Chapter 9
Air Pollution and Climate Change in Australia: A Triple Burden

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Abstract This chapter mainly focuses on air pollution, with less stress on the health problems of climate change, which, conceptually, is also a form of air pollution, due to the changing composition of atmospheric trace gases. Air quality in Australia is comparatively good, by global standards, due to its large area, low population, and widespread development. However, there are areas of Australia which have significant health problems from dirty air, particularly in association with coal-burning power stations, from the combustion of wood for heating during winter and from vehicles in the large cities. Australia is also a major exporter of greenhouse gases, both as fossil fuels (coal and gas), and of beef and sheep. Much can be done to reduce this triple burden of impaired air quality, domestic climate change and exported climate change, but this requires major changes to consciousness in Australia, and greater willingness to oppose vested interests which profit from ageing paradigms of progress which discount health and environmental costs. The falling cost of renewable energy, especially, gives hope that such challenges will be increasingly successful, but additional solutions are needed to reduce the burning of wood for heat.

Keywords Air pollution • Australia • Coal mines • Climate change • Social licence • Health

Introduction: Air Pollution and Health in Australia

When the British, in 1788, began their drawn-out process of invading and occupying the southern continent now called Australia, the indigenous people they displaced from most areas had a long and rich tradition of astronomical knowledge

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(Fuller et al. 2014). This tradition must have been helped, perhaps even inspired, by the brilliance of the heavens, whose glory was little impeded by significant light on the ground. However, a degree of particulate air pollution in Australia before colonisation is likely to have been frequent, due to the widespread indigenous practice of deliberately lighting fires to manage their landscape, a process today called ‘firestick farming’ (Gammage 2011; Jones 2012).

These traditional burning practices may have reduced the megafires which have occurred more recently in Australia (Attiwill and Adams 2013) and which have well-documented adverse health effects (Johnston et al. 2011). Today, the brilliance and inspiration of the night sky are invisible to many people globally, but the stars seen from rural Australia, on the whole, are countless and comparatively bright. Air pollution, on a continental scale in Australia, is minor, compared to Asia, due to the continent’s vast size, small population and the overwhelming reliance on electricity and gas for cooking. However, there are areas of Australia which have significant health problems from dirty air, particularly in association with coal-burning power stations, from the combustion of wood for heating during winter and from vehicular emissions in large cities. The adverse health and financial impacts of air pollution in Australia are significant and can and should be reduced.

When one of the authors of this chapter commenced medical school, in 1980 (in a city then notorious for industrial air pollution, by Australian standards), he was told that the adverse health effects of air pollution were trivial. This was misinformed, even then. London, for centuries, has been called the ‘big smoke’ (Brimblecombe 2011). Major smog events in the heavily industrialised but narrow (temperature inversion layer-susceptible) Meuse Valley, Belgium (1930); the steel town of Donora, Pennsylvania (1948) (also in a valley); and coal fire-dependent London (1952) had each been recognised as causing much mortality and morbidity. In London, up to 4000 extra deaths occurred in a few days (Nemery et al. 2001).

While these three spectacular increases in mortality were quickly recognised, the *chronic* health effects of air pollution have proven much harder to comprehend. Almost everyone in air-polluted London in the 1940s was exposed to air pollution, as in New Delhi today. Without a control population, relatively unexposed to air pollution, chronic diseases contributed to by regularly breathing even heavily polluted air may be regarded as ‘normal’ (Berridge and Taylor 2005).

Recognition of the harm of air pollution, including its interaction with smoking, was also long suppressed for political reasons (Snyder 1994; Berridge 2007). Smoke, dust, smogs, inhaled irritants and fumes have long been seen as necessary companions of development and, in some cases, of basic heating, cooking and transport. Relatedly, the adverse health effects of these exposures have been downplayed, ignored and in some places suppressed.

In the last decade, however, recognition of the harm from *visible* forms of air pollution has improved. In 2014 the World Health Organization (WHO) (2016) announced that about seven million people worldwide die prematurely from air pollution, about one in eight of total deaths, and more than double earlier estimates. Furthermore, affordable alternatives for many processes which cause air pollution are now emerging; this is likely to be a powerful contributor to lifting the taboo on the health harm of air pollution and to reducing the 'social licence' of polluters (Connor et al. 2009).

