



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

Port Hedland air quality 2024 annual monitoring report



Department of Water and Environmental Regulation
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Summary

- In 2022 the Department of Water and Environmental Regulation (department) took over the Port Hedland ambient air quality monitoring network that had previously been operated by the Port Hedland Industries Council.
- Key results of particle monitoring (PM₁₀ and PM_{2.5}) for 2024 are summarised below:
 - Based on the applied statistics, overall dust concentrations (PM₁₀) in Port Hedland and surrounds were intermediate when compared with the preceding four years and found to be neither the highest, nor the lowest.
 - The Port Hedland Air Guideline Value (AGV) was exceeded 30 times at the Taplin monitoring station, with 13 of these considered to be due to exceptional events, 7 attributed to industry and 10 to other sources.
 - Fine particles (PM_{2.5}) in smoke from bushfires were a stronger influence during some high particle events.
 - The *National Environment Protection (Ambient Air Quality) Measure* daily and annual guidelines for PM_{2.5} were not met at Taplin Street.
 - High dust events were dominated by the coarse dust fraction of PM₁₀, although there was a larger influence of fine particles in smoke (PM_{2.5}) compared to earlier years.
- The results of gas monitoring (nitrogen dioxide - NO₂ and sulfur dioxide - SO₂) showed that:
 - The *National Environment Protection (Ambient Air Quality) Measure* hourly and annual guidelines for NO₂ were met at Taplin Street.
 - The *National Environment Protection (Ambient Air Quality) Measure* hourly and daily guidelines for SO₂ were met at Taplin Street.

Acknowledgement of Country

The Department of Water and Environmental Regulation acknowledges the Traditional Owners of the lands on which we live and work throughout Western Australia and we pay our respects to Elders past and present. The Department recognises the practice of intergenerational care for Country and its relevance to our work and working with the community. The Department continues to move forward with a shared commitment to protect and conserve Country for our future generations.

1 Background

Dust emissions from port facilities and their influence on air quality have long been recognised as a significant issue in Port Hedland.

To address this, the State Government established the Port Hedland Dust Management Taskforce in 2009 to plan for and coordinate dust management in the town. The Taskforce released their *Port Hedland air quality and noise management plan* in 2010. The Plan proposed, among other recommendations, a Health Risk Assessment (HRA) of the impact of dust on the Port Hedland population. An ambient air quality monitoring network was established to inform the HRA. The network was operated by the Port Hedland Industries Council (PHIC).

The HRA was finalised by the Department of Health in 2016. This work focused on the potential impacts on human health from PM₁₀ (dust) inhalation by residents. A key outcome was the establishment of an interim air guideline value (AGV) for PM₁₀ of 70 µg/m³ averaged over a day as documented in the 2016 *Port Hedland Dust Management Taskforce Report* (Taskforce Report).

In October 2018, the Government released the *Port Hedland Dust Management Taskforce Report – Government Response*. It endorsed the key recommendations that the AGV continues to apply in residential areas of Port Hedland and that the operation of the ambient air quality monitoring network be transferred to the department. It also endorsed the implementation of planning controls to prohibit sensitive land uses and restrict population growth in the West End. The [Port Hedland Dust Taskforce documents](#) can be accessed at the WA government website.

This report summarises data from the monitoring network for the 2024 annual period.

2 Monitoring network

The department assumed management of the monitoring network on 1 January 2022. This document is the third annual monitoring report prepared by the department, with all reports available on the department's website. Previous reports were prepared by PHIC and these can be accessed through their website at [PHIC monitoring reports](#).

Port Hedland's current air quality can be viewed at the [Port Hedland air quality monitoring network website](#) where historical data can also be downloaded.

2.1 Monitoring sites

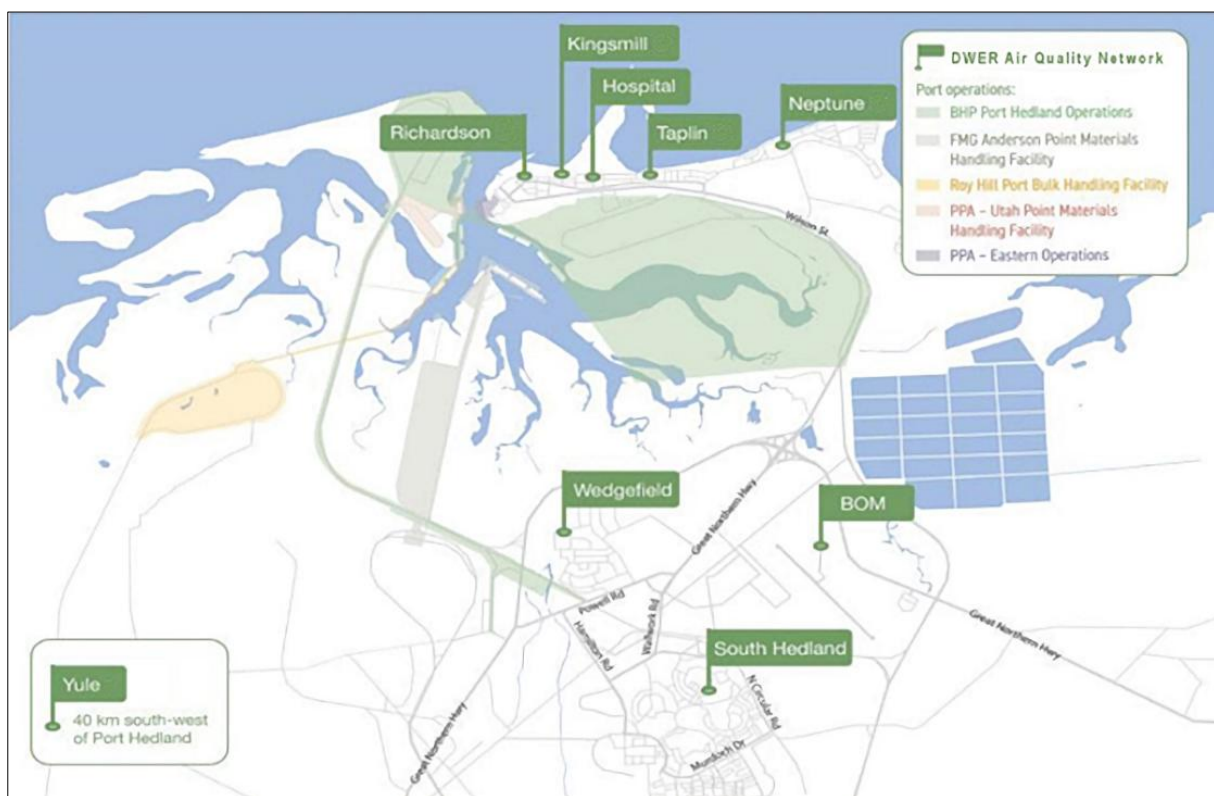


Figure 1 Monitoring station locations.

The Port Hedland ambient air quality monitoring network (network) consists of nine monitoring stations as shown in Figure 1. The network's spatial configuration is designed to record data at locations representing residential, light industrial and background areas. Residential stations are located where people live and include Richardson, Kingsmill, Hospital, Taplin, Neptune and South Hedland.

The area west of Taplin Street has been defined as a commercial precinct objective for land use (*Port Hedland West End Improvement Scheme No. 1*).

This planning policy restricts further residential development, and together with the implementation of a buyback scheme aims to reduce residential use in the future. The Taplin Street monitoring station is located on the boundary of the West End, proposed to transition

to a commercial precinct and the East End with its continuing residential use. Monitoring data from Taplin Street is therefore considered representative of dust concentrations experienced in the East End and comparison of Taplin Street concentrations against the AGV is used as a regulatory tool to protect residential receptors.

Whilst the Taplin Street monitor data are the basis of Government regulatory activities, the remaining monitors in the network ensure the adequacy of this regulatory approach.

Wedgefield is a light industrial area. Yule represents a regional background site while the Bureau of Meteorology (BOM) site near the airport is intended to represent a local background site.

Background sites are those considered not to be influenced by port emissions, whereas the other sites may be influenced by industrial emissions to varying degrees. Site location information is summarised in Table 1.

Table 1 Monitoring site location information.

Monitoring Station	Short Code	Description	Latitude	Longitude	Location category
BOM	BOM	Bureau of Meteorology site, Airport	-20.371508°	118.631353°	local background
Hospital	HO	Old Hospital site West End	-20.310125°	118.589019	Improvement Scheme No 1 – West End
Kingsmill	KI	Kingsmill Street, West End	-20.309717°	118.585187°	Improvement Scheme No 1 – West End
Neptune	NE	Neptune Place, East End	-20.303910°	118.622836°	Residential – East End
Richardson	RI	Richardson Street, West End	-20.310221°	118.578037°	Improvement Scheme No 1 – West End
South Hedland	SH	Acacia Way, South Hedland	-20.407376°	118.607549°	residential
Taplin	TA	Taplin Street, Boundary West End/East End	-20.309746°	118.599700°	Residential – West/East End border
Wedgefield	WE	Leehey Street, Wedgefield	-20.370454°	118.584820°	light industrial
Yule	YU	Yule River	-20.595167°	118.296311°	regional background

2.2 Monitoring methods and instruments

Particle monitoring is undertaken using Beta Attenuation Monitor (BAM) equipment applying A/NZ Standards (AS/NZS). Only validated data measured by these instruments are used for data analysis in this report.

In parallel with the BAMs, near real-time monitoring instruments are deployed to record particle concentrations over shorter intervals (10-minute averages). These 10-minute concentration data provide more immediate feedback than the BAMs which record clock-hour averages. Data from real-time monitors are used for displaying current (10-minute) particle concentrations on the public website and to generate concentration trigger alerts for real-time dust management actions by port operators.

Monitoring instruments measuring gaseous pollutants (sulfur dioxide and nitrogen dioxide) are also deployed in the network.

A summary of monitoring equipment and the associated AS/NZS is listed in Table 2.

Table 2 Monitoring methods and instruments.

Parameter	Equipment	Monitoring method / AS/NZ Standard	Monitoring locations								
			BOM	Hospital	Kingsmill	Neptune	Richardson	South Hedland	Taplin	Wedgefield	Yule
PM₁₀	BAM 1020	Beta attenuation AS/NZS 3580.9.12:2013	x	x	x	x	x	x	x	x	x
	BAM 1020 ¹								x ¹		
	ES-642 / BX-895	Laser nephelometry	x	x	x	x ²	x	x	x	x ²	x
PM_{2.5}	BAM 1020	Beta attenuation AS/NZS 3580.9.12:2013	x	x	x		x	x	x		x
	ES-642	Laser nephelometry	x	x	x		x	x	x		x
NO_x	Serinius 40 NO _x analyser	Chemi-luminescence AS 3580.5.1-2011					x		x		
SO₂	Serinius 50 SO ₂ analyser	Ultraviolet fluorescence AS 3580.4.1-2008 REC:2018					x		x		

¹ Duplicated monitor used as backup, ² BX-895

2.3 Network management

Supply, operation and maintenance of monitoring infrastructure

The department has engaged a third-party specialist contractor to operate and maintain the network. As part of their contract with the department, the contractor also supplies all monitoring instrumentation.

In 2024, a new modem and logger were installed at Neptune and Richardson received new wind sensors. The Taplin Street site received upgrades in form of a new driveway and landscaping.

Data management

The contractor undertakes data management, which includes the recording of monitoring data and instrument status data on a dedicated database, daily data checks, fault identification and data validation.

Validated data are provided by the contractor to the department, industry stakeholders, and to the public via the public website. Data is validated in monthly data packages with the previous month's raw data being made available as validated package by the 15th of the current month.

An automated exceedance alert notification is sent to the department and industry stakeholders when AGV exceedances occur at Taplin Street.

Compliance with AAQ NEPM protocols and Technical Papers is required, as specified in the contract between the department and the contractor. As a provider accredited by the National Association of Testing Authorities, the contractor has comprehensive quality control protocols and procedures in place.

An important aspect of data quality is that adequate data availability is achieved at each monitor. The AAQ NEPM *Technical Paper No. 5 – Data Collection and Handling* stipulates that for assessing annual compliance with NEPM guidelines, in addition to the 75% annual data availability requirement, at least 75% data availability per calendar quarter is required to account for seasonal effects on pollutant variability. Data availability for all averaging periods is calculated based on valid hours. Each hour also requires at least 75% valid data for that hour to be considered valid.

Pollutant analysis in this report therefore includes a table specifying the data availability rates achieved for that pollutant to document performance against this data quality criterion.

The department provides oversight by undertaking regular data reviews and by conducting targeted audits for compliance with quality control protocols. In addition, if network issues are identified, the department implements improvements to reduce the risk of reoccurrence.

An important recent improvement was the installation of an additional PM₁₀ BAM at Taplin. This was in response to a monitor fault that occurred in April 2018 and which remained undiscovered until the end of 2019, resulting in erroneous data recordings for that period.

Taplin is an important part of the network as it is used for reporting purposes. The duplication of the PM₁₀ BAM will minimise the risk of significant data gaps and thereby safeguard data integrity. The original BAM (BAM1) is used for reporting and the duplicated BAM (BAM2) is used as backup.

2.4 Air quality guidelines

The National Environment Protection Council (NEPC) has established air quality guidelines under the AAQ NEPM for criteria pollutants including PM₁₀, PM_{2.5}, NO₂ and SO₂ as shown in Table 3. These guidelines are used in the analysis of the 2022 monitoring data.

In Port Hedland the AGV of 70 µg/m³ for PM₁₀ 24-hour (daily) average is applied as endorsed by the State Government in 2018 through the *Port Hedland Dust Management Taskforce Report – Government Response*.

As described in the [Port Hedland Regulatory Strategy](#), the AGV is not an enforceable limit. Rather, it is applied in the same manner as the AAQ NEPM, which provides guidance on population exposure to air pollution through the application of nationally consistent guidelines and monitoring methods. The Port Hedland AGV aligns with the AAQ NEPM guidelines for particles by excluding exceedances caused by natural events, which are defined as bushfires, jurisdiction authorised hazard reduction burning, or continental-scale windblown dust.

The AGV is applied to residential areas, wherever people live on a permanent basis in Port Hedland. It is also used as a regulatory tool against which compliance is assessed.

Table 3 Air quality guidelines

Pollutant	Averaging period	Maximum concentration value	Reference
Particles as PM₁₀	1 day	50 µg/m ³	AAQ NEPM
	1 day	70 µg/m ³	AGV
	1 year	25 µg/m ³	AAQ NEPM
Particles as PM_{2.5}	1 day	25 µg/m ³	AAQ NEPM
	1 year	8 µg/m ³	AAQ NEPM
Nitrogen dioxide	1 hour	80 ppb	AAQ NEPM
	1 year	15 ppb	AAQ NEPM
Sulfur dioxide	1 hour	100 ppb	AAQ NEPM
	1 day	20 ppb	AAQ NEPM

3 Monitoring summary

3.1 Summary of Port Hedland meteorology

Port Hedland is situated in the Pilbara region, which is classified as arid tropical with hot summers and mild winters. Major rainfall events are associated with cyclonic systems. Cyclone season is between November and April. Temperature, rainfall and wind conditions affect air pollutant generation and dispersion and are therefore important meteorological factors to consider.

