Government of **Western Australia**
Department of **Water and Environmental Regulation**

Ambient dust monitoring campaign, Pinjarra

Department of Water and Environmental Regulation

August 2024

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Contents

Figures

Tables

Summary

This report presents a summary of the data the Department of Water and Environmental Regulation (the department) collected during a short-term air quality monitoring campaign in Pinjarra, Western Australia (WA). The campaign was undertaken in response to concerns expressed by community members regarding potential dust emissions from the nearby Alcoa Pinjarra Refinery operations.

An air quality monitoring station was operated at a community receptor location, chosen for its relevance, on the northeastern outskirts of the Pinjarra township, over three periods in 2023 and 2024 for about five months in total. The objective of the monitoring campaign was to assess ambient dust levels at the location for different times of the year, to help provide a more representative view. The monitoring station had this equipment:

- Two beta-attenuation (BAM) monitors to measure concentrations of particles in ambient air as particulate matter (PM) with a:
  - diameter of 10 micrometres (µg) or less (PM_{10})
  - diameter of 2.5 µg or less ($PM_{2.5}$) for public health assessment.
- A high-volume air sampler (HVAS) to measure the metals content of PM_{10} for public health assessment.
- A dust-deposition vessel for the assessment of amenity impacts, such as soiling of surfaces.
- A meteorological sensor to measure wind speed and wind direction to assist with data analysis and interpretation.

An independent contractor commissioned and operated the monitoring station on behalf of the department. The periods of monitoring were:

- Phase 1 – April to June 2023 (2 months) and August to September 2023 (1 month)
- Phase 2 – December 2023 to January 2024 (2 months).

There were problems with the operation of the BAM PM_{10} and HVAS PM_{10} monitors during the campaign, leading to data reliability issues. Consequently, the Phase 1 BAM PM_{10} data have not been included in this report. There were also limitations with the HVAS PM_{10} data, but these data are included in the report to provide an indication of dust and metals concentrations.

The BAM PM_{10} data for the summer period of monitoring (Phase 2), and the BAM $PM_{2.5}$ data for both phases of monitoring are considered to be reliable.

Based on the department's analysis, the campaign's findings for particle concentrations in relation to *National Environment Protection (Ambient Air Quality) Measure* (NEPM) health guidance were:

- There were no exceedances of the PM_{10} NEPM daily guideline of 50 µg/m^3, based on the BAM and HVAS data included in the analysis.

- Over the Phase 1 and 2 periods of monitoring there were two exceedances of the $PM_{2.5}$ NEPM daily guideline of 25 µg/m^3; one in April 2023 and one in January 2024, most likely due to smoke from fires in the area.
- Based on the available monitoring data, there was no indication of exceedances of the PM_{10} or $PM_{2.5}$ NEPM annual guidelines.

The campaign's findings for metals concentrations in PM_{10} samples were:

- There was no indication of exceedances of the available daily or annual health guidelines for the metals analysed.

The campaign's findings for deposited dust were:

- There were no exceedances of the deposited dust amenity guideline for the five monthly samples collected during the monitoring periods.

The department's analysis also looked at when PM_{10} and $PM_{2.5}$ hourly concentrations were elevated, and the average wind directions for these hours. Overall, there was a relatively small number of hours with elevated concentrations. Elevated $PM_{2.5}$ concentrations appear to be associated with smoke events. About 30 per cent of the small number of elevated PM_{10} hourly concentrations were from the general direction of the Alcoa operations.

The Department of Health has reviewed the results and advise that the measured concentrations of dust and metals do not represent a public health risk at the relevant location where the monitoring was conducted.

The contractor also provided a detailed technical report of the monitoring campaign. As that report was not suitable for a general audience and included the Phase 1 BAM PM_{10} data that the department considers to be unreliable, the department has prepared this summary report of the campaign.

1 Background

For several years, the department has received community complaints that express concerns around potential impacts of dust emissions in the Pinjarra area. Complainants have included Alcoa Pinjarra operations to the east of Pinjarra as a source of dust. In community meetings organised by the department and attended by the Department of Health, although primarily concerned about health impacts, some families have also described impacts on their amenity due to dust that is in the air and also being deposited on their properties.

In response, the department designed a short-term air quality monitoring campaign to assess the concentration and composition of airborne particles and levels of deposited dust. Community members gave permission for the monitoring to be undertaken on their property, which was representative of an outer residential site that is relatively close to the Alcoa residue area and other potential dust sources in the area.

An independent contractor was engaged to undertake the monitoring, which was conducted over three periods during 2023 and 2024 for a total of five months.

The monitoring campaign was designed to assess ambient dust levels at the location at different times of the year, with a focus on likely worst-case conditions during summer with higher temperatures and frequent easterly winds.

This report presents a summary of the data collected during the campaign.

1.1 Campaign objectives

The primary objective of the monitoring campaign was to measure the levels of airborne particles (PM_{10} and $PM_{2.5}$), the metals content of PM_{10} samples and levels of deposited dust at a location near the Pinjarra township that was relatively close to potential sources and compare these levels with air quality guidelines.

A secondary objective was to assess short-term airborne particle levels along with wind data to see if there was evidence of higher levels of particles coming from specific wind directions that may indicate a potential source.

1.2 Campaign area

Pinjarra is located 83 km south of Perth in the Peel region of Western Australia (WA). It has a population of about 4,000 people.

Pinjarra has a climate characterised by hot, dry summers and cool, wet winters. Figure 1 provides a summary of Pinjarra's climate, based on the Bureau of Meteorology (BOM) monitoring sites at Karnet and Dwellingup.

