9 September 2014

Director - Infrastructure Projects
Department of Planning and Environment
Number: SSI 13_6136
Major Projects Assessment
GPO Box 39
SYDNEY NSW 2001

Via online form:
http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=6136

NorthConnex Application Number: SSI 13_6136

My name is Richard Chard, Paediatric and Adult Cardiothoracic Surgeon, Clinical Associate Professor, Western Clinical School, University of Sydney
16A Bareena Avenue Wahroonga NSW 2076 email: rchard1@icloud.com

As a Medical Practitioner I am objecting to this project on medical grounds and I therefore attach my CV

Appendix 1   Curriculum Vitae

Please find below my submission in response to the exhibition of the EIS for NorthConnex.

Firstly I would like to state I **object** to the project as described in the EIS.

I have a high level of concern regarding the following issues and request that these be considered by NorthConnex and the Department of Planning. In regard to the NorthConnex tunnel, I am concerned about:

- **Residential placement of stack**

Placement of the northern ventilation stack in the centre of a densely populated residential area in Wahroonga, where 9,300 school children will be exposed, as well as multiple aged care facilities, hospitals, businesses and homes and the usual adult residents. This is, I understand the first time that a stack has been placed on residential land.

Solution: Choose more appropriate site as far as practicable from a residential area such as the Hornsby industrial area.

- **Inaccurate Use of weather data**

Meterological Data EIS 7.3 p463 appx G

The EIS uses weather data from stations remote from the stack locations that do not reflect the low average wind speeds in Wahroonga and West Pennant Hills.

Data has been collected from amateur weather stations much closer to the northern portal including 3 years of data collected 200 metres from the proposed stack site. See **Appendix 2**

Comparison with the wind velocity data from the EIS cited above and amateur weather station data included in Appendix 2 suggests that the modeling performed by NorthConnex does not reflect the real wind conditions in the local microclimate.

Detailed local weather data needs to be collected at multiple sites reflecting prevailing wind direction and topography. **It would require very considerable variances from the above data to alter the proposition that the area around the northern portal has long periods of low to no wind.**

Detailed local climate data needs to be gathered about the incidence and height of temperature inversions and all other relevant local microclimate data.

Solution – Complete detailed data over at least one year needs to be gathered.

- **Stack height too low/placed in valley**

The NorthConnex modeling based on CALPUFF and CALMET has much too low a resolution to be meaningful in the area within 1 kilometre of the stack. The modeling is more applicable to a high stack in a rural area from a power station, for example.

The proposed stack is in a valley with terrain features such as houses and trees which are close in size to the stack itself making dispersion problematic.

The terrain data used for the NorthConnex modeling is satellite based and has a resolution which is far too coarse to meaningfully account for the detailed topography, buildings and vegetation that needs to be taken into account in conjunction with the meteorological data.

Solution – A validated high resolution modeling system needs to be carried out by an independent expert. Detailed local microclimate (convective activity and inversions etc) topographical, vegetation, building and habitation data for the areas around the Stacks needs to be gathered and high resolution modeling needs to be performed. Exposure risk in all conditions but particularly low to no wind, temperature inversions and high emissions from in tunnel and surrounding road heavy traffic needs to be assessed.

Risk of undiluted fumigating plumes caused by local microclimate need to be assessed.

Toxic local plumes from the inevitable fire in the tunnel needs to be assessed, including the health risks of potential toxic loads on vehicles in the tunnel.
There is no credible way to prevent toxic and explosive loads in the tunnel.

- **Meaningful Environmental Assessment**

The above deficiencies illustrate that the framework in which the EIS was created is completely inadequate to assess the real implications of concentrated pollution sources such as stacks to a local high-density residential area. The fact that the submission is technically compliant clearly reflects a failure of regulatory authority to provide a scientifically valid safeguard to the community.

This failure should not allow the project to proceed until the necessary framework has been put in place and subjected to community scrutiny with funded community access to expert independent advice.

In view of the multiple failures of design and positioning of ventilation stacks in NSW e.g.– Lane Cove tunnel and M5 East tunnel, more representative assessment techniques for plume behaviour need to be designed and adopted.
The use of non-toxic smoke marker plumes observed by aerial drone under a wide range of wind and microclimate would test existing stack function and provide a better standard of safety to the community. The existing methods of performing monitoring with point collection of pollutant levels at significant time intervals is extremely suboptimal and does not provide a credible evaluation of real world conditions.

Further, the development should be subjected to this post installation testing if it proceeds, **as a condition of approval**, otherwise the community can have little confidence in the reassurances of the promotors (Government and NorthConnex).

Solution – the State Government should consult widely to establish community approved scientifically valid methods of modeling near field pollution behaviour including detailed longitudinal microclimate assessment and high resolution topographic and vegetation/building data. They should then establish standards for experimental verification of the modeling BEFORE construction commences.

- Strict post construction verification needs to take place. Any deficiencies must be corrected before operation of the project.

- **Medical Evidence of Adverse Effects of Air Pollution**

I am highly concerned about the multiple large scale research studies that suggest the impacts of air pollutants on health are serious. These include increased death from heart disease, increased risks of lung cancer, stroke, poor lung growth in children, increased asthma, and recent research suggesting low birth weight for pregnant women, increased autism, and congenital heart defects. These studies confirm air pollutants have prothrombotic and inflammatory effects on humans which cause the above health problems. As this is in the area in which I practice, I have real concerns that not enough material is available to assist an understanding of possible health problems here.

Appendix 3 contains a letter and literature review compiled by local medical practitioners including myself.

I endorse the contents and believe that the NAPM draft guidelines (**Appendix 4**) reflect my views about the protection of the community with an “exposure minimisation” framework for M2.5 and below particle exposure. This implies that any measure likely to, in any way, increase exposure to these pollutants needs to be treated cautiously – based on the *precautionary principle.*

My clinical practice in Cardiothoracic Surgery over the last 30 years has taught me that the diseases I regularly treat such as lung cancer and ischaemic heart disease occur in people with no otherwise identifiable risk factors. The data reviewed above suggests that this is an important previously missing risk factor. Lung cancer causes more cancer deaths in Australia than any other type. Ischaemic heart disease remains the commonest cause of death and premature death in Australia.

- **In Tunnel Air Quality**

I am concerned about the air quality within the tunnel which is shown in the EIS to have exceedences above standards for pollutants such as NO2, and M2.5 particulate matter. There is no prediction about Ultrafine particles (less than 1 micron) which also have a wide range of serious adverse health effects and should be fully assessed.

Factors such as:

- Piston effect (weak as best) diminishes as traffic slows, frequent congestion likely
- Piston effect is limited, only occurs from ground level to about 30cm

- Cross sectional area of tunnel very large in relation to vehicles hence minimal piston effect

- Most ventilation will rely on Jet fans which will probably have to run continuously rather than intermittently as stated

- Complete avoidance of portal emissions unlikely, reversed fans near portals will slow net flow significantly

- Dead space of slow air transit large from 30cm above road to just below Jet fans

Transit of air through the tunnel will vary according to position in tunnel in relation to piston effect – lower 30cm and fan effect upper part only. The net result will be an increase in in-tunnel pollutant level proportional to the number and nature of vehicles and rate of clearance of polluted air through the stacks and possibly portals. These levels are likely to be far higher than modeled because the air flow velocity in the tunnel is likely to be around 4 metres/second but the vehicle velocity will be 20metres/sec. This will lead to a net accumulation of pollutant even in the first part of the tunnel and becoming progressively higher as the end of the tunnel approaches. Note that inflow air at both ends is likely to be significantly polluted by surrounding traffic and still conditions during the morning and evening peak increasing the pollution levels of the inflow air.

The graphs generated from **Table 7-101 Page 516 Section 7.3 of the EIS Appendix 5** present a far more optimistic position than is likely from the above mental simulation.

The EIS contains modeling based on very conservative emissions predictions in terms of types of vehicle and maintenance state of vehicles. It contains projections of further significant decreases in vehicle pollutant output as has been experienced in the last 30 years. These predictions are absurdly optimistic because there is simply not much more that would significantly reduce the output of current vehicles. It takes no account of the fact that Australia's vehicle fleet has an average age of 10 years for cars and 10.8 years for trucks. The PIARC guidelines used are said to be over estimates yet it seems far more likely given the ageing vehicle fleet and deteriorating economic circumstances of Australia that emissions are more likely to rise because the new technology, if any, real benefit will not be affordable.

Modeling should be performed based on a realistic estimate of a real world vehicle fleet in real world state of maintenance.

The mix of vehicles projected for this tunnel by the EIS does not reflect the likely incidence of the heavier B double trucks in increasing use for heavy transport in Australia because of the high cost and scarcity of drivers. More freight per driver per trip makes sense. The emissions are calculated on a relatively low proportion of single trailer trucks. Emission levels increase rapidly with weight in a non-linear fashion so that heavier trucks created a disproportionately high increase in emissions. Combined with the uphill design unnecessarily placed for the northern tunnel emissions are likely to be far higher than predicted.

Air Quality Requirements Based on Medical Evidence

The enclosed graphs generated from **Table 7-101, Page 516 Section 7.3 of the EIS** demonstrate the levels of PM2.5 microparticulates in the north bound tunnel under what are described as peak hour conditions at 6pm in 2019 and 2029. They demonstrate levels which are far above what was described previously as safe (now subject to "exposure minimisation" principle). Namely, 24 hour exposure at a maximum of 25 micrograms/m3 and 1 year exposure at 8mcg/m3. The level demonstrated hits 300mcg/m3 half way along the tunnel and around 500mcg/m3 at the end of the tunnel.

These levels are in the range (300mcg/m3) that causes measurable adverse cardiovascular effects in susceptible individuals as described in the article by Mills et al (Ischaemic and Thrombotic Effects of Diesel Exhaust Inhalation in Men with Coronary Heart Disease, N Engl J Med 2007;357 1075-82).

There are many scenarios involving peak hour heavy traffic conditions, breakdowns, accidents and public holiday traffic in which prolonged exposure to this and far higher levels is likely for those in the tunnel.
It is clear that the longitudinal ventilation design for a tunnel of this length is hopelessly inadequate when compared with the standards required for optimal human health.

The scenario of following vehicles with high emissions such as heavy trucks or vehicles smoky because of inadequate maintenance is described in a paper by Knibbs, Luke D. Morawska, L et al(2009) *On-road ultrafine particle concentration in the M5 East road tunnel,* Sydney, Australia. Atmospheric Environment, 43 (22-23). Pp. 3510-3519. Measuring ultrafine particles following a smoky vehicle caused the counter to go off scale and the vehicle occupants to be seriously affected by the emissions. The graph of the episode in the article is instructive. This scenario is likely to be repeated in the projected tunnel with vehicles stuck behind high emitters in the confined space of the tunnel for long periods, even optimal transit time let alone high traffic, breakdown, accident conditions. Potential levels of M2.5, ultrafine and NO2 are likely to be in a range to cause acute toxicity, acute asthma attacks, and to trigger cardiovascular events such as heart attacks and strokes during the succeeding 24 hours.

The ventilation system must be designed to eliminate these types of exposure completely. The current best case in a practical sense is a surface road in which pollution levels can rise into an undesirable range as documented in the EIS. In the confined space of a longitudinally ventilated tunnel even the level experienced on a surface road cannot be achieved.

- **Portal Emissions**

I am concerned about the project including future provisions for portal emissions in densely populated areas, which will result in emissions remaining at ground level, and hence exposing the local population to pollutants. I am also concerned that NorthConnex's claim that there will be no portal emissions from current proposal cannot be verified.

The current ventilation plan involving portal emission avoidance by reversing the flow within a short distance of the portals by using reverse fan direction and then scavenging the emissions to be directed up the stack is unconvincing even at low traffic volumes and low pollution levels.

The combination of realistic estimation of pollutant load documented above and the surrounding traffic congestion likely to be common at both ends of the tunnel (but probably the South end worst,) combined with low wind and temperature inversions during peak hours particularly, means that portal emissions are likely to occur. If they do so they are likely to cause serious exposure to the local population around the portal. Given the demonstrated toxicity even at low concentration of the M2.5 microparticulates let alone ultrafines, NO2 and CO it underlines the need for portal emissions to be eliminated under all conditions for protection of the local communities.
It was stated at the NorthConnex Air Quality Information evening that portal emissions were never to take place and admitted by Mr Tim Parker that if they were demonstrated to take place that they would have to redesign the system.

The history of portal emissions from the M5 East tunnel occurring significantly associated with cessation of the fan ventilation, is not reassuring. The safety of the community should not be in the hands of tunnel operators prone to cost saving measures, mechanical breakdown or power failure.

Solution – Move the portals to an area as far as away as possible from residential areas.

- **Electricity Drain**

The massive electricity drain from this project will place a substantial strain on NSW electricity grid capability to meet maximum load, which is already borderline, particularly during peak periods such as hot weather in summer when air conditioning is maximum. The combination of cool emissions from the tunnel portal and stack with still conditions would cause a devastating pollution plume at ground level during heavy traffic conditions especially holiday weekends, common in summer.

Solution - This contingency needs to be modeled for and mitigated. Moving the portals is the only practical way of eliminating it. Modeling based on reasonably predictable pollutant levels needs to be carried out and if portal emissions are possible the ventilation system needs to be redesigned or the tunnel portal moved to a place where human exposure risk is eliminated.

- **ALTERNATIVE OPTIONS**

I am concerned that a full and transparent options assessment process was not undertaken to assess alternative designs for the project., as an EIS requirement. Unlike other tunnel projects in Sydney here there are alternatives for locating the stack and portals in non-residential areas.

EIS Chapter 4 Table 4-1 Page 33
DIRECTOR-GENERAL'S REQUIREMENT

An analysis of alternatives/options considered having regard to the project objectives (including an assessment of the environmental costs and benefits of the project relative to alternatives and the consequences of not carrying out the project), and the provision of a clear discussion of the route development and selection process, the suitability of the chosen alignment and whether or not the project is in the public interest.

Three broad corridor options were explored:
Type A – directly from Wahroonga to M2
Type B – from Berowra to M7/Windsor Road
Type C – from Calga to M7/west of Blacktown

Selection of the preferred option

Despite the requirement above, that analysis of the alternatives be provided, no credible analysis is contained within the **EIS sections, Chapter 4, Sections 4.1** on. The document is essentially a statement of opinion with attribution to several reports:

(F3 to Sydney ORBITAL LINK STUDY) (SKM2004).
The Pearlman Review 2007 –

Marla Pearlman went outside the terms of her review to state that the Calga to Parklea/M7 option with a second Hawkesbury River crossing was the best alternative to route traffic and particularly heavy transport to Sydney.

This remains the only sensible alternative.

In the so called analysis from the EIS - no mention is made of the severe limitations of tunnel developments, namely that

- NO DANGEROUS GOODS ARE PERMITTED within the tunnel and therefore at least 20% of heavy transport will continue to use the unimproved surface road (Pennant Hills Road).
- Dangerous goods classification is easily "gamed" by the trucking industry to avoid tolls.
- Traffic speed in a tunnel would be significantly less than a surface road. According to recent announcements by the Transport Minister appropriate motorways could have up to a 130kph limit versus 80kph in a tunnel (as are all road tunnels in Sydney at present)
- High vehicle speeds in the sensorily deprived environment of a long tunnel would be dangerous.
- Emergency services are far more easily delivered on a surface road
- The high energy consumption to provide ventilation.

- The environmental impact of converting a linear source of road traffic pollution into 2 point sources concentrating the pollution at either end in a heavily populated residential and educational area with inadequate provisions for dispersion.

Issues Related to Dangerous Goods Within Tunnels

What is the definition of a Dangerous load?

- Does it differ from what is Dangerous on a surface road?

- Who is responsible for ensuring that loads are appropriate? the trucking operator, the driver, the source company, the receiving company,? Or All?

- What penalties are applicable? How do authorities deal with the inevitable rogue operator?

- Who is responsible for policing RMS? If police, how will it be done? what are the likely variances from 100% compliance? Is that an acceptable risk?

- What effect will the policy have on Tunnel usage?

- Will it render the usage sufficient to justify the Project ? Judging by the compliance seen with vehicle height (a rather obvious parameter) in tunnels, the enforcement will need to be strict and compliance will be onerous for the trucking industry.

- The risk of "black swan" events is foreseeable, high and unquantifiable.

- One event like the recent explosion of 50 tonnes of Ammonium Nitrate on the Mitchell highway in Queensland on 5 September 2014 could take out everything and everybody in the Tunnel and the Tunnel itself – how will that type of accident be handled in NSW?

- The declared intent of the tunnel is to take heavy truck movements off Pennant Hills Road, thereby concentrating the risk of heavy truck incidents in the tunnel

- Heavy truck preponderance is unusual/unique in a long tunnel development.

- The sensorily deprived environment of a long tunnel can predispose elderly, tired, drugged and otherwise impaired drivers to do odd things, especially when multiple B Doubles are bearing down on them with only 2 lanes and nowhere to go, it all happens in an instant.

- A truck driver tailgating a driver who is slower than the truck wants to go, even if that is faster than the speed limit as happens constantly on Pennant Hills Road

-There will be numerous such potential events per hour in even moderate traffic conditions

Solution: All of the above can be avoided or minimised by a surface road.