A Hierarchy of Air Pollutants

Considerable effort has been expended trying to identify the 'worst' contributors to health among the scores of candidate air pollution components. The pollution episodes in the Meuse Valley and Donora were primarily a brew of industrial toxins, including particulate matter (PM) of varying sizes, sulphur dioxide (SO2), carbon monoxide and hydrofluoric acid. In the Belgian example, 30 different substances, released by 27 factories, were identified (Nemery et al. 2001). However, no single worst cause was proven (or scapegoated); then and perhaps still, it may be more realistic (and less reductionist) to consider that the health effects of air pollution accrued from a combination of exposures, whose concentration (in those cases, as is still sometimes true today) was greatly magnified by unusual weather conditions. In Donora, a zinc smelter was especially criticised, but, again, causation was eventually determined to be multifactorial, worsened (as in the Meuse Valley) by unfavourable weather and topography (Snyder 1994).

But this does not mean that all components of air pollution are either equally toxic or even that some are benign. Particulate matter is a complex mixture of solid and liquid particles, suspended in air as a result of the burning of coal, gasoline, diesel fuels and biomass such as wood (Sierra-Vargas and Teran 2012). The finest particulate matter, less than 1 micrometre (μm) in diameter (PM1), has been especially implicated in cardiovascular disease, as these particles are sufficiently tiny to not only penetrate deep into the respiratory tract but cross into the bloodstream in the alveoli, where gas exchange occurs (Martinelli et al. 2013). Larger particulate matter (PM10) has been identified as a cause of lung cancer (Raaschou-Nielsen et al. 2013) while ozone, carbon monoxide, nitrogen dioxide and sulphur dioxide all worsen asthma (Ierodiakonou et al. 2016). Diesel exhausts are much more harmful than car exhausts, containing 10–100 times the mass of particulate matter from cars, much of which has adsorbed (adherent) organic compounds derived from heavy carbon (Ristovski et al. 2012). In addition, some forms of air pollution bear heavy metals, including lead, which has been conclusively shown to impair childhood learning, above very low thresholds of exposure (McMichael et al. 1988).

In some (or many) cases, it is likely that synergisms occur between the various components of polluted air. Thresholds of exposure clearly exist, beyond which additional exposure is disproportionately harmful. Further complicating the challenge to identify the most toxic elements of air pollution is the varying susceptibility of populations. Even exposure to asbestos does not guarantee pathology (Terra-Filho et al. 2015).

A holy grail for researchers could be to determine the effects of lifelong population exposure to the various elements and combinations of air pollution, e.g. x years of exposure to a certain level of PM10, y years of exposure to ozone and z years of exposure to sulphur dioxide (average and peak). Added to this difficulty would be an estimate of the harm, acute and chronic, from numerous combinations of pollutants. But such levels of understanding are likely to take decades to evolve and may not be worth the effort. Meanwhile it is prudent to reduce exposure as much as is economically and socially possible, at the same time enhancing the resistance of exposed populations, through means such as reduced tobacco smoking and better nutrition.

Indoor and Outdoor Air Pollution

Although the burden of disease of air pollution, including in the global burden of disease studies (Lim et al. 2012), has long been divided into indoor (domestic or household) and outdoor (ambient) sources, this dichotomy has been recently been convincingly challenged. There are several reasons for this revision, particularly that solid cooking fuel such as straw, dung and wood, used indoors, with inadequate ventilation, is often sufficiently polluting and widespread to appreciably affect widespread ambient air pollution levels (Smith et al. 2014).

The Triple Burden of Air Pollution in and from Australia

The most recent estimates of the burden of disease of air pollution in Australia is low, compared to nations such as China and India (Lim et al. 2012), even on a per capita basis. However, it is far from trivial, as several case studies will illustrate.