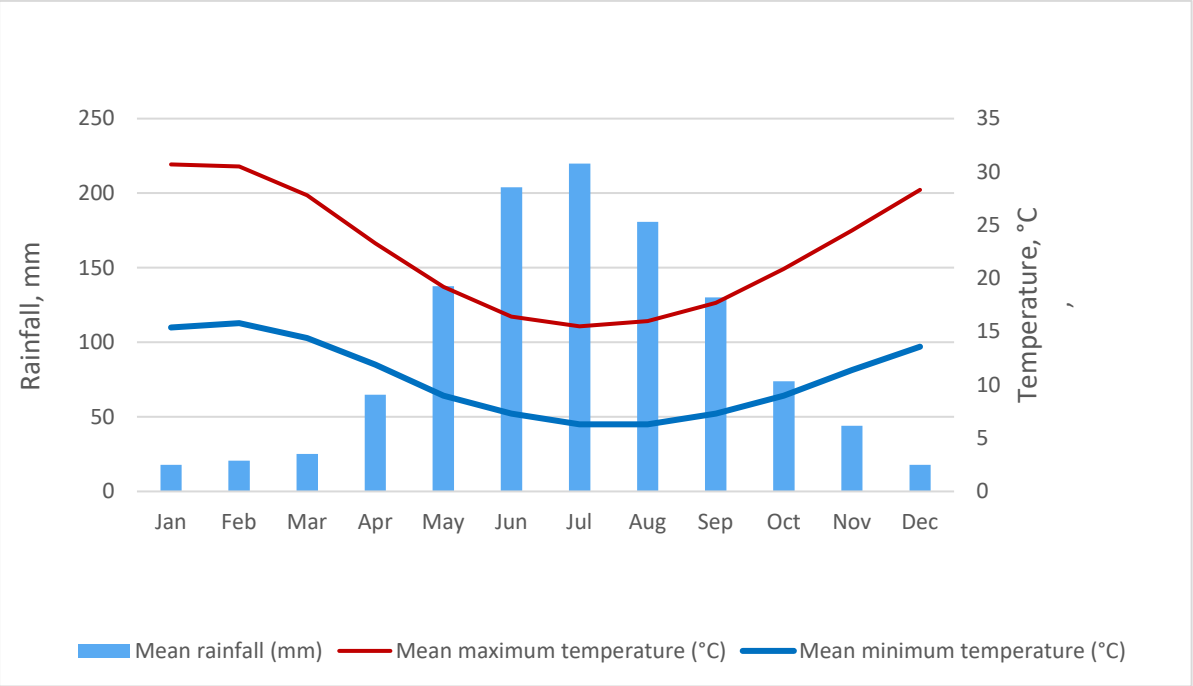

Figure 1 Pinjarra climatology based on BOM data at Karnet and Dwellingup

The region has various dust sources including industry operations, natural events and local activities, each of which may contribute to dust levels in the town.

In relation to the Pinjarra township, local sources of dust include:

- the Alcoa Pinjarra refinery, which is located about 3.5 km east of the town centre
- the racecourse located 1 km to the southeast of the town
- the train line running through the town, which transports a variety of industrial products
- unsealed roads
- adjacent agricultural land.

Alcoa Pinjarra operates several air quality monitoring stations in the vicinity of their operations. This campaign has been independent of Alcoa's air quality monitoring program.

1.3 Dust

In air quality terminology, "dust" and "particles" refer to particulate matter (PM) comprising very small solid particles of earth, organic matter, manufactured products or waste matter. These may become airborne by natural forces (such as wind) and/or by mechanical processes (such as crushing, grinding, milling, conveying, stockpiling or haulage). PM can also include combustion particles, organic compounds, metals, pollen and mould.

PM is classified into different size fractions based on the particle diameter (equivalent aerodynamic diameter) measured in micrometres (µm). The common size fractions are:

- $PM_{2.5}$ – particulate matter of approximately 2.5 µm or less.
- PM_{10} – particulate matter of approximately 10 µm or less.

These particle sizes are important for public health assessment as they are sizes small enough to breathe in and reach the areas of the respiratory tract and lungs, potentially causing health issues.

Figure 2 shows the $PM_{2.5}$ and PM_{10} size fractions compared with other common materials.

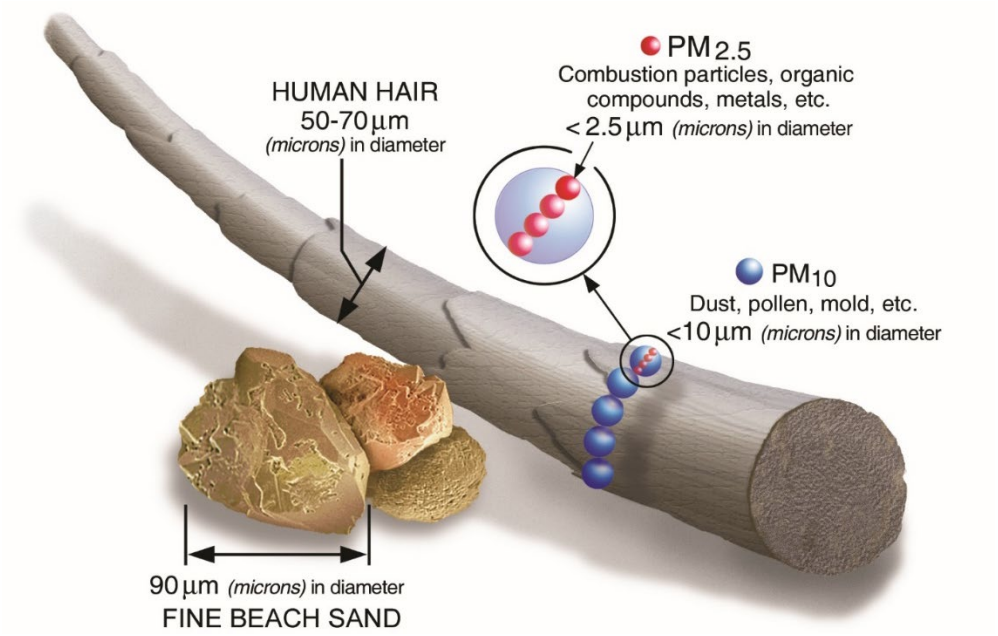

Figure 2 Size comparisons for particulate matter (PM) (USEPA 2018)

Deposited dust is defined as particles which, because of their size, rapidly settle from the air. These can cause impacts to amenity, such as soiling of vehicles, property, and other surfaces.

1.4 Metals

Metals occur naturally within the earth's crust, mainly in the form of solid metal particles or metals attached to the surface of other particles. Metals are elements and thus cannot be broken down, nor can their properties be altered easily.

Metals enter our bodies through food, drinking water and air. Small amounts of some metals, like iron and magnesium, are needed for good health, but too much can be harmful.

