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

Port Hedland air quality
2022 annual monitoring report



Department of Water and Environmental Regulation

Port Hedland Air Quality Series report no. 1 | May 2026

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June 2026

FIRST 116035

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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.
- The department completed a program of ambient air monitoring network upgrades in 2022.
- Key results of particle monitoring (PM_{10} and $PM_{2.5}$) for 2022 are summarised below:
  - Based on the applied statistics, overall dust concentrations (PM_{10}) 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 six times at Taplin Street, with three of these considered to be due to exceptional events and three attributed to industry
  - Fine particles ($PM_{2.5}$) in smoke from bushfires and other sources were not a significant driver of high particle events.
  - The *National Environment Protection (Ambient Air Quality) Measure* daily and annual guidelines for $PM_{2.5}$ were met at Taplin Street.
  - High dust events were dominated by the coarse dust fraction of PM_{10}.
- The results of gas monitoring (nitrogen dioxide - NO_2 and sulfur dioxide - SO_2) showed that:
  - The *National Environment Protection (Ambient Air Quality) Measure* hourly and annual guidelines for NO_2 were met at Taplin Street.
  - The *National Environment Protection (Ambient Air Quality) Measure* hourly and daily guidelines for SO_2 were met at Taplin Street, based on the available data (section 3.5).

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 PM_{10} (dust) inhalation by residents. A key outcome was the establishment of an interim air guideline value (AGV) for PM_{10} of 70 $\mu g/m^3$ 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 2022 annual period.

2 Monitoring network

The department assumed management of the monitoring network on 1 January 2022. This document is the first annual monitoring report prepared by the department, with the 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

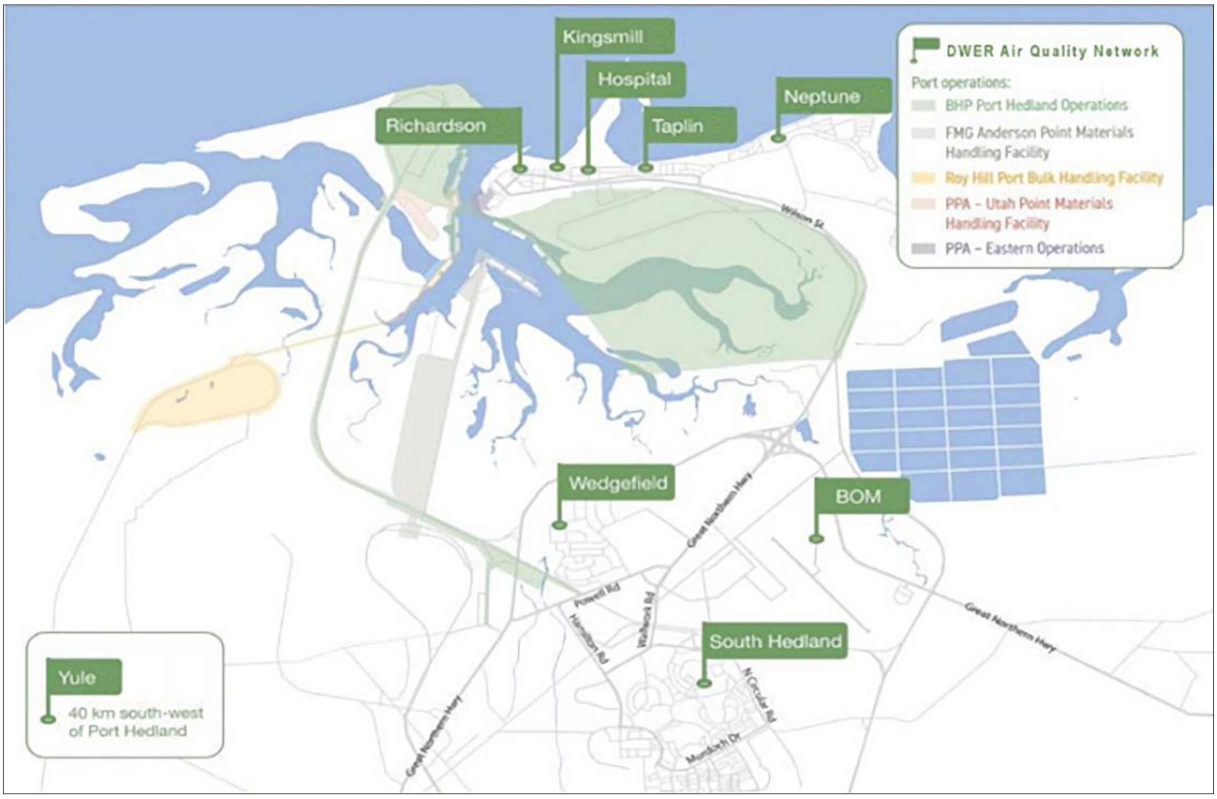


Figure 1 Monitoring station locations.

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 levels 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. A program of instrumentation upgrades and replacements was undertaken in 2022 as also shown in the table.

Table 2 Monitoring methods and instruments.

