CAR
Centre for Air pollution, energy and health Research

Patterns of Air Quality around Australia

Full Technical Report

December 2022

The accompanying document, *Patterns of Air Quality around Australia: Summary and Star Ratings, is a*vailable from www.car-cre.org.au

Our vision is for a healthier community through cleaner air and cleaner energy sources

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Prepared by

Rachel Tham, Fay Johnston, Ana Porta Cubas, Joy Tripovich, Shyamali Dharmage, Sharon Campbell and Graeme Zosky for the Research Translation Committee of the NHMRC Centre for Air pollution, energy and health Research (CAR). The views expressed are those of CAR and not necessarily those of other affiliated organisations.

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About us

The Centre for Air pollution, energy and health Research (CAR) is a NHMRC Centre for Research Excellence in Australia. It is a national group of researchers focusing on the health impacts of air pollution.

Our vision for healthier communities is the driving force behind our work.

Contact us

Please email us at car@sydney.edu.au or visit www.car-cre.org.au

Summary

About the project

This report illustrates variations in air quality measured at selected government air monitoring stations around Australia. Inspired by the health star rating system for food, which enables consumers to compare the relative healthiness of similar food products, we developed a five-star rating system that recognises the attributes of air quality that promote health. This facilitates easier recognition of regions where targeted interventions will improve community health.

To the best of our knowledge, this is the first time that an attempt has been made to simplify air quality information and trends for consumers and other stakeholders. We will continue to seek feedback to inform and refine future work in this area.

Our approach

We developed five criteria based on the amount of airborne particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$) measured at each air monitoring station. The criteria are based on both long-term and short-term concentrations of $PM_{2.5.}$ We included data from selected government air quality stations in each State and Territory that had at least 90% complete data available for every year since 2016. The rating criteria included (1) concentration and trends in yearly average and (2) frequency of days with elevated $PM_{2.5}$.

For each criterion we gave a full star if the air quality was better than average Australian conditions or on a good trend. A half-star indicated more typical air quality conditions for Australia, showing potential for improvement. No stars were given if air quality was worse than usual compared with most Australian locations or on a worsening trend. A higher star rating indicated better air quality.

To illustrate locations with strong seasonal variations in air quality, we presented the average air pollution for the warmer and cooler months at each station.

Main results

We have reported star ratings for 36 sites around Australia. The results ranged from half-a-star to four-and-a-half stars, with an average of two-and-a-half stars. One of the common reasons for reduced ratings was the influence of landscape fires, especially the Black Summer bushfires of 2019-2020, and annual savannah burning in the Top End of the Northern Territory. These caused multiple elevated pollution days and drove long-term trends. Another contributor in many locations was seasonal pollution from wood heater emissions.

Conclusions

While air quality in Australia is generally better than in many other places globally, this report highlights a wide variation in air quality around the country. There is considerable potential for interventions to protect health and improve air quality.

Background

Globally, air pollution is a major contributor to the burden of disease and premature mortality. Despite having comparatively lower levels of air pollution by global standards, a substantial preventable health burden is also experienced in Australia [1-3]. However, determining the influence of air pollution on individual and population health requires considerable technical expertise, and interpreting air quality information remains challenging for many people, including policy makers and health practitioners. Understanding the impacts of air quality, and how it influences health, requires knowledge of both short-term and long-term fluctuations in air pollution. Short-term fluctuations over hours or days are very important for the health of individuals in higher risk groups, such as infants, children, pregnant women, older people, and people living with chronic cardiovascular, respiratory and endocrine conditions [4]. However, exposure to air pollution over weeks to years are more crucial for overall long-term individual and population health. As with many other risk factors for chronic diseases, such as patterns of diet and physical activity, it is the everyday exposure to air pollution, rather than the infrequent extreme events, that ultimately has the biggest influence on health at a population level.

It is not simple for members of the community, health practitioners, policy makers or other stakeholders to find the relevant air quality information and place it in context for the health of individuals and communities. Public reporting and advice about air pollution tends to focus on short term fluctuations over hours or days. This is an important service, especially during extreme or prolonged events. However, information about long-term air pollution, in the form of yearly or seasonal trends is less readily available to the public.