PM_{10} samples for this campaign were analysed for the presence of metals and results compared with health guidelines.

2 Monitoring campaign scope

The original campaign scope was to monitor the following pollutants, over two different periods, for a total of four months:

- levels of ambient dust (as PM_{10} and $PM_{2.5}$) using beta-attenuation (BAM) monitors
- the levels of metals contained in the dust using a high-volume air sampler (HVAS)
- deposited dust using a dust deposition vessel
- wind speed, wind direction, humidity and temperature using a meteorological sensor.

An independent contractor supplied and operated the equipment at the monitoring site as shown in Figure 3. Local community members gave permission for the monitoring site to be located on private land as shown in Figure 4, which was representative of an outer residential site that is relatively close to the Alcoa residue area and other potential dust sources.

The monitoring site was about 150 m from the South Western Highway, 650 m north-west of the racecourse and 2.6 km west of the Alcoa operations boundary.

There were problems with the operation of the BAM PM_{10} monitor during the earlier stages of the campaign, leading to data recovery rates lower than that considered acceptable by the department for analysis. In response, the contractor monitored for an additional month, with the monitoring periods as follows:

- 17 April to 19 June 2023; 21 August to 21 September 2023 (referred to as Phase 1)
- 1 December 2023 to 31 January 2024 (referred to as Phase 2).

However, on account of further data reliability issues identified by the department as discussed in Section 4, the Phase 1 BAM PM_{10} data for the 2023 autumn and winter/spring periods have not been considered in the analysis.

Figure 3 Monitoring equipment setup

Figure 4 Department ambient air quality monitoring location

3 Monitoring methods

3.1 PM_{10}

The department specified that PM_{10} monitoring was to be undertaken using a beta attenuation monitor (BAM) in accordance with the Australian Standard method *AS/NZS 3580.9.11:2022 Methods for sampling and analysis of ambient air, Method 9.11: Determination of suspended particulate matter – PM_{10} beta attenuation monitors*.

This monitor is designed to operate continuously and provide hourly PM_{10} concentrations.

3.2 $PM_{2.5}$

The department specified that $PM_{2.5}$ monitoring was to be undertaken using a BAM in accordance with the Australian Standard method *AS/NZS 3580.9.12:2022 Methods for sampling and analysis of ambient air, Method 9.12: Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors*.

This monitor is designed to operate continuously and provide hourly $PM_{2.5}$ concentrations.

3.3 Metals in PM_{10}

The department specified that sampling of PM_{10} for metals content was to be undertaken using a High-Volume Air Sampler (HVAS) in accordance with the Australian Standard method *AS/NZS 3580.9.6:2015 Methods for sampling and analysis of ambient air, Method 9.6: Determination of suspended particulate matter — PM10 high volume sampler with size selective inlet — Gravimetric method*. The sampling was conducted mostly on a one-in-six-day regime.

The HVAS draws ambient air through a filter that collects dust particles over a 24-hour sample period. The filter is then sent for laboratory analysis.

During the campaign, the contractor collected 23 PM_{10} samples. A laboratory accredited with the National Association of Testing Authorities (NATA) Australia determined the mass of dust and metals on the filters.

The HVAS also provides PM_{10} concentration data when operated in accordance with the above Australian Standard.

3.4 Deposited dust

The department specified that deposited dust was to be measured with a dust deposition gauge in accordance with the Australian Standard method *AS/NZS*

3580.10.1-2016, Determination of particulate matter – Deposited matter – Gravimetric method.

This is a passive monitoring method, with airborne dust settling out of the air into a glass vessel over a monthly sampling period.

3.5 Meteorological monitoring

The department requested that meteorological monitoring was conducted to measure wind speed and direction to facilitate data analysis and interpretation. The monitoring was undertaken with a 10-m measurement mast in accordance with *AS/NZS 3580.14-2014, Meteorological monitoring for ambient air quality monitoring applications.*

4 Data quality

4.1 Data validation

The department's technical specialists have undertaken a data quality assessment of the data provided by the contractor, in accordance with standard procedures and with Australian Standard method *AS 3580.19:2020 Ambient air quality data validation and reporting*. The assessment comprises the following:

- Checking for spikes, flat-lines, negative or spurious data.
- Checking for equipment operational modes or status conditions that indicate invalid data, and instrument stability after power outages or maintenance.
- Checking that the instrument enclosure temperatures were between 20 and 30 degrees Celsius during operation.
- Examination of data trends and other indicators of instrument stability.
- Examination of log books, maintenance records, field sheets and chain of custody records.

As per *AS 3580.19*, the initial presumption is that all data are valid. However, following detailed checking of the dataset, the following limitations were identified:

- There was a large number of negative BAM PM_{10} data between April and September 2023, mainly overnight or early morning, followed by spikes in concentration. For these periods, the BAM $PM_{2.5}$ data appeared to be stable and reliable, without negative values. While the PM_{10} and $PM_{2.5}$ BAM instruments measure different particle fractions, the principle of measurement is the same and consequently both the PM_{10} and $PM_{2.5}$ data would be expected to display similar trends. Consequently, the BAM PM_{10} instrument was not functioning correctly over this period.
- Data spikes immediately following maintenance periods were considered invalid, as the instrument was likely to be restabilising, and the spikes were similar to those after extended periods of negative data.
- Maintenance records indicate that prior to restarting monitoring on 17 August 2023, technicians found the existing PM_{10} instrument to be faulty, and it was replaced.
- HVAS sampling records appear to be incomplete.

Noting these limitations, the BAM PM_{10} data considered invalid were removed and the dataset was reprocessed by the department following standard procedures to calculate exceedances and averages, and produce time series plots. The invalid data included all the Phase 1 PM_{10} data.

Based on available information, all the HVAS data were included in the analysis to provide an indication of dust and metals concentrations, noting that sample volumes were estimated by the department due to incomplete sampling records.

4.2 Data recovery

Following data reprocessing, data recovery was calculated using the *National Environmental Protection (Ambient Air Quality) Measure* (AAQ NEPM) *Technical Paper No.5 – data collection and handling* as shown in Table 1.