Rainfall

Rainfall data obtained from the Bureau of Meteorology (BoM) station at Port Hedland Airport are presented in Figure 2, which shows monthly rainfall for 2024 compared with long-term mean monthly rainfall for the period 1942–2024. Long-term annual mean rainfall at Port Hedland Airport is approximately 315 mm, while total recorded rainfall for 2024 was 101 mm. Rainfall was low throughout the year, with generally minor monthly totals and the highest rainfall occurring in August. Overall, 2024 was substantially drier than the long-term average and drier than recent years.

No tropical cyclones made landfall at or directly affected Port Hedland during 2024. While the regional cyclone season extended from November to April, cyclonic activity in the vicinity of Port Hedland did not result in significant rainfall or notable meteorological impacts at the monitoring location.

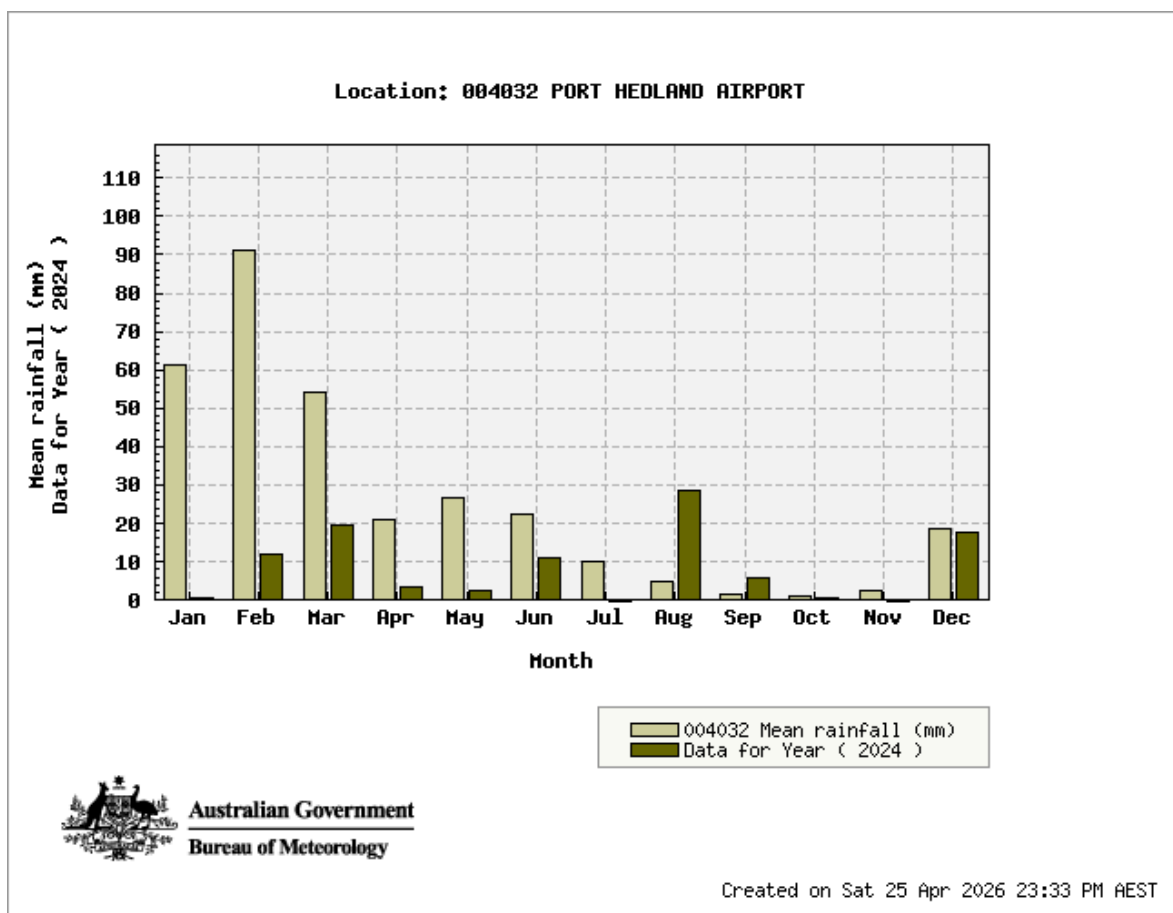


Figure 2 Mean monthly rainfall at Port Hedland Airport

Temperature

Temperature data from the Bureau of Meteorology (BOM) station are presented in Figure 3 and show monthly maximum temperatures for 2024 compared with the long-term monthly maximum temperature averages for the period 1942–2024. Overall, monthly maximum temperatures recorded in 2024 were higher than the long-term average for most months, with the exception of January and March, which were slightly below the historical average. The annual mean maximum temperature for 2024 was 34.5 °C, compared with the long-term annual mean of 33.4 °C, indicating that 2024 was warmer than average overall.

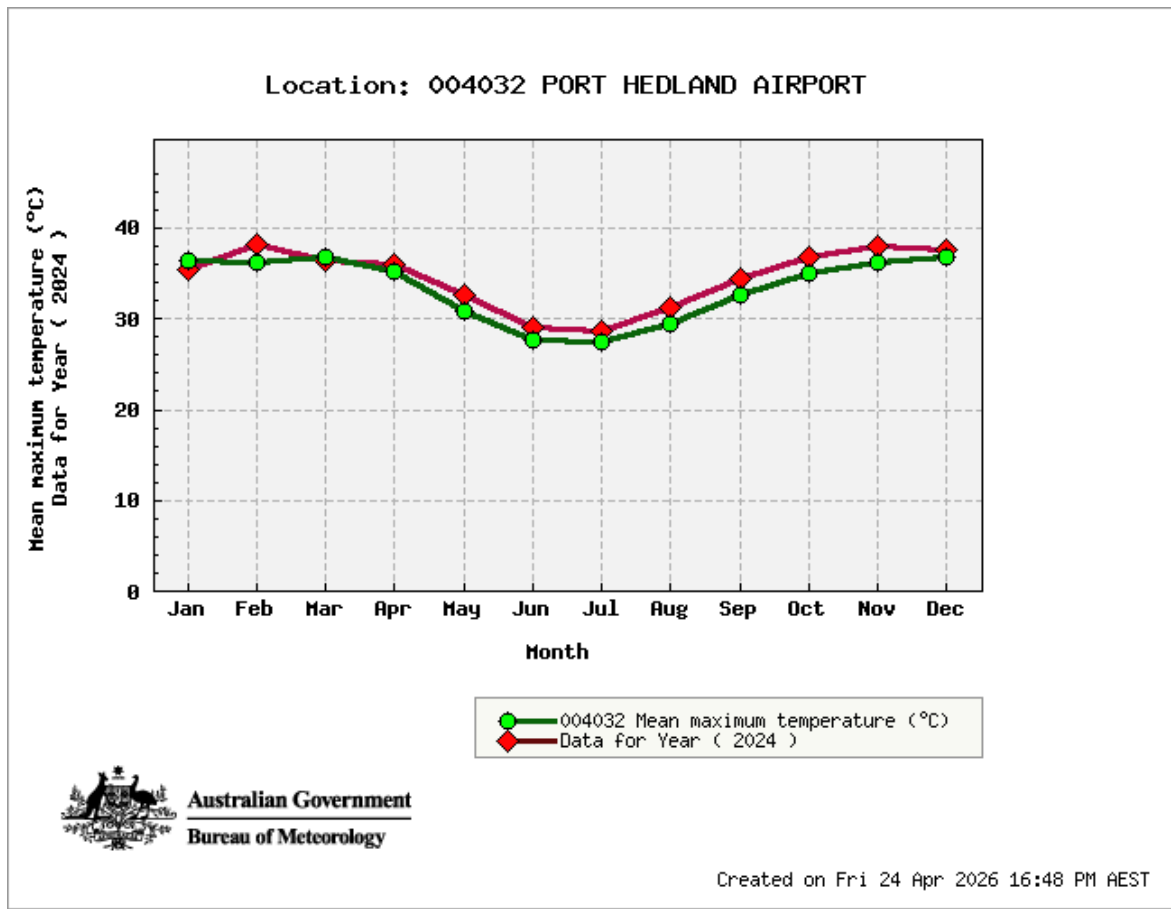


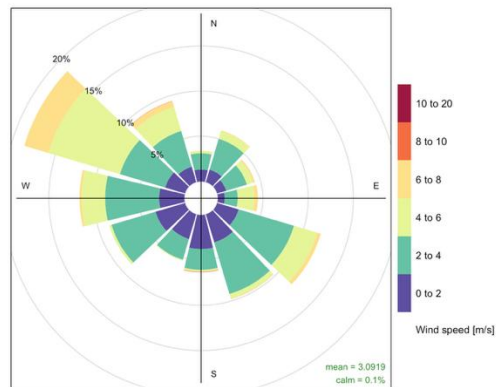
Figure 3 Mean monthly maximum temperature at Port Hedland Airport

Wind

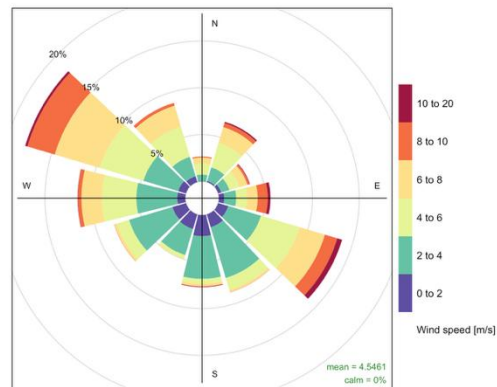
Figure 4 to Figure 6 provide an overview of wind direction and wind speed data averaged over 10-minute intervals from Taplin Street, BOM and Yule during 2024.

The data are presented as wind rose plots, showing the frequency of wind directions distributed over 12 direction segments. The colour coding reflects wind speed increments distributed over intervals derived from the data range. For each site, an annual plot and a set of four seasonal plots are presented. A summary of wind observations is:

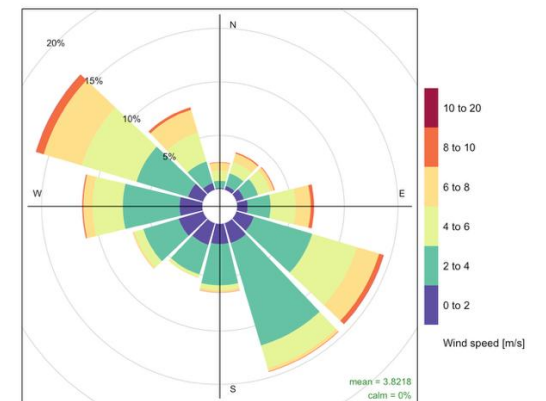
- Overall similar wind patterns are observed across the three sites with some site-specific differences in the distribution and frequency of wind directions.
- In the annual plots, the predominant wind directions of north-westerly, westerly and south-easterly are consistent across the sites.
- All sites have similar seasonal patterns with predominantly north-westerly and westerly winds in spring and summer and predominantly south-easterly winds in autumn and winter.
- A comparison of the annual data shows the highest mean wind speed of around 4.5 m/s at BOM, with lower annual mean wind speeds of 2.7 m/s at Taplin, and 3.8 m/s at Yule.



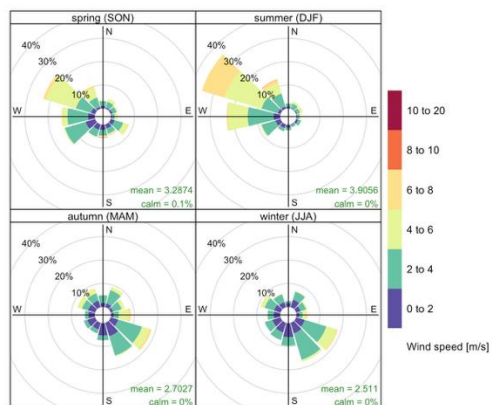
Frequency of counts by wind direction (%)



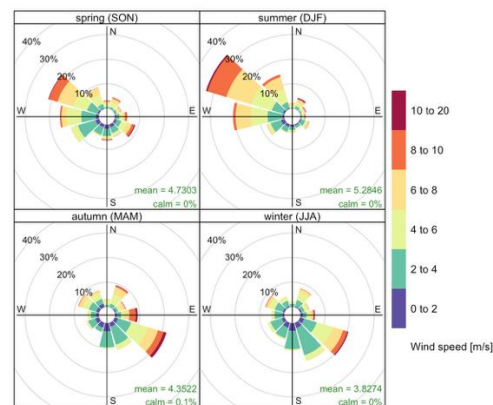
Frequency of counts by wind direction (%)



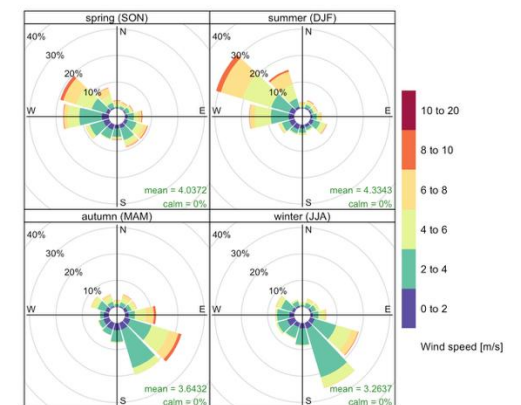
Frequency of counts by wind direction (%)



Frequency of counts by wind direction (%)



Frequency of counts by wind direction (%)



Frequency of counts by wind direction (%)

Figure 4 Taplin wind roses

top: annual, bottom: seasonal

Figure 5 BOM wind roses

top: annual, bottom: seasonal

Figure 6 Yule wind roses

top: annual, bottom: seasonal

3.2 Particles as PM₁₀

Particles are classified into different size fractions based on their aerodynamic equivalent diameter (AED) measured in micrometres or microns (µm). PM₁₀ particles have an AED of up to 10 µm. They can be derived from many different sources that include industrial emissions and natural sources. Particles of this size fraction are small enough to be inhaled and can cause health impacts.

Data availability

Adequate data availability rates are a prerequisite for valid data analysis.

Data availability rates for PM₁₀ monitoring during 2024 met the quarterly and annual thresholds with rates above 90% for the annual and quarterly data at most stations, except Neptune (Table 4). The lower availability rate at Neptune was the result of an incident in March 2024, where water ingress caused equipment faults. Despite this interruption, data availability in Q1 and Q2 is still above the acceptable threshold of 75%.