- **Surface Road Alternative not assessed**

The EIS contains no serious discussion of any surface road alternative but is essentially a statement of opinion and advocacy of NorthConnex's design.
Uncorroborated statements about "community consultation" with regard to the 2004 and 2007 reports are made in relation to support for NorthConnex's position. It is extremely unlikely that the true implications of a massive tunnel development ,both construction and operation, were presented to the "communities" in a way that would allow a meaningful choice to be made by those consulted.

Solution:NorthConnex should be required to provide a comprehensive analysis of Type B Corridor alternatives in the light of the true advantages and disadvantages of a predominant surface road alternative versus a tunnel twice as long as any other in Australia.

- **Assessment of alternatives in EIS**

No assessment of alternatives is provided in the EIS. There are brief statements, which are essentially dismissive of a variety of alternatives. NO analysis is provided.
The document contains statements of opinion as though the previous reports on the subject were relevant to current conditions and were made in the knowledge of the actual consequences in relation to the environment and potential improvement of traffic problems.

Solution - Detailed analysis of all alternatives with appropriate validated data comparisons of all aspects and issues needs to be provided by NorthConnex to justify their claims that their preferred alternative is superior.

- The whole process needs to be independently supervised including dominant community input.

Failure of the Planning Process

That this project has reached this stage demonstrates the fundamental failure of the Department of Planning and the political process to arrive at a valid solution to the problem.

They have uncritically accepted the numerous limitations listed above, in addition the design of the Pacific Highway/Pennant Hills Road interchange is likely to make for slow and cumbersome truck movements (which will ensure all traffic is slow). The Southern interchange feeds into a very busy traffic area with feeder and distributor roads already frequently blocked in both directions.

The tunnel is highly likely to become congested frequently, despite this the cheapest and least effective ventilation system has been selected. It is designed on false principles, such as the Piston effect, which does not work significantly in road tunnels, it is for rail tunnels. They give their game away with the passionate denunciation of filtration, even though it works in many overseas locations. Cost is no excuse for inadequate safeguards to health.

Insufficiently Critical Acceptance of Promotors Plan

The Northern Portal location has been selected because it is the cheapest option. The RMS already owns some of the land! With no credible model for dispersion of the pollutants and setting a precedent of polluting an established residential area. The scenario is that the Department of Planning had no credible solution to the problem, despite two enquiries. That lack of expertise is then presented with an unsolicited proposal with serious flaws by the dominant provider of Toll roads in the state.
They know that the only way to fund the project is cross subsidy from their existing toll roads, which will cement their monopoly position and secure their assets.
It allows them to get away with saddling the NSW community with a $3billion dollar lemon that will at most transiently contribute to solving the traffic congestion problems of Pennant Hills Road.

Solution - The process should have been that the Dept of Planning actually has the expertise to devise a solution to the problem,
It outlines the alternatives including community consultation and political input. The process is public and transparent.
A solution is arrived at and tenders are called for with detailed specifications.
If the specifications are properly written the failures outlined above will not occur.
The tenders should be assessed critically and independently by experts.

- **Alternative Suggestions**

1. No tunnel – instead, the Type B Corridor - predominantly surface road connection between Berowra and Baulkham Hills/Parklea

2. Surface Route
Serious thought should be given to using the Lane Cove National Park area to place an overhead road, perhaps with a short tunnel under Wahroonga. Such solutions work well in many parts of the world, minimally affecting the environment once established.

3. Make Pennant Hills Road Work

By far the majority of traffic on Pennant Hills Road is local traffic travelling along part of the potentially bypassed segment that will not use the Tunnel.

There is very little traffic between 9pm and 6am. Surely a truck tolling system penalising travel outside those hours would redirect much of the heavy transport to when the road is empty.
This could be combined with flashing amber lights and /or traffic light sequencing/synchronisation to facilitate transit times .
Why spend $3billion to supplement a resource one already has vacant for at least 8 hours of the day which could be more fully utilised?
Many other industries – health, hospitality etc etc operate 24/7, why shouldn't the trucking industry?
$3billion is a lot to pay so the truckies can travel during the day.
Stagger the local school hours to maybe7am, definitely 8am and 9am starts and fence the roads plus provide overhead bridges to eliminate school zone speed limits.
Reduce the number of traffic lights, limit the number of crossing points and add merge lanes to keep traffic stream moving.

Identify local travel requirements that can be facilitated by extra local roads or facilitated routes to keep local traffic off Pennant Hills Road (like Kurraba St Neutral Bay all the way to Mosman)
Place overpass or underpass intersections at Beecroft Road, Comenara Parkway, Castle Hill Road, Pennant Hills Road/ Yarara Road
Pollution levels would drop because dispersion would be improved and volume would be reduced by decreasing congestion. Dangerous goods would not be an issue.

4. Level Tunnel
If after analysis of the above points and a tunnel development is decided upon it should have a level grade on the North bound tunnel to minimise pollution and ventilation stacks and portals (also a source of pollution) should be as far as possible from residential areas on the North portal. This would mean opposite the Hornsby industrial area.

5. The Need for Filtration
I am concerned that the justification for not providing filtration for the stacks is cursory and unconvincing.

At least 50 tunnels in Japan have filtration and the technology is widely used elsewhere. Filtration is used extensively in industrial installations, power stations and mining.

The “exposure minimisation” goal for national PM2.5 exposure alone mandates all possible measures to reduce exposure. If tunnel stacks and portals are in positions likely to lead to any human exposure they need to be effectively filtered or moved regardless of cost.

To address my concerns I request that the following actions are undertaken:

1. The air quality and human health impact assessment need to be revised to address the issues raised above.
2. An independent options assessment process should be undertaken to assess alternative locations for the ventilation stack and portals.
3. To undertake a Life Cycle Analysis and assessment for the provision of filtration
4. A long term prospective controlled health study on children and residents in areas impacted by stack discharges be included as part of the conditions of approval. It must be independently supervised and funding guaranteed.
5. The Promotors and Government need to be insured against the likely acute and chronic adverse health effects potentially demonstrable by the study to provide adequate compensation to victims and avoid problems such as experienced by the victims of asbestos exposure and tobacco addiction.
6. Portal emissions from NorthConnex in the future are banned.
7. The Submissions Report/Preferred Project be exhibited to allow the community to respond to the revised information contained in the report.
8. The Department does not approve the project in its current form as it clearly does not meet the principles of Ecologically Sustainable Development as required by the Environmental Planning and Assessment Act.
9. All solution sections and discussion points in this submission be addressed.

Appendix 1

CURRICULUM VITAE

NAME:	**Richard Barry CHARD** **BDS (Hons) MB BS (Hons) FRACS FCSANZ** **Adult & Paediatric Cardiothoracic Surgeon** Clinical Associate Professor Western Clinical School Department of Surgery University of Sydney
PRACTICE ADDRESSES:	**(All correspondence)** **Suite 8** **Children's Hospital Medical Centre** **Hainsworth Street** **WESTMEAD NSW 2145** **Suite 503, Level 5** **SAN Clinic 185 Fox Valley Road** **WAHROONGA NSW 2076** **PH: 9687 9200 FAX: 9687 8300** **EMAIL: chardric@netspace.net.au**
DATE OF BIRTH:	26 March 1952
VMO APPOINTMENTS:	Westmead Hospital The Children's Hospital at Westmead

Westmead Private Hospital

Sydney Adventist Hospital, Wahroonga

SCHOOL EDUCATION:

Sydney Grammar School

DEGREES, DIPLOMAS & AWARDS:

DENTISTRY I
University of Sydney 1971

1972	Dental Prosector
1975	Richard Belitho Bush Memorial Prize. (General Proficiency) Awarded at the discretion of the Dean. H.J.V. Cusack Memorial Prize. (Operative Dentistry)
1976	John Stephen Hill Prize. (Clinical Operative Dentistry) Endodontic Society of N.S.W. Prize. (Endodontics) R. Morse Withycombe Prize. (Clinical Periodontics)

1976

Graduated Bachelor of Dental Surgery with Second Class Honours.

MEDICINE II
University of Sydney 1977

	University Results:	
Medicine I	Exempt	
Medicine II	Anatomy	Distinction
	Physiology	Credit
	Biochemistry	Credit
	Behavioural Science	Pass *
	Histology & Embryology	Pass *

* Partial exemption granted due to Dental Degree.

Medicine III	Pharmacology	High Distinction
Medicine IV	Clinical Science	Distinction
Medicine V	Medicine	Distinction
	Surgery	Distinction
	Paediatrics	Distinction
	Community Medicine	Distinction
	Psychiatry	High Distinction
	Obstets. & Gynae.	Credit

1979
Burroughs Wellcome Prize (Pharmacology)
Repatriation General Hospital, Concord, Prize.
(General Proficiency in Fourth Year)

1980
W.H. & E.A. Sharp Prize.
(Proficiency in Surgery and Clinical Surgery)
Hugh Gibson Memorial Prize.
(General Proficiency)
H.J. Ritchie Prize
(Proficiency in Clinical Medicine)
Repatriation General Hospital, Concord, Prize
(General Proficiency in Final Year)

1981

Graduated Bachelor of Medicine, Bachelor of Surgery, First Class Honours.

DEGREES, DIPLOMAS & AWARDS (Cont)

July 1982	Passed Part I Examination, Fellowship, Royal Australasian College of Surgeons.
July 1986	Foreign Medical Graduate Examination in Medical Sciences (F.M.G.E.M.S.). Passed 81% Basic Science, 85% Clinical Science.
April 1987	Travenol -Edwards Travelling Scholarship. Awarded by the Royal Australasian College of Surgeons to visit Cardiothoracic Surgical Centres in the United States of America and attend the American Association of Thoracic Surgeons Meeting.
November 1988	B.J. Amos Travelling Fellowship to support Clinical Training Overseas. $10,000 awarded by the Westmead Association.
October 1989	Passed Final Fellowship Examination, Royal Australasian College of Surgeons.

TRAINING:

1980	Option Term - Cardiac Surgery. Royal Alexandra Hospital for Children, Camperdown, NSW.
1981	Intern, Westmead Hospital, Westmead, NSW.
1982	Surgical Resident, Westmead Hospital, Westmead, NSW. (Neurosurgery, Cardiothoracic Surgery, Casualty, General Surgery)
1983	Senior Resident Medical Officer in Surgery, Westmead Hospital, Westmead, NSW. (Cardiothoracic Surgery, Ear Nose & Throat Surgery, General Surgery)
1984	General Surgery Registrar, Westmead Hospital, Westmead, NSW.
1985	Cardiothoracic Surgery Registrar, (Advanced Trainee), Westmead Hospital, Westmead, NSW.
1986	General Surgery Registrar, Westmead Hospital, Westmead, NSW.
1987	Paediatric Surgery (6 months) & General Surgery (6 months), Westmead Hospital, Westmead, NSW.
1988	Cardiothoracic Surgery Advanced Trainee, Westmead Hospital, Westmead, NSW.
1989	Cardiothoracic Surgery Advanced Trainee, Royal Alexandra Hospital for Children, Camperdown, NSW.
1990	Fellow in Surgery at the Harvard Medical School, Boston, Massachusetts USA. with the following Clinical Attachments;

January 1 - June 30	Division of Cardiac Surgery, The Brigham & Women's Hospital, Boston.
June 30 - December 31	Senior Resident in Cardiovascular Surgery, The Children's Hospital, Boston.
June 30 - December 31	Senior Resident in Cardiovascular Surgery, The Children's Hospital, Boston

APPOINTMENTS:

February 2014 to present	Head of Department, Cardiothoracic Surgery, Westmead Hospital
September 2005 to 2009	Deputy Director, Adolph Basser Cardiac Institute, The Children's Hospital at Westmead
1998 - 2006	Medical Director, Cardiothoracic Unit, Westmead Hospital
1 December 1997	Acting Director of Cardiothoracic Surgery, Westmead Hospital
1993 -	Visiting Cardiothoracic Surgeon:
	Westmead Hospital, Westmead, NSW
	The Children's Hospital at Westmead NSW
	Sydney Adventist Hospital, Wahroonga, NSW
	Westmead Private Hospital, Westmead, NSW
	The Sydney Children's Hospital, Randwick, NSW (until 2006)
	Cardiac Surgeon: NSW Children's Heart Service

PAST APPOINTMENTS:

January 1991 - January 1996

Staff Cardiac Surgeon, Royal Alexandra Hospital for Children, Camperdown, NSW

January 1991 - January 1993

Staff Cardiothoracic Surgeon, Westmead Hospital, Westmead, NSW

1990 Fellow in Surgery at the Harvard Medical School, Boston, Massachusetts, USA with the following attachment;

January 1 - June 30	Division of Cardiac Surgery, The Brigham & Women's Hospital, Boston
June 30 – December 31	Division of Cardiovascular Surgery, The Children's Hospital, Boston

TEACHING COMMITMENTS FOR THE FACULTY OF MEDICINE:

2002 Clinical Associate Professor, Western Clinical School, The University of Sydney

1998 Clinical Senior Lecturer, Western Clinical School, The University of Sydney

1999 – 2001 Undergraduate Medical Student Clinical Tutorials – 2nd Year Medical Students GMP

Supervising Student Attachments to the Cardiothoracic Surgery Unit

Undergraduate Lectures on Surgical Management of Lung Cancer and Thoracic Trauma

OTHER TEACHING COMMITMENTS:

College of Surgeons Supervisor of Training Children's Hospital Westmead from 2008 on

Member of The Board of Cardiothoracic Surgery, Royal Australasian College of Surgeons: from November 2005 until October 2008

Supervisor of Advanced Training in Cardiothoracic Surgery for NSW for the College of Surgeons: 1995 -2002

Regular teaching sessions associated with the Advanced Training of Cardiothoracic Surgeons within the College of Surgeons particularly related to congenital heart disease.

Lecture – Anatomy of the Thorax
Primary Fellowship Course
Royal Australasian College of Surgeons, Westmead Hospital. 1993 - 2001

Examiner for the Trial Examinations associated with the Course preparing for the final Fellowship of the Royal Australasian College of Surgeons held at Westmead Hospital.

Lectures on Cardiothoracic Trauma, Liverpool Trauma Course.

Cardiac Surgery for the Paediatric Intensive Care Staff, Royal Alexandra Hospital for Children.

Regular In-service Teaching Sessions, Resident Staff and Nurses, Cardiothoracic Unit, Westmead Hospital.

The Trauma Course for Emergency Room Medical and Nursing Staff held at Westmead Hospital annually. 1993 - 2000

PUBLICATIONS:

Aorta-coronary Bypass Grafting with Polytetrafluoroethylene Conduits. Early and Late Outcome in Eight Patients. R.B. Chard, D.C. Johnson, G.R. Nunn, T.B. Cartmill. J. Thorac. & Cardiovasc. Surg. 94:132-134, 1987.

Acute Herniation Through a Posterolateral (Bochdalek) Diaphragmatic Hernia in an Adult. R.B. Chard, I.C. O'Rourke. Med. J. Aust. 146:218, 1987.

Management of Ascending Aortic Dissection: Experience with the USCI Intraluminal Prosthesis and a Method of Aortic Valve Repair. R.B. Chard, G.R. Nunn, D.C. Johnson, T.B. Cartmill. Aust. & N.Z. J. Surg. 57:943-949, 1987.

Comparison of Early and Late Dimensions and Arrhythmogenicity of Cryolesions in the Normothermic Canine Heart. R.B. Chard, G.B. Hunt, D.C. Johnson, D.L. Ross. J. Thorac. & Cardiovasc. Surg. 97:313-318, 1989.

The Use of Desmopressin (DDAVP) in the Management of Aspirin Related and Intractable Haemorrhage after Cardiopulmonary Bypass. R.B. Chard, C.A. Kam, G.R. Nunn, D.C. Johnson, W. Meldrum-Hanna. Aust. & N.Z. J. Surg. 1990,60,125-128.

Congenital Obstruction of the Caudal Vena Cava in a Dog. R. Malik, G.B. Hunt, R.B. Chard, G.S. Allen. J.A.V.M.A. Vol. 197, No. 7, October, 1990.

Effect of Ventriculotomy on Post Infarction Ventricular Tachycardia in a Canine Model. G.B. Hunt, R.B. Chard, D.L. Ross. International Journal of Cardiology, 38 (1993) 73-90.

Optimal Approach to the Mitral Valve: Dissection of the Interatrial Groove. R.I. Larbalestier, R.B. Chard, L.H. Cohn. Annals of Thoracic Surgery 1992; 54: 1186-8.

Localised Supravalvar Aortic Stenosis: A New Technique for Repair. R.B. Chard, T.B. Cartmill. Annals of Thoracic Surgery. 1993;55:782-4.

Invited Comment: Surgical Difficulty in Localised Supravalvar Aortic Stenosis. Reply. Annals of Thoracic Surgery. 1993; 56; 1440.

Salvage of Infected Truncus Arteriosus Repair with Antibiotic Bonded Vascular Graft. B. French, R.B. Chard, G.F. Sholler, T.B. Cartmill. Annals of Thoracic Surgery 1994; 57;754-5.

Gelatin Resorcinol Formaldehyde Glue in Acute Aortic Dissections. I.A. Nicholson, R.B. Chard, G.R. Nunn. Asia Pacific J Thoracic Cardiovasc. Surg. 1995; 4(1).

Surgical Procedure for the Cure of Atrioventricular Junctional ("AV node") Reentrant Tachycardia: Anatomic and Electrophysiological Effects of Dissection of the Anterior Atrio-nodal Connections in a Canine Model. J Am Coll Cardiol 1994, September 24 (3) : 784-94.