Air pollution in Australia (and some other countries) has a triple burden. Other than tobacco, which is not further discussed in this chapter, the main forms of air pollution in Australia occur via the inhalation of airborne pollutants including particulate matter from coal dust, coal smoke and gaseous products of coal burning such as sulphur dioxide. Also important are combustion products of biomass burning including of wood (especially particulates); industrial emissions from manufacturing; refineries and chemical production; motor vehicle exhausts, including diesel fumes; and pollen. These cause direct and sometimes prolonged harm, especially to vulnerable groups, particularly people with pre-existing disease and the elderly. Health conditions known to be contributed to by air pollution include respiratory diseases (e.g. asthma, chronic bronchitis and lung cancer), some cardiovascular diseases (e.g. heart attacks and strokes), some infectious diseases and some forms of cancer, including lung cancer and, possibly, leukaemia and others (Colagiuri et al. 2012; Filippini et al. 2015).

The prolific per capita combustion of fossil fuels (mainly for transport and electricity generation) and the ingestion of meat and meat products in Australia (especially from sheep and cattle, each of which produces the greenhouse gas methane) mean Australians make a disproportionate contribution to human-made climate change, which in turn is having increasingly profound adverse health effects (Butler et al. 2016). The effects of climate change are inexorably growing and will be far higher in the future (Butler and Harley 2010).

Climate change is a form of air pollution for several reasons. Disguising this recognition, the main greenhouse gases (carbon dioxide (CO2), methane and nitrous oxide) are completely invisible and odourless at atmospheric concentrations. CO2 is essential for plant life and harmless to humans when inhaled, even at levels far higher than 400 parts per million and its present level, an increase of 45% from the pre-industrial period. Further, the harm that greenhouse gases impose on human health is different to other forms of air pollution.

However, by altering the heat-trapping characteristics of the global atmosphere, greenhouse gases contribute to extreme weather events, sea level rise, altered dynamics of some infectious diseases and other events with adverse health consequences. Some extreme weather events, such as drought, can contribute to migration and conflict, where significant other precursors for conflict exist (Bowles et al. 2015; Schleussner et al. 2016). A leaked copy of the fifth Intergovernmental Panel on Climate Change (IPCC) assessment was reported as warning of hundreds of millions people being displaced by 2100 (McCoy et al. 2014). Of interest, and consistent with the increasingly recognised way in which authorities have long downplayed the risk of air pollution, this warning was changed in the final report to the much less disturbing, unquantified statement 'climate change is projected to increase displacement of people (medium evidence, high agreement)' (IPCC 2014).

Recognising the potential health harm from greenhouse gas accumulation, the US Environmental Protection Agency (2009) identified the main greenhouse gases as air pollutants. Time will tell if this strong position survives the administration of US President Trump (Mathiesen 2016).

The third way air pollution from Australia harms health is via its exports of fossil fuels and of digastric (ruminant) sheep and cattle, which also make important contributions to climate change (McMichael et al. 2007). Australians thus not only make substantial contributions to climate change and its harm to health from their culture but also profit from it. It is a disturbing paradox but plausible that the burden of disease from climate change, due to these exports of greenhouse gases, will continue to rise, even as the burden of disease from other forms of air pollution in Australia continues to fall.

Australian Case Studies of Air Pollution

Air pollution in Australia may have a comparatively low burden of disease by global standards, but there is increasing recognition that it imposes heavy economic and social costs, including a national health bill of up to A$24.3B each year (National Environment Protection Council 2014). Recent studies point to coal mining and coal-fired power generation as major contributors to these large and growing costs.

Reducing air pollution concentrations has a significant health benefit. A study in the USA found that a reduction of 10 micrograms per cubic metre (μ/m3) in the concentration of fine particulate matter (PM2.5) explained as much as 15% of the overall increase in life expectancy in the study areas which occurred between the late 1970s and the early 2000s (Pope et al. 2009). This improvement followed determined efforts in the USA to improve air quality. Similarly, legislation in Australia has resulted in cleaner air but probably from a less polluted starting point. In lieu of comparable national-scale studies, we discuss several categories and case studies. Collectively, these examples illustrate that the health effects of air pollution in Australia are far from trivial and can and should be reduced.