Table 4 Data availability for PM₁₀

Monitoring Station	Data availability rates (%)				
	Q1	Q2	Q3	Q4	Annual
Kingsmill	96.9	95.2	92.8	96.8	95.4
Richardson	98.9	94.1	98.4	93.2	96.2
Hospital	99.8	98.4	99.9	99.6	99.4
Neptune	80.1	82.7	92.1	99.8	88.7
Taplin	95.6	99.8	96.7	99.7	97.9
Wedgefield	90.9	89.6	90.9	95.6	91.7
BOM	99.5	98.6	99.8	99.1	99.3
South Hedland	94.7	86.8	85.8	95.6	90.7
Yule River	98.1	95.8	95.5	94.9	96.1

Daily averages

PM₁₀ monitoring data collected during 2024 are summarised as a simple statistic of daily guideline exceedance counts as presented in Table 5.

Table 5 Comparison against air quality guidelines

Monitoring Station	AAQ NEPM Daily average 50 µg/m ³ Number of days > 50 µg/m ³	Port Hedland AGV Daily average 70 µg/m ³ Number of days > 70 µg/m ³	AAQ NEPM Annual average 25 µg/m ³ Annual concentration µg/m ³
Richardson	96	35	47
Kingsmill	92	52	48
Hospital	88	51	48
Taplin	58	30	40
Neptune	26	17	31
South Hedland	24	17	28
Wedgefield	132	114	66
BOM	32	19	29
Yule	26	19	23

Compliance with the AAQ NEPM PM₁₀ guidelines has not been assessed, as these guidelines are not applied in Port Hedland. Comparison against the AAQ NEPM values is therefore used as a statistical indicator only. This comparison shows:

- Exceedances of the AAQ NEPM daily PM₁₀ guideline (50 µg/m³) generally decrease across the Port Hedland peninsula with increasing distance from port operations (Richardson, Kingsmill, Hospital, Taplin and Neptune).
- Richardson, closest to the port, recorded the highest number of AAQ NEPM exceedances (96), followed by Kingsmill (92) and Hospital (88).

- Taplin (58) and Neptune (26) recorded fewer AAQ NEPM exceedances, consistent with their location further from port operations.
- The lowest number of AAQ NEPM exceedances in monitored residential areas occurred at South Hedland (24).
- Wedgefield recorded the highest number of AAQ NEPM exceedances overall (132), reflecting strong local dust influences, particularly vehicle movements on nearby unsealed roads.
- The BOM site recorded more exceedances (32) than Yule (26), likely reflecting the influence of localised dust sources such as nearby clearing and earthworks activities.

Regulatory application of the Port Hedland Air Guideline Value (AGV) has only been assessed at Taplin (see next section). For other locations, AGV exceedances are used for comparative purposes only. This comparison shows:

- AGV exceedances across the peninsula are broadly consistent with the AAQ NEPM exceedance pattern, with higher exceedance counts at Kingsmill (52) and Hospital (51) and lower counts at Taplin (30) and Neptune (17).
- Richardson represents an exception to this pattern, recording fewer AGV exceedances (35) than Kingsmill and Hospital despite being closest to the port.
- Neptune and South Hedland recorded the lowest number of AGV exceedances in monitored residential areas (17 each).
- Wedgefield recorded the highest number of AGV exceedances overall (114), consistent with strong local source influences rather than proximity to port operations.

Regulatory application of the AGV at Taplin

Exceedance counts of the AGV at Taplin are an important regulatory indicator and are referenced in premises' licences as dust management and reporting conditions. Exceedance information is used to inform regulatory decision-making by assessing the contribution of regulated emission sources. For AGV exceedances to meaningfully inform the regulation of premises, a clear relationship must be established between monitored exceedances and dust emissions from those premises.

Using data from the ambient monitoring network alone for this purpose has inherent limitations, as the network was designed to measure dust concentrations and potential impacts in the community rather than to accurately attribute dust contributions from individual premises or industry as a whole to the concentrations recorded at Taplin. In addition, distinguishing and quantifying contributions from multiple fugitive dust sources located in close proximity to one another, and in the presence of local and background dust, is inherently complex and would require a more intensive and multi-pronged monitoring approach than is currently in place.

Given these limitations, the method used to assess and attribute exceedances is undertaken at a high level. Exceedances are grouped into three broad source categories: exceptional (E), regulatory (R) and other (O). Attribution is assigned where a source is considered to

have made a substantial contribution to the exceedance. Accordingly, attribution statements indicate the likely cause(s) rather than providing definitive source apportionment. A key focus of the method is to ensure that it is clearly defined and replicable. Further details are provided in the Appendix.

Exceedance attribution

Exceptional is used when exceptional or natural events such as bushfires or regional dust storms have adversely affected regional air quality and caused an exceedance at Taplin Street. A regulatory event means that the exceedance has likely been substantially contributed to by industry emissions and an attribution to other exceedances accounts for substantial contributions from non-industry local and background sources.

During 2024 the AGV was exceeded 30 times at the Taplin monitoring station, with 13 of these considered to be due to exceptional events, 7 attributed to industry and 10 to other sources.

Table 6 AGV exceedance summary at Taplin

Date of exceedance	Daily average PM ₁₀ µg/m ³	Assessment of result*
1/01/2024	88	E
2/01/2024	137	E
3/01/2024	94	E
8/01/2024	163	E
9/01/2024	221	E
10/01/2024	130	O
11/01/2024	72	O
12/01/2024	90	E
13/01/2024	90	O
19/01/2024	78	O
23/01/2024	105	E
24/01/2024	82	E
25/01/2024	106	E
26/01/2024	96	E
5/02/2024	79	E

Date of exceedance	Daily average PM ₁₀ µg/m ³	Assessment of result*
8/02/2024	85	O
19/02/2024	73	R
29/02/2024	70	O
22/04/2024	152	O
1/05/2024	74	R
25/05/2024	98	R
19/06/2024	157	O
9/08/2024	72	R
1/09/2024	71	R
2/09/2024	78	O
20/12/2024	77	E
21/12/2024	73	O
22/12/2024	70	R
27/12/2024	99	E
28/12/2024	87	R

*Exceptional event (E)

Regulatory event (R)

Other exceedance event (O)

Annual averages

Table 5 includes the annual average concentrations for each station to allow comparison with the AAQ NEPM guideline of 25 µg/m³. In 2024, annual average concentrations exceeded the guideline at all monitoring locations except Yule. Yule remained below the guideline value, while the highest annual average concentration was recorded at Wedgefield.

The spatial pattern of annual average PM₁₀ concentrations is generally consistent with that observed for daily averages, with higher concentrations recorded at western peninsular and industrial locations and lower concentrations towards the east. In the West End, Richardson, Kingsmill and Hospital recorded higher annual averages than Taplin, Neptune (East End) and South Hedland. Elevated annual average concentrations at Wedgefield reflect strong local dust influences, while lower concentrations at the Yule site are consistent with its background location.

Notably, BOM has a higher annual average than South Hedland, consistent with previous observations of localised dust sources nearby.

PM₁₀ trend analysis

The objective of the PM₁₀ trend analysis is to describe features of dust concentrations recorded in 2024 and compare these with the four preceding years. The use of multiple statistics and more complex data analysis in addition to calculating guideline exceedance counts supports a sound approach to assessing particle levels.

Reliance on the number of AGV exceedances as the sole statistic to describe PM₁₀ dust concentrations in Port Hedland can limit the ability to draw meaningful conclusions from the data.

Taplin monthly trend

Figure 7 presents monthly summary statistics for PM₁₀ hourly concentrations at Taplin in the form of a “box and whisker” plot for 2024 and for 2020 - 2023. The plot includes minimum and maximum concentrations, median concentrations, and selected percentiles. The height of the coloured boxes shows the data spread between the 25th and 75th percentiles. The extent of the whiskers indicate the minimum and maximum concentrations, with outliers removed for readability. The median hourly concentration is indicated by the horizontal bar located in each box.

A clear seasonal trend at Taplin is evident, with lower concentrations in winter and higher concentrations in summer in both datasets. Higher ambient temperatures in summer (Figure 3) are likely to contribute to these increased dust concentrations. A dry start to the year would likely have contributed to the higher concentrations in January and February 2024.

Figure 4 shows that the predominant wind direction in summer was from a west/north-westerly direction, which also increases the likelihood of dust contributions at Taplin from port sources, while the predominant south-easterly wind directions in winter decreases the likelihood of dust contributions from port sources.

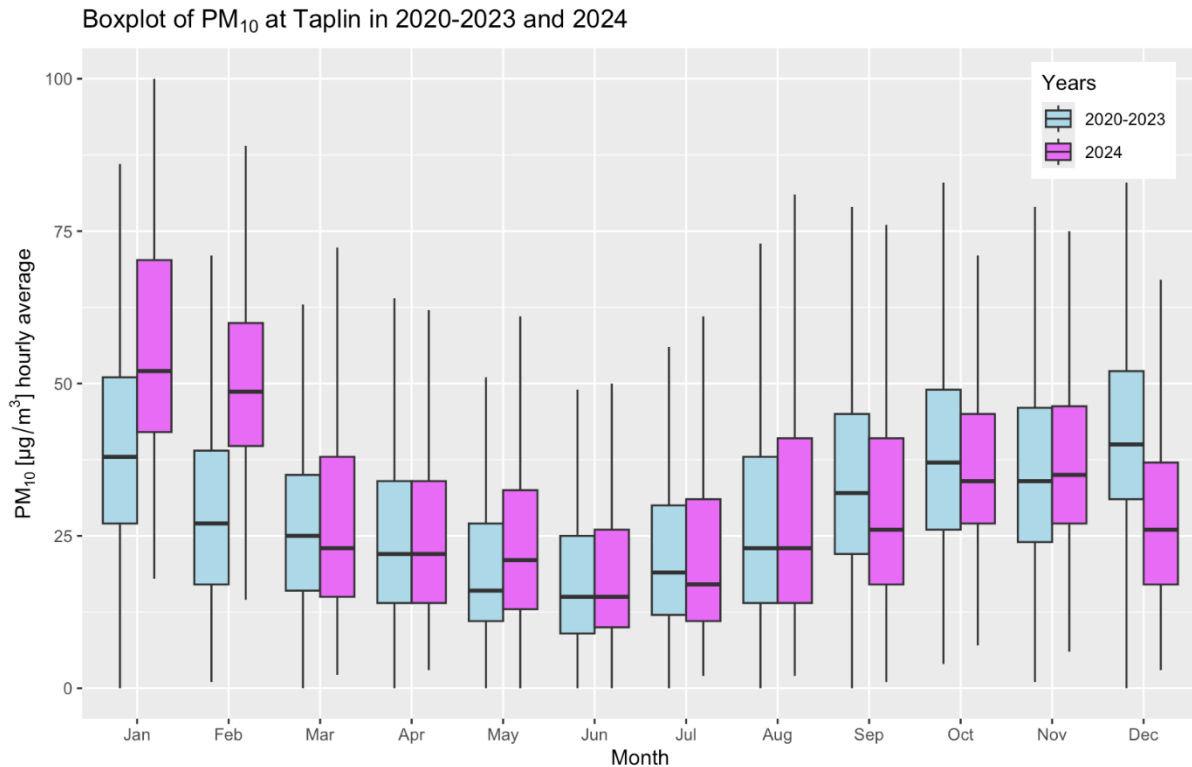


Figure 7 Monthly variability of Taplin PM₁₀ hourly averages for 2024 and 2020–23

Comparison of sites

While summary statistics like exceedance counts and “box and whisker” plots give some insight into the data trends, a more complex statistical approach has been used to investigate whether there was overall more or less dust in 2024 compared to the four preceding years.

This approach calculates the frequency distribution of daily concentration data points and generates a curve showing the accumulated frequency of daily concentrations over a year. In the discussion below we refer to the curves as accumulated frequency curves.

The accumulated frequency curves are shown in Figure 8 which has site-specific curves for 2024 comparing peninsular sites in an east to west direction with increasing proximity to port premises (Neptune, Taplin, Hospital, Kingsmill and Richardson).