Combined Coronary Artery Bypass Grafting and Carotid Endarterectomy. M. Vicaretti, J.P. Fletcher, A.J. Richardson, R. Allen, S. Hazelton, G.R. Nunn, D.C. Johnson, W. Meldrum-Hanna, R.B. Chard, P. Klineberg. Cardiovascular Surgery 5:3,266-270 1997.

PUBLICATIONS (cont):

Combined Coronary Artery Bypass Grafting and Abdominal Aortic Aneurysm Repair. M. Vicaretti, J.P. Fletcher, A. Richardson, R.B. Chard, P. Klineberg, I. Nicholson. Cardiovascular Surgery, June 1994 Vol. 2 No. 3 340-343.

Ventricular Assist Devices in Paediatric Cardiac Surgery. R.B. Chard, R. Costa, G.R. Nunn, T.B. Cartmill. Annals of Thoracic Surgery. 1995; 60:S 535-8.

Improved Intraoperative Assessment of Aortic Stentless Valves Using Transoesophageal echocardiography. Morris MJ, Chard RB, Meldrum-Hanna W, Paterson H. Br J Anaesth. 78(Supp 2):22 (1997)

Surgical Management of Complete Atrioventricular Septal Defect with Abnormal Right Ventricular Outflow Tract. Cartmill T, Yaku H, Nunn G, Chard R, Hawker R, Sholler G. Asia Pacific Heart Journal. 1997; 6(1).

Combined Coronary Artery Bypass Grafting and Abdominal Aortic Aneurysm Repair; An Update of the Westmead Experience. Vicaretti M, Fletcher J, Richardson A, Allen R, Hazelton S, Tomlinson P, Nunn G, Meldrum-Hanna W, Chard R, Paterson H, Klineberg P. The Aust. NZ. J Surg. 1997 67 Suppl. 1.

Establishment and First Audit of a New Perioperative Echocardiography Service. Morris MJ, Klineberg PL, Chard RB, Hanrahan V, Harrison K, Larcos G, Mudaliar Y, Meldrum-Hanna W, Paterson H, Shaw D. Asian Cardiovasc Thorac Ann 6:300-5 (1998)

Congenital Heart Surgery in Adults: An Australian Experience of 379 Cases. Kariappa SM, Assaad NN, Chard RB, Hughes CF, Celermajer DS. Asia Pacific Heart Journal 1998;7(1)

Tunnelling Versus Open Harvest Technique in Obtaining Venous Conduits for Coronary Bypass Surgery. Tran HM, Meldrum-Hanna W, Chard RB, Paterson HS. Eur J Cardiothorac Surg. 14:602-6 (1998)

Surgical Management of Complete Atrioventricular Septal Defect with Abnormal Right Ventricular Outflow Tract. Cartmill T, Yaku H, Nunn G, Chard R, Hawker R, Sholler G. Asia Pacific Heart Journal. 1997; 6(1).

Combined Coronary Artery Bypass Grafting and Abdominal Aortic Aneurysm Repair; An Update of the Westmead Experience. Vicaretti M, Fletcher J, Richardson A, Allen R, Hazelton S, Tomlinson P, Nunn G, Meldrum-Hanna W, Chard R, Paterson H, Klineberg P. The Aust. NZ. J Surg. 1997 67 Suppl. 1.

Establishment and First Audit of a New Perioperative Echocardiography Service. Morris MJ, Klineberg PL, Chard RB, Hanrahan V, Harrison K, Larcos G, Mudaliar Y, Meldrum-Hanna W, Paterson H, Shaw D. Asian Cardiovasc Thorac Ann 6:300-5 (1998)

Congenital Heart Surgery in Adults: An Australian Experience of 379 Cases. Kariappa SM, Assaad NN, Chard RB, Hughes CF, Celermajer DS. Asia Pacific Heart Journal 1998;7(1)

Tunnelling Versus Open Harvest Technique in Obtaining Venous Conduits for Coronary Bypass Surgery. Tran HM, Meldrum-Hanna W, Chard RB, Paterson HS. Eur J Cardiothorac Surg. 14:602-6 (1998)

PUBLICATIONS (cont):

Right ventricular dysfunction in congenitally corrected transposition of the great arteries. Tim S Hornung, Elizabeth J Bernard, David S Celermajer, Edgar Jaeggi, Robert B Howman-Giles, Richard B Chard, Richard E Hawker. American Journal of Cardiology Volume 84, Issue 9, Pages 1116-1119, 1 November 1999

Mechanism, localization and cure of atrial arrhythmias occurring after a new intraoperative endocardial radiofrequency ablation procedure for atrial fibrillation. Stuart P Thomas, Graham R Nunn, Ian A Nicholson, Arianwen Rees, Michael P J Daly, Richard B Chard, David L Ross. J. Am. Coll. Cardiol. 2000;35;442-450

Reoperation and Coarctation of the Aorta: The Need for Lifelong Surveillance. Manganas C, Illiopoulous P, Chard R, Nunn G. Annals of Thoracic Surgery. 2001;72:1222-1224

Use of the Medtronic Freestyle Bioprosthesis as a Right Ventricle to Pulmonary Artery Conduit. N Kang, D Andrews, GR Nunn, RB Chard
Annals of Thoracic Surgery 2001;71:S361-S364

Update; Congenital Supravalvar Aortic Stenosis
N Kang, GR Nunn, DR Andrews RB Chard. Annals of Thoracic Surgery 2001 72:661-662

Further Surgical Interventions Late After Repair of Coarctation of the Aorta – 30 Year Follow Up of Over 600 Patients – The Need for Lifelong Surveillance of the Aorta and Left Heart Structures. J Iliopolis; C Manganas; R B Chard; G R Nunn. Annals of Thoracic Surgery 2001;72:1222-1224

Epidural Anaesthesia for Cardiac Surgery: Effects on Tracheal Intubation Time and Length of Hospital Stay. M C Priestley; L Cope; R Halliwell; P Gibson; R B Chard; M Skinner; P L Klineberg. Anaesthesia and Analgesia, September 2001.

Repair of Distal Aortic Arch Aneurysm through a Left Thoracotomy using Deep Hypothermic Circulatory Arrest, Annals of Thoracic Surgery, August 2002. R B Chard; N Kang.

Comparison of epicardial and endocardial linear ablation using handheld probes. Stuart P Thomas, Duncan J.R. Guy, Anita C. Boyd, David L. Ross, Richard B. Chard. Ann Thorac Surg 2003;75:543-548

Mid-Term Results for Double Inlet Left Ventricle and Similar Morphologies: Timing of Damus-Kaye-Stansel. Andrew J B Clarke, Shingo Kasahara, David R Andrews, Stephen G Cooper, Ian A Nicholson, Richard B Chard, Graham R Nunn and David S Winlaw. Ann Thorac Surg 2004;78:650-657

Circulatory arrest for repair of postcoactation site aneurysm. Nicholas Kang, Andrew J B Clarke, Ian A Nicholson, Richard B Chard. Ann Thorac Surg 2004;77:2029-2033

Levosimendan for low cardiac output: a pediatric experience. Jonathan R Egan, Andrew J B Clarke, Stephen Williams, Andrew D Cole, Julian Ayer, Stephen Jacobe, Richard B Chard, David S Winlaw. (Affiliation: Pediatric Intensive Care Unit, Children’s Hospital at Westmead, Sydney, Australia). Journal of intensive care medicine (J Intensive Care Med) 2006 May-Jun Vol. 21 Issue 3 Pg. 183-7 ISSN: 0885-0666 (Print) United States. 16672640 (Publication Type: Journal Article)

PUBLICATIONS (cont):

Outcomes following surgery for congenital Heart Disease in low-birthweight infants. Dimmick S, Walker K, Badawi N, Halliday R, Cooper SG, Nicholson IA, Sherwood M, Chard RB, Hawker R, Lau KC, Jones O, Grant PW, Sholler G, Winlaw DS
Journal of Paediatrics and Child Health. 43(5): 370-5. 2007 May

Use of Sildenafil and nitric oxide in the management of hypoxaemia owing to pulmonary arteriovenous fistulas after total cavopulmonary connection.
Bhate S, Rossiter-Thornton M, Cooper SG, Gillis J, Cole AD, Sholler GF. Chard RB, Winlaw DS
Journal of Thoracic and Cardiovascular Surgery. 135(2):446-8, 2008 Feb

Two-dimensional and three-dimensional transthoracic echocardiography in surgical planning for right atrial metastatic melanoma. *European Journal of Echocardiography*. 9, 286-288. Chong, J., Richards, D., Chard, R., McKay, T., Thomas, L. (2008)

Recombinant activated factor V11 following paediatric cardiac surgery. *Journal of Intensive Care Medicine*. 24(2), 116-121. Kylasam, S., Mos, K., Fijtin, S., Webster, B., Chard, R., Egan, J. (2009)

The negative impact of Alagille syndrome on survival of infants with pulmonary atresia
Blue GM, Mah JM, Cole AD, Lal V, Wilson MJ, Chard RB, Sholler GF, Hawker RE, Sherwood M; Winlaw DS
Journal of Thoracic and Cardiovascular Surgery 133(4):6, 1094-6 Apr

Outcomes for Surgical Treatment of Atrial Fibrillation Using Cryoablation During Concomitant Cardiac Procedures. Rahman, N., Chard, R., Thomas, S. (2010), *Annals of Thoracic Surgery*. 90(5), 1523-1527.

Five-year Analysis of Operative Mortality and Neonatal Outcomes in Congenital Heart Disease. *Heart, lung & circulation.* 20(7), 460-7. Padley, J., Cole, A., Pye, V., Chard, R., Nicholson, I., Jacobe, S., Baines, D., Badawi, N., Walker, K., Scarfe, G., Leclair, K., Sholler, G., Winlaw, D. (2011)

Hoarseness and chest pain in Eisenmenger syndrome with pulmonary artery aneurysm. *Circulation.* 125(20), 2517-2519. Chang, M., Chard, R., Yiannikas, J. (2012)

Accepted for Publication, Annals of Thoracic Surgery

Tailored strategies for staged management of complex congenital cardiac lesions
Running head: Staging strategies for cardiac disease Oct 2013
Yishay Orr MBBS PhD FRACS   Richard B. Chard, BDS, MBBS, FRACS

REGULAR INVITED REVIEWER OF ARTICLES FOR PUBLICATION:

The Journal of Thoracic and Cardiovascular Surgery, USA

The Annals of Thoracic Surgery, USA

The Asian Annals of Cardiovascular and Thoracic Surgery, Singapore

The Asia Pacific Heart Journal, Australia

Heart, Lung and Circulation, Australia

PRESENTATIONS

The Management of Pulmonary Atresia with Intact Ventricular Septum. R. Hawker, G. Sholler, R.B. Chard, C. Whight, T.B. Cartmill. Annual Scientific Meeting, Cardiac Society of Australia & New Zealand. May, 1985.

The Management of Acute Ascending Aortic Dissection Using the USCI Intraluminal Prosthesis. R.B. Chard, G.R. Nunn, D.C. Johnson, T.B. Cartmill. Annual Scientific Meeting, New South Wales State Committee, Royal Australasian College of Surgeons, October, 1986; Quarterly Meeting, New South Wales Cardiothoracic Surgeons Association. April, 1986.

Myocardial Cryolesions Produced at Normothermia. G.B. Hunt, R.B. Chard, D.L. Ross, D.C. Johnson. Meeting, Cardiac Society of Australia & New Zealand. October, 1987.

Multiple Myocardial Cryolesions Produced on Normothermia Bypass: Early and Late Dimensions and Arrhythmogenicity. R. B. Chard, G.B. Hunt, D.C. Johnson, D.L. Ross. Inter-General Scientific Meeting, Thoracic Section, Royal Australasian College of Surgeons. Surfers Paradise, October, 1988.

Experience With a Canine Model of Chronic Ischaemia Ventricular Tachycardia. R.B. Chard, G.B. Hunt, D.L. Ross, D.C. Johnson. Quarterly Meeting, New South Wales Cardiothoracic Surgeons Association. November, 1988.

The Surgical Repair of Complete Atrio-ventricular Canal Defect in Children Under Two Years of Age. A.M. Diqer, R.B. Chard, G.R. Nunn, T.B. Cartmill. General Scientific Meeting, Royal Australasian College of Surgeons. Melbourne, May, 1989.

PRESENTATIONS (cont):

The Results of Staged Repair of Interrupted Aortic Arch: 1983-1988. R.B. Chard, A.M. Diqer, T.B. Cartmill, G.R. Nunn. General Scientific Meeting, Royal Australasian College of Surgeons. Melbourne, May, 1989.

The Optimal and Universal Approach to the Mitral Valve: Dissection of the Interatrial Groove: (Waterston's Plane). R.J. Larbalestier, L.H. Cohn, R.B. Chard. Dept. Cardiac Surgery, Brigham & Women's Hospital, Harvard Medical School, Boston, MA. USA. Cardiac Society of Australia & New Zealand. Perth, August, 1991.

Anatomical and Electrophysiological Effects of Surgery for Atrioventricular Junctional Reentrant Tachycardia. M.A. McGuire, M.C. Robotin, D.C. Johnson, J.P. Bourke, A.S. Yip, R.B. Chard, P. Grant, B.I. Dewsnap, D.A. Richards, J.B. Uther, D.L. Ross. Australian and New Zealand Journal of Medicine 1991; Supplement 2 (21) 4: 546.

Congenital Supravalvar Aortic Stenosis: A New Technique for Repair. Castaneda Society Meeting. Boston Children's Hospital, Boston, MA. USA. May 1992. Inter-General Scientific Meeting. Royal Australasian College of Surgeons, Southport, Queensland. October, 1992.

Bi-directional Cardiopulmonary Anastomosis in the Palliation of Single Ventricle. R.H. Hawker, R.B. Chard, H.D. Bedi. International Congress of Paediatric Cardiology. Kuala Lumpur. May, 1992.

Improved Results in Surgical Correction of Tetralogy of Fallot with Complete Atrioventricular Canal Defect. R.B. Chard, G.R. Nunn, T.B. Cartmill. Presented at the World Congress of Paediatric Cardiology and Cardiac Surgery. Paris. 21st to 25th of June, 1993.

Bi-directional Glenn Shunts in the Palliation of Cyanotic Congenital Heart Disease. H.S. Bedi, R.E. Hawker, R.B. Chard, G.R. Nunn, T.B. Cartmill. Presented at the World Congress of Paediatric Cardiology and Cardiac Surgery. Paris, 21st to 25th of June, 1993.
Combined Coronary Artery Bypass Grafting and Abdominal Aortic Aneurysm Repair. M. Vicaretti, J.P. Fletcher, P. Klineberg, A. Richardson, R.B. Chard, I. Nicholson.

Presented at:

- General Scientific Meeting of the Royal Australasian College of Surgeons. Adelaide. May, 1993.

- International Congress of Vascular Surgery. Lisbon, Portugal. September, 1993.

- Inter-General Scientific Meeting of the Royal Australasian College of Surgeons. Southport, Queensland. November, 1993.

- Annual Scientific Meeting of the Australian and New Zealand College of Anaesthetists. Launceston. May, 1994.

PRESENTATIONS (cont):

Ventricular Assist Devices in Paediatric Cardiac Surgery. R.B. Chard, R. Costa, G.R. Nunn, T.B. Cartmill. Society for Paediatric Cardiovascular Surgery, Boston USA 20 April, 1995.

Experience with the Telectronics Subpectoral AICD. B Mahon, H Paterson, R Chard, W Meldrum-Hanna, G Nunn. The Annual Scientific Meeting RACS 1995.

Acute Aortic Transection: Diagnosis and Management at Westmead Hospital Over Ten Years. P. Laniewski, R.B. Chard, G.R. Nunn, W. Meldrum-Hanna. Presented at Inter GSM Cardiothoracic Surgeons. Noosa, Queensland. October, 1996.

Adult Congenital Heart Disease: Surgical Management of 356 Patients Over Fifteen Years at Westmead and Royal Prince Alfred Hospitals. S. Kalliappin, D. Celermajer, R.B. Chard, T.B. Cartmill, G.R. Nunn, D.C. Johnson. Presented at the Cardiac Society of Australia and New Zealand. May, 1996.

Evolution of Surgical Techniques for Implanting the Medtronic Freestyle Valve: DTM Lai, RB Chard, HS Saw, HS Paterson, W Meldrum-Hanna, GR Nunn. Department of Cardiothoracic Surgery, Westmead Hospital, Sydney Australia. The 7th Annual Meeting of The Asian Society for Cardiovascular Surgery May 28 – June 1 1999, Singapore

Early Results of Extracardiac Fontan Procedure: DTM Lai, RB Chard, GR Nunn, SG Cooper, KC Lau, RE Hawker, GF Sholler, TB Cartmill. Adolf Basser Cardiac Institute, Royal Alexandra Hospital for Children, Sydney, Australia.

- The 7th Annual Meeting of The Asian Society for Cardiovascular Surgery, May 28 – June 1, 1999, Singapore.
- Annual Scientific Congress RACS Auckland NZ. May 1999.

Use of The Medtronic Freestyle Valve in the Paediatric Population: DTM Lai, RB Chard, GR Nunn. Adolf Basser Institute of Cardiology, Royal Alexandra Hospital for Children, Sydney, Australia. The 7th Annual Meeting of The Asian Society for Cardiovascular Surgery, May 28 – June 1, 1999. Singapore

Commissuroplasty: A Method of Valve Repair for Mitral Endocarditis: DTM Lai, RB Chard. Department of Cardiothoracic Surgery, Westmead Hospital, Sydney, Australia. The 7th Annual Meeting of The Asian Society for Cardiovascular Surgery, May 28 – June 1, 1999, Singapore.