Parameter	Period	Valid hours %	Total sampling days	Valid days	Valid days %
PM_{10}	17 April – 21 September 2023	NA	NA	NA	NA
$PM_{2.5}$	17 April – 21 September 2023	98%	93	91	98%
PM_{10}	1 December 2023 – 31 January 2024	98%	62	62	100%
$PM_{2.5}$	1 December 2023 – 31 January 2024	98%	62	61	98%

Table 1 Data recovery

Consequently, the data included in the analysis presented in Section 5 are:

- PM_{10} – Phase 2, December 2023 to January 2024
- $PM_{2.5}$ – Phase 1 and 2, April 2023 to January 2024
- HVAS PM_{10} and metals – Phase 1 and 2, April 2023 to January 2024
- Dust deposition gauge results (five monthly samples).

5 Results and analysis

5.1 PM_{10} and $PM_{2.5}$

Daily averages

Using the BAM and HVAS data, PM_{10} concentrations were compared with the *National Environmental Protection (Ambient Air Quality) Measure* (NEPM) daily health guideline of 50 µg/m^3 and the $PM_{2.5}$ concentrations were compared with the NEPM daily health guideline of 25 µg/m^3.

We have also included comparisons of daily averages over the same periods from other air quality monitoring stations (AQMS) operated by the department.

The BAM $PM_{2.5}$ and BAM/HVAS PM_{10} concentrations are included as time series plots in Appendix 1 and a summary of the data is discussed below. The BAM data in comma-separated values (CSV) tabulated format are also available on the department's website (Appendix 5).

During the campaign, the PM_{10} daily guideline was not exceeded based on the included dataset. The highest daily concentrations of PM_{10} of 44 µg/m^3 and 44 µg/m^3 were recorded by the HVAS on 23 April 2023 and by the BAM on 19 December 2023 respectively.

The $PM_{2.5}$ daily guideline was exceeded twice during the campaign, on 23 April 2023 and 21 January 2024. These results are shown in *Table 2*.

Date of exceedance	Daily $PM_{2.5}$ (µg/m^3) NEPM daily guideline 25 µg/m^3
23/04/2023	42.3
21/01/2024	28.2

Table 2 $PM_{2.5}$ daily guideline exceedances

The $PM_{2.5}$ daily guideline exceedance on 23 April 2023 was likely due to smoke from prescribed burns in the South West based on information from the Department of Biodiversity, Conservation and Attractions (Appendix 2). As discussed further in Section 5.4, it appears that light winds from the north carrying smoke from the previous day were responsible for the exceedance. As a comparison, the Armadale AQMS recorded four days of exceedances of the daily guideline between 20 and 23 April.

The $PM_{2.5}$ daily guideline exceedance on 21 January 2024 was likely due to recirculated smoke from bushfires, based on information from Emergency WA (Appendix 2), noting that 17 fires were active in the South West. As discussed further in Section 5.4, it appears that winds from the south-west carrying smoke were

responsible for the exceedance. As a comparison, the Mandurah AQMS also recorded an exceedance of the daily guideline on this day.

Table 3 shows the number of exceedances of the NEPM daily guidelines recorded at other department monitoring stations during the Phase 1 and 2 periods.

AQMS	PM_{10} daily guideline 50 µg/m³ Number of days > 50 µg/m³	$PM_{2.5}$ daily guideline 25 µg/m³ Number of days > 25 µg/m³
Armadale	4	16
Busselton	1	2
Caversham	2	6
South Lake	1	6

Table 3 PM_{10} and $PM_{2.5}$ NEPM daily guideline exceedances at other department AQMS during the campaign

Annual averages

The results were compared with PM_{10} and $PM_{2.5}$ annual guidelines, assuming that the limited period of data collection is representative of the entire year and can be reliably extrapolated to estimate annual average concentrations. The estimated annual averages for PM_{10} and $PM_{2.5}$ were below the guidelines as shown in Table 4. Table 5 shows the annual concentrations recorded at other department monitoring stations for 2023.

Period	Average PM_{10} (µg/m³) NEPM annual guideline 25 µg/m³	Average $PM_{2.5}$ (µg/m³) NEPM annual guideline 8 µg/m³
Phase 1	12.3[1]	5.6
Phase 2	23.5[2]	7.7
Annual (estimate only)	16.8[3]	6.5

1. Based on Phase 1 HVAS data.
2. Based on Phase 2 BAM data.
3. Combined Phase 1 HVAS and Phase 2 BAM PM_{10} data, noting different lengths of monitoring.

Table 4 PM_{10} and $PM_{2.5}$ seasonal and annual concentrations

AQMS	Annual PM_{10} (µg/m^3) NEPM annual guideline 25 µg/m^3	Annual $PM_{2.5}$ (µg/m^3) NEPM annual guideline 8 µg/m^3
Armadale	17.0	10.9
Busselton	12.9	5.9
Caversham	14.7	6.8
South Lake	13.5	5.9

Table 5 PM_{10} and $PM_{2.5}$ annual average concentrations at other department AQMS for 2023

5.2 Metals in PM_{10}

The HVAS PM_{10} samples collected were analysed in a NATA accredited laboratory for a suite of 32 substances including metals and metalloids as detailed in Appendix 3.

As discussed in Section 4.1, air sample volumes used to calculate metals concentrations were estimated by the department, due to incomplete sampling records. Consequently, there are limitations with the data, but these are included in the report to provide an indication of dust and metals concentrations.

For 16 of the metals analysed, daily and/or annual ambient air guidelines from the department's draft *Guideline – Air emissions* or guidelines derived in consultation with the WA Department of Health (DoH) were used. For the other metals, the department has not adopted guidelines.

As was done for the PM_{10} and $PM_{2.5}$ data, annual averages for the metals analysed were also estimated, assuming that the limited period of data collection is representative of the entire year. Where a daily concentration was below the laboratory's limit of detection (referred to as the Practical Quantitation Limit, or PQL), half of the PQL was assumed for the calculation of the annual average.

Note that beryllium, which was not detected in any of the samples, has an annual guideline lower than the PQL. Consequently, the laboratory analytical method is unsuitable for comparison against the annual guideline for this element.