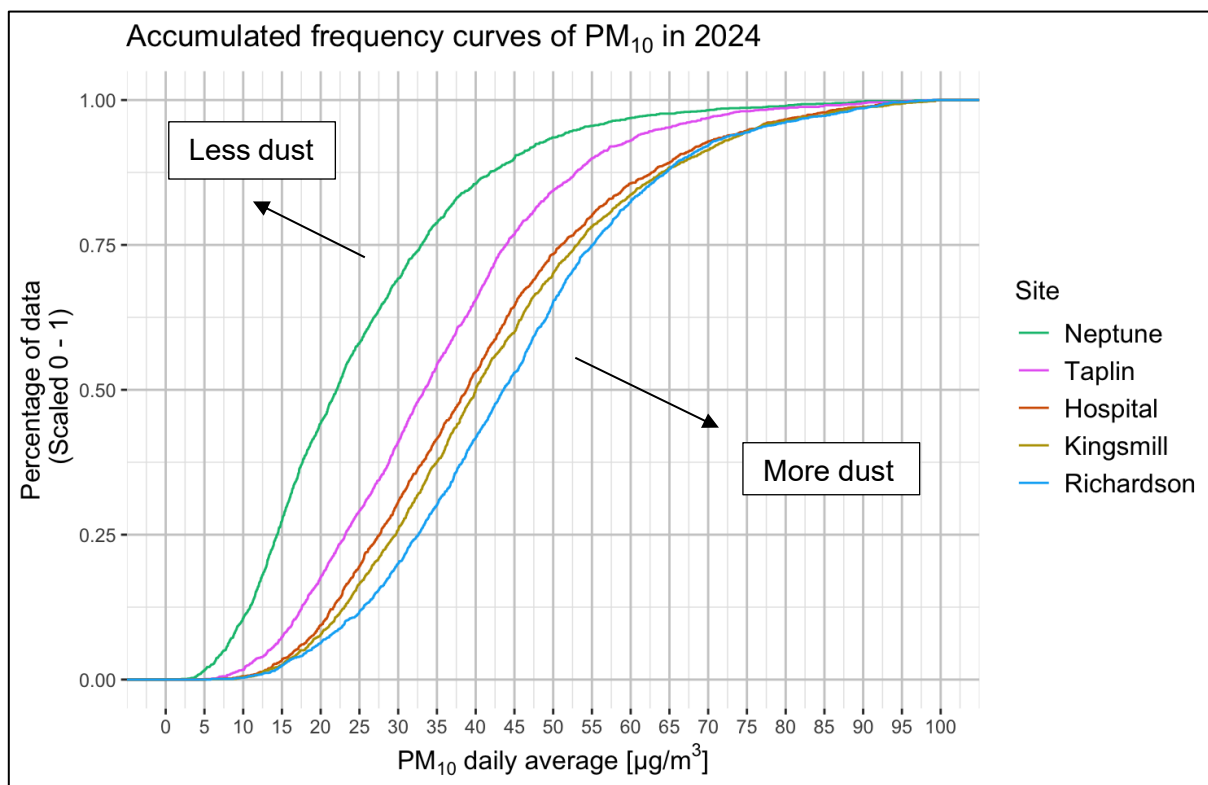
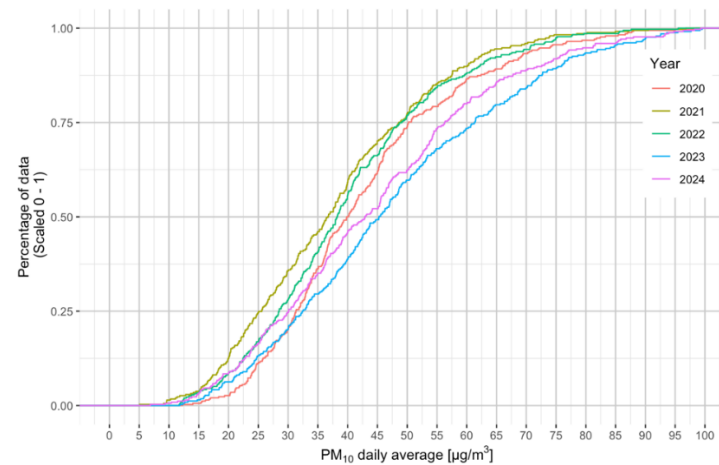
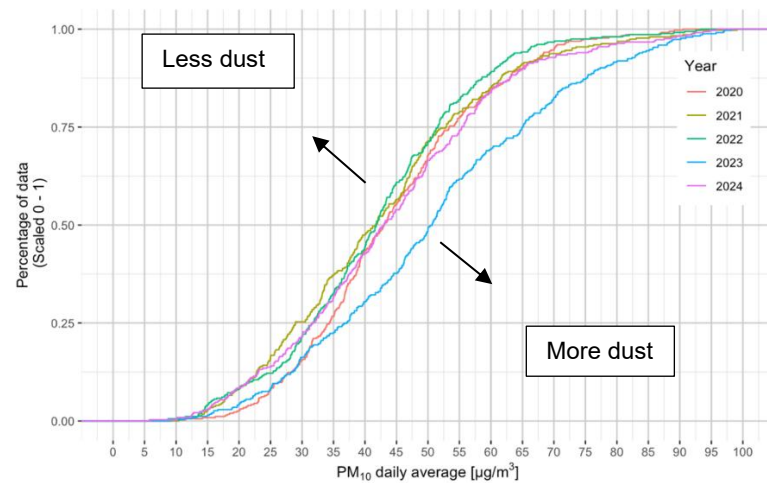


Figure 8 Comparison of dust concentrations at Port Hedland peninsular locations for 2024

In Figure 8, the x-axis represents daily average PM₁₀ concentrations and for each concentration point on the curve the corresponding y-axis value shows the proportion of points in the data set which are of less or equal value. The y-axis starts at 0 and goes to 1, which is comparable to a 0 to 100% scale. Each dataset to which the statistical treatment is applied generates a unique curve showing the frequency distribution. Important features to compare are the shape of the curve, its position along the x-axis and how it is different from other curves in the same plot. For example, a dataset with overall lower PM₁₀ concentrations will produce a curve that is positioned more to the left of the graph than a curve representing overall higher PM₁₀ concentrations, which will be positioned further to the right. A steeper (more vertical) slope indicates that concentrations are clustered together while a flatter (more horizontal) curve indicates that concentrations are more spread out.

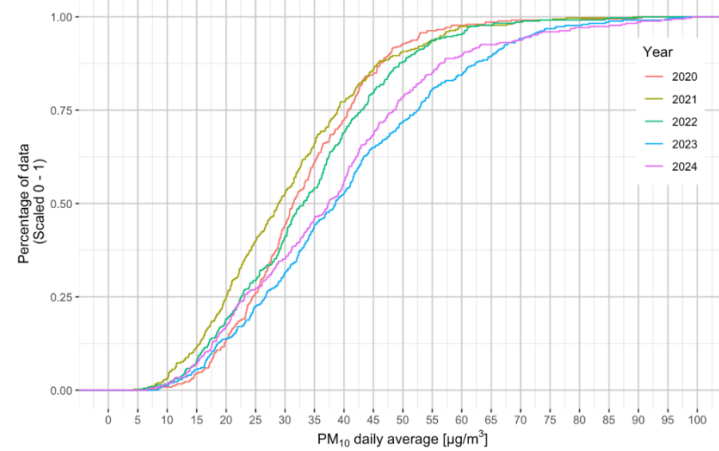
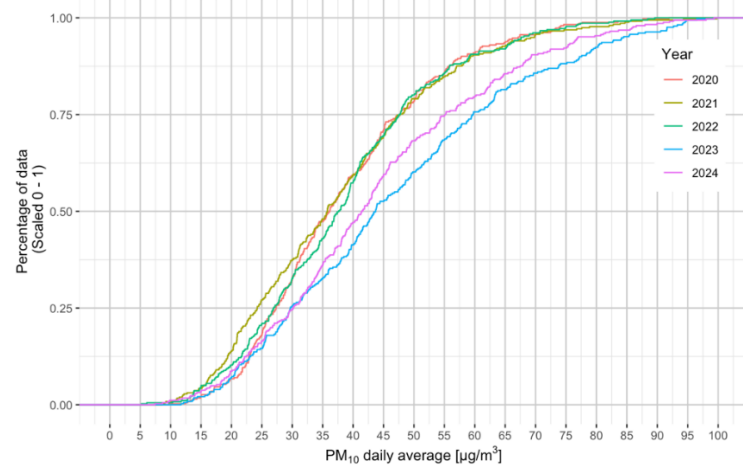
Figure 8 shows that for 2024, in common with monitoring data for other years, there is a clear trend of more dust when moving from the East End to the West End.

Figure 9 shows frequency curves for the years 2020 – 2024 grouped by site. Richardson, Hospital, Taplin and Neptune have been chosen to represent peninsular sites for this data visualisation. Each site's graph contains five curves, one for each calendar year. This comparison indicates that 2024 was an intermediate year in terms of overall dustiness for the peninsular sites for the years considered, except for Neptune where 2024 was dustier than earlier years, noting there is limited variation at this location.



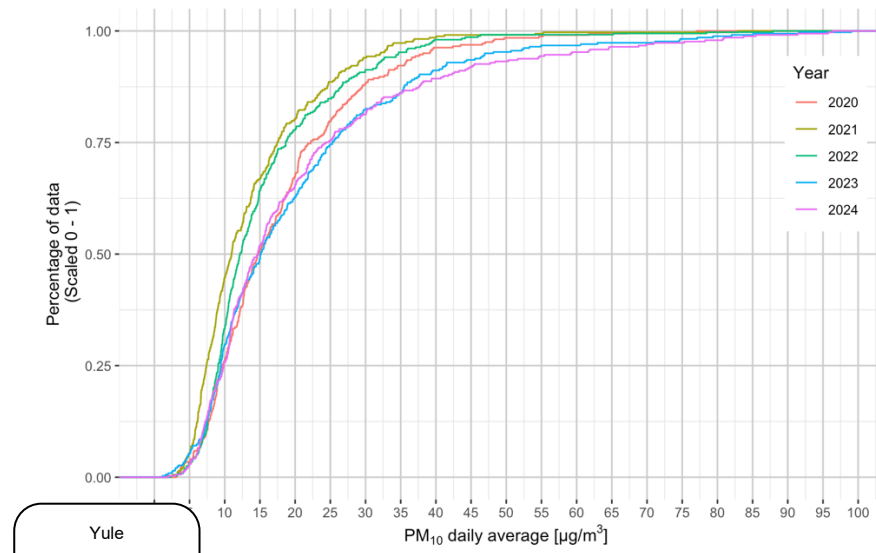
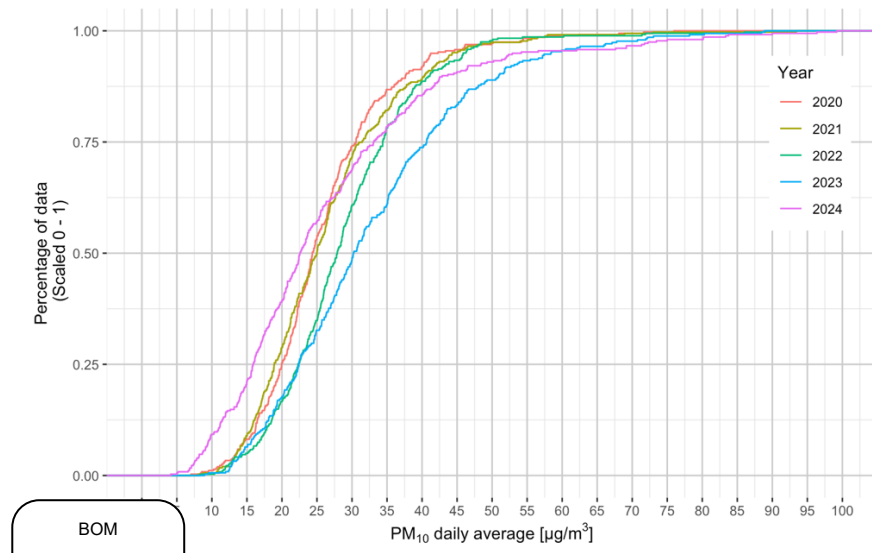
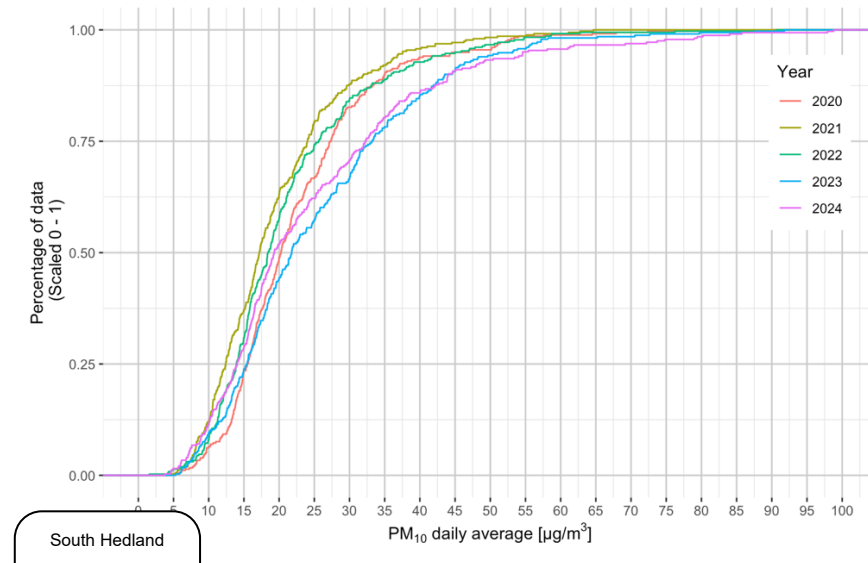
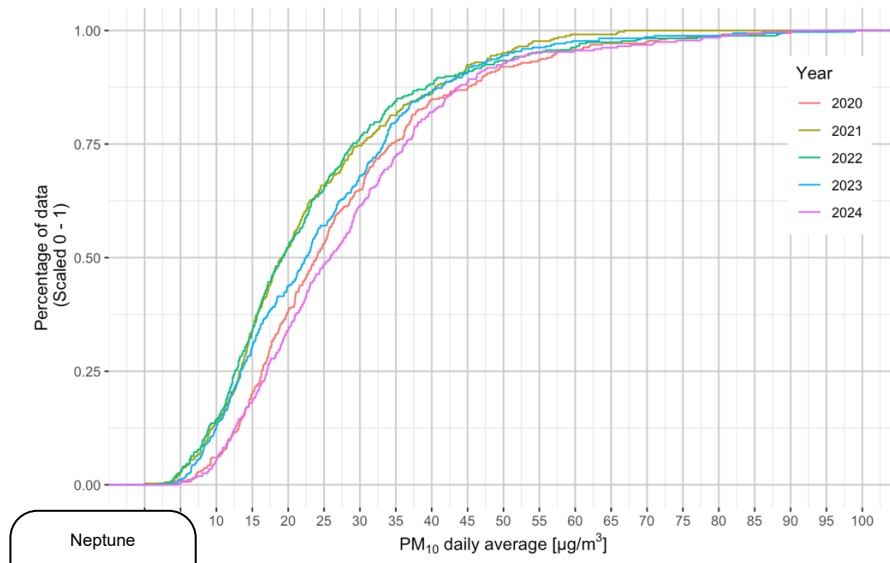
Richardson

Kingsmill



Hospital

Taplin



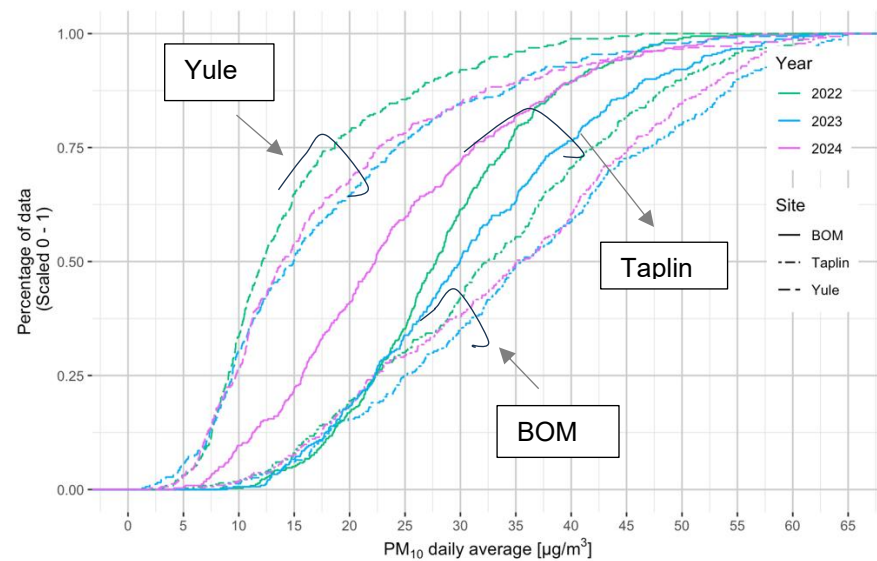


Figure 9 Accumulated frequency curves of PM₁₀ for selected non-peninsular locations for 2020 – 2024 and comparison of Taplin with Yule and BOM for 2022 - 2024.