Aims

Our project aimed to develop a simple rating system that illustrates patterns of air quality throughout Australia, including information on both long-term and short-term air pollution which are both important determinants of health. The specific objectives were to enable people across Australia to: (1) visualise how air quality in one location compares to other sites, and (2) provoke thought and discussion about the main drivers of the overall ratings and identify opportunities for air quality and health improvement.

Our approach

We evaluated concentrations of particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$), also known as fine particulate matter, measured at selected government-operated air quality monitoring stations located within residential areas around Australia over the period 2016 - 2021. Air monitoring stations were included if they reported nearly complete data for this period. Daily and annual averages of $PM_{2.5}$ were calculated to identify pollution days and long-term trends. We also examined variations between cooler and warmer seasons.

The air pollutant evaluated - $PM_{2.5}$

$PM_{2.5}$ was selected because it is one of the most important ubiquitous air pollutants affecting community health. Due to its tiny size, $PM_{2.5}$ can penetrate deep into the lungs and cross into the blood stream, and also cross directly from the nose into the brain [5]. Communities with higher levels of $PM_{2.5}$ are more likely to have higher rates of illness and death from diseases affecting the heart, lungs and brain [6]. This association is generally stronger in places with lower rather than higher pollution levels including Australia [3, 7, 8].

The main source of $PM_{2.5}$ in Australia is combustion. This includes the burning of wood for home heating, the burning of petrol or diesel for transport, and the burning of coal for power generation. Burning vegetation such as bushfires and planned burns is an intermittent but large source of combustion particulate matter [9, 10]. Modifying the ways in which we use combustion is one of the most effective ways to improve air quality and health.

Data collection and processing

Selection of air quality monitoring stations

We selected air monitoring stations located in or near residential areas that had more than 90% of data available each year from 2016 to 2021. Due to space constraints in the accompanying report, *Patterns of Air Quality around Australia: Summary and Star Ratings*, not all eligible stations in Sydney, New South Wales and Tasmania were included. The main aim of this project was to highlight geographic variation, rather than to report on every eligible station. In Sydney four of 18 eligible stations and in Tasmania eight of 35 eligible stations were included.

After initial selection of potential sites, each jurisdiction was contacted with a summary of the suggested sites and preliminary findings for their feedback. Based on their responses and interpretation, additional sites were identified, and some sites were removed.

Data sources

Hourly $PM_{2.5}$ data in $\mu g/m^3$ (micrograms per cubic metre) were obtained through several sources linked to government air quality monitoring stations.

Data from 2016 to 2020 were obtained via the Centre for Air pollution, energy and health research Data Analysis Technology (CARDAT) Platform [11]. This online research platform collates air pollution directly from all government air quality monitoring stations around Australia [12, 13]. Data from 2021 were obtained directly from the air quality reporting agency in each jurisdiction.

Some data from June 2020 to the end of 2021 are indicative as they had not been formally confirmed by the responsible agencies at the time of this report.

Calculating annual average $PM_{2.5}$

Hourly $PM_{2.5}$ data was checked for non-valid readings, and these were replaced with 'missing data'. The 24-hour period was included if ≥75 % of readings were valid or not missing. Hourly $PM_{2.5}$ was aggregated to calculate average 24-hour (daily) $PM_{2.5}$ levels from midnight to midnight.

The number of days per year for which 24-hour average data were available was calculated. Stations which had <90% of days in a year with valid $PM_{2.5}$ data were excluded.

For stations which met the inclusion criteria we calculated annual average $PM_{2.5}$ for 2016 to 2021. We then calculated the mean of annual average $PM_{2.5}$ for the 5-year period 2016 – 2020 to quantify the long-term burden of $PM_{2.5}$.