Experience with the Telectronics Sub-Pectoral AICD. Mahon B, Paterson HS, Chard RB, Meldrum-Hanna W, Nunn GR. Royal Australasian College of Surgeons Annual Scientific Meeting 1996

Tunnelling Versus Open Harvest Technique in Obtaining Venous Conduits for Coronary Bypass Surgery. Tran HM, Paterson HS, Chard RB, Meldrum-Hanna W. 13th Biennial Asian Congress on Thoracic and Cardiovascular Surgery, Sydney 1997. 44th Annual Conference of Indian Association of Cardiovascular Surgeons 1998.

Early and Late Results of Post-Infarction Ventricular Septal Rupture. Sankar M, Pang K, Paterson HS, Chard RB, Nunn GR, Meldrum-Hanna W. 13th Biennial Asian Congress on Thoracic and Cardiovascular Surgery, Sydney, 1997.

PRESENTATIONS (cont):

Strategies for Improved Surgical Outcome – Extra Cardiac Conduit Fontan. RB Chard at Innovation and Achievement – A Cardiac Surgical Meeting to mark the Retirement of Professor Timothy B Cartmill. Royal Alexandra Hospital for Children, Westmead, Sydney. 1998

Experience with the Telectronics Sub-Pectoral AICD. Mahon B, Paterson HS, Chard RB, Meldrum-Hanna W, Nunn GR. Royal Australasian College of Surgeons Annual Scientific Meeting 1996

Tunnelling Versus Open Harvest Technique in Obtaining Venous Conduits for Coronary Bypass Surgery. Tran HM, Paterson HS, Chard RB, Meldrum-Hanna W. 13th Biennial Asian Congress on Thoracic and Cardiovascular Surgery, Sydney 1997. 44th Annual Conference of Indian Association of Cardiovascular Surgeons 1998.
Early and Late Results of Post-Infarction Ventricular Septal Rupture. Sankar M, Pang K, Paterson HS, Chard RB, Nunn GR, Meldrum-Hanna W. 13th Biennial Asian Congress on Thoracic and Cardiovascular Surgery, Sydney, 1997.

Strategies for Improved Surgical Outcome – Extra Cardiac Conduit Fontan. RB Chard at Innovation and Achievement – A Cardiac Surgical Meeting to mark the Retirement of Professor Timothy B Cartmill. Royal Alexandra Hospital for Children, Westmead, Sydney. 1998

Perioperative Transoesophageal Echocardiography – Advanced Course. ANZCA Sydney 8 April 2001. Adult Congenital Heart Disease.

Symposium on Atrial Fibrillation. 13th ASEAN Congress of Cardiology. June 23 – 26, 2000. Singapore.

When Do I Replace the Asymptomatic Aortic Valve? 13th ASEAN Congress of Cardiology. June 23 – 26, 2000. Singapore.

Circulatory Arrest for the Repair of Distal Arch Aneurysm. N Kang, I A Nicholson, R B Chard. Westmead Hospital, NSW, Australia. Inter General Scientific Meeting RACS Noosa, Queensland. October 2001

Long-Term Follow Up After the Star Procedure: An Intraoperative Radiofrequency Ablation Procedure for Atrial Fibrillation. AC Boyd, DJ Guy, SP Thomas, I Nicholson, G Nunn, RB Chard, DL Ross. 49th Annual Scientific Meeting Cardiac Society of Australia and New Zealand. Auckland, New Zealand 5 – 8 August, 2001.

Posterior Left Atrial Floor-Coronary Sinus are Critical Sites for Left Atrial Flutter after Attempts at Curative Surgery for Atrial Fibrillation Using Radiofrequency Energy. DJ Guy, SP Thomas, AC Boyd, I Nicholson, G Nunn, RB Chard, DL Ross. 49th Annual Scientific Meeting Cardiac Society of Australia and New Zealand. Auckland, New Zealand 5 – 8 August, 2001.

PRESENTATIONS (cont):

Staged Palliation of Patients with Single Ventricle Pathology and Arch Obstruction without Circulatory Arrest – Focus on the Timing of Damus-Kaye-Stansel (DKS) Connection. D. Winlaw, D. Andrews, R. Chard, I. Nicholson, S. Cooper, K. C. Lau, R. Hawker, G. Sholler, G. R. Nunn. 49th Annual Scientific Meeting Cardiac Society of Australia and New Zealand. Auckland, New Zealand 5 – 8 August, 2001.

Star Procedure – Surgical Use of Radiofrequency Ablation for the Cure of Atrial Fibrillation. RB Chard, IA Nicholson, G Nunn, DJ Guy, SP Thomas, AC Boyd, DL

Ross. 49th Annual Scientific Meeting Cardiac Society of Australia and New Zealand. Auckland, New Zealand 5 – 8 August, 2001.

Direct Surgery for Atrial Fibrillation – Evolution. Authors: R B Chard, I A Nicholson, S J Thomas. Presented at the General Scientific Meeting of the Royal Australasian College of Surgeons, Brisbane; May 2003.

Surgery of the Late Complications of Repaired Coarctation of the Aorta. Author: R B Chard. Presented at the General Scientific Meeting of The Royal Australasian College of Surgeons, Brisbane, May 2003.

The Surgical Management of Adult Patients with Ebstein's Anomaly. Author: R B Chard. Presented at the General Scientific Meeting of The Royal Australasian College of Surgeons, Brisbane, May 2003.

Peri-valvar Aortic Stenosis and Left Ventricular Hypertrophy (LVH) vs Hypertrophic Obstructive Cardiomyopathy (HOCM): Pitfalls in Diagnosis. C.Ayoub, R. Chard, D. Brieger, J. Yiannikas, Cardiac Society of Australia and New Zealand ASM 2013

Surgical Management of Late Complications of Coarctation of the Aorta. Invited presentation Techno Practicum Meeting, RACS, Sydney March 2014

INVITED SPEAKER:

19 – 21 March 2010	Tongariro Cardiac Surgery Meeting, Rotorua New Zealand Pulmonary Valve Replacement – Technique and Indications Atrial Fibrillation Surgery with Cryocath Technique and Wetlabs
28 April 2007	Valvular Disease – Clinical Decision Making Master Class in Cardiology Sydney Convention Centre
2 – 5 Nov 2006	4th Mulu Rafflesia Heart Valve Symposium – Chiang Rai, Thailand Aortic Valve Endocarditis Techniques of Aortic Root Enlargement Selection of Aortic Valve Repair and Replacement Techniques Wetlab Demonstrations
23 Sep 2006	Cardiology Retreat – Sanofi-Winthrop Complex Aortic Surgery

INVITED SPEAKER (cont):

March 2005	Mitral Valve Endocarditis – Surgical Aspects Meeting in Honour of Professor Lawrence H Cohn, Harvard Medical School held in Sydney, March 2005.
June 2005	What's New with Valve Disease? Presented at The Cardiology Retreat, Lilianfels, Blue Mountains, NSW

	Atrial Fibrillation Surgery – Who and When? Presented at The Cardiology Retreat, Lilianfels, Blue Mountains, NSW
May 2005	The Surgical Management of Adults with Congenital Heart Disease. Presented at the Cardiology Symposium, Sydney Adventist Hospital.
19 – 21 Sep 2002	2nd Five-Continent Symposium on Cardiovascular Medicine. Beijing, Peoples Republic of China. "Invited Topic": Prospect and Evaluation of Bioprosthetic Valve and Mechanical Valve
25 Jun – 1 Jul 2002	Stentless Aortic Valve Replacement. 2nd Mulu Rafflesai Heart Valve Symposium – The Aortic Valve. Kuching, Sarawak, Malaysia The Pulmonary Autograft (Ross Procedure) – Personal Experience. 2nd Mulu Rafflesai Heart Valve Symposium – The Aortic Valve. Kuching, Sarawak, Malaysia
12 – 13 May 2002	Annual Scientific Congress. Adelaide. Freestyle Valve Workshop
2 June 2001	*New Techniques in Aortic Valve Replacement. ASEANZ Conference,* Melbourne, Australia.
7 April 2001	Congenital Heart Disease in the Adult Patient Comprehensive Review of Peri-operative Transoesophageal Echocardiography. Westmead Anaesthetic Society, Sydney Australia
29 February 2001	Intra-operative Radiofrequency Lesions for Cure of Atrial Fibrillation Medtronic Cardiology and Cardiac Surgery Symposium, Sapporo Japan
23 - 26 June 2000	Invited speaker at the 13th Asean Congress of Cardiology, Singapore - Surgical Management of Atrial Fibrillation - When Do I Replace the Asymptomatic Aortic Valve
2 December 1999	Invited speaker "Newer Surgical Approaches to the Aortic Valve" – Pulmonary Autograft and "David Operation" to Adult Congenital Heart Disease Cardiology Group at The Intercontinental Hotel, Sydney Australia

INVITED SPEAKER (cont):

11 - 12 Nov 1999	Invited Speaker introducing Stentless Valve technology (Medtronic Freestyle Valve) to Surgeons and Cardiologists in The People's Republic of China. - Lectures and Wetlab Workshop, Sheraton Hotel, Xian, China
12 – 19 Sept 1999	Course Convener at the Dharma Vira Heart Centre

	Sir Ganga Ram Hospital, Delhi, India Two day Symposium on Stentless Aortic Bioprostheses (Medtronic Freestyle Valve) introducing the surgical techniques to Surgeons and Cardiologists in India - Lectures, Wetlab Workshop and Surgical Cases (cont) o The Bombay Hospital, Mumbai, India o The Lokmanya Tilak Municipal Medical College Hospital, Sion, Mumbai, India One Day Symposium on Stentless Aortic Valves - Holiday Inn, Krishna, Hyderabad, India, Wetlab and Lectures - Demonstration of Surgical Cases o The Nizam's Institute of Medical Sciences Hospital Hyderabad, India
July 1999	Invited speaker on clinical experience and surgical techniques using Stentless Aortic Bioprostheses (Medtronic Meeting), Peppers Guest House, Hunter Valley, NSW - Wetlab Workshop Demonstration
28 May 1999	Invited speaker at The 7th Annual Meeting of The Asian Society for Cardiovascular Surgery Pre-Congress Stentless Valve Workshop at Gleneagles Hospital, Singapore - Conducted Wetlab and Panel Discussions in the management of Aortic Valve and Root Pathology using new generation bioprosthesis
November 1998	Conducted Freestyle Valve Users Group Meeting associated with Inter GSM of Cardiothoracic Section of RACS
23 – 31 July 1998	Invited guest by Singapore Cardiac Society – Introduction of Stentless Valve Technology to the Asian Region with invited delegates from Singapore, Malaysia, Indonesia, Korea, Taiwan, Vietnam, India and Thailand - Lectures and Wetlab Workshop at Mount Elizabeth Hospital, Singapore - Lecture at Singapore General Hospital - Demonstration Surgical Cases at o Mount Elizabeth Hospital o National University Hospital of Singapore o Kuching, East Malaysia

INVITED SPEAKER (cont):

4 December 1997	Invited guest of the Singapore Cardiac Society Conducted Course on Implantation of Stentless Aortic Bioprostheses (Medtronic Freestyle)

	- Lectures, Wetlab Workshop and Demonstration Surgical Cases at Gleneagles Hospital, Singapore
12 April 1997	Stentless Valve Educational Workshop at The Sheraton on the Park Hotel, Sydney, Australia. Sponsored by Medtronics Australia Limited.

ADMINISTRATIVE ACTIVITIES:

Executive Australasian Society of Cardiac and Thoracic Surgeons – immediate past president from October 2008 to November 2010

President of the Australasian Society of Cardiac and Thoracic Surgeons, from November 2005 to October 2008

Vice President of the Australasian Society of Cardiac and Thoracic Surgeons, November 2003 to November 2005

Deputy Director, Adolph Basser Cardiac Institute, The Children's Hospital at Westmead, from August 2005

Member of The Medical Staff Council Executive, Westmead Hospital. 1996 -1999

National Representative of the Australian Society of Cardiac and Thoracic Surgeons on the Medicare Schedule Relative Value Study Review Task Force. 1998, 1999, 2000, 2001

Head of Department of Cardiothoracic Surgery, Westmead Hospital. 1997 – 2006

Member of the Data Analysis Committee: National Cardiothoracic Surgery Database Australian Society of Cardiac and Thoracic Surgeons 1999 – 2000

Australian Representative for Clinical Evaluation Section for International Standard ISO 5840 Cardiac Valves.

ROYAL AUSTRALIAN COLLEGE OF SURGEONS APPOINTMENTS:

Examiner in Cardiothoracic Surgery from 2001 to current

Member of the National Board of Cardiothoracic Surgery from Nov 2005 until Oct 2008

Supervisor of Cardiothoracic Surgical Training – The Children's Hospital at Westmead, Sydney

Co-ordinator of Advanced Training in Cardiothoracic Surgery for NSW

President, Australasian Society of Cardiac and Thoracic Surgeons 2006, 2007, 2008 – The Society incorporates the College of Surgeons Section of Cardiothoracic Surgery (one of the nine Specialist Societies). Established permanent office with full time Executive Officer in Sydney (moved from Melbourne). Initiated modernisation of Society Constitution.

PROFESSIONAL ACTIVITIES:

Member of The Society of Paediatric Cardiovascular Surgeons, Aldo-Castaneda based at the Boston Children's Hospital, Harvard Medical School, Boston, Massachusetts, USA.

Member of The Cardiac Society of Australia and New Zealand.

Member of The Australasian Society of Cardiac and Thoracic Surgeons.

Member of The Association of Thoracic and Cardiovascular Surgeons of Asia.

Member of The Australian Medical Association.

ADVISORY POSITION WITH GOVERNMENT

Member of the Panel of Experts with the Health Care Complaints Commission of NSW since April 2004.

INTERESTS:

Congenital heart disease in adults and children.

The surgical management of arrhythmias, particularly atrial fibrillation and the associated problems with valvular and congenital heart disease.

The surgical management of aortic valve and root disease, particularly the avoidance of anticoagulation with strategies such as stentless bioprostheses, homografts and pulmonary autografts.

The surgical management of structural heart disease, particularly tricuspid and mitral valve reconstruction and the development of new techniques and devices.

The management of thoracic aortic disease.

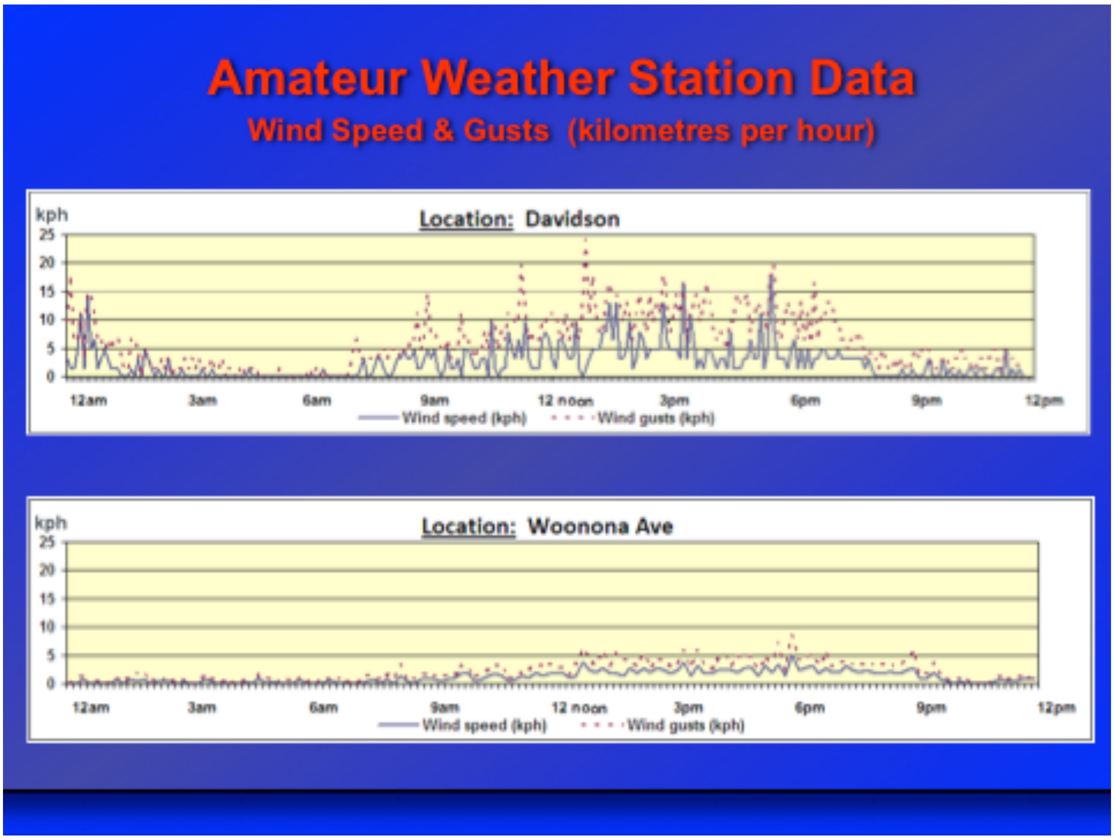
The combined management of extra thoracic vascular disease. Such as Thoraco-Abdominal Aneurysms

The surgical management of the inferior vena cava in association with abdominal surgeons.