3.3 Particles as PM_{2.5}

PM_{2.5} is defined as particles with an AED of up to 2.5 µm. PM_{2.5} is a subfraction of PM₁₀ and therefore the PM₁₀ fraction consists of both coarse particles (PM₁₀ minus the PM_{2.5} fraction) and a fine particle fraction (PM_{2.5} only). Exposure to elevated levels of PM_{2.5} has been associated with adverse health effects.

PM_{2.5} can be generated from various sources. In urban environments PM_{2.5} is mostly emitted from anthropogenic combustion sources such as motor vehicles and wood heaters. In non-urban areas bushfires can be a significant source of PM_{2.5}. Consequently, the proportion of PM_{2.5} in urban PM₁₀ is often higher than in regional particles due to more combustion sources and their constant emissions in urban areas. While bushfires can significantly contribute to higher proportions of PM_{2.5} in regional PM₁₀, their occurrences are episodic and associated with major smoke events with high particle concentrations. In mining industry settings, PM_{2.5} emissions can be generated from processing of materials and from bulk handling of fine materials. Unlike PM_{2.5} emissions from bushfires, emissions from industrial activities are usually more constant and at lower concentrations.

The HRA recognised that in Port Hedland the proportion of PM_{2.5} in PM₁₀ is similar to other regional areas, which reflects the lower contribution from combustion sources (mainly motor vehicles) that is typical of large cities.

Data availability

Adequate data return rates are a prerequisite for valid data analysis.

Data availability rates for PM_{2.5} monitoring met the quarterly and annual thresholds with rates above 90% for annual and quarterly data (Table 7).

Table 7 Data availability for PM_{2.5}

Monitoring Station	Data availability rates (%)				
	Q1	Q2	Q3	Q4	Annual
Richardson	99.1	91.7	98.4	94.8	96.0
Kingsmill	NA				
Hospital	99.9	98.4	99.9	99.6	99.4
Taplin	95.6	99.8	95.2	99.8	97.6
Neptune	NA				
South Hedland	96.9	92.1	91.4	97.3	94.4
Wedgefield	NA				
BoM	97.3	95.5	99.6	96.1	97.1
Yule	97.8	95.7	95.6	95.1	96.0

NA = Not Applicable (no monitor at this location).

Daily averages

PM_{2.5} monitoring data collected during 2024 are summarised as a simple statistic of AAQ NEPM daily guideline exceedance counts as presented in Table 8.

The number of exceedances was similar across the network, with the maximum count at Hospital (14) and the minimum count at Yule (7).

Annual averages

Table 8 shows the annual average concentrations for each station to allow comparison with the AAQ NEPM annual guideline. The guideline was not met at Richardson, Hospital and Taplin. The guideline was met at South Hedland, BOM and Yule.

Table 8 Comparison against PM_{2.5} guidelines

Monitoring Station	Number of days > 25µg/m ³	Performance against AAQ NEPM Daily average 25 µg/m ³	Annual average (µg/m ³)	Performance against AAQ NEPM Annual average 8 µg/m ³
Richardson	10	not met	11	not met
Kingsmill	NA	NA	NA	NA
Hospital	14	not met	10	not met
Taplin	12	not met	11	not met
Neptune	NA	NA	NA	NA
South Hedland	9	not met	6	met
Wedgefield	NA	NA	NA	NA
BOM	10	not met	5	met
Yule	7	not met	4	met

NA = Not Applicable (no monitor at this station)

PM_{2.5} analysis

Figure 10 presents monthly summary statistics for PM_{2.5} hourly concentrations at Taplin in the form of a “box and whisker” plot for 2024 and for 2020 - 2023. The plot includes minimum and maximum concentrations, median concentrations and selected percentiles. The height of the coloured boxes shows the data spread between the 25th and 75th percentiles. The extent of the whiskers indicates the minimum and maximum concentrations, with outliers removed for readability. The median hourly concentration is indicated by the horizontal bar located in each box.

Boxplot of PM_{2.5} at Taplin in 2020-2023 and 2024

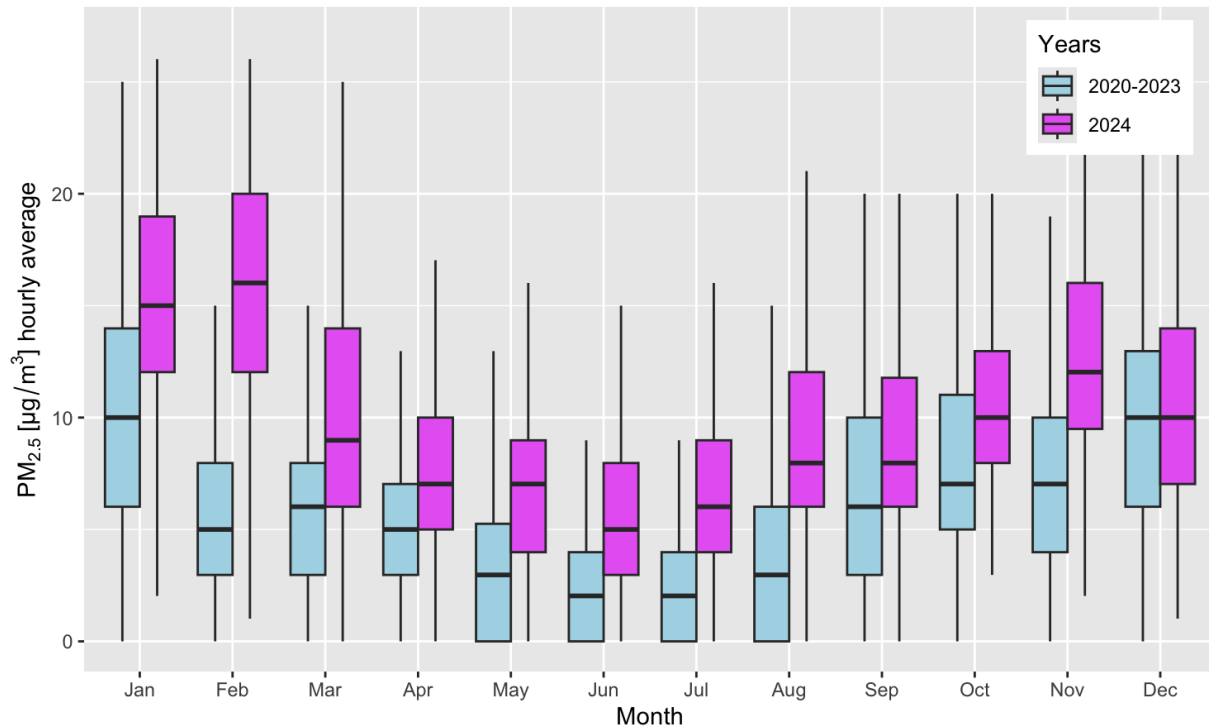


Figure 10 Comparison of monthly variability of PM₁₀ hourly concentrations

Data for each month of 2024 can be compared with the previous four years' data for that month. Hourly concentrations in 2024 were higher than those for earlier years, especially at the start of the year. Similar to the PM₁₀ results, the dry start to the year would likely have contributed to the higher concentrations due to smoke and additional windblown dust.

Airborne particles created by combustion sources such as fires generally have a high proportion of PM_{2.5}. This means that the PM_{2.5}/PM₁₀ ratio can be used as an indicator of the contribution from combustion sources when analysing PM_{2.5} and PM₁₀ monitoring data. That is, a higher ratio value indicates a higher proportion of PM_{2.5} and therefore combustion sources may be an important cause of elevated particle concentrations. A lower ratio value indicates a lower proportion of PM_{2.5} and therefore combustion sources are not likely to be a major contributor to elevated particle concentrations.

To investigate whether fine particles (PM_{2.5}) play a significant role in PM₁₀ events that exceed guidelines a targeted statistical approach examining PM_{2.5}/PM₁₀ ratios is applied. The approach is illustrated and explained in Figure 11.

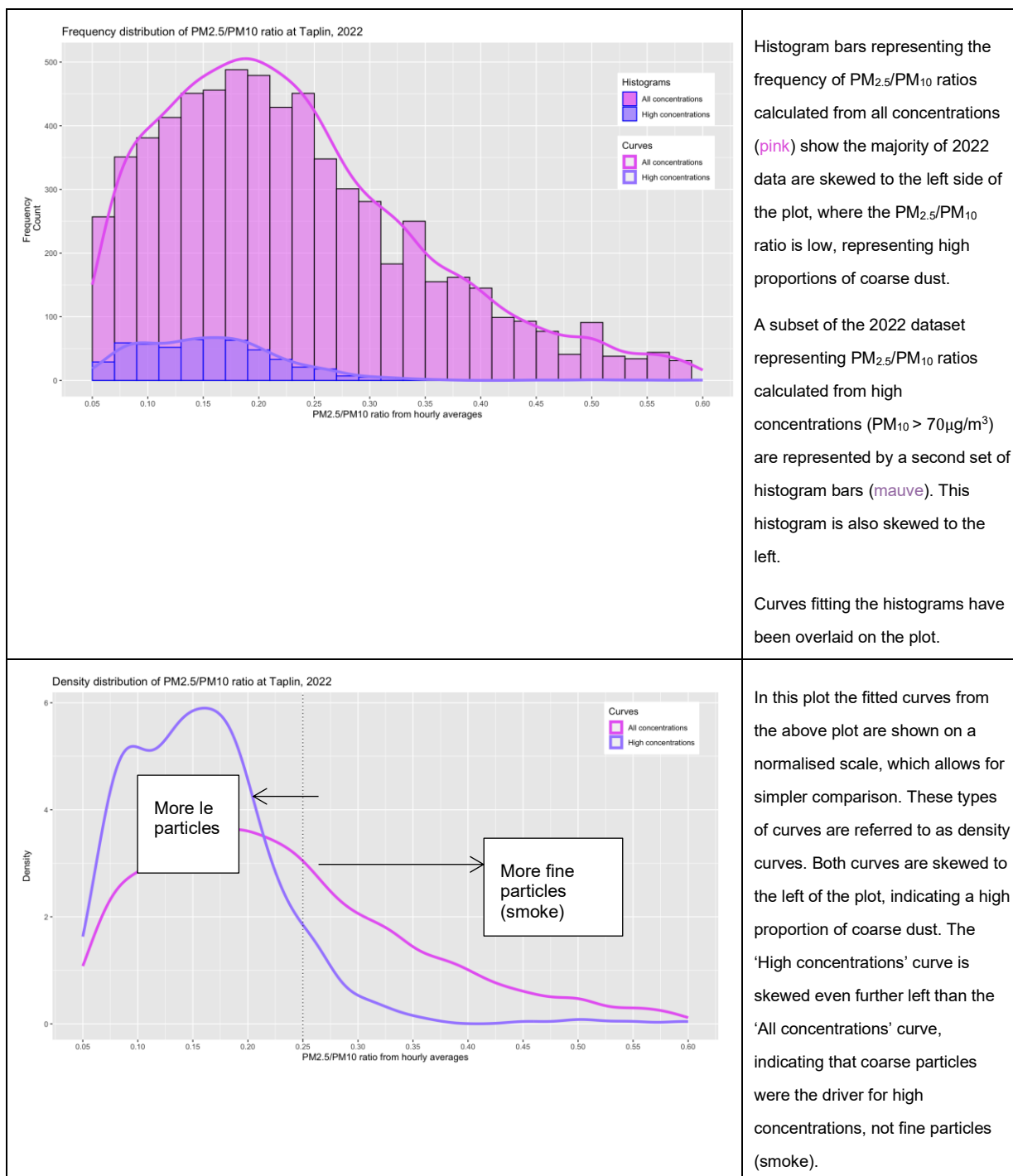


Figure 11 Analytical approach to investigate the contribution of $PM_{2.5}$ to elevated particle concentrations.

The ratio data are presented as density curves, which show the frequency distribution of the ratio values. The $PM_{2.5}/PM_{10}$ ratio is displayed on the x-axis while the frequency is displayed on the y-axis.

In Figure 12, two graphs are provided for each monitoring site, with graph “(a)” (left side) using all available data and graph “(b)” (right side) only using data where PM_{10} hourly averages were greater than $70\mu g/m^3$. The “(b)” graphs therefore only include $PM_{2.5}/PM_{10}$ ratio values for this

subset of data, so that we can specifically examine ratios at higher PM_{10} concentrations. Each site graph contains five annual curves reflecting 2020 - 2024.

Each curve is generated using available hourly average concentration data for a selected calendar year. The “N” values shown in the graph legends are the number of data points used to generate the curves. To achieve optimal graphing the x-axes have been truncated so that the key features of the curves are appropriately scaled for visual examination.

Interpretation of key features of density curves

An important feature of the curve is its peak, which shows where the most common ratio occurs. If the peak of the curve is to the left side of the graph, it means that lower $PM_{2.5}/PM_{10}$ ratio values are more common in the sample. A low $PM_{2.5}/PM_{10}$ ratio means that there is a small proportion of $PM_{2.5}$ in the PM_{10} fraction of particle mass. If the peak of the curve is at the right side of the graph, it indicates that there are more of the higher $PM_{2.5}/PM_{10}$ ratio values, meaning higher proportions of $PM_{2.5}$ in the PM_{10} fraction.

Variability in ratios

Reviewing the (a) graphs in Figure 13 for each site allows comparison of annual variability. For example, at Richardson the lowest $PM_{2.5}/PM_{10}$ ratios occurred in 2020, followed by 2021, 2019 and 2022 with 2018 showing the highest ratios. This ranking is similar across sites with some minor variations. For example, Hospital had lower ratios in 2021 than in 2020. 2022 had the third highest contribution of $PM_{2.5}$ at most sites.

While all the peninsular sites and BOM have quite similar (a) graphs, the Yule graphs differ significantly. The shape of all annual curves in the Yule (a) graph are skewed more to the right, indicating higher proportions of $PM_{2.5}$ compared with other sites.

Ratios at higher PM_{10} concentrations

To further understand the influence of fine particles on overall particle levels during periods of elevated concentrations, a subset of data where PM_{10} hourly averages were high ($>70 \mu g/m^3$) are presented in the Figure 12 (b) graphs. The objective of this analysis is to assess whether the $PM_{2.5}/PM_{10}$ ratio changes when particle concentrations are higher.