Industry

Australia has been free of dramatic episodes of mortality from industrial air pollution, similar to the Meuse Valley and Donora. Pockets of industrialised air pollution exist, some of it little contaminated by pollution from traffic or domestic sources, due to small populations and isolation. Examples include Port Pirie, South Australia (the world's third largest lead-zinc smelter); Broken Hill, New South Wales (NSW); and Mount Isa, Queensland. Contamination of surfaces with dust containing lead and other heavy metals in these towns is still problematic, with exposures in children likely to reduce school performance (Taylor et al. 2013, 2014). In fact, the studies which conclusively showed that lead exposure reduced children's abilities (with, presumably, lifelong consequences) were undertaken at Port Pirie (McMichael et al. 1988). Despite attempts to reduce lead pollution in these smelting towns, problems persist. While levels are lower than at their peak, in some places they may again be worsening (Taylor et al. 2014).

Other sources of industrial air pollution include cement works, steel mills and coal-burning thermal power stations. In response to long-standing concerns about the health effects of air pollution near heavy industry, a cross-sectional study was conducted in the two steel-making cities in NSW (Newcastle and Wollongong) using data from 1993 to 1994. It found a dose-response relationship between PM10 levels and chest colds in primary school children but no relationship with SO2 exposure (Lewis et al. 1998). Each of these cities is large enough to also experience significant traffic pollution, and in fact control groups in these studies were still exposed to a significant level of PM10, of about 15 μg/m3. The authors commented that the results they found provided evidence of health effects at lower levels of outdoor air pollution in the Australian setting than was then expected. Note however, even in 2016, that the 'standard' level for PM10 exposure in Australia is 50 μg/m3 averaged over 24 h and 25 μg/m3 averaged over 1 year (NSW Environment Protection Authority and Office of Environment and Heritage 2016).

Traffic

Motor vehicles enable the movement of millions of people but have obvious drawbacks, including congestion, noise, cost, accidents and greenhouse gas emissions. In many locations, motor vehicle emissions merge with industrial and other sources of air pollution. A widely cited study from Europe (albeit using data now quite dated) concluded that about half of all mortality caused by air pollution was from motorised traffic (Künzli et al. 2000). Motor vehicles have been described as the dominant cause of air pollution in Australia (Barnett 2013); however, this is disputed by the National Environment Protection Council (2014). Certainly, in some regions and seasons, sources other than traffic, particularly wood heaters ($PM_{2.5}$ in urban areas), coal-fired power stations (SO_x, NO_x and $PM_{<2.5}$ in non-metro environments) and coal mines (PM_{10}, in non-metropolitan regions), are more important.

Air pollution from motor vehicles has been linked with the general range of respiratory and cardiac conditions, including atopy (Bowatte et al. 2015), and, possibly, congenital birth defects (Hansen et al. 2009; Padula et al. 2013). One study, based in Adelaide, South Australia, with an estimated population of 1.4 million in 2030, concluded that shifting 40% of vehicle kilometres travelled away from fossil fuel powered passenger vehicles to walking, cycling and public transport would lower annual average urban $PM_{2.5}$ concentrations by approximately 0.4 $\mu g/m^3$, saving about 13 deaths per year and preventing 118 disability-adjusted life years (DALYs) per year, due to improved air quality. It pointed out that additional health benefits may be obtained from improved physical fitness through active transport and fewer traffic injuries (Padula et al. 2013). Electric vehicles, if fuelled by renewable energy, will also improve air quality.

Diesel fumes

The carcinogenic effect of diesel exhaust products has long been suspected, and diesel was raised to Level-1 (most carcinogenic) by the International Agency for Research on Cancer in 2012 (Swanton et al. 2015). In recognition, the mayors of four major global cities have promised to ban the use of all diesel-powered cars and trucks from their streets, by 2025 (McGrath 2016). To date, no leader of an Australian city has indicated that they will match this.