Calculating high and moderate air pollution days

We used the daily average $PM_{2.5}$ to classify days of moderate or high air pollution in 2021. A **high pollution** day was defined as day when the average 24-hour $PM_{2.5}$ exceeded the Australian National Environment Protection Measure (NEPM) 24-hour standard of 25 $\mu g/m^3$. A **moderate pollution** day was defined as a day when the average 24-hour $PM_{2.5}$ exceeded the World Health Organization (WHO) 24-hour guideline level of 15 $\mu g/m^3$ but remained lower than the NEPM 24-hour standard of 25 $\mu g/m^3$. We counted the number of days when average 24-hour $PM_{2.5}$ met the definition of either moderate or high pollution.

Cooler and warmer seasonal differences in $PM_{2.5}$

We also examined differences in the average $PM_{2.5}$ during the cooler and warmer seasons of the year. We initially defined seasons using the Australian Bureau of Meteorology Climate Glossary [14] as Spring (the transition months of September, October and November); Summer (the hottest months of December, January and February); Autumn (the transition months of March, April and May); and Winter (the coldest months of June, July and August). We then split and aggregated the transition months with the hottest and coldest months as follows:

- Cooler months – May, June, July, August, September and October
- Warmer months – November, December, January, February, March, April

In the tropical region of the Top End of the Northern Territory the cooler months correspond to the monsoon dry season, and the warmer months correspond to the wet season.

Developing the individual star ratings

The star rating for each station was based on the combined results of five criteria. These are described in Table 1. The more stars, the better the air quality for health. The highest rating possible was five stars and the lowest was zero.

The combined star rating for each station was classified by colour as follows:

Green - three or more stars. Green indicates above average air quality in that area. However, there may be specific individual criterion that could be improved, and any improvement in these will improve community health.

Yellow – two to two-and-a-half stars. Yellow indicates more typical air quality conditions for Australia. Air quality is generally good but there is room for improvement. Modest improvements in air quality in these areas will improve community health and wellbeing and lead to substantial economic benefits.

Orange – less than two stars. Orange indicates that the overall air quality is worse than typically seen in most Australian locations. Working to improve air quality should be a high priority in these regions. There is potential for substantial improvements in health and substantial health economic savings.

Table 1: Criteria used to determine the star rating of each air monitoring station

Criteria	Why this is important	Full star	Half star	No star
Average air pollution ($PM_{2.5}$) over a five-year period (2016-2020)	Long-term exposure to air pollution causes greater health impacts than brief daily fluctuations	Met the WHO guideline for yearly average $PM_{2.5}$ (≤5 µg/m^3)	Met the Australian NEPM standard for yearly average $PM_{2.5}$ (≤8 µg/m^3)	Did not meet the Australian NEPM standard
Average air pollution ($PM_{2.5}$) in 2021	A more recent indicator of long-term exposure than the 2016-2020 average	Met the WHO guideline for yearly average $PM_{2.5}$ (≤5 µg/m^3)	Met the Australian NEPM standard for yearly average $PM_{2.5}$ (≤8 µg/m^3)	Did not meet the Australian NEPM standard
Change from the 2016-2020 average to 2021 average	Ongoing reduction in long-term air pollution is an important goal for improving health	$PM_{2.5}$ in 2021 was lower than the previous five-year average	No change in $PM_{2.5}$ (+/- 2%) between 2021 and the previous five-year average	$PM_{2.5}$ was higher in 2021 than the previous five-year average
*Number of days in 2021 with **high** pollution*	Short-term increases in $PM_{2.5}$ can make existing illnesses like asthma or heart disease even worse	No high pollution days	Up to 10 high pollution days (Daily average $PM_{2.5}$ above Australian NEPM standard of 25 µg/m^3)	More than 10 high pollution days
*Number of days in 2021 with **moderate** pollution*	Moderate increases in air pollution make existing illnesses like asthma and heart disease worse, and if persistent, can contribute to long-term air pollution	No moderate pollution days	Up to 10 moderate pollution days (Daily average $PM_{2.5}$ above the WHO guideline of 15 µg/m^3 but not above the Australian NEPM standard)	More than 10 moderate pollution days

WHO = World Health Organization NEPM = National Environment Protection Measure

Results

Stations

A total of 36 stations were included. The number of air quality monitoring stations with relatively complete data from 2016 varied considerably between jurisdictions (Table 2).

