Wlodarczyk J. Air pollution and hospital admissions in Sydney, Australia, 1990 to 1994. Am j Public Health. 1998; 88: 1761-1766

Petroeschevsky A, Simpson R, Thalib L, Rutherford S. Associations between outdoor air pollution and hospital admissions in Brisbane, Australia (in preparation)

Churches T, Corbett S. Asthma and air pollution in Sydney. NSW Health Department, Public Health Bulletin1991; 2: 72-73.

Abramson M, Driver J, Farish S, Ong EK, Knox RB. Air pollution, meteorological conditions, air-borne pollen and asthma admissions: a spectral and state-space analysis, (abstract), Aust NZ J Med 1994; 24: 449.

Goldsmith J, Friger M, Abramson M. Association between health and air pollution in time series analyses. Arch Environ Health 1996; 52: 359 - 67.

Christie D. Spencer L. Senthilselvan A. Air quality and respiratory disease in Newcastle, New South Wales. Medical Journal of Australia 1992; 156(12): 841-4

1.3 Australian Daily Hospital Emergency Department Attendance Studies

Rennick G, Jarman F. Are Children with Asthma Affected by Smog? Med J Aust 1992; 156: 837-841.

Smith MA, Jalaludin B, Byles JE, Lim L, Leeder S. Asthma presentations to emergency departments in Western Sydney during the January 1994 Bushfires. Int J Epidemiol 1996; 25(6): 1227-1236

Voight T, Bailey M, Abramson M. Air Pollution in the Latrobe Valley and its impact upon respiratory morbidity. Aust NZ J Public Health 1998; 22(5): 556-561

1.4 Australian Studies of Short Term Changes in Respiratory Symptoms

Henry R, Bridgeman H, Wlodarczyk J, Abramson R, Adler J, Hensley M. Asthma in the Vicinity of Power Stations II. Outdoor Air Quality and Symptoms. Pediat Pulmonol 1991; 11: 134-40.

Pilotto LS, Douglas RM, Attewell RG, Wilson SR. Respiratory effects associated with indoor nitrogen dioxide exposure in children. International Journal of Epidemiology 1997; 6(4): 788-96

Salome CM et al. Effects of nitrogen dioxide and other combustion products on atmospheric subjects in a home like environment. Eur Resp J 1996; 9: 910-918

Vlokmer RE, Ruffin RE, Wigg NR, Davis N. The prevalence of respiratory symptoms in South Australian preschool children II: Factors associated with indoor air quality. J Peadiatr Child Health 1995; 31(2): 116-120

Garrett MH, Hooper MA, Hooper BM, Abramson MJ. Respiratory symptoms in children and indoor exposure to nitrogen dioxide and gas stoves. Am J Respir Crit Care Med 1998; 158(3), 891-5

1.5 Australian Air Pollution and Respiratory Symptom Prevalence Studies

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Lewis P, Hensley M, Wlodarczyk J, et al. Outdoor air pollution and children's respiratory symptoms in the steel cities of NSW. MJA 1998; 169: 459-463

1.6 Australian Air Pollution and Lung Function Studies

Jalaludin B, Chey T, O'Toole B, Smith W, Capon A, Leeder S. Acute effects of ambient ozone and peak expiratory flow rates in a cohort of Australian children. International Journal of Epidemiology (in press)

Jalaludin B, O'Toole B, Smith M, Leeder S. Acute effects of bushfires on peak expiratory flow rates in children with wheeze: a time series analysis. Australian and New Zealand Journal of Public Health (in press)

1.7 Other Australian Studies of the Health Effects of Air Pollution

Denison L, Dawson B. Health risk assessment: evaluation of the impact of particle emissions from the city link tunnels ventilation system. Proceedings 14th International Clean Air and Environment Conference, October 1998

Marks GB. A critical appraisal of the evidence for adverse respiratory effects due to exposure to environmental ozone and particulate pollution: Relevance to air quality guidelines. Aust NZ J Med 1994; 24(2); 202-213

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Freeman D, Cattell FC. The risk of lung cancer from polycyclic aromatic hydrocarbons in Sydney air. Med J Aust 1988; 149(11-12)612-615