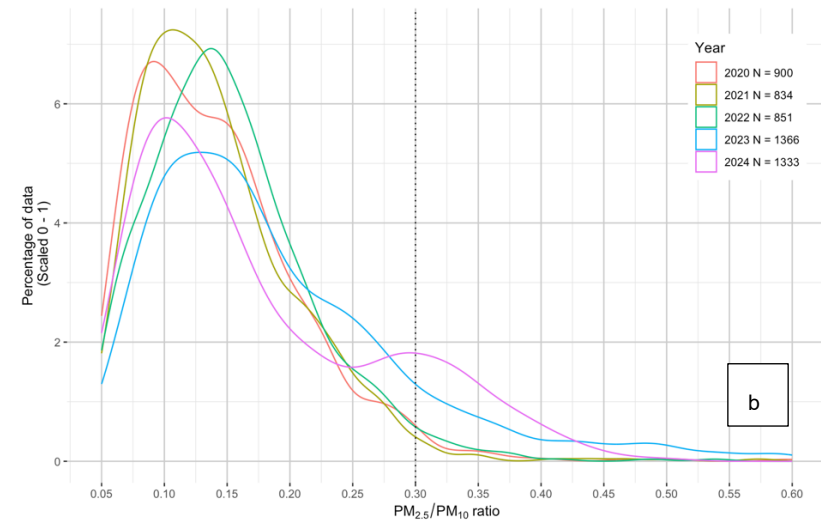
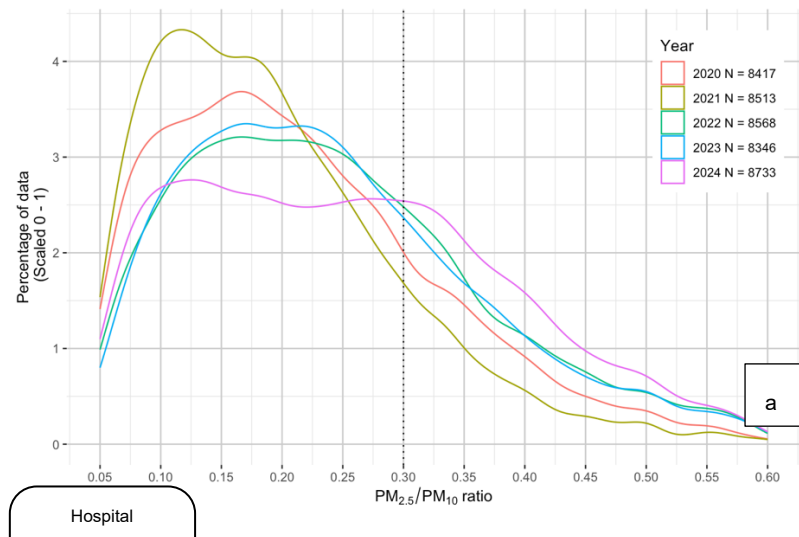
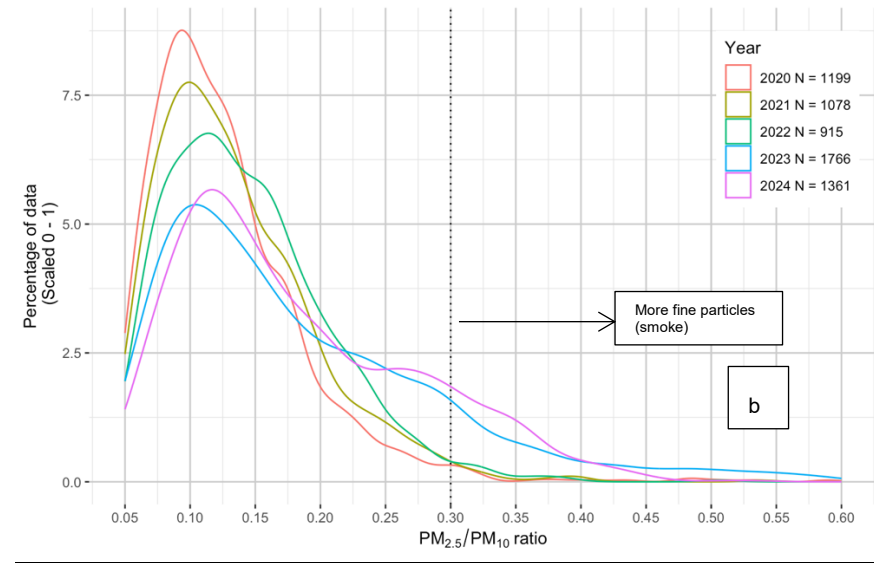
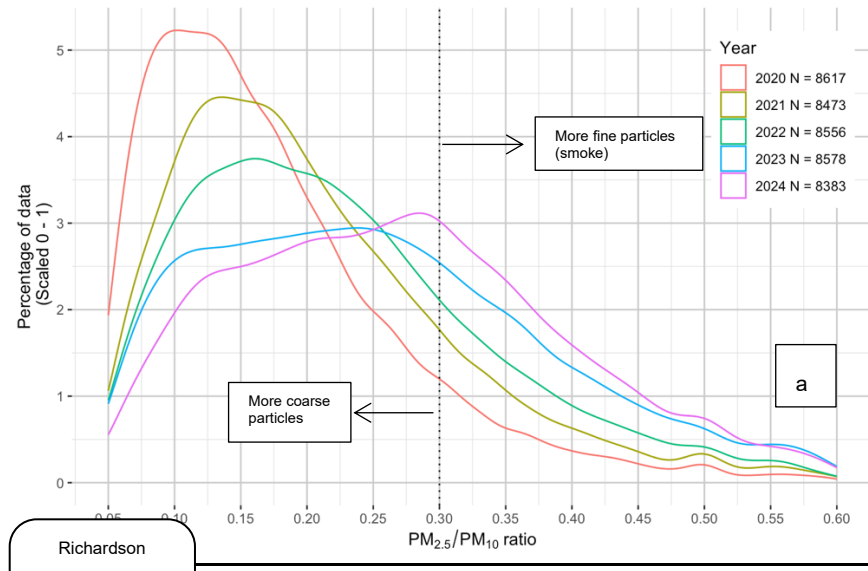
If $PM_{2.5}/PM_{10}$ ratios are higher when PM_{10} concentrations are high, then this would result in differences between the (a) and (b) curves, with (b) curves having peaks shifted to the right. If the curves for the (a) and (b) graphs are similar, or if (b) curves have peaks more to the left side of the graphs, this would mean that $PM_{2.5}$ is not a more significant contributor to high PM_{10} concentrations.

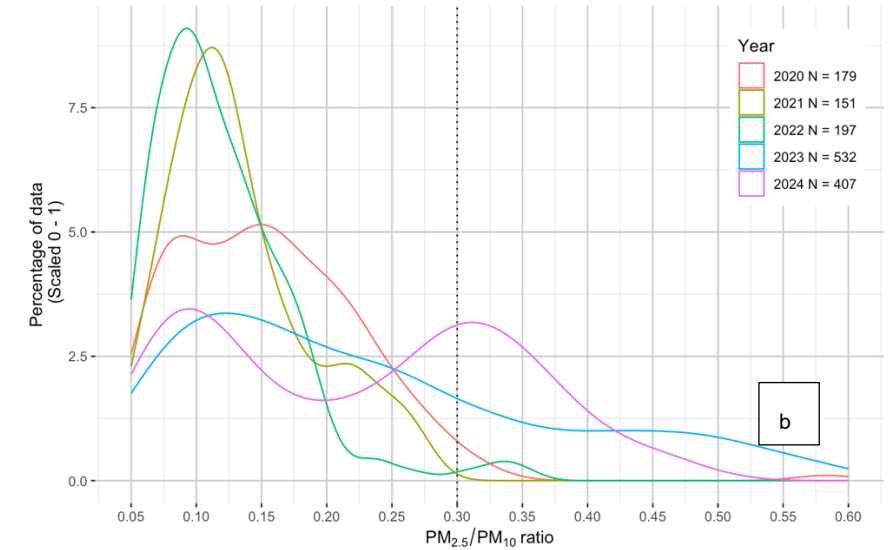
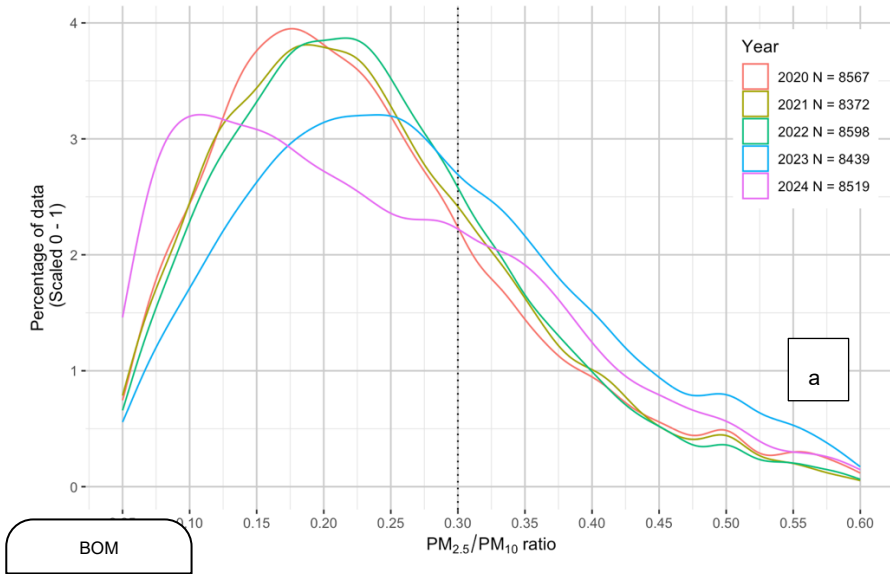
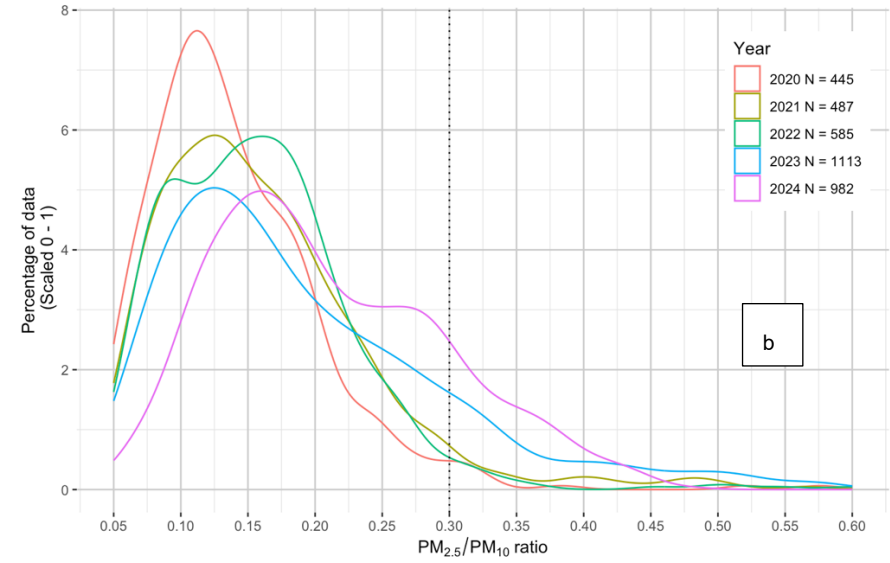
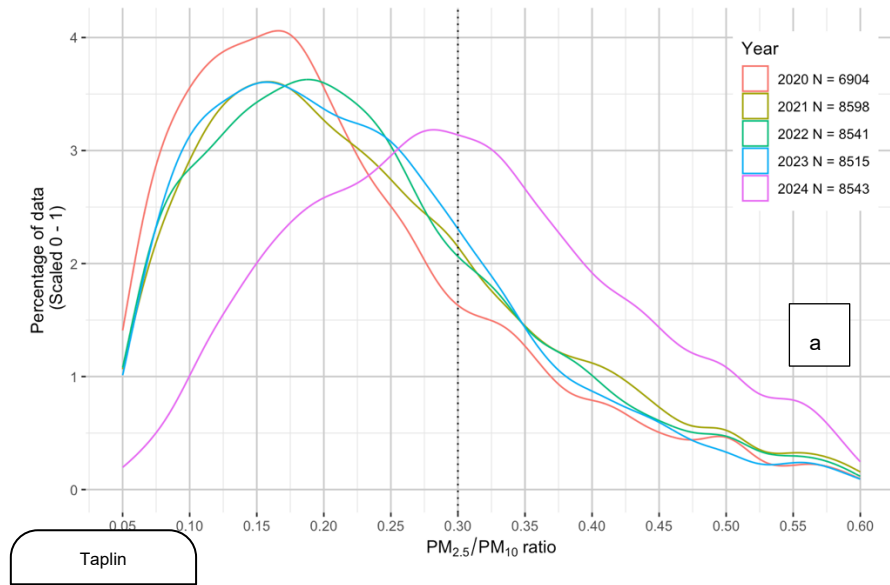
When comparing the (a) and (b) graphs for the peninsular locations, it is evident that while coarse particles are still the dominant component of high dust concentrations, the proportion of fine particles was increased in 2024, compared to the previous four years. This is illustrated in the (b) curves as a secondary lower peak. The bimodal curve shape appears more pronounced in a west to east direction, with Richardson showing a less pronounced secondary peak than Hospital and Taplin, indicating that the source influencing the increasing proportion

of fine particles is located further away from the port, while the coarse particle proportion increases with proximity to the port.

At the non-peninsular sites of BOM and Yule the (b) curves reveal a stronger influence of fine particles on high dust events than at the peninsular sites. A very pronounced bimodal curve at Yule indicates that there were two types of high dust events at this location, one strongly influenced by coarse particles (dust storm) and one influenced by fine particles (smoke from fires).

The data analysis indicates that fine particles from smoke have likely had a stronger influence on high particle concentrations at all sites than in previous years and in particular on sites further away from the port. Coarse particles remain a major contributor to high dust events, particularly at locations close to the port.