Biomass and Dust

Woodsmoke

Although deliberate biofuel combustion for cooking and heating is modest in Australia compared to many low-income countries, fine particle pollution from

Fig. 9.1 In June (winter) 2016, a layer of woodsmoke settles over Armidale, a city in rural NSW of approximately 25,000 people, located at an elevation of almost 1000 m on the New England Tableland (Credit: Nathan Smith, Armidale Regional Council)

wood heaters is also a problem in some of Australia's larger cities. In Sydney, for instance, wood smoke accounts for 47% of annual PM2.5 emissions and up to 75% of particle emissions during winter (NSW Environment Protection Authority and Office of Environment and Heritage 2016). Without decisive government action to ban, replace and improve domestic wood heaters, health costs of A$8.1B are projected over 20 years in New South Wales alone (AECOM 2011).

Several urban areas in Australia experience particularly high ambient air pollution not only as a result of household use of firewood for heating but also because they are prone to inversion layers, in which a layer of warmer air above the smoke traps a cooler, polluted layer below. Three such places are the Tuggeranong valley (population c90,000) in southern Canberra (Australian Capital Territory); the smaller, regional cities of Launceston (Tasmania); and the Armidale (NSW) (see Fig. 9.1). In all these cases, winters are cold and wood fuel is comparatively cheap, abundant, and available.

Recognising the extent of air pollution in Launceston, coordinated strategies were undertaken in 2001 to reduce emissions from wood smoke, involving community education, enforcement of environmental regulations and wood heater replacement programme. A study in this city, then with a population 67,000, examined changes in daily all-cause, cardiovascular and respiratory mortality during the 6.5-year periods before and after June 2001. Mean daily wintertime concentration of PM10 fell markedly, from 44 μg/m3 (1994–2000) to 27 μg/m3 (2001–2007). This was associated with a statistically significant reduction in annual mortality among males and with lower cardiovascular and respiratory mortality during the winter months, for both males and females (Johnston et al. 2013).

Forest Fires

Smoke from bushfires in Australia is modest compared to South East Asia but is increasingly recognised to have adverse public health effects (Johnston et al. 2011; Price et al. 2012). A study of air pollution from savanna fires in Darwin, Northern Territory, examined the association between PM10 and daily emergency hospital admissions for cardiorespiratory diseases during each fire season from 1996 to 2005. It also investigated whether the relationship differed in indigenous Australians. Using modelled (rather than recorded) data, this study found an association between higher PM10 levels and daily hospital admissions that was greater in indigenous people (Hanigan et al. 2008).

Dust

Some cities in Australia experience periodic dust storms, worsened by drought and land clearing. Though fairly transient, these also impair air quality and have been found to be associated with increased mortality (Johnston et al. 2011).

Mining

Many forms of mining are associated with ill health, including from occupational exposure to toxic substances in poorly ventilated spaces including radiation daughter products, dust and fumes. Population exposure from the smelting of heavy metals (such as lead) is well documented, with exposure via inhalation and from contact with contaminated dust, including from children playing. Coal is hazardous to health not only from its mining but also its deliberate combustion (Castleden et al. 2011), which in Australia is mostly for electricity production and for steel production.

Solastalgia, Noise and Health Complaints in the Hunter Valley

The Hunter valley is a rural region of NSW, once best known for its vineyards and horse studs. However, in recent years the number of open cut coal mines has greatly increased, leading to great distress by some of its inhabitants. The term 'solastalgia' (loss of solace, formerly experienced in the same geographical setting, but gone, due to changes such as noise, industrialisation and air pollution) was coined in part to describe this distress (Albrecht et al. 2007). Additionally, in this location, many residents, civil society and local government groups have struggled to be heard by corporations and state governments, altering the region's social fabric and adding to their distress, depression, anxiety and ill health (Higginbotham et al. 2010). In limited support of these concerns, a study using general practitioner data from 1998 to 2010 found that the rate of respiratory problems in the Hunter Valley region did not fall significantly over time, in contrast to other rural areas of NSW (Merritt et al. 2013).