Surgical management of chest wall deformities.

Appendix 2

Representative Graphs are presented. The full data set is available.



Appendix 3

Medical Evidence regarding aderse health effects of air pollution from tunnel portal and stack placement in residential suburb

There exists an overwhelming amount of medical evidence on the adverse health effects of air pollution, and as such, we have selected some of the most relevant and significant articles to present our concerns.

A recent study released in The Lancet, one of the most prestigious international medical journals, reported the adverse health effects in 367,251 people with long term exposure to air pollution. These people were followed for an average length of 13 years, during which 29,076 died.
The study found that there was a significantly increased risk of death in the participants exposed to particle matter. This risk was even found in individuals whose exposure was within concentration ranges well below the current European standard (1).

Another major study conducted by the American Cancer Society enrolled approximately 1.2 million adults in 1982 for an ongoing prospective mortality study.
Fine particulate and sulfur oxide--related pollution were associated with an increased risk of lung cancer and death from heart and lung diseases. Each 10-microg/m increase in fine particulate air pollution was associated with approximately a 4%, 6%, and 8% increased risk of all-cause, cardiopulmonary, and lung cancer mortality, respectively (2).

A WHO press release in October 2012 stated that after thoroughly reviewing the latest available scientific literature, the world's leading experts concluded that there is sufficient evidence that exposure to outdoor air pollution causes lung cancer. They also noted a positive association with an increased risk of bladder cancer (3).
The most recent WHO data indicates that in 2010, 223,000 deaths from lung cancer resulted from air pollution (4).

Medical evidence is overwhelmingly clear that long term exposure to air pollution increases death rates.

A local study by Cowie et al looking at health effects of the Lane Cove tunnel in Sydney, NSW studied participants before and after the opening of the tunnel. The study found that residents living within 650m of the tunnel ventilation stack reported more upper and lower respiratory symptoms and had lower lung volumes in the first 2 years after the tunnel opened (5). There was also, unfortunately, no consistent evidence of improvement in respiratory health in residents living along the bypassed main road, despite a reduction in traffic from 90,000 to 45,000 vehicles per day.

A recent study using data from numerous international studies looked at dose response relationships for PM 2.5 (6). The results suggested a relatively steep exposure–response function at very low levels of exposure to PM 2.5At very low levels of exposure excess mortality risks are similar for lung cancer and CVD mortality. A relative risk of 1.3 was found for cardiopulmonary disease secondary to PM2.5 levels of 24.5 micrograms/m3.

Current air quality modelling guidelines consider a level of less than 50 micrograms/m3 to be safe. This is equivalent to the risks associated with exposures to moderate to high levels of second hand cigarette smoke.
A potential explanation regarding the steep exposure–response for CVD mortality at low levels of exposure and the levelling off at high exposures is a saturation phenomenon whereby relatively low levels of exposure are capable of activating relevant biological pathways.
There is substantial and growing evidence that long-term exposures to PM2.5 from cigarette smoke, ambient air pollution, or both affect multiple physiologic pathways. Even low levels of exposure to PM 2.5 from second hand smoke and ambient air pollution have been associated with pulmonary and systemic oxidative stress, inflammatory vascular dysfunction, increased platelet activation and blood viscosity, atherosclerosis, IHD, and altered cardiac autonomic function.

In eight different communities in Switzerland, lung function in adults was negatively associated with PM10, nitrogen dioxide, and sulphur dioxide all of which are pollutants arising from vehicle exhausts (7). The pollutants also increased symptoms of bronchitis (8). In children from ten Swiss communities, the same pollutants were found to be associated with symptoms of bronchitis (9).

In children living in 24 communities in Canada and the USA, significant associations were reported between exposure to fine particles and lung function and symptoms of bronchitis (10-12).

Exposure to particulate pollution is associated with reduced lung function growth in children (13), and even children relocating from high to low pollution areas (or vice versa) were shown to experience changes in lung function growth that mirrored changes in exposure to particulate matter (14).

Gauderman et al followed school children from the age of 10 for 8 years to observe the effects of air pollution on lung development. He showed that lung development is significantly affected through reductions in FVC, FEV1 and MMEF, as would be expected of the children had been exposed to maternal smoking(15).

Studies from across the world have consistently shown that both short- and long-term exposures to particulate matter are associated with a host of cardiovascular diseases, including heart attack, heart failure, abnormalities of heart rhythm, strokes and increased death from cardiovascular causes (16).

Evidence from cellular/toxicological experiments, controlled animal and human exposures and human panel studies have demonstrated several mechanisms by which particle exposure may both trigger acute events as well as prompt the chronic development of cardiovascular diseases. Particulate matter inhaled into the pulmonary tree may instigate remote cardiovascular health effects via three general pathways: instigation of systemic inflammation and/or oxidative stress, alterations in autonomic balance, and potentially by direct actions upon the vasculature of particle constituents capable of reaching the systemic circulation. In turn, these responses have been shown to trigger acute arterial vasoconstriction, endothelial dysfunction, arrhythmias and pro-coagulant/thrombotic actions (17).

In both short-term and long-term studies, air pollution has an effect on cardiac deaths and hospital admissions in addition to respiratory effects. Plasma viscosity, as well as heart rate and concentrations of C-reactive protein, were increased (18-20), all of which can contribute to an increased risk of cardiovascular events.
Studies in Boston, MA, USA, showed that nitrogen dioxide and PM2·5 were associated with life-threatening arrhythmia leading to therapeutic interventions by an implanted cardioverter defibrillator (21), and that PM2·5 concentrations were higher
in the hours and days before onset of myocardial infarction in a large group of patients (22).

Hoffman et al found that long-term residential exposure to high traffic is associated with the degree of coronary atherosclerosis. Participants living within 50m of a busy road had an odds ratio of 1.63 for developing coronary artery calcification compared with a control group (23).
Older subjects (greater than or equal to 60 years of age) and women were found by Künzli et al, to have a 15.7% stronger association between particle matter exposure and carotid intimal thickening, ie the risk of stroke. (24)

In a study of 1,705 Boston-area patients admitted to hospital with strokes, the risk of stroke was increased by 34 percent on days when traffic pollutants were classified by federal regulators as "moderate," which is defined as a minimal danger to health. These results suggest that exposure to $PM_{2.5}$ concentration generally considered safe by the US EPA increase the risk of stroke onset within hours of exposure (25).

One of the most commonly measured chemicals arising from car emissions is nitrogen dioxide. Associations between natural-cause and respiratory mortality have been found to be statistically significant for NO_2 and black smoke (26).

Giulia et al studied the effects of long-term exposure to both fine particulate matter (≤ 2.5 µm; $PM_{2.5}$) and nitrogen dioxide (NO_2) on risk of death (27). This large study of over 1.2 million subjects strongly supports that long-term exposure to NO_2 and $PM_{2.5}$ increases risk of death, especially from cardiovascular causes.

Traffic emissions contain substances that can be measured and that cannot be measured or are accounted for in standard pollution modelling.

Dozens of volatile and semivolatile organic compounds can be detected in vehicle exhaust, along with numerous metals and oxides of sulfur, nitrogen, and carbon. While the adverse effects of these chemicals have been extensively studied surrounding open roadways, the hazards to local residents and commuters resulting from the presence of tunnel emission chemicals are less well known (28).

It is the unknown substances that potentially pose a great health risk in themselves.

The recognition that ultrafine particles (mass median diameter <0·1 micrometer) are more toxic when inhaled than PM10 suggests that their ability to be absorbed into tissues and the circulation, and their greatly increased surface area, might be important factors in determining cardiopulmonary toxicity (29). These particles are not currently modelled for in air quality impact evaluations, yet they may pose a great health risk.

In the local study by Cowie et al, which looked at the health impacts on locals living near the Lane Cove Tunnel Stack, the study found that there was an increase in the number of adverse health effects among residents living around the stack. It also went on to suggest that these effects may have occurred due to unmeasured pollutants. (5)

Diesel particulates and ozone have been shown to increase the synthesis of the allergic antibody IgE in animals (30), and human beings (31), which would increase sensitisation to common allergens (32). By interacting together and with other environmental factors, particulates and gaseous air pollutants can have long-term effects on allergic individuals.

Short term and long term health impacts have been well studied internationally. The findings of increased airway inflammation and symptoms in subjects after only 2 hours exposure at a heavily trafficked location indicate that even short-term exposures to traffic-related air pollution has adverse health effects (33).

Fischer et al found that outdoor pollutant levels correlated with those measured indoors in 36 houses exposed to air traffic pollution. A substantially larger contrast (about a factor two) was found for outdoor concentration of the particulate components BaP, total polycyclic aromatic hydrocarbons, absorption coefficient (`soot') and the gas-phase components benzene and total volatile organic compounds. The contrasts for these pollutants were substantially larger than the estimated contrast in average NO_2 (22%). (34)

Pregnant women exposed to sulphur dioxide from traffic pollution are more likely to give birth to low birth-weight babies. (35)
Exposure to traffic-related air pollution, nitrogen dioxide, $PM_{2.5}$, and PM_{10} during pregnancy and during the first year of life is associated with autism (36).

Higher levels of long-term exposure to both $PM_{2.5-10}$ and $PM_{2.5}$ have been found to carry an association with significantly faster cognitive decline, i.e. can accelerate the development of dementia. (37).

A study of 137 Brisbane school children at 25 schools by Mazaheri (38) analyzing alveolar concentrations of ultrafine particles concluded that children's exposure during school hours was more strongly influenced by urban background particles than

traffic near the school. The study also found that the highest dose intensity occurred during outdoor times at school and when children were more active.
There are large numbers of children in the immediate area surrounding the stack, attending schools.
These background levels of ultrafine particles could be significantly affected by an unfiltered exhaust stack within close proximity of multiple schools.

Buonanno et al (39) studied particle concentrations at schools in several different urban locations. In general, children attend school during day time hours on weekdays when traffic intensity is high.
It has been proven, that outdoor pollutants are able to penetrate inside the buildings, influencing indoor concentration levels on the basis of traffic, meteo-climatic and urban characteristics with regard to airborne particles. Indeed, indoor pollutants were found to explain a number of health effects even at concentrations significantly lower than outdoors.

In a separate study, Buoanno et al (40) looks at the health effects of dose related particle exposure on children. Significant differences were found for asthmatics, children with allergic rhinitis and sensitive to allergens compared to healthy subjects. At present, it is not known which particle size, morphology or chemical components are most strongly related to the negative effects on human health and further research in this field is required.
These effects have received more attention in relation to children, because they inhale a higher dose of airborne particles relative to lung size when compared with adults. Nevertheless, the major difficulty facing epidemiological studies of ultra fine particles is mostly related to the estimation of individual exposure levels. The most common current approach assumes that each person in a given region has the same exposure level, which is often obtained from a few air quality monitors and reflects the mean concentrations in the entire urban area or community.
This approach could lead to significant errors in the estimation of individual exposure to air pollutants because the actual exposure is strongly related to the time activity of the individuals. Furthermore, the use of mean air pollution levels smoothes peak air pollution concentrations and thus, may result in unreliable estimates of exposure (Manigrasso et al., 2013).

Furthermore, several authors have suggested that short term fluctuations in aerosol concentrations of particles increase morbidity and mortality (Brugge et al., 2007; Strak et al.,)
A recent study by the OECD has found that Australia is amongst only 14 out of 34 developed countries in the world where deaths from air pollution have increased in the past 5 years. In between 2005 and 2010, the number of deaths from air pollution in Australia increased by 68 per cent. Evidence suggested that road transport was probably responsible for about half of all deaths from air pollution. The economic cost for Australia was about $5.8 billion in 2010, up from $2.9 billion just five years earlier (41).

References:

1. Beelen R. Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project . Lancet 2014; 383: 785–95

2. Pope 3rd CA. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA 2002; 287: 1132–41.

3. WHO PRESS RELEASE N° 221 17 October 2013 IARC: Outdoor air pollution a leading environmental cause of cancer deaths.

4. Straif K. IARC Scientific Publication No. 161: Air Pollution and Cancer IARC Scientific Publication No. 161
Air Pollution and Cancer eISBN 978-92-832-2161-6

5. Cowie. Respiratory Health before and after the Opening of a Road Traffic Tunnel: A Planned Evaluation PLoS ONE 7(11): e48921. doi:10.1371/journal.pone.0048921

6. Pope C. Lung Cancer and Cardiovascular Disease Mortality Associated with Ambient Air Pollution and Cigarette Smoke: Shape of the Exposure–Response Relationships. Environmental Health Perspectives| November 2011 number 11 volume 119 III

7. Ackermann-Liebrich U. Lung function and long term exposure to air pollutants in Switzerland. Study on Air Pollution and Lung Diseases in Adults (SAPALDIA) Team. *Am J Respir Crit Care Med* 1997; 155: 122–29.

8. Zemp E. Long-term ambient air pollution and respiratory symptoms in adults (SAPALDIA study). *Am J Respir Crit Care Med* 1999; 159: 1257–66.

9. Braun-Fahrlander C. Respiratory health and long-term exposure to air pollutants in Swiss schoolchildren. Am J Respir Crit Care Med 1997; 155: 1042–49.

10. Dockery DW, Cunningham J, Damokosh AI, et al. Health effects of acid aerosols on North American children: respiratory symptoms. *Environ Health Perspect* 1996; 104: 500–05.

11. Raizenne M, Neas LM, Damokosh AI, et al. Health effects of acid aerosols on North American children: pulmonary function. *Environ Health Perspect* 1996; 104: 506–14.

12. Spengler JD, Koutrakis P, Dockery DW, Raizenne M, Speizer FE. Health effects of acid aerosols on North American children: air pollution exposures. *Environ Health Perspect* 1996; 104: 492–99.

13. Gauderman WJ. Association between air pollution and lung function growth in southern California children. *Am J Respir Crit Care Med* 2000; 162: 1383–90.

14. Avol EL. Respiratory effects of relocating to areas of differing air pollution levels. *Am J Respir Crit Care Med* 2001; 164: 2067–72.

15.. Gauderman J. The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age. N Engl J Med 2004; 351:1057-1067

16. Brook R. Cardiovascular effects of air pollution. Clinical Science (2008) 115, (175–187)

17. Nemmar A Diesel exhaust particles in lung acutely enhance experimental peripheral thrombosis. Circulation. 2003 Mar 4;107(8):1202-8.

18. Peters A. Increased plasma viscosity during an air pollution episode: a link to mortality? *Lancet* 1997; 349: 1582–87.

19. Peters A. Particulate air pollution is associated with an acute phase response in men; results from the MONICA-Augsburg Study. *Eur Heart J* 2001; 22: 1198–204.

20. Peters A. Increases in heart rate during an air pollution episode. *Am J Epidemiol* 1999; 150: 1094–98.

21. Peters A. Air pollution and incidence of cardiac arrhythmia. Epidemiology 2000; 11: 11–17.

22. Peters A. Increased particulate air pollution and the triggering of myocardial infarction. Circulation 2001; 103: 2810–15.

23 . Hoffman B. Residential Exposure to Traffic Is Associated With Coronary Atherosclerosis. Cirulation 2007 Jul 31;116(5):489-96.

24. Künzli N Ambient air pollution and atherosclerosis in Los Angeles. Environ Health Perspect. 2005 Feb;113(2):201-6.

25. Wellenius G. Ambient Air Pollution and the Risk of Acute Ischemic Stroke. Arch Intern Med. 2012;172(3):229-234. doi:10.1001/archinternmed.2011.732.

26. Beelen R. Long-Term Effects of Traffic-Related Air Pollution on Mortality in a Dutch Cohort (NLCS-AIR Study). Environ Health Perspect. Feb 2008; 116(2): 196–202.

27. Giulia. Long-Term Exposure to Urban Air Pollution and Mortality in a Cohort of More than a Million Adults in Rome. Environ Health Perspect; DOI:10.1289/ehp.1205862

28. Kuykendall J. Chemicals present in automobile traffic tunnels and the possible community health hazards: A review of the literature August 2009, Inhalation Toxicology Vol. 21, No. 9 , Pages 747-792

29. Brown DM. Sizedependent proinflammatory effects of ultrafine polystyrene particles: a role for surface area and oxidative stress in the enhanced activity of ultrafines. Toxicol Appl Pharm 2001; 175: 191–99.

30. Hashimoto K. Exposure to diesel exhaust exacerbates allergen-induced airway responses in guinea pigs. AmJ Respir Crit Care Med2001; 164: 1957–63.

31. Fujieda S. Combined nasal challenge with diesel exhaust particles and allergen induces in vivo IgE isotype switching. Am J Respir Cell Mol Biol 1998; 19: 507–12.

32. Nel AE. Enhancement of allergic inflammation by the interaction between diesel exhaust particles and the immune system. J Allergy Clin Immunol 1998; 102: 539–54.

33. Cowie. A randomised cross-over cohort study of exposure to emissions from a road tunnel ventilation stack BMJ Open 2012;2:e001201 doi:10.1136/bmjopen-2012-001201

34. Fischer P. Traffic-related differences in outdoor and indoor concentrations of particles and volatile organic compounds in Amsterdam. Atmospheric Environment 01/2000; DOI:10.1016/S1352-2310(00)00067-4

35. M Bobak Outdoor air pollution, low birth weight, and prematurity. Environ Health Perspect. Feb 2000; 108(2): 173–176.