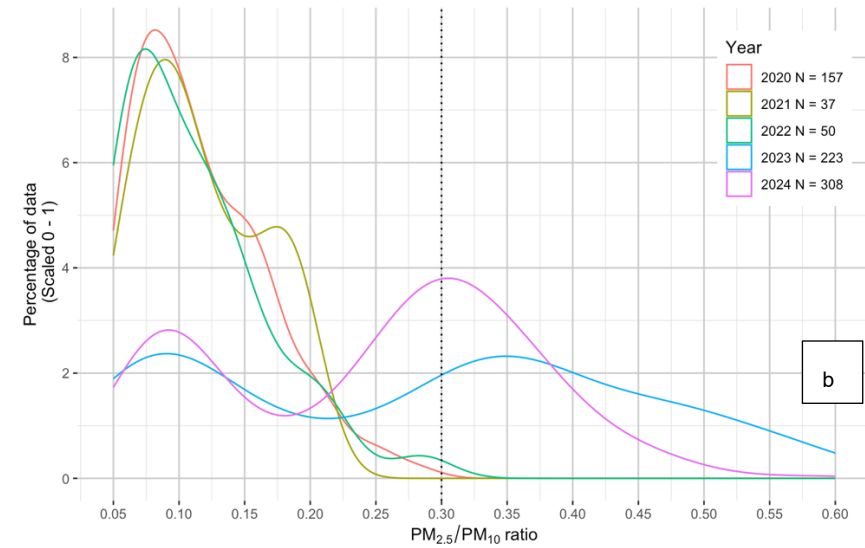
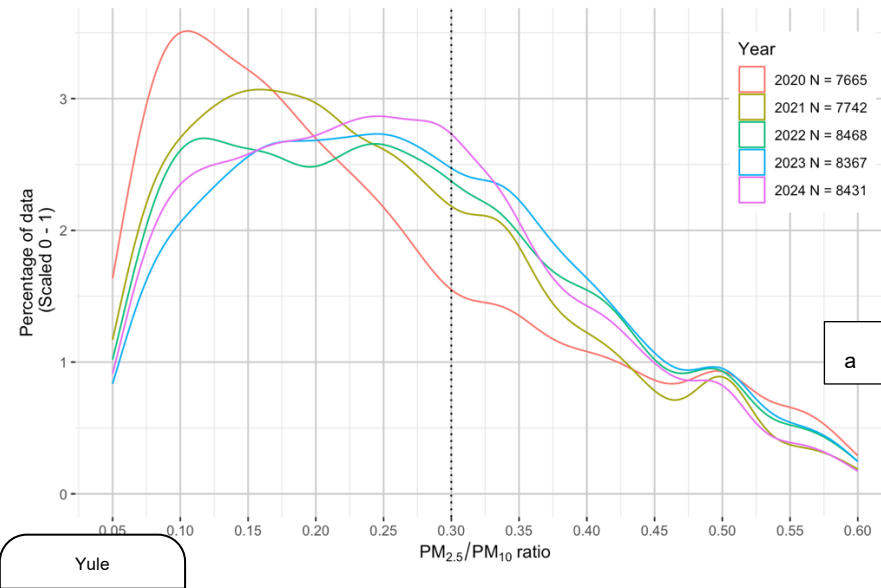


Figure 12 Comparison of $PM_{2.5}/PM_{10}$ ratio as density curves

3.4 Nitrogen dioxide

Nitrogen oxides, comprising nitric oxide (NO) and nitrogen dioxide (NO₂) are primarily generated through burning fuel and are emitted from cars, trucks, locomotives, heavy machinery and ships, as well as power plants and industrial processes.

NO in ambient air is harmless whereas NO₂ is an air pollutant. NO₂ is monitored at two locations in Port Hedland, at Taplin and at Richardson.

Data availability

Adequate data availability rates are a prerequisite for valid data analysis.

Data availability rates for NO₂ monitoring met the thresholds with rates above 75% for all annual and quarterly data at Taplin (Table 9).

Table 9 Data availability for NO₂

Monitoring Station	Data availability rates (%)				
	Q1	Q2	Q3	Q4	Annual
Richardson	87	82	82	84	84.
Taplin Street	78	83	85	79	82

Concentrations compared against guidelines

An overview of NO₂ concentrations and comparison with the AAQ NEPM guidelines at Taplin is presented in Table 10. Both the maximum 1-hour average and the annual average values are significantly lower than the guidelines.

Table 10 NO₂ concentrations compared with guidelines at Taplin

Monitoring Station	Max 1 hr average NO ₂ ppb	Comparison with AAQ NEPM 1 hr average 80 ppb	Annual average NO ₂ ppb	Comparison with AAQ NEPM annual NO ₂ 15 ppb
Richardson	41	met	8	met
Taplin	42	met	7	met

NO₂ trend analysis

Figure 13 presents monthly summary statistics for NO₂ hourly concentrations at Taplin in the form of a “box and whisker” plot for 2024 and for 2020 - 2023. The plot includes minimum and maximum concentrations, median concentrations, and selected percentiles. The height of the coloured boxes shows the data spread between the 25th and 75th percentiles and the extent of the whiskers indicate the minimum and maximum concentrations. The median hourly concentration is indicated by the horizontal bar located in each box.

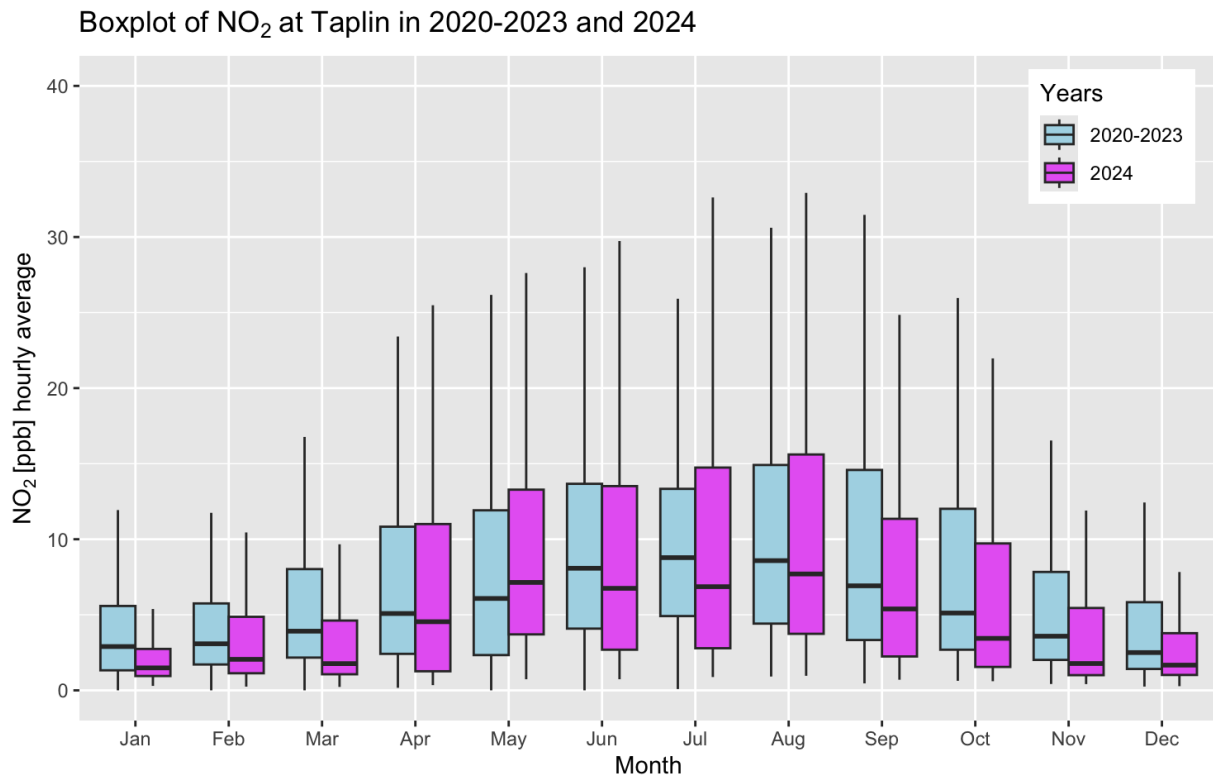


Figure 13 Variability of NO₂ hourly average by month at Taplin

The 2024 and 2020–23 datasets are broadly similar with generally higher NO₂ concentrations in winter than in summer. Reduced concentrations of NO₂ in summer occur because of photochemical reactions under the influence of high solar radiation that produce ozone, which is formed from NO₂. Seasonal changes in the predominant wind direction can also influence NO₂ concentration, where the change in wind direction places the monitor downwind from emission sources.

3.5 Sulfur dioxide

The largest anthropogenic source of SO₂ in the atmosphere is the burning of fossil fuels. Locomotives, ships and other vehicles running on diesel fuel or similar distillates as well as industrial processes that burn coal contribute to SO₂ emissions.

Data availability

Adequate data availability rates are a prerequisite for valid data analysis.

Data availability rates for SO₂ monitoring met the thresholds with rates above 75 per cent for all annual and quarterly data (Table 11).

Table 11 Data availability for SO₂

Monitoring Station	Data availability rates (%)				
	Q1	Q2	Q3	Q4	Annual
Richardson	90	85	86	89	87
Taplin	78	87	86	86	84

Concentrations compared against guidelines

A comparison of the available data against the AAQ NEPM guidelines is presented in Table 12. Both the maximum 1-hour average and the daily average concentrations were well below the guidelines.

Table 12 Maximum 1 hr average and maximum daily average for SO₂ at Richardson and Taplin

Monitoring Station	Max 1 hr average SO ₂ [ppb] AAQ NEPM 100 ppb	Max daily average SO ₂ [ppb] AAQ NEPM 20 ppb
Richardson	11	4
Taplin	7	5

SO₂ trend analysis

Figure 14 presents monthly summary statistics for SO₂ hourly concentrations at Taplin in the form of a “box and whisker” plot for 2024 and 2023. The plot includes minimum and maximum concentrations, median concentrations, and selected percentiles. The height of the coloured boxes shows the data spread between the 25th and 75th percentiles and the extent of the whiskers indicate the minimum and maximum concentrations. The median hourly concentration is indicated by the horizontal bar located in each box.

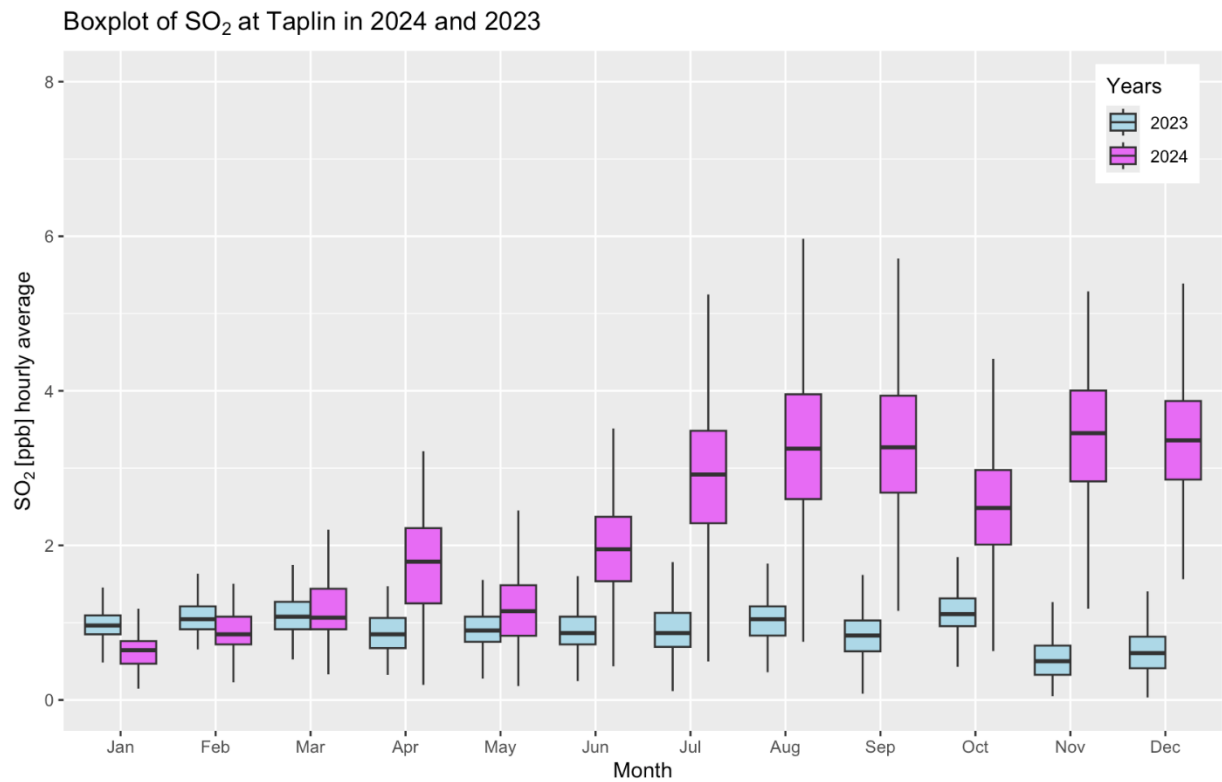


Figure 14 Variability of SO₂ hourly average by month at Taplin

Noting the overall low levels of SO₂, the monthly data show a generally low level of variability in hourly concentrations at Taplin for 2023. For 2024, there were higher concentrations from June to December. These differences in concentrations could be related to proximity to emission sources and changes in weather patterns. The analysis of future years' data may assist in discovering meaningful patterns.

Glossary

Term	Description
Air Quality Guideline (AGV)	Daily average of 70 $\mu\text{g}/\text{m}^3$ PM₁₀ applied to residential areas, wherever people live on a permanent basis, excluding natural events. In departmental documents, also referred to as Port Hedland AGV. Defined and endorsed for continuing implementation in: <u>Port Hedland Dust Management Taskforce Report</u>
Daily average	The daily averaged concentrations of pollutants are calculated based on hourly data over a 24-hour period, from midnight to midnight. Concentrations are referenced by the time at the end of the averaging period. The end time of the averaging period determines the calendar day to which the averaging periods are assigned
Dust	A generic term used in this report synonymously with PM₁₀ describing particles that have an aerodynamic equivalent diameter of up to 10 μm.
Micrograms per cubic metre ($\mu\text{g}/\text{m}^3$)	Measurement unit used to quantify concentrations as mass per unit volume. In this report, applied to concentrations of dust and particles. A concentration of 1 $\mu\text{g}/\text{m}^3$ means that one cubic metre of air contains one microgram of dust/particles.
Natural or exceptional event	Defined in the Regulatory Strategy as: <i>Consistent with the National Environment Protection (Ambient Air Quality) Measure, natural events are defined as bushfires, jurisdiction authorised hazard reduction burning, or continental-scale windblown dust.</i> Natural event has the same meaning as exceptional event.

Parts per billion (ppb)	Measurement unit describing concentrations. In this report, applied to gas concentrations of NO ₂ and SO ₂ . A concentration of 1 ppb means 1 part of gas per billion parts of air.
Particles	In air quality, the word “particle” commonly refers to very small solid particles of earth, organic matter, manufactured products, waste matter or combustion derived particles that may become airborne by natural forces (such as wind) and/or by mechanical processes (such as crushing, grinding, milling, conveying, stockpiling or haulage). The general term for these types of particles is “dust”. Particles are also known as particulate matter (PM).
PM ₁₀	Describes a size fraction of particles, specifically particles with an aerodynamically equivalent diameter up to 10 µm.
PM _{2.5}	Describes a size fraction of particles, specifically particles with an aerodynamically equivalent diameter up to 2.5 µm. Smoke from bushfires can contain large amounts of these fine particles.
Peninsula	Describes the geographical location of Port Hedland including the West End and East End. The monitoring stations at Richardson, Kingsmill, Hospital, Taplin and Neptune are referred to as peninsular stations in this report.
Port emissions	General term used for emissions from the port, also referred to as industry emissions.
Regulatory Strategy	A document published by the department. It outlines the application of the AGV Guideline. The assessment of exceedences of the AGV are based on the Regulatory Strategy

Appendix

Exceedance analysis

The method used by the department to attribute exceedances to different source categories is described below. Selected data examples are used to illustrate the approach.