Coal Mining

A range of health impacts associated with power stations and coal mines has been studied. In Australia's coal mining regions, including the Hunter Valley, Latrobe Valley and Central Queensland, the vast majority of coarse particle (PM10) pollution is generated by open-cut coal mines. Adults living near coal-fired power stations have been reported as experiencing a higher risk of death from lung, laryngeal and bladder cancer, skin cancer (other than melanoma) and asthma rates and respiratory symptoms (Colagiuri et al. 2012). Children and infants are especially impacted, experiencing higher rates of oxidative deoxyribonucleic acid (DNA) damage, asthma and respiratory symptoms, preterm birth, low birth weight, miscarriages and stillbirths, impaired foetal and child growth and neurological development.

The adverse health impacts of Australia's fleet of coal-fired power stations have been estimated at A$2.6B per annum (Beigler 2009). In the Hunter Valley alone, the adverse health impacts of coal-fired power stations have been estimated at A $600M per annum (Armstrong 2015) (Fig. 9.2).

Fig. 9.2 Uncovered coal wagons in Newcastle, NSW, releasing an obvious stream of particles credit John Nella

The Morwell Coal Mine Fire

In early 2014, a fire burned for 45 days in the Hazelwood open-cut coal mine in the industrialised Latrobe Valley of Victoria started by an adjacent bushfire. This triggered one of the worst short-term episodes of air pollution in Australian history. Several communities were affected by smoke, particularly the township of Morwell, with a population of about 15,000, located less than a kilometre from the fire. The concentration of smoke contaminants was regularly monitored in several locations, by the Environment Protection Authority of Victoria, including in South Morwell (Reisen et al. 2016). The level of PM2.5 briefly peaked at over 700 μg/m3, 32 times the reporting standard of 25 μg/m3 averaged over 24 h (Fisher et al. 2015). Despite this, no one was compulsorily evacuated from Morwell nor even strongly advised to leave. Limited monitoring of the affected population is now being undertaken (Fisher et al. 2015). A Victorian Government inquiry into the mine fire concluded that there was a high probability that air pollution contributed to an increase in mortality during the fire and that the fire harmed the health of many in this community.

Black Lung in Australian Miners

Pneumoconiosis (‘black lung’) is a well-known occupational hazard for coal miners, occurring from overexposure to coal dust, first described in the seventeenth century. In Australia, however, which requires compulsory participation by miners in X-ray screening programs, no cases were reported for over 30 years, until recently (Cohen 2016). This was though due to better dust control in mines, a study from 2002 reported that, in 6.9% of measurements, dust exposure in 33 longwall coalmines in NSW exceeded the Australian National Standard (Castleden et al. 2011). A more recent audit of underground coal mines in Queensland found that an increasing number of workers are exposed to harmful concentrations of respirable dust, well above regulatory limits (Commissioner for Mine Safety and Health 2015). The reappearance of pneumoconiosis is thus perhaps not surprising, but what was surprising was that precautionary X-rays in miners were misread over a long period, thus contributing to complacency (Cohen 2016).

Air Pollution, Urban Forests and Pollens

Increasing the number of trees in urban areas has long been suggested as a means to reduce air pollution and lower the heat island effect (Benjamin et al. 1996). Trees reduce the quantity of particulate matter, by making available a large surface area of bark and leaves (especially of evergreens or in spring to autumn) on which gases and particles can be deposited. They can also help decompose some air pollutants, including ozone, by releasing gases (Grote et al. 2016).

However, some trees have a significant ‘ozone-forming potential’ (Grote et al. 2016), with some species reported to have up to four orders of magnitude more capacity to release photochemically reactive hydrocarbons than others (Benjamin et al. 1996). Eucalyptus trees, which are well known for producing a blue haze in some settings (hence the ‘Blue Mountains’, near Sydney, NSW), may have a significant effect in Australian settings on air pollution, by their release of hydrocarbons that may contribute to smog, but the net effect of this appears understudied. An increased urban forest, planted to improve air quality, might also elevate the risk of urban bushfires.

Some tree species also have significant quantities of wind-dispersed pollen, allergens, which can cause severe distress in vulnerable people, including asthma and possibly mood changes. For example, there are credible claims that exposure to allergens is a factor underpinning the long observed rise in suicides in spring (Kõlves et al. 2015). Grass pollens, however, may be more problematic than from trees, including in thunderstorm asthma (D’Amato et al. 2007). A study in Darwin found an association between Poaceae grass pollen and the sale of antihistamine medication (Johnston et al. 2009).