Table 2: Air monitoring stations included in the report by jurisdiction

State/Territory	Capital city stations	Regional stations
Australian Capital Territory	Civic, Florey and Monash	Nil
New South Wales	Campbelltown West, Liverpool, Richmond, Rozelle	Newcastle, Singleton, Wagga Wagga, Wollongong
Northern Territory	Palmerston, Winnellie	Nil
Queensland	Cannon Hill, Rocklea, South Brisbane, Springwood	Nil
South Australia	Adelaide Central Business District (CBD), Netley (Adelaide West), North Haven (Adelaide north-west Le Fevre 2)	Nil
Tasmania	Hobart (New Town)	Campbell Town, Devonport, Geeveston, Huonville, Launceston (Ti-tree Bend), Longford, New Norfolk
Victoria	Alphington, Footscray	Geelong South, Traralgon
Western Australia	Caversham, Duncraig	Bunbury, Busselton

Nil = No eligible stations

Star ratings

Across Australia, the average star rating for air quality stations was two-and-a-half stars. This ranged from a half-star in Darwin and Busselton, to four-and-a-half stars in Hobart (Figure 1, Tables 3-11).

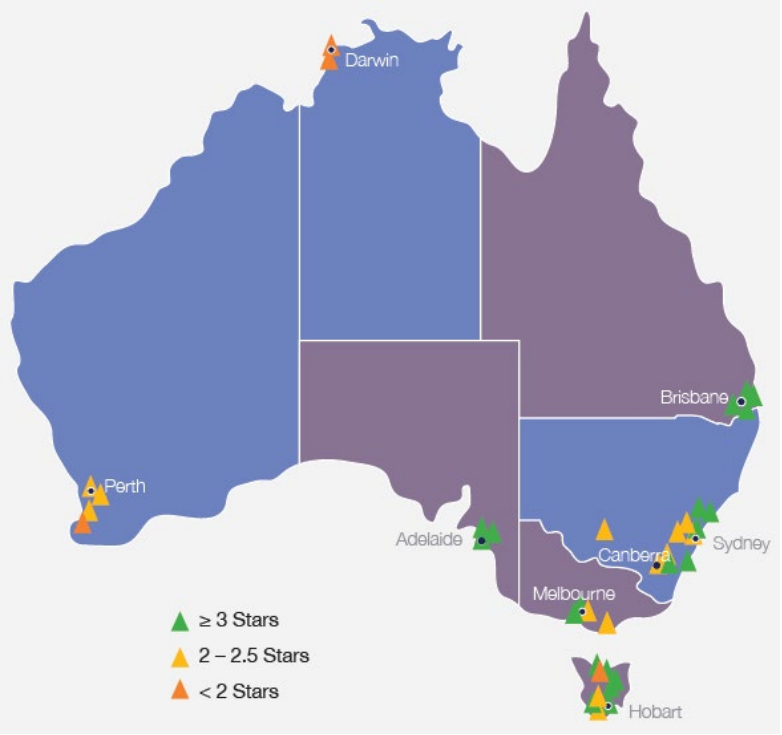

Figure 1: Locations of monitoring stations colour-coded according to their star rating

Results and comments by station

Individual station star rating, data for criteria, and cooler and warmer month average $PM_{2.5}$ are reported in Tables 3-10 by jurisdiction and in alphabetical order.

Infographics summarising the overall star ratings and seasonal differences for stations in each State and Territory are provided in the accompanying document: *Patterns of Air Quality Around Australia – Summary and Star Ratings*.