36. Heather E. Traffic-Related Air Pollution, Particulate Matter, and Autism FREE JAMA Psychiatry. 2013;70(1):71-77

37. Weuve J. Exposure to Particulate Air Pollution and Cognitive Decline in Older Women. Arch Intern Med. 2012;172(3):219-227. doi:10.1001/archinternmed.2011.683

38. Mazaheri et al. School Children's Personal Exposure to Ultrafine Particles in the Urban Environment. Environ Sci Technol. 2014 Jan 7;48(1):113-20. doi: 10.1021/es403721w. Epub 2013 Dec 9

39. Buonanno . Airborne particle concentrations at schools measured at different spatial scales. Atmospheric Environment. 2013, 67, pp. 38-45.

40. Buonanno.Health effects of daily airborne particle dose in children: Direct association between personal dose and respiratory health effect. Environ Pollut. 2013 Sep;180:246-50. doi: 10.1016/j.envpol.2013.05.039. Epub 2013 Jun 19

41. OECD. The Cost of Air Pollution Health Impacts of Road Transport. 21 May 2014 ISBN :9789264210448 (PDF) ; 9789264210424 (print) DOI :10.1787/9789264210448-e

Appendix 4

Draft Variation to the National Environment protection (Ambient Air Quality) Measure

Impact Statement

Prepared for:
National Environment Protection Council

July 2014

DISCLAIMER

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the National Environment Protection Council.

While reasonable efforts have been made to ensure that the contents of this publication are factually correct, the National Environment Protection Council does not accept responsibility for the accuracy or completeness of the contents, and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this publication

CONTENTS

Contents iii

EXECUTIVE SUMMARY

Introduction

The National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) establishes national standards and a nationally consistent framework for the monitoring and reporting for six common air pollutants. The pollutants are:

➢ carbon monoxide (CO) ➢ nitrogen dioxide (NO_2) ➢ sulfur dioxide (SO_2)

➢ lead (Pb)

➢ photochemical oxidants as ozone (O_3)

➢ particulate matter (PM) with an aerodynamic diameter of less than 10 micrometres (µm) (known as PM_{10}).

In 2003 the AAQ NEPM was varied to include monitoring and reporting protocols and advisory reporting standards for particles with an aerodynamic diameter of less than 2.5 µm, known as $PM_{2.5}$ (NEPC 2002).

An initial review of the AAQ NEPM was completed in 2011 (NEPC 2011). In 2012 COAG agreed that the review of the AAQ NEPM particle standards would be prioritised for the following reasons:

- ➢ There is strong evidence that exposure to PM has adverse effects on human health, and a lack of evidence for a concentration threshold below which health effects do not occur. This means that there are likely to be adverse health effects at the concentrations currently experienced in Australian cities, even where these are below the current standards and goals (see Table ES1).
- ➢ PM_{10} standards are at times exceeded in nearly all regions of Australia (DSEWPC 2011); however, such exceedances can occur as a result of uncontrollable natural events.
- ➢ The potential health benefits of reducing population exposure to PM – and the associated monetary savings for society – are larger than those for other air pollutants.
- ➢ The range of cost-effective abatement policies and actions available for PM is larger than that for other pollutants.

In the decade since the AAQ NEPM was varied there have been significant developments in the understanding of the effects of PM on health and the environment, as well as improvements in monitoring methods.

This Impact Statement has been prepared for the National Environment Protection Council (NEPC) with reference to the requirements of the NEPC Act.

This Impact Statement collates and analyses available information about PM in Australia. It considers the feasibility, costs and benefits of amending the standards and goals relating to

PM, as currently defined in the AAQ NEPM. It also considers a framework for reducing population exposure to PM.

The Impact Statement outlines the basis for options being considered by government.

The NEPC acts require that both the draft NEPM and the Impact Statement be made available for public consultation for a period of at least two months. NEPC must have regard to the Impact Statement and submissions received during public consultation in deciding whether or not to vary the AAQ NEPM.

In addition to addressing the requirements of the NEPC Act, impact statements are developed in keeping with the requirements of the Council of Australian Governments.

Key issues considered in this Impact Statement include:

- metrics used to quantify PM in the AAQ NEPM
- numerical values of the PM standards
- form of the PM standards (e.g. allowed exceedances) ➢ options for an exposure-reduction framework for PM.

Other recommendations concerning specific technical matters (e.g. monitoring methods and protocols, site locations) are being considered through existing processes, and are outside the scope of this Impact Statement.

Executive summary vii

Preferred options

The preferred options for revising the AAQ NEPM are summarised in Table ES1. It is also proposed that the advisory reporting standards for $PM_{2.5}$ could be made performance standards.

Table ES1: Summary of preferred options

Aspect	Metric	To be included in AAQ NEPM?	Numerical value	Form of standard
Air quality standards	PM_{10} – annual mean	Yes	No standard with consideration of 20 µg/m^3	–
	PM_{10} – 24-hour mean	Yes	40 - 50 µg/m^3	To be agreed
	$PM_{2.5}$ – annual mean	Yes	8 µg/m^3	–
	$PM_{2.5}$ – 24-hour mean	Yes	25 µg/m^3	To be agreed
Exposure-reduction framework co-option	Exposure index based on average $PM_{2.5}$ concentration at urban AAQ NEPM monitoring sites within a jurisdiction	Yes	Continual improvement and/or no deterioration. Exposure index used to assess progress in reducing population exposure	To be agreed 3 year rolling average

The analysis of the PM monitoring data has indicated that the numerical values shown in Table ES1 would be achievable given the current monitoring networks and trends in concentration. Tighter standards than these are unlikely to be achievable in all jurisdictions. No single preferred option for the 24-hour PM_{10} standard has been identified. The form of the standards has also been left for consultation.

For exposure reduction, meeting a target of a 10% reduction in the annual mean $PM_{2.5}$ concentration between 2015 and 2025 is unlikely to be achievable in practice. The issues and inconsistencies associated with the measurement of $PM_{2.5}$, coupled with the need to detect relatively small changes in concentrations, mean that checking progress towards any target would also be very challenging. A more practical approach would involve the development of an exposure index based on monitoring to track population exposure for major urban areas (e.g. using a three-year rolling average $PM_{2.5}$ concentration, as in Europe). Variations of this approach, such as introducing population weightings for different monitoring sites, could be considered as potential refinements.

Consultation

Input is sought from all stakeholders on the options outlined in the Impact Statement.

- ➢ Do you agree with the introduction of an annual PM_{10} standard, given the apparent adverse health effects of coarse particles and their prevalence in some regions?
- ➢ Do you support upgrading the current AAQ NEPM advisory reporting standards for $PM_{2.5}$ to compliance standards?
- ➢ Do you support the preferred numerical values for new/revised 24-hour and annual $PM_{2.5}$ and PM_{10} standards? Which value for the 24-hour PM_{10} standard do you consider to be the most appropriate, and why?
- ➢ What is your preferred option for the form of the 24-hour PM_{10} and $PM_{2.5}$ standards? Should the options be trialled?
- ➢ Do you have any comments regarding the possible inclusion of PM metrics, other than PM_{10} and $PM_{2.5}$, in the future?
- ➢ Do you agree with the preferred form of the exposure-reduction framework under which an exposure index based on monitoring would be used to track population exposure for major urban areas?

  Feedback is also welcomed on the analysis and conclusions, and any other aspect of the Impact Statement. A summary of issues on which feedback is sought is included in Appendix F.

viii Impact statement on the draft variation to the AAQ NEPM

All submissions are public documents unless clearly marked 'confidential' and may be made available to other interested parties, including by being published on the NEPC website. Stakeholders should indicate if their submission is confidential or clearly indicate sections that may contain confidential or sensitive information that is not for publication.

Feedback received during the public comment period will be used to inform the development of the AAQ NEPM variation.

The NEPC Act requires that both the draft AAQ NEPM variation and the Impact Statement be made available for public consultation for a period of at least two months. The consultation period will occur over a ten week period from July to October 2014. The views of stakeholders on these documents are being sought through written and online submissions.

Online submissions are preferred and can be made via < www.nepc.gov.au > Written submissions may also be made and can be sent to:

The Executive Officer
National Environment Protection Council Department of the Environment
GPO Box 787
Canberra ACT 2601

Email: nepc@environment.gov.au

The closing date for submissions is Friday 10 October 2014.

Following the public consultation period, the NEPC is required to prepare a summary of the issues raised in submissions and responses to them. In deciding whether or not to make the AAQ NEPM variation, the NEPC must take both the Impact Statement and the summary of submissions and responses into account.

The following documents have been released by the NEPC to facilitate public consultation on the NEPM variation:

- ➢ Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for $PM_{2.5}$, PM_{10}, 0_3, NO_2 and SO_2 (referred to in this Impact Statement as the Health Risk Assessment (HRA))
- ➢ Summary for Policy Makers of the Health Risk Assessment on Air Pollution in Australia
- ➢ Economic Analysis to Inform the National Plan for Clean Air (Particles) (referred to in this Impact

  Statement as the Economic Analysis)

- ➢ Evaluating Options for an Exposure Reduction Framework in Australia
- ➢ Methodology for Valuing the Health Impacts of Changes in Particle Emissions

Characteristics and measurement of airborne PM

Airborne PM is a complex mixture of substances that are derived from a range of sources and processes. The contributions of these sources and processes, and the physical and chemical properties of PM vary according to many factors.

PM is often classified as being primary or secondary in origin. Primary particles are emitted directly into the atmosphere. Natural sources of primary particles include wind erosion, bush fires and the production of marine aerosol. Anthropogenic (human-made) sources involve fuel combustion (e.g. power generation, domestic wood heaters, vehicles), mechanical suspension (e.g. entrainment of dust from roads at coal mines), or abrasion/fragmentation (e.g. tyre wear). Industrial activities may involve combustion processes, mechanical processes or chemical processes. Secondary particles are not emitted directly but are formed in the atmosphere through chemical reactions involving inorganic or organic gas-phase components. The main gaseous precursors are oxides of nitrogen (NO_X), ammonia (NH_3), sulfur oxides (SO_X) and volatile organic compounds (VOCs). Studies have shown that secondary particles can contribute significantly to PM concentrations.

Executive summary ix

Airborne particles are measured using various metrics which relate to particle size, and the two metrics that are used most commonly are PM_{10} and $PM_{2.5}$. A variety of instruments and methods are available for measuring PM_{10} and/or $PM_{2.5}$. The measurement of $PM_{2.5}$ is inherently more difficult, partly because there is a much smaller mass to measure. The Impact Statement summarises the main PM measurement methods in use in Australia. The AAQ NEPM reference method for monitoring PM_{10} and $PM_{2.5}$ in Australia is the manual gravimetric method. Some automated and continuous methods can also be used as alternatives to the reference method.

Effects and monetary costs of PM

Health effects

Since the AAQ NEPM variation in 2003 there have been significant advances in the understanding of the health effects of PM. These effects are diverse in scope, severity and duration. They include premature mortality, aggravation of cardiovascular disease and aggravation of respiratory disease. Outdoor air pollution has also recently been classified as carcinogenic to humans, with an emphasis on PM in general and specifically PM in diesel engine exhaust (IARC 2012, 2013).

The recent advances have been reviewed in a number of key documents (e.g. USEPA 2009; WHO Regional Office for Europe 2013), and can be summarised as follows:

➢ For $PM_{2.5}$:
o There is sufficient evidence to conclude that long-term and short-term exposure causes illness and

death from cardiovascular conditions, and is likely to cause respiratory conditions.
o Associations have been observed between exposure and reproductive and developmental effects.

➢ For PM_{10}:
o There is extensive evidence that short-term exposure is associated with health effects, and that these

effects are independent of the effects of $PM_{2.5}$.
o There is evidence of a causal relationship between short-term exposure and cardiovascular and

respiratory effects and mortality.
o There is less evidence that long-term exposure has health effects that are independent of those caused

by long-term exposure to $PM_{2.5}$, nevertheless WHO recommends a long-term air quality standard. ➢ For other PM metrics:

○ There is increasing, but as yet limited, epidemiological evidence on the association between short-term exposure to ultrafine particles (i.e. particles with an aerodynamic diameter of less than 0.1 μm) and health. This is an area of ongoing research.

○ While there is some evidence that the relationship between PM and health effects depends on chemical composition (e.g. black carbon, secondary organic aerosol (SOA) and secondary inorganic aerosol (SIA)), the evidence is insufficient to conclude that this relationship is causal.

For $PM_{2.5}$ and PM_{10} the effects observed in Australia and New Zealand are consistent with those reported in the international literature.

Long-term studies have not provided evidence of a threshold for health effects. There is also evidence that exposure to PM at levels experienced in Australian cities is associated with health effects. There would therefore be health benefits from reducing exposure below these levels, and setting standards as low as reasonably achievable.

Other effects

Airborne PM also has adverse impacts on ecosystems, agriculture, visibility, cultural heritage and climate. However, the main focus of public concern is currently on its effects on human health, and these generally account for the majority of the external monetary costs associated with the impacts of air pollution.

x Impact statement on the draft variation to the AAQ NEPM

Monetary benefits of reducing PM concentrations

Any reduction in exposure to particle pollution will have public health benefits. The health cost of particle air pollution in the NSW Greater Metropolitan is estimated to be around $4.7 billion per year (NSW DEC 2005; Jalaludin et al. 2011). The greatest proportion (>99%) of the health costs accrue from avoiding premature deaths due to long-term exposure to $PM_{2.5}$.

Policy context and legislation

AAQ NEPM

AAQ NEPM standards and goals

The AAQ NEPM provides a nationally consistent framework for the monitoring and reporting of ambient air quality in Australia, and establishes air quality standards and goals:

➢ Air quality standards are expressed as a maximum allowable concentration for a given averaging period. ➢ Air quality goals are expressed in terms of 'maximum allowable exceedances' to be achieved within 10

years.

The standards and goals of the AAQ NEPM aim to guide policy formulation that allows for the adequate protection of health and wellbeing. Under the current AAQ NEPM, participating jurisdictions (Commonwealth, states and territories) are required to undertake monitoring and public reporting of air pollution and generate data that assist jurisdictions in formulating air quality policies. The AAQ NEPM does not prescribe sanctions for non- compliance with AAQ standards or goals and the AAQ NEPM itself does not compel or direct air pollution control measures.

The specific standards and goals that are set out for short-term (24-hour average) and long-term (annual average) PM_{10} and $PM_{2.5}$ concentrations in the AAQ NEPM are summarised in Table ES2. The standard for PM_{10} reflects the health-based evidence that was available that informed the making of the AAQ NEPM (NEPC 1998). The advisory standards for $PM_{2.5}$ were also underpinned by the available health evidence, including a risk assessment based on monitoring in four cities over a three-year period (NEPC 2002).

Table ES2: Air quality standards and goals for PM_{10} and $PM_{2.5}$ in the AAQ NEPM

(a) Advisory reporting standards

Use of AAQ NEPM standards by jurisdictions

All states and territories manage emissions and air quality in relation to certain types of sources (e.g. landfills, quarries, crematoria and coal mines). Generally speaking, the jurisdictions have legislation or guidance which includes facility design goals, licence conditions or other ways to protect local communities from the impacts of air pollutants in residential areas outside facility site boundaries. Where this is the case, the AAQ NEPM standards are sometimes used as the criteria for air quality assessments.

The AAQ NEPM standards are currently being used in a variety of locations and contexts, some of which are inconsistent with the original intention of the AAQ NEPM. The AAQ NEPM standards are designed to be applied at locations that are representative of overall air quality in those areas. However, as noted above, they are also sometimes applied at other locations as part of environmental assessment, for example, at the boundary of an industrial facility (i.e. a ‘hot spot’). Some jurisdictions are considering alternatives to this approach (e.g. risk- based guidelines for PM in New South Wales (NSW)).

Pollutant	Standard Averaging period	Maximum concentration	Goal (maximum allowable exceedances within 10 years)
PM_{10}	24 hours	50 µg/m3	5 days per year
$PM_{2.5}$[(a)]	24 hours 1 year	25 µg/m3 8 µg/m3	Not applicable. Goal is to gather sufficient data nationally to facilitate a review of the advisory reporting standards

Executive summary xi

Exposure reduction

In Australia for non-threshold pollutants such as PM, overall health outcomes in a population are driven by large- scale exposure to the prevailing average concentrations, rather than by relatively small-scale exposure to higher concentrations. Where there are no exceedances of air quality standards there may be no impetus to implement measures to further reduce exposure to PM. This has compelled a shift in the approach to air quality management, and in some countries and regions (notably the European Union) this has taken the form of an ‘exposure-reduction framework’. The scientific support for the exposure-reduction approach to managing PM has been strengthened by the latest health findings; however, there are currently no targets for exposure reduction in the AAQ NEPM.

International air quality standards and exposure-reduction frameworks

Air quality standards

The Impact Statement reviewed the air quality standards for PM_{10} and $PM_{2.5}$ that are used internationally. Air quality guidelines have been developed for the most common pollutants by the World Health Organization (WHO). These guidelines are based solely on health considerations, and are used as the basis for development of air quality standards in many countries.

There is currently no annual mean PM_{10} standard in the AAQ NEPM. Coarse particles are a significant problem in some areas of Australia. Increasing evidence for the adverse effects on health of coarse particles, as distinct from fine particles, suggests that there may be benefits from an annual mean PM_{10} standard.

The WHO numerical guideline for 24-hour PM_{10} of 50 µg/m^3 has been adopted in Australia and elsewhere (but not in the United States), even though the number of permitted exceedances is greater in Australia than in the WHO guideline. However, fewer exceedances of the standard are provided for in Australia than in most other countries/regions (an exception being New Zealand).