Climate Change and Health in Australia

The health effects of climate change in Australia include primary (direct, comparatively obvious) effects such as from climate change-exacerbated heatwaves, droughts, fires and floods; secondary (less obvious, indirect) including changes in allergens and atopic diseases and infectious diseases and rising food prices and impaired nutrition; and tertiary (highly indirect, catastrophic), including regional war and mass migration (Butler and Harley 2010).

Primary Health Effects

Already, extreme events, contributed to by climate change, are increasing in Australia. Although the death toll of rural suicide from droughts in Australia has recently declined (probably due to better intervention) (Hanigan et al. 2012), this improvement may not last; living with chronic depression due to loss of livelihood and other trauma (e.g. being forced to shoot suffering stock) is still likely to be high, as is the health toll from exposure to floods and, sometimes, resultant displacement. Prolonged, extreme heat in Australia is also documented to cause excessive deaths and morbidity, particularly in vulnerable sub-groups (Nitschke et al. 2011).

Secondary Health Effects

As this chapter was being finalised, the population of the Victorian state capital, Melbourne, experienced the worst episode of 'thunderstorm asthma' to ever occur in Australia. This caused the premature death of at least eight people, most or all of whom were comparatively young (Calligeros et al. 2016). Thousands were hospitalised and overwhelmed emergency services, including by generating ambulance calls every 4.5 s. This was contributed to by a wet spring, humidity and a hot day in late spring (Calligeros et al. 2016). It is plausible that climate change may make such episodes more frequent. The major source of the allergens involved in this appears to be rye grass, rather than tree pollen.

The pattern of some infectious diseases in Australia, including Ross River virus and dengue fever, is also likely to be subtly altered by climate change (Williams et al. 2016). There are many other examples, such as melioidosis and leptospirosis (Currie 2001). However, an increase in mortality from altered infectious diseases epidemiology is unlikely to be marked.

Tertiary Health Effects

Australia is a very wealthy country, though the distribution of health and other forms of security is increasingly unequal. The most dire health effects of climate change are likely to be long avoided in Australia; however, the country is already subtly affected by conflict in the Middle East, Afghanistan and parts of sub-Saharan Africa. Some of this turmoil (which also has led to the current global refugee crisis) can be attributed to climate change, interacting with social factors, including poverty, poor governance, discrimination and limits to growth (Bowles et al. 2015; Butler 2016; Schleussner et al. 2016).

The Australian government, with wide public support, has practised human rights abuses of asylum seekers for well over a decade (Newman et al. 2013). A possible explanation for this behaviour is fear, rather than overt cruelty. That is, most Australians may support a strong 'fend' (deterrence) signal to asylum seekers because they wish to prevent additional refugees seeking protection in Australia, a rich country widely perceived as underpopulated. Unfortunately, however, Australia, by cutting its foreign aid, and by aggressively exporting products that contribute to climate change, is continually seeding conditions likely to increase refugee numbers, including in countries in its region. As sea level rise and other manifestations of climate change worsen in poor, 'developing' countries in South Asia (Singh et al. 2016) and the Pacific, the number of people seeking refuge in Australia is likely to climb steeply.

Towards Solutions

Industry and Weak Legislation

In Australia, state and national air pollution laws provide few opportunities for impacted communities to seek a legal remedy. National air pollution standards are determined by Australia's nine[1] environment ministers, meeting as the National Environment Protection Council, yet are governed by state and territory laws. The Council's decision-making has been described as taking a 'lowest common denominator' approach, resulting in standards that reflect the position of the state or territory least inclined to regulate polluters. But even these low standards are not always met; each jurisdiction adopts a different approach, drawing from a regulatory toolbox that includes consent conditions for major polluters, environmental pollution licences, pollution monitoring, auditing, annual reports and various compliance mechanisms. In sharp contrast, in the USA, the US Environment Protection Authority has the power to impose sanctions on states that fail to comply with air pollution standards, which are set centrally.