Table 6 presents the maximum daily concentrations and estimated annual averages for those metals for which guidelines are available. There were no guideline exceedances. It was assumed that all the aluminium (Al) was present in the form of aluminium oxide (Al_2O_3), and all the iron (Fe) was present in the form of iron oxide (Fe_2O_3).

As discussed in Section 6, DoH has reviewed the results for the 32 metals analysed and advise that the measured concentrations do not represent a public health risk.

Substance	Highest daily concentration ($\mu g/m^3$)	Daily guideline ($\mu g/m^3$)	Estimated annual average concentration ($\mu g/m^3$)	Annual guideline ($\mu g/m^3$)
Alumina (Al_2O_3)	3.02	10.00	0.870	NA
Antimony	Not detected (ND[1])	NA	0.003	0.03
Arsenic	0.0015	0.03	0.0007	0.003
Beryllium	ND	NA	0.0007[2]	0.0002
Chromium	0.017	0.50	0.0017	NA
Cobalt	ND	0.10	0.0007	0.10
Copper	0.01	1.00	0.003	NA
Iron (Fe_2O_3)	4.72	120	0.82	N/A
Lead	0.005	N/A	0.0023	0.50
Manganese	0.01	0.15	0.003	NA
Mercury	ND	N/A	0.00007	0.20
Molybdenum	0.005	12.00	0.002	NA
Nickel	0.01	0.14	0.0011	0.02
Uranium	ND	NA	0.0013	0.04
Vanadium	0.01	1.00	0.0021	NA
Zinc	1.00	50.00	0.065	NA

1. Not detected (ND) means the result is below the laboratory PQL
2. The laboratory's PQL is above the annual guideline.

Table 6 Daily and annual metals concentrations compared to the guidelines

5.3 Deposited dust

Five deposited dust samples (one per month) were collected during the campaign monitoring. There were no exceedances of the adopted amenity criterion for total solids of 4 g/m^2/month as shown in Table 5.

Sample	Dust as total solids (g/m^2/month)
1 – 13 April to 15 May 2023	2.61
2 – 15 May to 16 June 2023	1.44
3 – 21 August to 21 September 2023	2.30
4 – 1 December 2023 to 2 January 2024	1.72
5 – 2 January to 2 February 2024	0.44

Table 7 Deposited dust results

5.4 Hourly concentrations

Combining short-term (hourly averaged) data on particle concentrations and wind directions can indicate whether there are certain wind directions associated with higher particle concentrations. Note that this type of analysis does not identify specific particle sources.

The analysis comprises:

- "Wind rose" plots, which show the frequencies of wind speed and direction. Wind directions are distributed over 16 segments that align with compass points such as north, north-east and south-south-west. The colour coding of the segments reflects wind speed ranges.

- Combined PM_{10}, $PM_{2.5}$ and wind data as "pollution rose" plots, which show the frequency of particle concentration ranges distributed over the same 16 wind direction segments. The segment colour coding for the particle concentrations is the same as that used for the Air Quality Index (AQI) on the department's website (Air quality index - Department of Water and Environmental Regulation (der.wa.gov.au)).

- The plots include a pink shaded sector that represents winds from the general direction of the Alcoa operations. The sector assigned is between 60 degrees to 140 degrees.

These data have been examined:

- Pollution roses and wind roses for the Phase 1 and Phase 2 periods of monitoring, where the plots are shown side by side for the same period to compare general patterns. Note that Phase 1 PM_{10} data are not included as discussed in Section 4.

- Pollution roses for all the hours when the hourly concentrations exceeded the daily particle guidelines. The daily guideline is compared to hourly data to highlight periods of high short-term levels, even though the overall daily average may not have exceeded the NEPM guideline.

- Pollution roses for days when daily particle guidelines were exceeded. These figures also include a time series plot which shows how particle concentrations varied over the day.

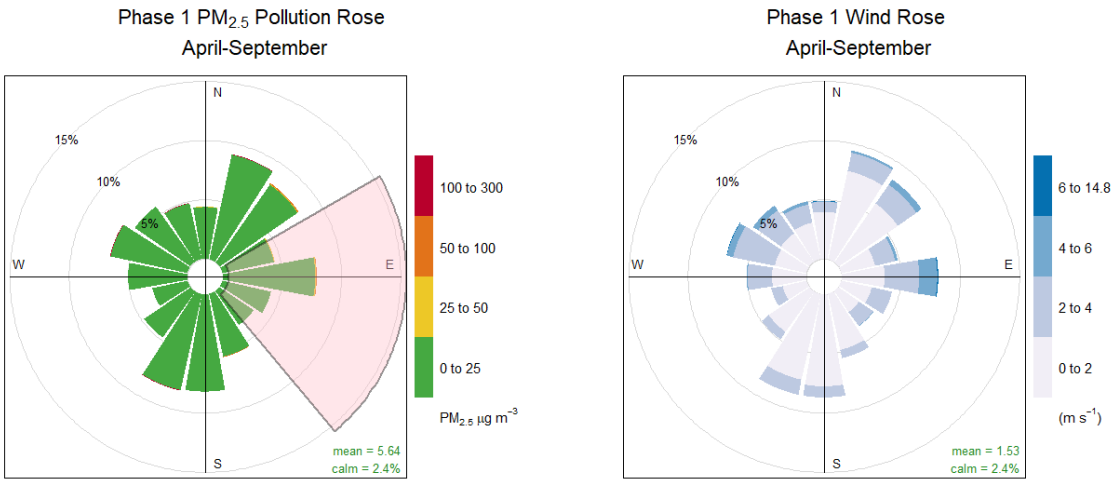

Figure 5 $PM_{2.5}$ pollution rose and wind rose for Phase 1

Figure 5 contains all the Phase 1 hourly $PM_{2.5}$ concentration data and the corresponding hourly wind data. The wind rose (plot on right side) shows higher frequencies of north-easterly, easterly, southerly and south-south-westerly wind directions over the Phase 1 period. Higher wind speeds are mostly from north-easterly, easterly and north-westerly directions. The pollution rose (plot on left side) shows that hourly concentrations are generally low (green) in all directions. There are lower frequencies of higher concentrations (yellow to red), which appear to reflect the directions with higher wind speeds.