Australian Capital Territory

Table 3: Australian Capital Territory: data for criteria, cooler and warmer month averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Civic	8.9	4.9	Lower	0	32	5.0	4.8	3
Florey	10.8	6.1	Lower	3	23	7.1	5.1	2
Monash	10.7	6.8	Lower	9	43	8.3	5.3	2

The high values for average $PM_{2.5}$ in 2016-2020 were driven by extreme values for 2019 and 2020, coinciding with pollution impacts from the 2019-20 Black Summer bushfires. Average $PM_{2.5}$ in 2021 was lower than the average of the previous five years. During 2021 the monitoring station located in the city centre reported no high pollution days compared with those located in the residential suburbs. All moderate pollution days were associated with the cooler months of the year and are likely to reflect emissions from wood heaters [15, 16]. The average $PM_{2.5}$ in the city centre did not differ as much by cooler and warmer months as the suburban residential areas of Florey and Monash which experienced much higher average $PM_{2.5}$ during the cooler months. This is also likely to be influenced by the location of wood heaters.

New South Wales

Table 4: New South Wales: data for criteria, cooler and warmer month averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Sydney								
Campbelltown West	8.5	6.3	Lower	4	3	5.9	6.6	2.5
Liverpool	9.9	7.6	Lower	4	21	8.5	6.7	2
Richmond	8.7	6.7	Lower	4	12	7.7	5.8	2
Rozelle	7.9	6.3	Lower	3	9	6.9	5.7	3
Regional								
Newcastle	8.5	6.2	Lower	0	3	6.8	5.6	3
Singleton	8.6	6.3	Lower	0	6	6.3	5.4	3
Wagga Wagga	9.3	6.3	Lower	0	12	6.3	5.7	2.5
Wollongong	7.7	5.7	Lower	0	2	5.1	6.3	3.5

Average $PM_{2.5}$ values were generally lower in 2021 than the average of the previous five years for all New South Wales stations. The 2016-2020 average was increased by high values in 2019-2020 attributable to smoke from the 2019-2020 Black Summer bushfires. High pollution days in 2021 were recorded only within Sydney, and a larger number of moderate pollution days were recorded in Sydney compared with the regional centres. Apart from Campbelltown West (southwest Sydney) and Wollongong (south of Sydney) average $PM_{2.5}$ was generally higher during the cooler months than the warmer months. This might be due to wood heater emissions which have been identified as the primary human made source of $PM_{2.5}$ in Sydney [17]. Regional stations generally had better star ratings than the Sydney-based stations.

Northern Territory

Table 5: Northern Territory: data for criteria, cooler and warmer month averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Palmerston	8.0	9.7	Higher	14	58	15.1	3.8	0.5
Winnellie	7.5	11.6	Higher	27	60	16.0	3.9	0.5

In contrast to other jurisdictions, average $PM_{2.5}$ in Darwin in 2021 was higher than the average of the previous five years. This is consistent with a worsening trend that has been reported elsewhere [18]. The number of high pollution and moderate pollution days were much higher than in other jurisdictions. These occurred during the cooler months in association with local and regional savannah burning. Average $PM_{2.5}$ during the cooler months was much higher than during the warmer months.

Queensland

Table 6: Queensland: data for criteria, cooler and warmer month averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Cannon Hill	7.2	6.3	Lower	0	1	7.3	5.9	3.5
Rocklea	7.0	4.6	Lower	0	1	5.4	3.8	4
South Brisbane	8.0	6.6	Lower	0	0	7.3	5.4	4
Springwood	5.7	4.8	Lower	0	1	5.6	3.4	4

Average $PM_{2.5}$ was lower in 2021 than the average of the previous five years. As for other eastern states, this is likely due to the influence of pollution from the Black Summer bushfires in 2019-2020 on the five-year average from 2016-2020. During 2021, Brisbane did not record any high pollution days and only a minimal number of moderate pollution days. Average $PM_{2.5}$ during the cooler months was generally higher than during the warmer months.