Exceptional event attribution

The term exceptional event is defined in the *National Environment (Ambient Air Quality) Protection Measure* (AAQ NEPM) as “a fire or dust occurrence that adversely affects air quality at a particular location, and causes an exceedance of 1 day average standards in excess of normal historical fluctuations and background levels, and is directly related to: bushfire; jurisdiction authorised hazard reduction burning; or continental scale windblown dust.”

The AAQ NEPM is available at <https://www.legislation.gov.au/F2007B01142/2016-02-03/text>

The department’s use of the term exceptional event in Port Hedland is derived from the above definition and is adapted to the Port Hedland context, where the one-day average standard relates to the AGV, not the PM₁₀ 24hr average (AAQ NEPM guideline) and where the ambient monitoring network is designed to detect influences on air quality from port emissions.

This is a point of difference between the Port Hedland network and a typical NEPM network, which has its performance monitors not generally placed in close proximity to industry emissions.

An assessment of an exceptional event is informed by simultaneous exceedance of the AGV at Taplin Street (TA) and at Yule (YU) monitors. Examples of how the department assesses exceptional events based on data from the ambient monitoring network is provided in Table 13 and Table 14

Table 13 Example 1: Exceptional event – Dust Storm

Comparison of daily averages [ug/m ³] across sites			Assessment
Site	Pollutant		The comparison of sites shows that exceedances occurred at Taplin and at Yule River (a background station not influenced by port emissions.) It is therefore likely that there was a dust storm, comparable to what the AAQ NEPM describes as continental scale windblown dust, which affected the Pilbara region on the day. PM_{2.5} concentrations were relatively low indicating that the main contribution to the exceedance was from the coarse fraction of PM₁₀. <u>Conclusion:</u> Exceptional event (dust storm)
	PM ₁₀	PM _{2.5}	
RI	79	15	
KI	71	NA	
HO	81	13	
TA	124*	19	
NE	57	NA	
SH	65	13	
BOM	72	15	
YU	115	22	
* Red indicates exceedance of AGV			

Table 14 Example 2: Exceptional event - Bushfire

Comparison of daily averages [ug/m ³] across sites			Assessment
Site	Pollutant		The comparison of sites shows that exceedances occurred at Taplin and were widespread across the network sites, including Yule River. PM_{2.5} concentrations were elevated across the network sites, including Taplin and Yule River. The PM_{2.5}/PM₁₀ ratio at Taplin was 0.5. High PM_{2.5} concentrations and high PM₁₀/PM_{2.5} ratios indicate a substantial contribution of fine particles to the exceedance. Fine particles are present in smoke from fires. It is therefore likely that there was a bushfire, which substantially contributed to the exceedance at Taplin. <u>Conclusion:</u> Exceptional event (bushfire)
	PM ₁₀	PM _{2.5}	
RI	157	76	
KI	187	NA	
HO	188	80	
TA	133*	75	
NE	110	NA	
SH	132	75	
BOM	140	72	
YU	115	69	
* Red indicates exceedance of AGV			

Identification of regulatory events

The remaining exceedances, which are not classified as exceptional events, are further analysed to assess whether industry emissions or non-industry dust was a more substantial contributor to the exceedance.

The following key data and assessment concepts are considered in the assessment of exceedance attribution to background or industry.

1) Review of time series data

In addition to the daily averages recorded at network locations as shown in the examples for exceptional event assessment, 10-minute average data for PM₁₀, wind speed and wind direction are visualised. Figure 15 illustrates these time series data for an exceedance day.

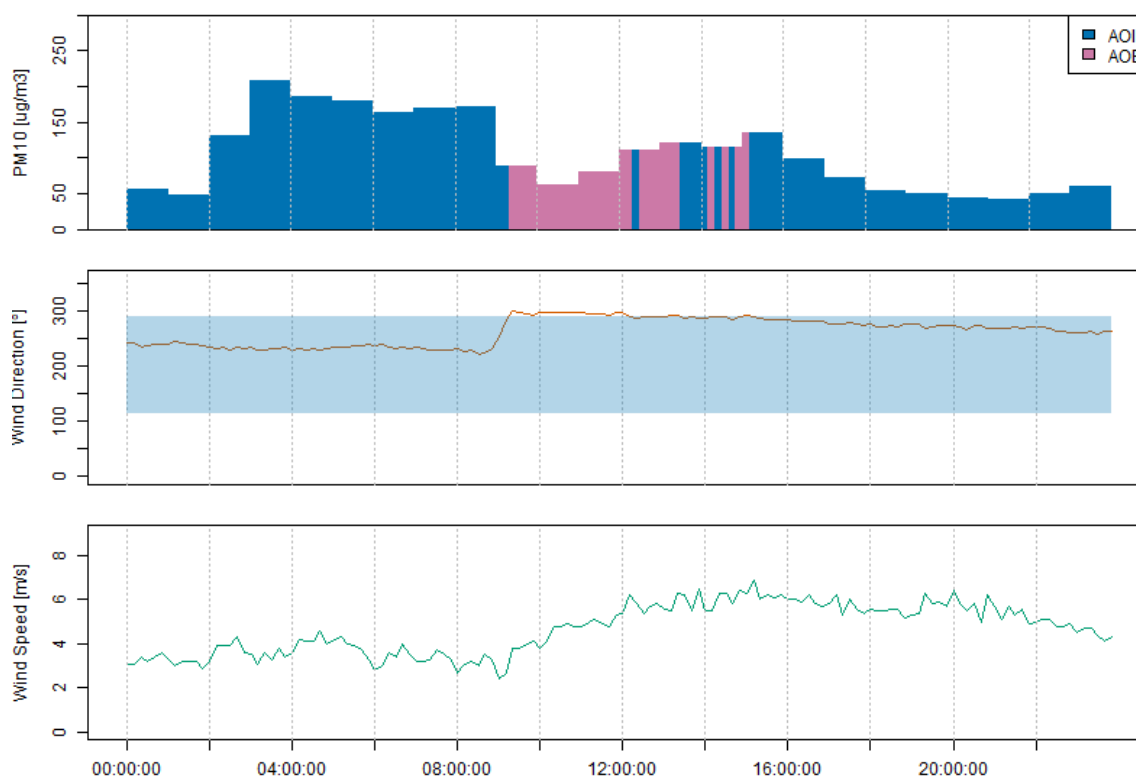


Figure 15 Summary graph for PM₁₀, wind direction and wind speed as 10-min average data

Note: AOI = Arc of industry influence (115° - 290°), AOB = Arc of background

Time series data for PM₁₀, wind direction and windspeed allow interpretation of dust concentrations in relation to changing meteorological conditions throughout the exceedance day. The association of a wind direction with each PM₁₀ data point helps interpret the locations of contributing dust sources. In particular, this aids the assessment of whether substantial contributions to the overall dust concentration for that day have likely come from the port prescribed premises.

2) Attribution according to wind arcs

The arc of influence (AOI) refers to a defined sector within which windblown dust from a specific location is likely to travel towards and potentially impact a defined receptor. For the purpose of this guideline, the Taplin Street monitor is used as the primary indicator of potential dust impacts on receptors.

A combined arc of industry influence, ranging from 115° to 290° has been defined. It encompasses all individual premises.

Figure 16 illustrates the method of dust attribution whereby dust concentrations generated while the wind is blowing from the arc of industry influence, are attributed to industry. Figure 16 shows industry attribution in blue.

In Figure 16 these attributions are summed for the exceedance day, attributing dust load percentages to industry and background.

A contribution from industry is considered substantial when it is >50% of the total contribution. This result is shown in Figure 16 for the example exceedance day.

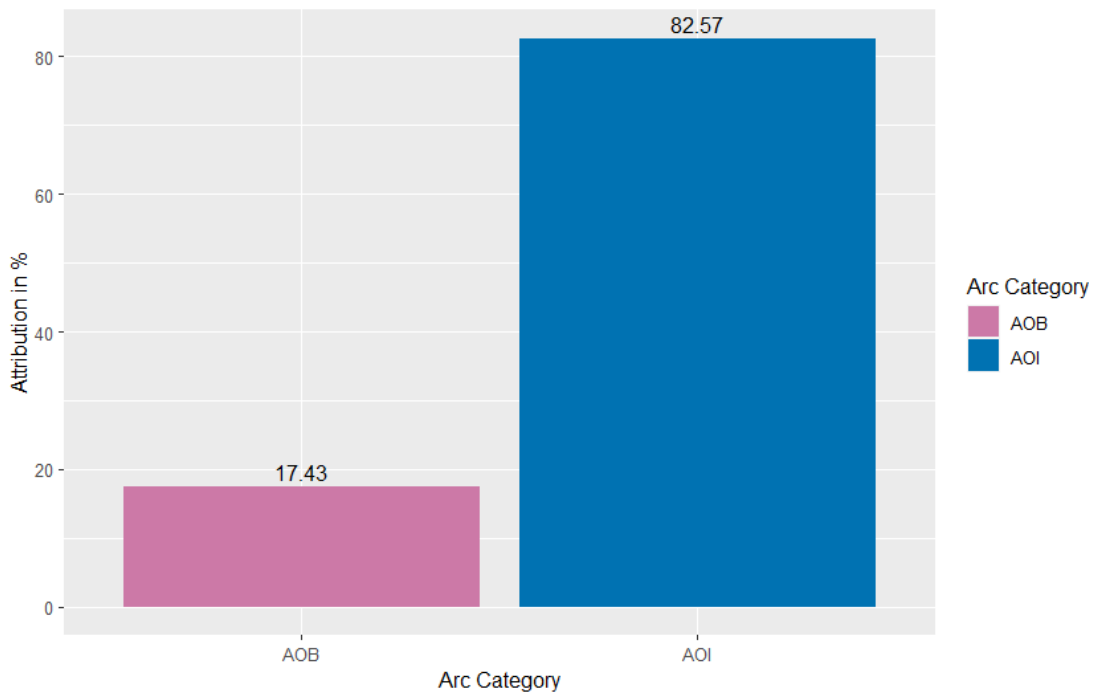


Figure 16 Dust load attribution according to arc of influence

3) Background exceedances and local sources

Exceedances at the background monitor Yule River are often indicative of regional dust events but all network monitors can experience exceedances from local sources near the monitor. Whether such local sources have substantially contributed to an exceedance at Taplin Street requires a review of time series data from other monitors located in the pathway of the presumed local source and Taplin Street.

Alternatively, an exceedance at Taplin Street with no corresponding elevated dust concentrations at nearby monitors could be caused by a nearby source.

The department undertakes further data analyses as required to assess each exceedance.

Example: Exceedance day November 2023

An example of where further analysis involving time series data from several network locations was used when assessing an exceedance at Taplin is the exceedance day during November 2023. A comparison of concentrations at Taplin and Yule indicated that it was not an exceptional event, owing to the PM₁₀ concentration at Yule being below the AGV threshold and due to identifying that a substantial dust contribution was from the arc of industry influence.

Site	PM ₁₀ 24hr average [$\mu\text{g}/\text{m}^3$]
Taplin	76
Yule	63
BOM	67

However, a comparison of time series data from Taplin, Yule and BOM (Figure 17) shows that there was a short-term background dust event that is reflected in both Yule and BOM time series data. This short-term event has likely substantially contributed to the exceedance at Taplin.

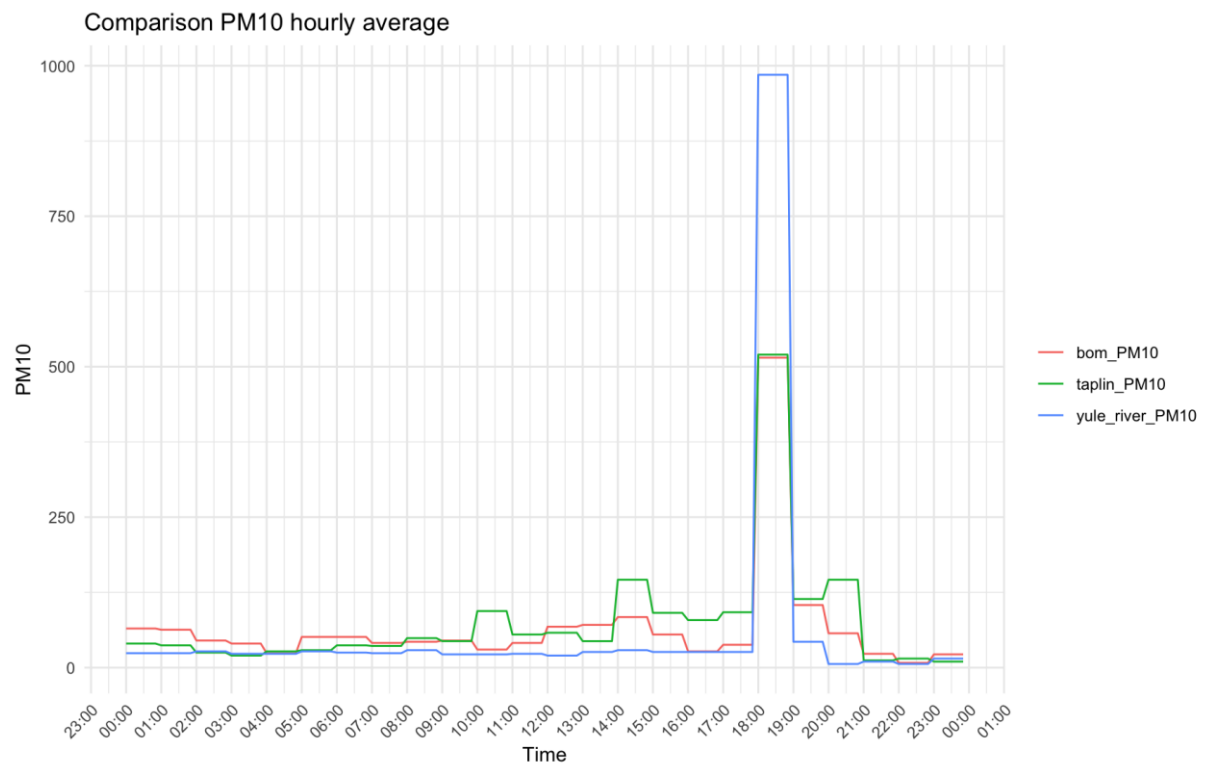


Figure 17 Hourly averages for Taplin Street, BOM and Yule River

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