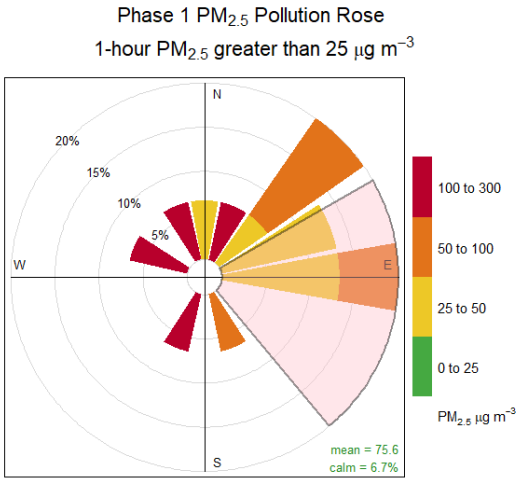

Figure 6 Phase 1 $PM_{2.5}$ pollution rose for concentrations above 25 µg/m^3

Figure 6 shows all the Phase 1 $PM_{2.5}$ hourly concentrations above the daily particle guideline, which is an indicator of the direction of only the elevated concentrations of $PM_{2.5}$. There was a total of 16 hours during Phase 1 when the $PM_{2.5}$ concentration was above the daily guideline, which represents less than 1% of the dataset.

The wind directions with the highest frequencies of these concentrations are north-east to east. The source of particles measured from the east and east-north-east (four of the 1-hourly measurements) potentially includes sources within the general direction of Alcoa operations. All four hours were during 22 April 2023, which was a period of regional smoke impacts. The highest concentrations (red sectors in Figure 6) also reflect the $PM_{2.5}$ exceedance day in April 2023 (Figure 11).

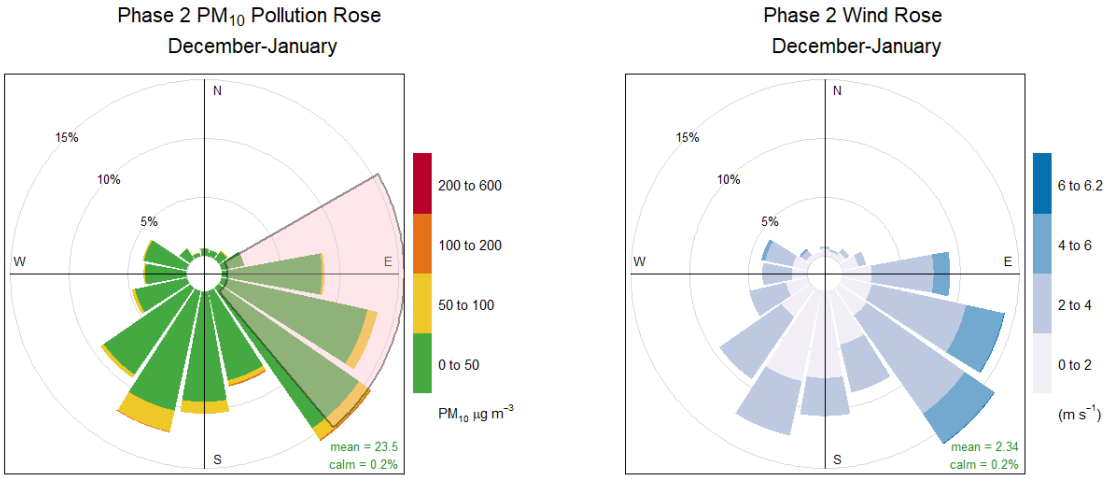

Figure 7 PM_{10} pollution rose and wind rose for Phase 2

Figure 7 contains all the Phase 2 hourly PM_{10} concentration data and the corresponding hourly wind data. The wind rose (plot on right side) shows higher frequencies of easterly to south-easterly, and south-south-westerly wind directions

over the Phase 2 period. Higher wind speeds are mostly from easterly to south-easterly directions. The pollution rose (plot on left side) shows that hourly concentrations are generally low (green) in all directions. There are lower frequencies of higher concentrations (yellow to red), including hourly concentrations above 100 µg/m^3 that were mostly from south-east and south-south-east directions. The source of particles from these directions potentially includes sources at the Alcoa operations.

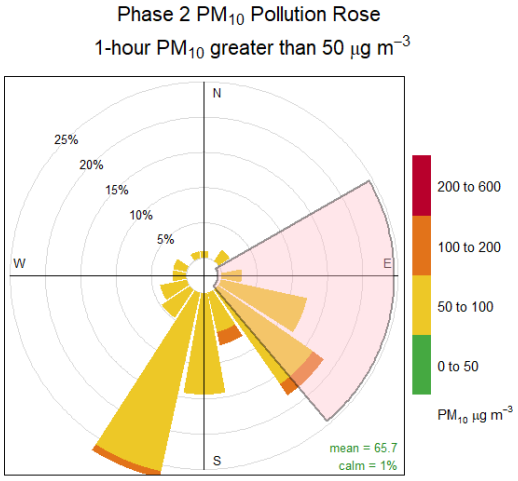

Figure 8 Phase 2 PM_{10} pollution rose for concentrations above 50 µg/m^3

Figure 8 shows all the Phase 2 PM_{10} hourly concentrations above the daily particle guideline, which is an indicator of the direction of only the elevated concentrations of PM_{10}. There was a total of 109 hours during Phase 2 when the PM_{10} concentration was above the daily guideline, which represents about 8 per cent of the dataset.

The wind directions with the highest frequencies of these concentrations are east-south-east to south-south-west. The source of particles measured from the east-south-east and south-east direction (37 of the 1-hourly measurements) are within the general direction of Alcoa operations. The particle concentrations during these hours do not appear to be related to smoke.