South Australia

Table 7: South Australia: data for criteria, cooler and warmer month averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Adelaide CBD	6.5	6.0	Lower	0	2	5.6	6.4	3.5
Netley	7.3	5.6	Lower	0	2	5.8	5.3	3.5
North Haven	6.2	5.1	Lower	1	1	4.7	5.4	3

All reported Adelaide stations were located on the Adelaide Plains as no stations in the Adelaide Hills met the inclusion criteria. Average $PM_{2.5}$ was lower in 2021 than the average of the previous five years. During 2021 only one site, North Haven, reported a single high pollution day and only a minimal number of moderate pollution days. There was no clear pattern in the differences between $PM_{2.5}$ during the cooler and warmer months. At two stations, average air quality was better in the cooler months, and at one station average air quality was better during the warmer months.

Tasmania

Table 8: Tasmania: data for criteria, cooler and warmer month averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Campbell Town	5.6	3.9	Lower	0	9	5.5	2.3	4
Devonport	5.4	4.1	Lower	0	6	5.8	2.3	4
Geeveston	9.3	6.2	Lower	9	37	9.9	2.4	2
Hobart	3.6	2.6	Lower	0	4	3.7	1.4	4.5
Huonville	5.7	4.2	Lower	1	13	6.3	2.0	3
Launceston	5.6	4.1	Lower	1	15	6.2	1.9	3
Longford	10.2	6.4	Lower	15	23	9.8	2.7	1.5
New Norfolk	8.9	6.1	Lower	15	45	9.6	2.5	2

There was notable variation in average $PM_{2.5}$ across the sites in Tasmania. However, the average $PM_{2.5}$ was lower in 2021 than the average of the previous five years at all stations. Three sites (Geeveston, Longford and New Norfolk) had a number of high pollution days which correlates with the higher average $PM_{2.5}$ during the cooler months. $PM_{2.5}$ during the cooler months was higher than during the warmer months in all stations reflecting wood heating as the dominant source of air pollution in Tasmania [8]. Reasons for the improvement in 2021 have not been studied. Parts of Tasmania experienced severe bushfire smoke impacts in 2016 and 2019, which would have influenced the 2016-2020 average. However, it is possible that an exceptionally warm winter in 2021 [19] could have resulted in a reduced need for domestic heating and lower winter pollution.

Victoria

Table 9: Victoria: data for criteria, cooler and warmer month averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Alphington	7.5	7.1	Lower	4	10	7.6	6.8	2.5
Footscray	7.6	5.2	Lower	0	6	5.2	5.2	3.5
Geelong South	6.6	5.6	Lower	0	13	6.1	5.6	3
Traralgon	8.7	7.2	Lower	2	14	8.4	6.0	2

At all Victorian stations the average $PM_{2.5}$ in 2021 was lower than the average of the previous five years. As for other eastern states, this could have been due to the influence of pollution from the Black Summer bushfires in 2019-2020 on the five-year average from 2016-2020. In 2021 the Alphington site reported higher average $PM_{2.5}$, more high pollution and moderate pollution days and slightly higher average $PM_{2.5}$ during the cooler months. However average $PM_{2.5}$ did not vary by season at Footscray. In 2021 both Traralgon and Geelong recorded higher average $PM_{2.5}$during the cooler months compared with the warmer months. They both recorded a similar number of high pollution and moderate pollution days.

Western Australia

Table 10: Western Australia: data for criteria, cooler and warmer months averages, and star ratings

Station	Average $PM_{2.5}$ 2016-2020 ($\mu g/m^3$)	Average $PM_{2.5}$ 2021 ($\mu g/m^3$)	Change 2016-20 to 2021	High pollution days 2021 (n)	Moderate pollution days 2021 (n)	Cooler months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Warmer months average $PM_{2.5}$ in 2021 ($\mu g/m^3$)	Stars
Caversham	8.0	6.9	Lower	6	20	6.8	7.1	2.5
Duncraig	7.4	6.7	Lower	6	14	6.1	7.3	2.5
Bunbury	8.4	6.5	Lower	4	17	6.6	6.4	2
Busselton	8.1	8.4	Higher	8	28	9.6	7.1	0.5

The average $PM_{2.5}$ was lower in 2021 than the average of the previous five years in all sites except Busselton. Busselton recorded the highest number of high pollution and moderate pollution days and average $PM_{2.5}$ was higher during the cooler months than the warmer months. Caversham, Duncraig and Bunbury also recorded several high and moderate pollution days but the average $PM_{2.5}$ was higher during the warmer months than the cooler months. There are several well-established sources of reduced air quality in the southwest Western Australia, including the impacts of smoke from prescribed burning, bushfires and domestic wood heaters [10]. However, the relative contributions of these sources at each station since 2016 is unclear.