The annual advisory mean standard for $PM_{2.5}$ of 8 µg/m^3 in Australia is lower than the current WHO guideline. The current 24-hr $PM_{2.5}$ advisory reporting standard of 25 µg/m^3 is identical to the WHO 2005 guideline.

Although the Australian PM standards are numerically lower than, or equivalent to, those in other countries and regions, it is not straightforward to interpret such comparisons and they do not necessarily mean that the Australian standards are more stringent. For example, to a large degree the lower standards in Australia are made possible by relatively low natural background concentrations and the absence of significant anthropogenic transboundary pollution (which is a major issue in Europe, for example). However, as noted earlier, there would still be health benefits in Australia from setting the PM standards as low as reasonably achievable. Also, there are differences in implementation; where they are applied; and there is no sanctions associated with non- compliance with the standards and goals in Australia, whereas there is in other countries and regions.

Exposure-reduction framework

The most prominent example of an exposure-reduction framework is the one that is currently applied in the European Union (EU) through Directive 2008/50/EC. The EU exposure-reduction approach is based on monitoring of $PM_{2.5}$. Exposure is assessed using an average exposure indicator (AEI) which is calculated as a three-year running annual mean concentration, averaged over all urban background sampling sites in a Member State. The exposure-reduction target applicable to each Member State is a percentage reduction by 2020, with the required reduction being dependent on the baseline concentration in 2010. The Directive also sets an 'Exposure Concentration Obligation', expressed as an AEI of 20 µg/m^3, to be met by 2015. This sets a minimum obligation on all Member States.

To understand and quantify population exposure accurately in Australia, information would be required on both (i) the long-term average spatial distribution of air pollution and (ii) the spatial distribution of the population in each urban area. The tools and data to develop an exposure-reduction framework such as the one applied in the EU would include detailed emissions inventories based on a relatively fine grid, comprehensive airshed dispersion models, and high-quality monitoring data. The current AAQ NEPM monitoring networks can provide an indication of the exposure in the area represented by each monitoring site; however, the adoption of an EU-style exposure- reduction framework would require a very significant investment of resources.

xii Impact statement on the draft variation to the AAQ NEPM

Airborne PM in Australia

Emissions inventories and projections

Five jurisdictions in Australia, including the major urban centres of Sydney, Melbourne, Brisbane, Perth and Adelaide have developed emissions inventories; however, there is varying consistency across the jurisdictional inventories and projections in terms of nomenclature, methodology and overall quality.

The most important sectors of activity also differ by jurisdiction. For example, in NSW the largest source of PM_{10} and $PM_{2.5}$ is coal mining. In metropolitan areas wood heaters, diesel engines and industry are significant sources. Domestic/commercial sources (notably wood heaters) are the most important in Tasmania (TAS). In Victoria (VIC), the largest sources are wood heaters, industry and diesel vehicles. Mobile sources are also important contributors to PM_{10} and $PM_{2.5}$ in some jurisdictions.

In all jurisdictions emissions of PM_{10} and $PM_{2.5}$ have been projected to increase between 2011 and 2036, based on, for example, Australian Bureau of Statistics population and industry forecasts. However, the projections vary considerably from jurisdiction to jurisdiction. For example, in NSW, Queensland (QLD) and Western Australia (WA) there is a projected increase in PM_{10} emissions of around 65%, whereas in VIC and South Australia (SA) it is around 10%. The projected increase in $PM_{2.5}$ emissions ranges from 8% in VIC to around 65% in WA.

Ambient PM concentrations

The air quality environment in Australia is characterised with respect to PM_{10} and $PM_{2.5}$, so that the options for the AAQ NEPM variation can be framed in an appropriate context. This work required analysis of the PM_{10} and $PM_{2.5}$ data from the government-run air pollution monitoring stations in all jurisdictions.

PM concentrations in Australia vary temporally and spatially as a consequence of many different influencing factors. On a day-to-day basis PM concentrations are very variable. Extreme events (notably natural bush fires and dust storms) are often associated with the highest levels of pollution. Various methods are used to measure PM in Australia, and the ability to assess trends can be affected by changes in instrumentation, the relocation of monitoring sites, or a change in the distribution of sites. All of these have occurred in Australia. Notwithstanding, in most jurisdictions there has been a reduction in overall annual mean PM_{10} and $PM_{2.5}$ concentrations between 2003 and 2012, although in some jurisdictions the concentrations have not decreased significantly. Overall state- average annual mean $PM_{2.5}$ concentrations in 2012 were below the advisory standard of 8 $\mu g/m^3$; however, it is unclear that the downward trends in annual mean concentrations will continue in the future, especially given that the projections in state inventories show that PM_{10} and $PM_{2.5}$ emissions are likely to increase under a business- as-usual (BAU) scenario, in spite of controls on emissions from several sectors. Anthropogenic emissions of secondary PM precursors are also predicted to increase in the future.

There continue to be exceedances of the 24-hour PM standards and goals at many monitoring sites. For the 24- hour mean PM_{10} standard (50 $\mu g/m^3$), weather, climate and natural events are major factors affecting exceedances. There are no strong underlying trends in the patterns of exceedance. For the advisory 24-hour mean $PM_{2.5}$ standard (25 $\mu g/m^3$), there have been exceedances at most monitoring sites and in most years.

PM composition

Secondary and natural PM contribute significantly to PM_{10} and $PM_{2.5}$. The primary anthropogenic $PM_{2.5}$ component typically represents around 30%–50% of $PM_{2.5}$. This partial contribution of primary sources complicates air quality management. One of the largest $PM_{2.5}$ components is secondary ammonium sulfate. The relatively slow formation rate of sulfate means that it contributes to PM concentrations on regional scales. Sea salt is an important natural component of PM, even at inland locations, through transport from the coast. There are strong seasonal patterns in PM composition. In inland regional centres of NSW wood smoke is the dominant source of $PM_{2.5}$ during the winter, but is much less important in summer.

Statement of the problem and rationale for government intervention

The need to reduce atmospheric concentrations of PM derives principally from its well-recognised and quantified effects upon human health. The recent historical trend of decreasing ambient concentrations of PM_{10} and $PM_{2.5}$ is expected to be reversed in the future due to growth in population, economic activity and emissions, with

Executive summary xiii

subsequent increases in population exposure and the incidence of adverse health outcomes, and increases in the monetary costs of air pollution to society.

It is likely to be more difficult to meet the national air quality standards and goals for PM in the future without further intervention. There is an ongoing risk that Australian public health will not be sufficiently protected. Intervention is considered necessary to prompt and accelerate policies and measures to reduce population exposure to particulate air pollution. The extent to which government needs to be involved is informed by environmental and economic data. Updating the AAQ NEPM will reduce these adverse effects by highlighting potential problems and assisting jurisdictions in the formulation of air quality policies to reduce emissions from different sectors.

Government involvement should aim to reduce ambient concentrations of PM_{10} and $PM_{2.5}$, especially in populated areas, taking into account the practical limitations on what can be achieved using traditional methods (i.e. reducing primary anthropogenic emissions). This needs to be guided by data on PM concentrations and composition. It is known, for example, that a significant proportion of PM is natural and/or secondary in nature. Measures to reduce primary anthropogenic PM emissions should therefore be accompanied by measures to reduce emissions of secondary PM precursors.

Possible approaches and options

General framework

Several alternative types of air quality management framework have the potential to address the problems identified above. The main alternatives are (i) variation of the AAQ NEPM, (ii) Commonwealth legislation, (iii) voluntary guidelines, (iv) an inter-governmental agreement or (v) no change to the current framework. To date the AAQ NEPM framework has allowed for a nationally consistent mechanism for the setting and implementation of air quality standards and goals, and for the monitoring and reporting of air quality against them. The most effective way to ensure future consistency in national air quality management and data collection would be a variation to the existing AAQ NEPM, with states and territories using the AAQ NEPM provisions in their own jurisdiction, as is currently done.

Status of the PM standards

Assuming that an AAQ NEPM variation is the preferred approach, the main choices to be made are whether monitoring and reporting of the $PM_{2.5}$ standards should be of an advisory nature or be adopted as a performance standard, and whether the limits of the existing PM standards should be revised.

PM metrics and averaging periods

The AAQ NEPM currently specifies a 24-hour standard for PM_{10} concentrations, and advisory reporting standards for 24-hour and annual mean $PM_{2.5}$ concentrations. The addition of an annual mean standard for PM_{10} is proposed on health grounds. There is currently insufficient data from monitoring networks and health studies in Australia to allow for the consideration of options relating to metrics other than PM_{10} and $PM_{2.5}$. Consequently, the options that have been considered here relate solely to the metrics PM_{10} and $PM_{2.5}$, and to annual and 24- hour averaging periods in each case.

Numerical values for the PM standards

Potential new air quality standards for both PM_{10} and $PM_{2.5}$ were considered as options for varying the AAQ NEPM. The options – shown in Table ES3 – were based on international guidance (e.g. WHO and the United States Environmental Protection Agency (USEPA)), but were also informed by Australian conditions.

One aspect for consideration is whether single-year or multi-year averages are used for the monitoring data when comparing measurements with the standards; for example, a three-year averaging period is used in the US. This is not explicitly addressed in the Impact Statement however.

Table ES3: Options and sub-options – air quality standards

Action	Options	Sub-option[(a)]	Standard[(b)]
Particle standards	PM_{10} annual mean	$A20PM_{10}$	20 µg/m^3
		$A16PM_{10}$	16 µg/m^3
		$A12PM_{10}$	12 µg/m^3
	PM_{10} 24-hour mean	$D50PM_{10}$	50 µg/m^3
		$D40PM_{10}$	40 µg/m^3
		$D30PM_{10}$	30 µg/m^3
	$PM_{2.5}$ annual mean	$A10PM_{2.5}$	10 µg/m^3
		$A08PM_{2.5}$	8 µg/m^3
		$A06PM_{2.5}$	6 µg/m^3
	$PM_{2.5}$ 24-hour mean	$D25PM_{2.5}$	25 µg/m^3
		$D20PM_{2.5}$	20 µg/m^3
		$D15PM_{2.5}$	15 µg/m^3

1. (a) A = annual mean; D=daily mean
2. (b) Current standards are shown in bold

Form of 24-hour standards

The 'form' of a standard refers to the way in which the standard is interpreted and applied. The form of the standard prescribes the approach used to compare actual air quality measurements with the numerical value of the standard. For the annual mean concentration this is relatively straightforward, as only one value is obtained from the measurements. For the 24-hour standard it is more complicated, as there is a need to decide which of the daily measurements in a year should be compared with the standard. For example, in the US, the form of the standard relates to the use of descriptive statistics, and in the case of the 24-hour standard for $PM_{2.5}$ the 98th percentile (averaged over three years) is used. A percentile is a value below which a given percentage of observations in a sample fall. The 98th percentile for the 24-hour $PM_{2.5}$ standard excludes the highest 2% of measured concentrations from comparison with the standard. The 98th percentile was selected as it represents a balance between limiting peak (extreme event) pollutant concentrations and providing a stable regulatory target (USEPA 2011). In the US and Europe there is also the possibility for jurisdictions to remove the data for natural or exceptional events (such as bush fires and dust storms) prior to comparing measurements with the standard.

Four options for the form of the 24-hour standards are to be considered for the AAQ NEPM:

- ➢ Business as usual option. A rule that allows a fixed number of exceedances of a PM standard in a given year (as is currently the case for PM_{10}), but with no exclusion of data for activity specific exceptional events. The fixed number of allowable exceedance days (e.g. five days per year) would be based on an estimated number of exceptional events. For reporting purposes the occurrence of exceptional events will be recorded, and various statistics will be presented (including percentiles), but these will not be used when comparing measured concentrations with the standard.
- ➢ A rule that allows a fixed number of exceedances of a PM standard in a given year, based on the exclusion of data for activity specific exceptional events. This is similar to the approach used in the EU.
- ➢ A rule in which the 98th percentile PM concentration in a given year is compared with a standard, but with no specific exclusion of data for exceptional events. For reporting purposes the occurrence of exceptional events will be recorded and various statistics will be presented (including percentiles), but these will not be used when comparing measured concentrations with the standard.
- ➢ A rule in which the 98th percentile PM concentration in a given year is compared with a standard, but with the exclusion of data for exceptional events. This is similar to the approach used for $PM_{2.5}$ in the US.

Executive summary xv

The form of the 24-hour standards should also result in an appropriate balance between the annual mean and 24-hour standards. For example, where these two metrics are applied together there may be a tendency at a given monitoring site for one of them to be exceeded more frequently than the other. From a health and economic perspective – and hence in terms of policy – it is advisable to place more emphasis on the annual mean standard than on the 24-hour standard. As long as separate annual and 24-hour standards are in place, this should not present a practical problem. However, if the numerical value and form of the 24-hour standard are defined so that it is exceeded more frequently than the annual mean standard, this would lead the 24-hour standard to be the controlling standard, with greater potential for action to be focused on short-term concentrations.

Applicability of the AAQ NEPM standards

The approach whereby the AAQ NEPM standards for PM are based on measurements at sites that reflect the general exposure of populations in large metropolitan areas is planned to be maintained. Under this general exposure approach the standards and goals are applicable to urban sites away from sources of pollution, such as busy roads and industrial stacks. Individual jurisdictions can employ complementary methods to inform development applications for proposed infrastructure and industrial proposals in a variety of locations and contexts.

Feasibility of an exposure-reduction framework

The introduction of an exposure-reduction framework into the AAQ NEPM has been considered as a 'co-option'. It is assumed that progress towards reducing exposure would be framed in terms of the monitored $PM_{2.5}$ concentration in major urban areas (as in the AEI approach used in the EU), or an equivalent modelling approach. Two options have been considered, as shown in Table ES4. Option ER1 includes the target of a 10% reduction in the annual mean $PM_{2.5}$ concentration between 2015 and 2025 assessed in the Economic Analysis project. Option ER2 would involve a similar approach, without a specific numerical target but with an explicit aim of continual improvement and/or no deterioration of air quality.

Table ES4: Options and sub-options – exposure-reduction

(a) The 'exposure index' could either be specified as a single year average or a multi-year average (for example, a three-year average is used in the EU). It is likely that the exposure index would apply only to agglomerations with a population above a certain threshold.

A complete understanding of population exposure in Australia would involve significant investment. However, undertaking first steps towards characterising exposure based on the existing monitoring network would require little or no investment on the part of the jurisdictions. The robustness of the exposure index in a given jurisdiction will increase as jurisdictions monitor $PM_{2.5}$ at more sites.

Option	Sub-option	Description[(a)]	Target
Exposure-reduction framework co-option	ER1	'Exposure index' based on average $PM_{2.5}$ concentration at metropolitan AAQ NEPM monitoring sites	10% reduction in the annual mean $PM_{2.5}$ concentration between 2015 and 2025
	ER2	'Exposure index' based on average $PM_{2.5}$ concentration at metropolitan AAQ NEPM monitoring sites	Continual improvement and/or no deterioration of air quality. Exposure index is used to assess progress in terms of reducing exposure

xvi Impact statement on the draft variation to the AAQ NEPM

Impact analysis

Analysis of monitoring data

Numerical values of standards

It is important to consider the achievability of the various options for varying the AAQ NEPM. The impact analysis explores the achievability of the different options and sub-options across Australia with respect to the historical data (for 2003–2012) and trends. Achievability was judged in terms of the likelihood that concentrations will meet a given standard/goal within a reasonable time period, based on the historical trends. This work was complementary to the assessment that was conducted for future concentrations in the Economic Analysis project.

In the Economic Analysis some options were found to be unfeasible in most jurisdictions because the standard was very close to, or below, the regional background concentration. Such conclusions were based on broad generalisations about PM composition which were made to ensure a consistent approach across jurisdictions. The distinction between different PM components was not explicitly considered in the impact analysis, as insufficient local data on PM composition were available in all jurisdictions. However, the different PM components were implicitly included in the measurements.

The literature on health suggests that it would be advisable to include an annual mean standard for PM_{10} in the AAQ NEPM. The monitoring data and the future projections from the Economic Analysis indicate that a value for the standard of 20 µg/m^3 could be achievable and economically beneficial.

The PM_{10} monitoring data (and the Economic Analysis) indicate that a tightening of the 24-hour standard for PM_{10} (currently 50 µg/m^3) could encourage future improvements in air quality.

For annual mean $PM_{2.5}$ the monitoring data (and the Economic Analysis) indicate that a value for the standard of 8 µg/m^3 would be achievable and economically beneficial. Most jurisdictions are already complying with this on an average basis. A move to a standard of 6 µg/m^3 however, would appear unrealistic given the background levels of air pollution, and the projected growth in population and emissions.

The $PM_{2.5}$ monitoring data indicate that of the options for a 24-hour standard, the most realistically achievable approach would be to retain the 25 µg/m^3 standard.

Form of 24-hour standards

There is no single analysis that can be done to confirm whether any one form of a 24-hour standard is systematically 'better' than any other form of the standard. The most suitable form depends on the objective of the monitoring and the required level of stringency. It is likely that the jurisdictions will want to identify local issues that affect the form of the standards, and therefore this issue has been left for the consultation phase.