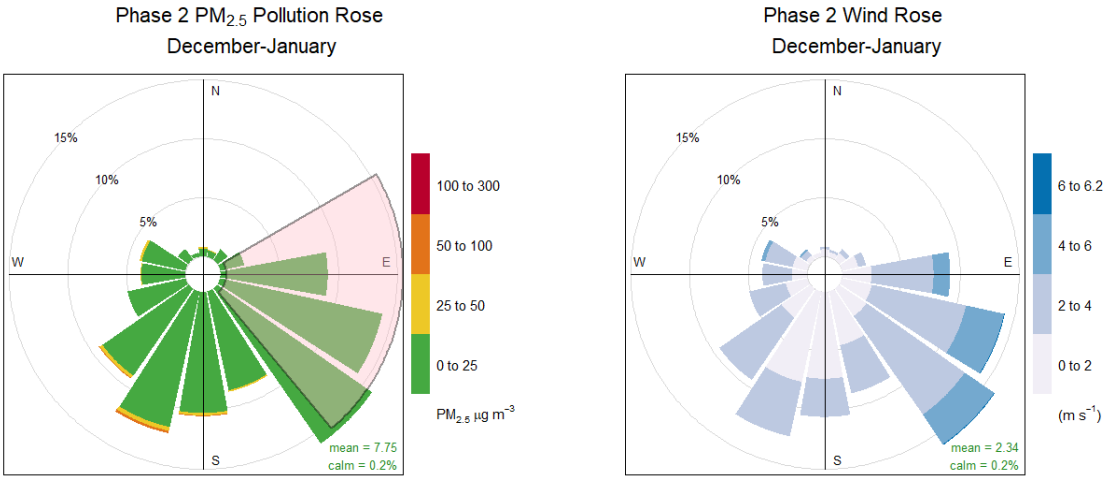

Figure 9 $PM_{2.5}$ pollution rose and wind rose for Phase 2

Figure 9 contains all the Phase 2 hourly $PM_{2.5}$ concentration data and the corresponding hourly wind data. The wind rose (plot on right side) shows higher frequencies of easterly to south-easterly, and south-south-westerly wind directions over the Phase 2 period. Higher wind speeds are mostly from easterly to south-easterly directions. The pollution rose (plot on left side) shows that hourly concentrations are generally low (green) in all directions. There are lower frequencies of higher concentrations (yellow to red) from south-south-east to south-west direction, which do not reflect the directions with higher wind speeds. That is, hourly concentrations above 25 µg/m^3 were mostly from south to south-west directions, which are less likely to include sources at the Alcoa operations.

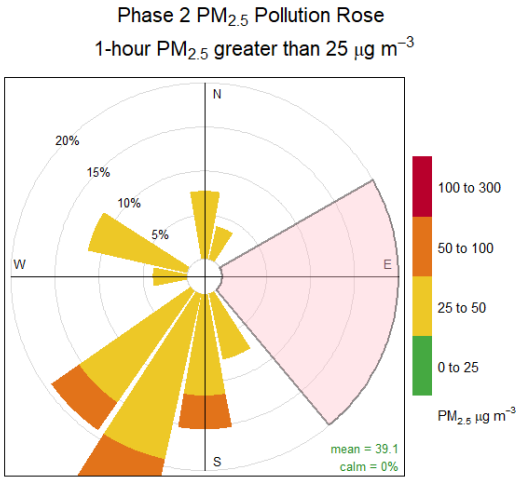

Figure 10 Phase 2 $PM_{2.5}$ pollution rose for concentrations above 25 µg/m^3

Figure 10 shows all the Phase 2 $PM_{2.5}$ hourly concentrations above the daily particle guideline, which is an indicator of the direction of only the elevated concentrations of $PM_{2.5}$. There was a total of 27 hours during Phase 2 when the $PM_{2.5}$ concentration was above the daily guideline, which represents about 2 per cent of the dataset. Most

of these elevated hourly concentrations appear to be related to smoke from bushfires.

The wind directions with the highest frequencies of these concentrations are south to south-west. Particles measured from these directions are not likely to include sources at the Alcoa operations.

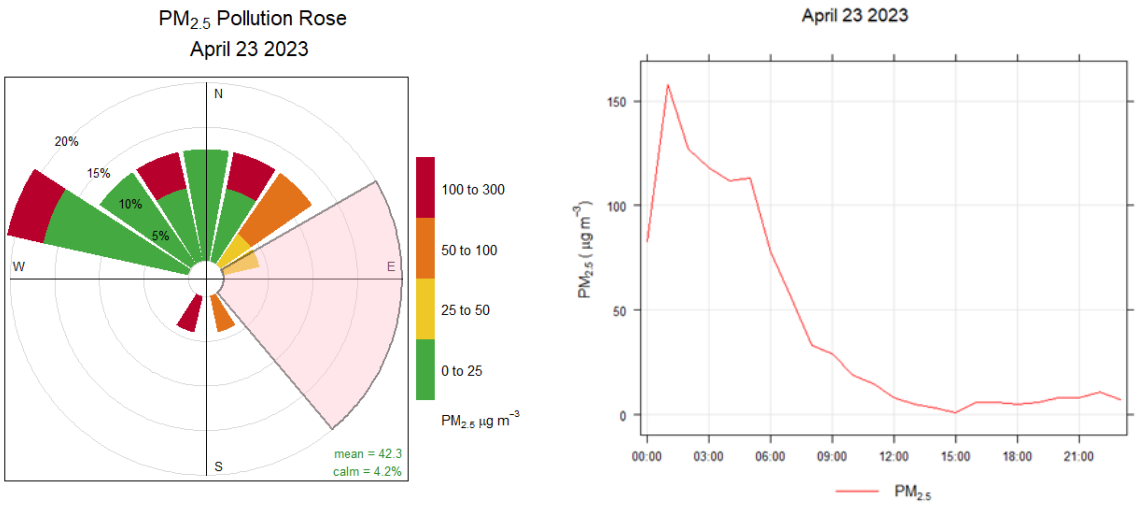

Figure 11 $PM_{2.5}$ pollution rose and concentration time series for exceedance day 23 April 2023

Figure 11 shows that hourly $PM_{2.5}$ concentrations between about 75 and 160 µg/m^3 were measured overnight (midnight to 6:00am) from north-east to south-west directions. The most likely source was smoke from planned burns in the area.