In Australia, prosecutions for breaching licences or causing environmental harm from air pollution are infrequent, fall far short of the real costs of the harm caused and are generally inadequate to compel companies to invest in pollution control. Consequently, air pollution-impacted communities in Australia look to the regulatory systems in other countries for models that may be effective here.

Community Action and Organising

Air pollution consistently ranks highly among environmental concerns, particularly in communities that experience elevated levels of pollution due to specific local or regional sources. The weak legal and regulatory framework for air pollution control in Australia described above, coupled with increasing air pollution levels, leads citizens to initiate and participate in various forms of community action.

The starting point for many people is a desire to know as much as possible about what they're breathing. Residents in polluted communities assert their 'right to know' by phoning pollution hotlines, approaching polluters directly and accessing government websites and reports for monitoring data. Although state and territory governments conduct air pollution monitoring in many locations, few provide ready access to the data they collect, and there are significant 'black spots': regions that experience high levels of pollution but where governments permit and tolerate self-monitoring by industry but with no public access to these data. In the vast coalfields of Central Queensland, for instance, there is no government or independent

[1] Six state, two territorial and one federal.

monitoring for more than a million square kilometres, and community members have no legal right to access industry monitoring data. The power generators in the Latrobe Valley have, for years, monitored local pollution, free of any obligation to share their results.

In response to this suppression of information, community members have sometimes turned to citizen science. In the Hunter Valley, North West New South Wales and South East Queensland, community members have documented an increase in air pollution concentrations as coal train pass, confirming their long-held concerns.

Community members value and participate actively in dialogue with industry and regulators. In the Hunter Valley and other industrialised regions, there are community consultative committees for most major polluting facilities. These 'CCCs' create a forum for community members to air concerns, seek information and articulate their expectations. Alas, in the authors' experience, they to date rarely achieve tangible pollution reduction outcomes. Information flow is primarily one-way, that is, neither industry nor government is very responsive.

The right to know, access to reliable data and dialogue are important but not substitute for demonstrable pollution control and reduction. Too frequently, government regulators are seen to be 'captured' by polluting industries and unwilling to exercise their full statutory powers to protect polluted communities. When 'polite' mechanisms fail, as they often do, citizens need to reply on a more 'activist' suite of tools that include media commentary, parliamentary politics, legal action and protest.

Conclusion: Low-Hanging Fruit: Immediate Co-benefits for Health and Climate Change

Enough is known about the sources and impacts of air pollution to enable the development of air pollution control plans for our major cities and other polluted regions. Pollution hotspots including the Newcastle, Gladstone, coalfields of New South Wales and Queensland and Hunter and Latrobe Valleys should have action plans that incorporate 'best practice' air pollution reduction strategies that have worked elsewhere, monitoring and evaluating arrangements to facilitate adaptive management and active community involvement.

The catalogue of 'no regrets' pollution control action that have worked in other countries includes introducing strict emission standards for power stations and motor vehicles, implementing a rapid and just transition from coal-fired power generation to renewable energy, banning new wood heaters and replacing existing ones, covering and washing coal trains, enclosing coal stockpiles and facilitating the uptake of electric vehicles.

Polluters and regulators need to be much more transparent and more accountable. This requires a change in political will and almost certainly necessitates a strong national approach to air poll. Leaving states to adopt diverse approaches to air pollution, management and regulation has failed to curb air pollution in Australia. The health benefits of controlling air pollution in Australia warrant a much stronger approach. There also needs to be a much greater appreciation of the health and economic costs of air pollution and climate change. It is enormously misleading to claim that coal-fired electricity is 'cheap'. Coal mining, coal combustion and coal export cause significant health costs, in the past, present and future. Furthermore, the price of alternatives such as wind and solar continues to fall. Reducing emissions from the burning of wood and the combustion of vehicular fuel is more challenging, but much can also be accomplished in these spheres too, including electric vehicles, public transport and, in the foreseeable future, domestic production and consumption of solar energy, incorporating batteries.

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