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Guest C, Morgan P, Moss JR, Woodward AJ, McMichael AJ. Abatement of tropospheric ozone: effects of strategies to improve air quality on public health and other sectors. Aust NZ J Public Health 1996; 20: 301-308

1.8 Australian Pb Studies

Fett MJ, Mira M, Smith J, et al. Community prevalence survey of children's blood lead levels and environmental lead contamination in inner Sydney. Med J Aust 1992; 157: 441-445

Williams C, Calvert GD, Gan, et al. Evaluation of Possible Environmental Sources of Lead Affecting Children in Port Kembla, Kemblawarra, Warrawong and Cringila. Illawarra Environmental Health Unit Report, March 1995

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Alan Bell. Blood Lead Levels of Some Children in New South Wales. Med J Aust. 1981; 1: 23-26

Galvin J, Stephenson J, Wlodarczyk J, et al. Living Near a Lead Smelter: An Environmental Health Risk Assessment in Boolaroo and Argenton, New South Wales. Aust J Public Health 1993; 17: 373-8

Vampini G, McMichael A, Rovertson E, et al. The Port Pirie Study: A Prospective Study of Pregnancy Outcome and Early Childhood Growth and Development in a Lead-Exposed Community - Protocol and Status Report. Environmental Research 38, 19-23 1985

Mira M, Bawden-Smith J, Causer J, et al. Blood Lead Concentrations of Preschool Children in Central and Southern Sydney. MJA 1996; 164: 399-402

Kent N, Garcia-Webb P, Byrnes E, et al. Blood Lead Levels in Children in Perth, Western Australia. Aust J Public health 1993; 17: 379-81

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Taylor J, Bazelmans J, Golec R, et al. Declining Blood lead Levels in Victorian Children. Aust J Public Health 1995; 19: 455-9

Aldrich R, Toneguzzi R, Wlodarczyk J, Hensley M, et al. Opporunistic Blood Lead Testing in a Paediatric Inpatient Population. Aust NZ J Public Health 1997; 21: 163-7

Kries IA, Galvert GD, Gan I, et al. Illawarra Child Blood Lead Study 1994. Illawarra Environmental Health Unit Preliminary Report 1994.

Cooney GH, Bell A, McBride W, et al. Neurobehavioural Consequences of Prenatal Low Level Exposures to Lead. Neurotoxicol Teratol 11(2) 95-104, 1989

De Silva PE, Donnan MB. Blood Lead Levels in Victorian Children. Med J. Aust., 1980, 2: 315-318

Rathus M, Latham S, Golding G, et al. Blood Lead Levels in Queensland Children.
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Gulson BL. Mizon KJ, Korsch MJ, Howarth D. Importance of monitoring family members in establishing sources and pathways of lead in blood. Sci Total Environ 1996; 188(2-3): 173-182

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ATTACHMENT 2 -
SUMMARY OF ROUTINELY COLLECTED AUSTRALIAN STATE AND TERRITORY HOSPITAL ADMISSIONS DATA

State	Contact	Database Name	Availability in Electronic Format	Comments
ACT	Health Status Monitoring Section ACT Dept of Health and Community Care GPO Box 825 CANBERRA ACT 2601	ACT Hospital Morbidity Data	July 1992 onwards	• All public and private hospitals
WA	Manager Hospital Morbidity Information System Health Department of Western Australia PO Box 8172 Stirling Street PERTH WA 6849	WA Hospital Morbidity Database System	1971	• All public and private hospitals
Tas	A/Manager Data Collection Unit Hospitals and Ambulance Service Department of Health and Human Services GPO Box 125B HOBART TAS 7001	Tasmanian Inpatient Morbidity System	July 1989 onwards	• All public hospitals. • Some private hospitals since July 1991
Qld	Manager, Client Services Health Information Centre Queensland Health GPO Box 48 BRISBANE QLD 4001	Queensland Hospital Admitted Patient Data Collection	1980 onwards	• All private and public hospitals
SA	Manager, Data Management Unit Information Management Services Department of Human Services PO Box 65 Rundle Mall ADELAIDE SA 5000	Integrated South Australian Activity Collection	July 1985	• All public and private hospitals
Vic	Manager, Information Analysis Unit Acute Health Division Victorian Department of Human Services 555 Collins St MELBOURNE VIC 3000	Victorian Admitted Episodes Dataset	June 1987 onwards	• All public hospitals from June 1987. • All private hospitals from June 1996
NSW	Director, Information Management and Clinical Systems Branch NSW Health Department Locked Mail Bag 961 NORTH SYDNEY NSW 2060	Inpatient Statistics Collection data base	January 1990	• All Sydney public hospitals since January 1990. • All public and private hospitals since July 1993
NT	Director of Business Information Management Territory Health Services PO Box 40596 CASUARINA NT 0811	NT Hospital Activity Data	1991 onwards	• All public hospitals