The current approach used in the AAQ NEPM – a fixed number of allowed exceedances per year – is straightforward in terms of definition and application, but is arbitrary in nature. It is also difficult to compare results across jurisdictions. For example, the geographical size of Australia means that there are very different climatic influences on PM concentrations in different jurisdictions, and the scale of human activity is vastly different in say, Sydney and Darwin. There can be more than the permitted number of exceedances in one year due to natural events alone. A percentile rule is simple to apply, and the Australian jurisdictions are already calculating percentile values in their AAQ NEPM submissions. Percentiles provide stable and practical reference points for tracking trends in air quality, although they do not aid the understanding of the causes of high-pollution events. A natural or exceptional events rule can overcome some of the confusion concerning the concept of allowable exceedances (either in terms of a fixed number of days or through a percentile) by identifying the real-world causes of pollution events.

The Impact Statement examined specific combinations of standard and allowed exceedance days. This indicated which forms of the standards would be likely to be achievable, but provided no information on the division between those exceedances resulting from human activity and those resulting from natural events. Whilst the jurisdictions already provide basic information on the reasons for exceedances, the formal inclusion of a natural/exceptional events rule in the air quality standards would require the development of a consistent and more advanced approach. A trial could be conducted to test such an approach.

Executive summary xvii

HRA project

The HRA project addressed the period 2006–2010, and can therefore be said to have characterised current exposure to PM, and the effects of the air quality standard options in relation to this current exposure.

The key elements of the HRA were as follows:

- ➢ Hazard assessment which involved a review of the literature on the health effects of air pollution.
- ➢ Exposure assessment. Baseline (current) exposures and exposures for each air quality standard sub- option were calculated from measured PM concentrations. Calculations were done with and without the influence of extreme pollution events such as bush fires. The HRA estimated exposure in 32 Australian conurbations, including the major metropolitan areas. It should be noted that the results of the HRA do not actually reflect the real-world impacts of setting standards. Rather, they reflect the impact of different exposure scenarios in which the ambient concentrations are set at the values of the options for the standards. However, the HRA assessment does provide a useful indication of what might happen in the future should projected increases in emissions lead to an increase in the $PM_{2.5}$ concentration.
- ➢ Risk characterisation. Population data, mortality data and hospitalisation data for the 32 conurbations were combined with exposure data to estimate city-specific deaths and hospitalisations attributable to the exposures for the baseline and the sub-options. Natural background concentrations were subtracted from the exposure data in order to determine the health effects attributable to human activity.

  It was found that decreasing short-term exposure to PM_{10} would reduce attributable hospital admissions for childhood respiratory disease and pneumonia/bronchitis in people aged 65 and above. For the short term (daily) sub-options $50PM_{10}$, $40PM_{10}$ and $30PM_{10}$ these health outcomes would be reduced by around 30%, 50% and 65% respectively over the four cities of Sydney, Melbourne, Brisbane and Perth Morgan et al. (2013).

  Morgan et al. (2013) commented that for long-term exposure to $PM_{2.5}$ the HRA results are generally consistent with previous Australian and US estimates. Annual mortality attributable to baseline long-term exposure to $PM_{2.5}$ is estimated to be equivalent to approximately 1590 deaths, or 2.2%, in the four cities. Only the sub-option $6PM_{2.5}$ would produce meaningful reductions in long-term mortality relating to $PM_{2.5}$ compared with baseline exposures (equivalent to a reduction of approximately 530 deaths or 34%).

The long-term (annual) sub-option $8PM_{2.5}$ (and also $10PM_{2.5}$) would equate to an increase in exposure based on current $PM_{2.5}$ concentrations. This is because annual mean $PM_{2.5}$ concentrations at most monitoring sites are currently lower than 8 $\mu g/m^3$.

Decreasing short-term (daily) exposure to $PM_{2.5}$ – as per the sub-options $25PM_{2.5}$, $20PM_{2.5}$ and $15PM_{2.5}$ – would reduce attributable cardiovascular hospital admissions and attributable childhood asthma hospital emergency department attendance by around 30%, 45% and 60% respectively over the four cities (Morgan et al. 2013).

It was also noted in the HRA Summary for Policy Makers that the health effects of short-term exposure to $PM_{2.5}$ are driven primarily by the numerous mid-range values within the concentration distribution, and not by the peak exposure days. Therefore, control strategies that focus primarily on reducing extreme days are less likely to achieve reductions in $PM_{2.5}$ exposures that most contribute to health effects, compared with an approach that focuses on reducing the middle range of the $PM_{2.5}$ exposure distribution.

Economic Analysis

The Economic Analysis project addressed the period 2011–2036, and therefore characterised potential future exposure. The project examined the costs and benefits of introducing a package of potentially feasible national abatement measures over the 25-year period relative to a BAU scenario. The actual air quality standard sub- options in Table ES2 were incidental to this process in the sense that there was no requirement for ambient concentrations to be the same as the standards, as in the HRA project. Rather, the project assessed the likely achievability of the sub-options by 2036 given the trends in emissions and the implementation of the abatement measures. The exposure-reduction target (option ER1) was assessed in a similar way, except for the period 2015–2025.

xviii Impact statement on the draft variation to the AAQ NEPM

Not all possible national and state-based abatement measures were considered in the Economic Analysis. The potential benefits would be greater if all possible abatement measures could be assessed. In other words, the benefits identified in the Economic Analysis are likely to be representative but are probably conservative.

Under the BAU scenario it was estimated that there would be overall increases in the population-weighted PM concentrations over the period 2011–2036 due to increases in emissions. For PM_{10} the increase would be between 0.2 $\mu g/m^3$ and 2.4 $\mu g/m^3$, depending on the jurisdiction. $PM_{2.5}$ would increase by up to 1.5 $\mu g/m^3$, depending on the jurisdiction; the exception was Victoria, where there would be a slight reduction in the $PM_{2.5}$ concentration. As emissions increased slightly during the period 2011–2036, this reduction must be due to a change in the spatial distribution of the population (i.e. people moving away from areas with higher concentrations to areas with lower concentrations).

The increases in concentration under the BAU scenario would be offset in some jurisdictions by the introduction of any national abatement measures to reduce primary anthropogenic PM emissions. The scale of the concentration reductions was modest, but the monetised health benefits in the airsheds considered in the analysis were substantial. The scale of concentration reductions was limited by the contribution of natural and secondary particles to $PM_{2.5}$. However, reductions in primary anthropogenic PM emissions are also likely to be associated with reductions in the emissions of secondary PM precursors, whereas in the Economic Analysis it was assumed (because of the absence of a suitable model) that the secondary PM contribution would be constant with time. This means that the benefits calculated in the Economic Analysis represent a conservative estimate.

By 2036 the health benefit of meeting each standard was estimated at around \$20.7 billion to \$21.7 billion, and the net benefit after the costs of abatement measures were included was around \$6.4 billion to \$7 billion). It should be noted that the health benefits for the individual standards are not additive.

Meeting the target of a 10% reduction in the annual mean $PM_{2.5}$ concentration between 2015 and 2025 (option ER1) would require very significant additional abatement measures in most jurisdictions. It is concluded that the proposed exposure-reduction target is currently unlikely to be feasible in practice. Nevertheless, it is important to emphasise the likely benefits of an exposure-reduction framework. Even where an AAQ NEPM standard is not exceeded there is a health benefit associated with reducing concentrations, and an exposure-reduction framework provides an appropriate mechanism for this. Therefore, the incorporation of option ER2 into the AAQ NEPM should be considered. This would involve the development of an exposure index for $PM_{2.5}$ for assessing progress against an implicit aim of continual improvement and/or no deterioration of air quality. Option ER2 could be adopted at little or no additional cost to the jurisdictions.

Summary of information for each sub-option

The information obtained for each of the options for the PM_{10} and $PM_{2.5}$ standards is summarised in Table ES5. The main aspects to note are as follows:

- ➢ The latest health findings indicate that it would be advisable to include an annual mean standard for PM_{10} in the AAQ NEPM. This is supported by enHealth. The historical PM_{10} monitoring data and the future projections from the Economic Analysis indicate that a value for the standard of 20 µg/m^3 would be practicable and appropriate.
- ➢ The PM_{10} monitoring data and Economic Analysis indicate that a tightening of the 24-hour standard for PM_{10} (currently 50 µg/m^3) could encourage future improvements in air quality. A change to a standard of 40 µg/m^3 would be possible, particularly in most urban areas. However, it would be advisable to retain the 50 µg/m^3 standard as an option to be considered during consultation. As moving to the lower value could present some difficulties in certain jurisdictions, an alternative would be to consider an intermediate option of 45 µg/m^3. Additionally a move to a lower standard could mean that the 24-hour standard is exceeded more frequently than the annual mean standard, and therefore becomes the controlling standard.
- ➢ For annual mean $PM_{2.5}$ the monitoring data and the Economic Analysis indicate that a value for the standard of 8 µg/m^3 would be appropriate. Most jurisdictions are already complying with this on an average basis. A move to a standard of 6 µg/m^3 would be unrealistic given background levels of air pollution and the projected increases in population and emissions.

Executive summary xix

➢ The $PM_{2.5}$ monitoring data indicate that the options for a 24-hour standard of 20 µg/m^3 and 25 µg/m^3 would be feasible. However, if the zero-exceedance rule is retained it would be more realistic to retain the 25 µg/m^3 standard. In the Economic Analysis it was concluded that meeting a standard of 20 µg/m^3 would be unlikely to be feasible given the large reductions in primary emissions that would be required in several jurisdictions.

The findings for the exposure-reduction options are also summarised in Table ES5. Option ER1 is unlikely to be feasible in practice, and option ER2 should be considered.

Other considerations

Resourcing implications for jurisdictions

The resourcing obligations imposed on the jurisdictions by varying the AAQ NEPM PM standards predominantly relate to monitoring and reporting requirements (as currently exist). Monitoring and reporting costs are currently being incurred by jurisdictions and would not be expected to change simply by changing the numerical value of the standards, except perhaps if an annual average PM_{10} standard is introduced. As PM_{10} is already being measured under the AAQ NEPM, any such increase should be small. An expansion of the $PM_{2.5}$ monitoring network, commensurate with adoption of formal standards should these be introduced, would be expected over time. Costs associated with the phase-in of $PM_{2.5}$ instrumentation, where it currently don't exist, would be managed over time with planned instrument upgrades and monitoring site refurbishment.

The establishment and management of an exposure-reduction framework according to the options defined in Table ES4 would entail little or no extra cost. If the jurisdictions choose to assess population exposure in detail through an EU-style exposure-reduction framework, then the costs associated with setting up emissions inventories, regional dispersion models and additional monitoring stations would become more significant.

Costs to industry and business

Options for tighter AAQ NEPM monitoring and reporting standards for ambient particle emissions are presented. The AAQ NEPM itself does not compel or direct pollution control measures. The application of AAQ NEPM standards is at the discretion of individual jurisdictions, and subject to jurisdiction's review processes.

Direct costs associated with the AAQ NEPM standards relate to monitoring and reporting levels of air pollution.

Meeting proposed monitoring and reporting standards for particles would result in significantly improved net economic benefits compared to current standards in terms of improved health outcomes. The proposals include a number of options. If the tightest annual PM_{10} option were supported in the consultation process, this could have implications for the way jurisdictions choose to manage future licence conditions for some industries.

Social impacts

The AAQ NEPM aims to guide policy formulation for the adequate protection of human health and wellbeing. The AAQ NEPM itself does not compel or direct pollution control measures and accordingly, there are no direct social impacts associated with the variation.

The application of AAQ NEPM standards is at the discretion of individual jurisdictions, and subject to jurisdiction's review processes. Meeting proposed monitoring and reporting standards for particles would result in significantly improved net economic benefits compared to current standards in terms of improved health outcomes.

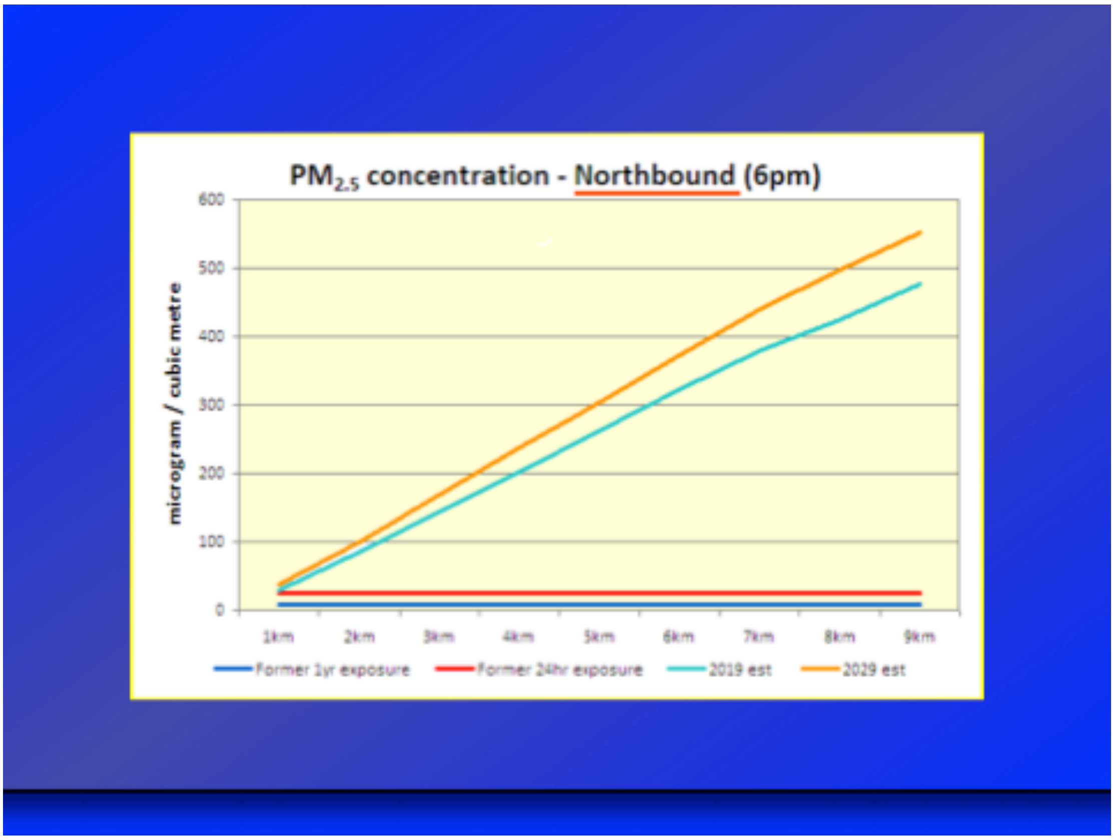
xx Impact statement on the draft variation to the AAQ NEPM

Table ES5: Summary of information for each sub-option

Action	Option	Sub-option	Standard[a]	Achievability based on analysis of ambient PM data[b]	Conclusions from HRA (change in current exposure)	Conclusions from Economic Analysis (2036)			
						Feasible in principle?[b]	Further emission reduction required (by state)?[c]	Emission reductions likely to be achievable?	Net benefit ($, 2011 prices)
Air quality standards	PM_{10} annual mean	A20PM_{10}	20 μg/m^3	Likely	N/A	Yes	WA	Yes	$6.4 billion
		A16PM_{10}	16 μg/m^3	Unlikely	N/A	Yes	NSW, VIC, QLD, WA, NT	No	–
		A12PM_{10}	12 μg/m^3	Very unlikely	N/A	No	–	–	–
	PM_{10} 24-hour mean	D50PM_{10}	50 μg/m^3	Likely	Decrease	Yes	None	No reduction required	–
		D40PM_{10}	40 μg/m^3	Likely	Decrease	Yes	TAS	Yes	$6.6 billion
		D30PM_{10}	30 μg/m^3	Unlikely	Decrease	No	–	–	–
	$PM_{2.5}$ annual mean	A10$PM_{2.5}$	10 μg/m^3	Likely	Increase[d]	Yes	None	No reduction required	–
		A08$PM_{2.5}$	8 μg/m^3	Likely	Increase[d]	Yes	TAS	Yes	$6.5 billion
		A06$PM_{2.5}$	6 μg/m^3	Unlikely	Decrease	Yes	NSW, QLD, SA, WA, TAS, NT, ACT	No	–
	$PM_{2.5}$ 24-hour mean	D25$PM_{2.5}$	25 μg/m^3	Likely	Decrease	Yes	TAS, ACT	Possible	$6.9 billion
		D20$PM_{2.5}$	20 μg/m^3	Likely	Decrease	Yes	TAS, ACT	No	–
		D15$PM_{2.5}$	15 μg/m^3	Unlikely	Decrease	No	–	–	–
Exposure-reduction framework	Co-option	ER1	10% reduction in exposure to $PM_{2.5}$ between 2015 and 2025, based on monitoring	N/A	N/A	No	All except NT	No	N/A
		ER2	Continual improvement and/or no deterioration. Exposure index, based on monitoring	N/A	N/A	Yes	N/A	N/A	N/A

1. (a) Current standards are shown in bold.
2. (b) On average for Australia (does not apply to individual sites).
3. (c) In addition to the reductions that could be achieved by implementation of a package of all feasible of national measures.
4. (d) Equates to an increase in exposure based on current $PM_{2.5}$ concentrations because annual mean $PM_{2.5}$ concentrations at most monitoring sites are currently lower than 8 μg/m^3.

Appendix 5


PM2.5 concentration - Northbound (6pm)
microgram / cubic metre
600
500
400
300
200
100
0
1km
2km
3km
4km
5km
6km
7km
8km
9km
Former 1yr exposure
Former 24hr exposure
2019 est
2029 est