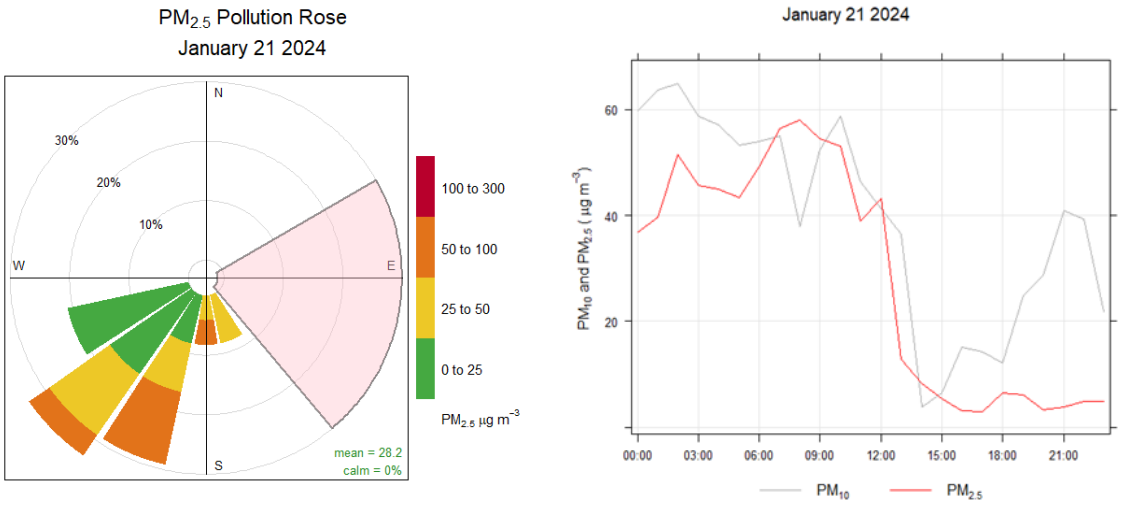

Figure 12 $PM_{2.5}$ pollution rose and concentration time series for exceedance day 21 January 2024

Figure 12 shows that hourly $PM_{2.5}$ concentrations between about 40 and 60 µg/m^3 were measured from midnight to midday from south to south-west directions. The most likely source was smoke from bushfires in the South West. The time series plot

(left side of Figure 12) also indicates that $PM_{2.5}$ comprised a large proportion of PM_{10} over this period, which is characteristic of smoke pollution.

A summary of the analysis in this section is:

- Of key interest are the PM_{10} and $PM_{2.5}$ hourly concentrations that were elevated and the average wind directions for these hours. Overall, there were a relatively small number of hours with elevated concentrations.

- For Phase 1 $PM_{2.5}$, a small number of higher hourly concentrations occurred when winds were from the general direction of the Alcoa operations. All of these hours were during 22 April 2023, which was a period of regional smoke impacts.

- For Phase 2 PM_{10}, a small number of higher hourly concentrations occurred when winds were from the general direction of the Alcoa operations. Most of these do not appear to be related to smoke.

- For Phase 2 $PM_{2.5}$, wind directions associated with higher hourly concentrations were not from the general direction of the Alcoa operations. These hourly concentrations appear to be related to regional smoke impacts.

- Overall, there was a relatively small number of hours with elevated concentrations across both monitoring phases. Elevated $PM_{2.5}$ concentrations appear to be associated with smoke events. About 30 per cent of the small number of elevated PM_{10} hourly concentrations were from the general direction of the Alcoa operations.

6 Review by WA Department of Health

The department works closely with the Environmental Health Directorate of the WA Department of Health (DoH) when assessing the results of air quality monitoring campaigns. This summary report was reviewed by DoH and their input has been included in this document.

7 References

National Environment Protection Council 2021, *National Environment Protection (Ambient Air Quality) Measure*.

National Environment Protection Council 2001, *National Environmental Protection (Ambient Air Quality) Measure (NEPM) Technical Paper No.5 – data collection and handling.*

Standards Australia 2014, *AS/NZS 3580.14-2014, Meteorological monitoring for ambient air quality monitoring applications.*

Standards Australia 2015, *AS/NZS 3580.9.6:2015 Methods for sampling and analysis of ambient air, Method 9.6: Determination of suspended particulate matter – PM10 high volume sampler with size selective inlet–- Gravimetric method.*

Standards Australia 2016, *AS/NZS 3580.10.1-2016, Determination of particulate matter – Deposited matter – Gravimetric method.*

Standards Australia 2022, *AS/NZS 3580.9.11:2022 Methods for sampling and analysis of ambient air, Method 9.11: Determination of suspended particulate matter – PM10 beta attenuation monitors.*

Standards Australia 2022, *AS/NZS 3580.9.12:2022 Methods for sampling and analysis of ambient air, Method 9.12: Determination of suspended particulate matter – PM2.5 beta attenuation monitors.*

United States Environmental Protection Agency 2018, *Particulate matter (PM) pollution,* Research Triangle Park, NC. www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM.

8 Shortened forms and glossary

Equivalent aerodynamic diameter	Diameter of a spherical particle of density 1 g/cm^3 which exhibits the same aerodynamic behaviour as the particle in question
BoM	Bureau of Meteorology
DOH	Western Australian Department of Health
The department	The department represents the Department of Water and Environmental Regulation and its predecessors such as the former Department of Environment Regulation and former Department of Environment and Conservation
HVAS	High volume air sampler
NEPM	*National Environmental Protection (Ambient Air Quality) Measure*. NEPMs are a special set of national objectives designed to help protect or manage particular aspects of the environment. www.nepc.gov.au/nepms
PM	Particulate matter
$PM_{2.5}$	Particulate matter with a diameter up to 2.5 µm (micrometres)
PM_{10}	Particulate matter with a diameter up to 10 µm (micrometres)
PQL	Practical Quantitation Limit: the minimum concentration of a compound that can be measured within specified limits of precision and accuracy for a particular laboratory and analytical method
USEPA	United States Environmental Protection Agency

Appendices

The following appendices are available on the Ambient dust monitoring campaign, Pinjarra webpage:

Appendix 1 BAM and HVAS time series particle concentration data

Appendix 2 Planned burn and bushfire information

Appendix 3 HVAS filter analysis results for PM_{10} and metals

Appendix 4 Laboratory analysis reports

Appendix 5a Monitoring data in tabulated format – Phase 1 (P1_processed_hr_NA_PM10.csv)

Appendix 5b Monitoring data in tabulated format – Phase 2 (P2_processed_hr.csv)