Discussion

The background concentrations of air pollution in most areas of Australia are relatively low when compared with other countries around the world [20]. However, this is not uniform across the country. This report uses a simple format to highlight the wide local variation in air quality and emphasise the considerable potential for improvements in population health through local interventions to improve air quality and protect health.

Overall, many parts of Australia have good air quality when considered from an annual average perspective. However, there are parts of Australia where there are seasonal differences in $PM_{2.5}$ which results in poorer air quality over the period of weeks to months. The most prominent seasonal differences were in Darwin, parts of Tasmania, and Busselton in southwest WA. Smoke impacts from seasonal savannah burning for fire management in the NT is the driver of poor air quality in Darwin, as seen in the $PM_{2.5}$ levels during the dry season (cool months) [18]. Outside prolonged bushfire seasons, smoke emitted from wood heaters drives important seasonal impacts during the cool months in the ACT [15], parts of NSW [21], parts of Tasmania [8] and south-west WA [10].

Cities with the largest and densest populations, such as Sydney and Melbourne, have a range of important sources of higher concentrations of $PM_{2.5}$ which do not have strong seasonal signals.

The smoke emitted from the widespread and prolonged severe bushfires experienced across Australia during the Black Summer of 2019 to 2020 [22] were strong drivers of the lower star ratings over the 5-year long term average. In 2021, most eastern states showed a good trend towards improvement which is likely due to the lack of fire impacts, contributions of COVID-19 lockdowns and associated reduced traffic sources, and an unusually warm winter which would have reduced the use of wood heaters [19].

Population groups exposed to increased concentrations of $PM_{2.5}$ over longer periods of time are at higher risk of diseases affecting the cardiovascular (heart and blood vessels), respiratory (lungs, nose, throat) and nervous (brain and nerve) systems. However, there is substantial evidence to show that there is no safe threshold for exposure to $PM_{2.5}$, which means that any action taken to reduce levels of $PM_{2.5}$ would improve health outcomes in affected communities.

To the best of our knowledge, this is the first time in Australia an attempt has been made to simplify air quality information and trends for consumers and other stakeholders. We will continue to seek feedback to inform and refine future developments in this area. This report also highlights geographical gaps in existing air monitoring. Addressing these gaps is crucial to identifying residential areas that would benefit from air pollution abatement strategies or interventions.

This project has used publicly available and routinely collected data, which is cost efficient. This will enable ongoing assessment of long-term air quality trends across Australia. Since 2016, additional air quality monitoring stations have been established across Australia and many of these can be included in future reports.

There are limitations that need to be considered. The star ratings represent the air quality at individual monitoring stations and do not capture patterns across larger areas. Therefore, accurate air pollution exposure on the broader community is not quantified. Some stations were not included in this report due to incomplete data and so some regional or local variations may not have been reported. As a pilot project, we aimed to illustrate the variations in air quality. Therefore, in Tasmania and NSW we reported representative sites of high and low star ratings, rather than including every station due to space constraints within graphical illustrations. In addition, the

technical approaches applied in air quality monitoring stations varies between jurisdictions. This highlights the need for national harmonisation of these approaches to minimise any measurement differences between States and Territories.

Conclusions

In Australia, air quality is better than in many other countries, but current air pollution challenges exist. These include emissions from landscape fires and wood heaters. Minimising air pollution from these sources will lead to improved health outcomes in the community. Reducing dependence on combustion, including wood burning, working to mitigate climate change to reduce the risk of future bushfire disasters, and improving the management of bushfire smoke impacts are all pathways towards achieving this goal.

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