ATTACHMENT 3 -
SUMMARY OF ROUTINELY COLLECTED AUSTRALIAN HOSPITAL EMERGENCY DEPARTMENT ATTENDANCE DATA

State	Contact	Database Name	Availability in Electronic Format	Comments
ACT	The Canberra Hospital GPO Box 11 WODEN ACT 2611 Calvary Public Hospital GPO Box 254 JAMISON CENTRE ACT 2614		August 97 onwards June 97 onwards	• Both hospitals in ACT with ED, ie The Canberra Hospital, Calvary Public Hospital
WA	Health Department of Western Australia PO Box 8172 Stirling Street PERTH WA 6849			• Some public hospitals only
Tas	Hospitals and Ambulance Service Department of Health and Human Services GPO Box 125B HOBART TAS 7001			• Some hospitals from 1994. • All public hospital anticipated to commence in 2001
Qld	Health Services Queensland Health GPO Box 48 BRISBANE QLD 4001			• Some public hospitals only
SA	Not available			
Vic	Victorian Department of Human Services 555 Collins St MELBOURNE VIC 3000	Victorian Emergency Minimum Dataset	Collected centrally since October 1995	• All public hospitals. • Data quality in first few years needs to be investigated for each hospital
NSW	NSW Health Department Locked Mail Bag 961 NORTH SYDNEY NSW 2060	Emergency Department Data Collection Data Base	December 1994 onwards	• Increased from 30 hospitals in 1994 to 57 hospitals in 1999. • Public hospitals only. • All major hospitals in Sydney. • Data quality may vary between hospitals
NT	Territory Health Services PO Box 40596 CASUARINA NT 0811	Outpatient Attendance Dataset	1995 onwards	• All public and private hospitals

ATTACHMENT 4 -
STUDIES IN PROGRESS, BEING PLANNED AND AREAS REQUIRING FURTHER STUDY IN AUSTRALIA.

4.1 Studies in progress

- Melbourne Mortality Study, Vic EPA
- Melbourne Hospital Admission Study, Vic EPA
- Melbourne Asthma Hospital Admissions Study, Monash University
- Perth Mortality Study, WA DoE
- Perth Hospital Admissions Study, WA DoE
- Sydney Mortality Study 1994-1998, NSW Health
- Sydney Asthma Hospital Admission Study 1994-1998, NSW Health
- Sydney Hospital Attendance Study 1994-1998, NSW Health
- Diary Study of Lung Function and Air Pollution in Newcastle and Wollongong, Newcastle Environmental Toxicology Research Unit
- Diary Study of Lung Function and Air Pollution in Sydney, Western Sydney Public Health Unit
- SA study of symptoms and lung function, Dept of Public Health, University of Adelaide

4.2 Planned studies

- Coordination of standardised methodologies for daily mortality and hospital usage studies in Brisbane, Sydney, Melbourne and Perth. Combined analysis of these studies.

4.3 Filling the Gaps in Australian Epidemiological Studies

- Acute studies
- Chronic studies
- Pb Studies
- Exposure:
  - data and modelling
  - personal exposure studies
  - time activity patterns for use in exposure estimation
- Benchmarking/coordinating studies nationally and internationally:
  - comparable analytical methodologies
  - comparable age by health outcome (ie diagnosis) effect estimates
- Meta analyses / pooled analyses