Para-meter	Equip-ment	Monitoring Method / AS/NZ Standard	Monitoring locations								
			BOM	Hospital	Kingsmill	Neptune	Richardson	South Hedland	Taplin	Wedgefield	Yule
PM_{10}	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
NOx	Serinius 40 NOx analyser	Chemi-luminescence AS 3580.5.1-2011					x		x		
SO_2	Serinius 50 SO_2 analyser	Ultraviolet fluorescence AS 3580.4.1-2008 REC:2018					x		x		

Note: (shaded) equipment upgraded or new in 2022.

[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.

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 PM_{10} 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 PM_{10} 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 PM_{10}, $PM_{2.5}$, NO_2 and SO_2 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/m^3 for PM_{10} 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 PM_{10}	1 day 1 day 1 year	50 µg/m^3 70 µg/m^3 25 µg/m^3	AAQ NEPM AGV AAQ NEPM
Particles as $PM_{2.5}$	1 day 1 year	25 µg/m^3 8 µg/m^3	AAQ NEPM AAQ NEPM
Nitrogen dioxide	1 hour 1 year	80 ppb 15 ppb	AAQ NEPM AAQ NEPM
Sulfur dioxide	1 hour 1 day	100 ppb 20 ppb	AAQ NEPM 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 BOM station at the Port Hedland Airport are presented in Figure 2, which shows monthly mean rainfall for 2022 compared with monthly mean rainfall for the years 1942 – 2022. Long-term annual mean rainfall (1942 - 2022) was 316 mm and annual mean rainfall for 2022 was 385 mm. High rainfall events occurred in February and May 2022, which may be related to Cyclone Anika that was active between February and March 2022, making landfall east of Port Hedland near Wallal.

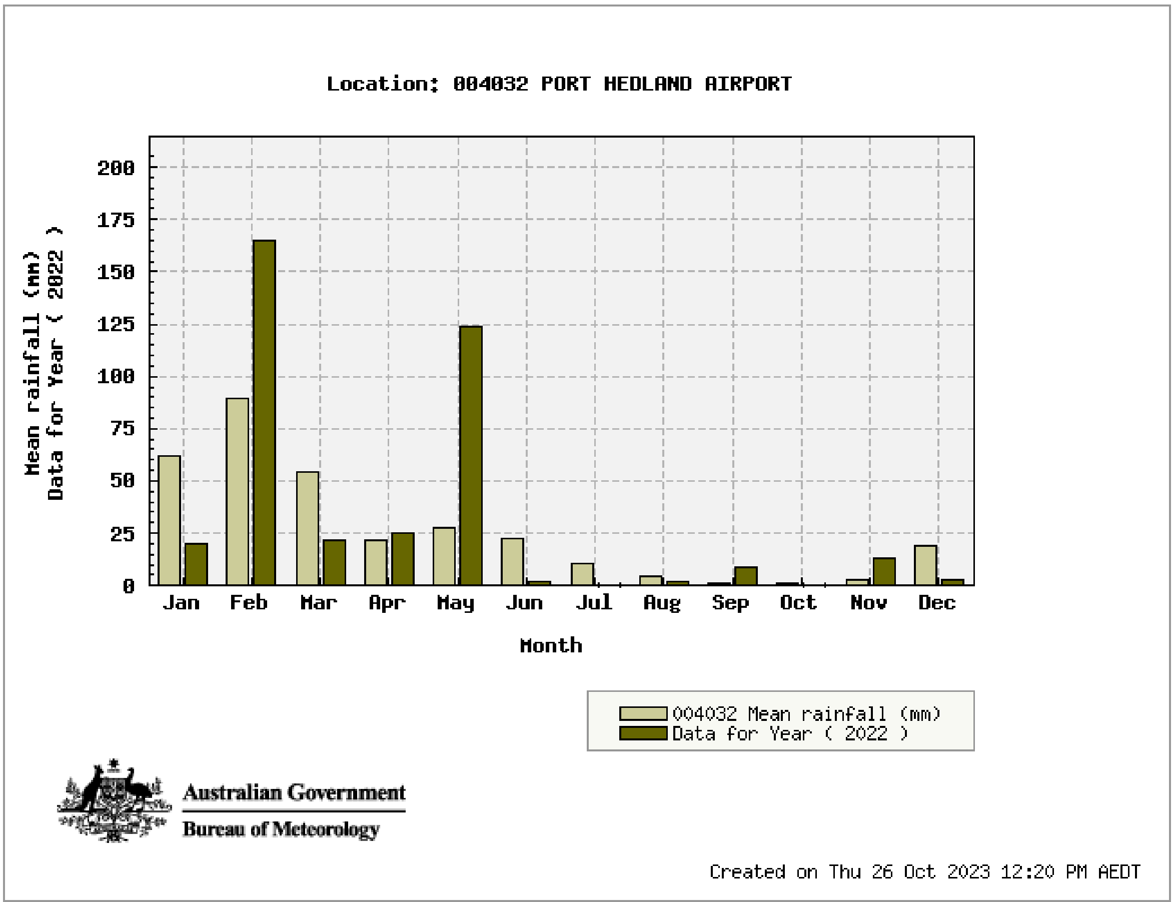


Figure 2 Mean monthly rainfall at Port Hedland Airport

Temperature

Temperature data from the BOM station are presented in Figure 3 and show monthly maximum temperature for 2022 compared with monthly maximum temperature for the years 1942 – 2022. The annual mean maximum temperature for both 1942 - 2022 and for 2022 was 33.4°C.

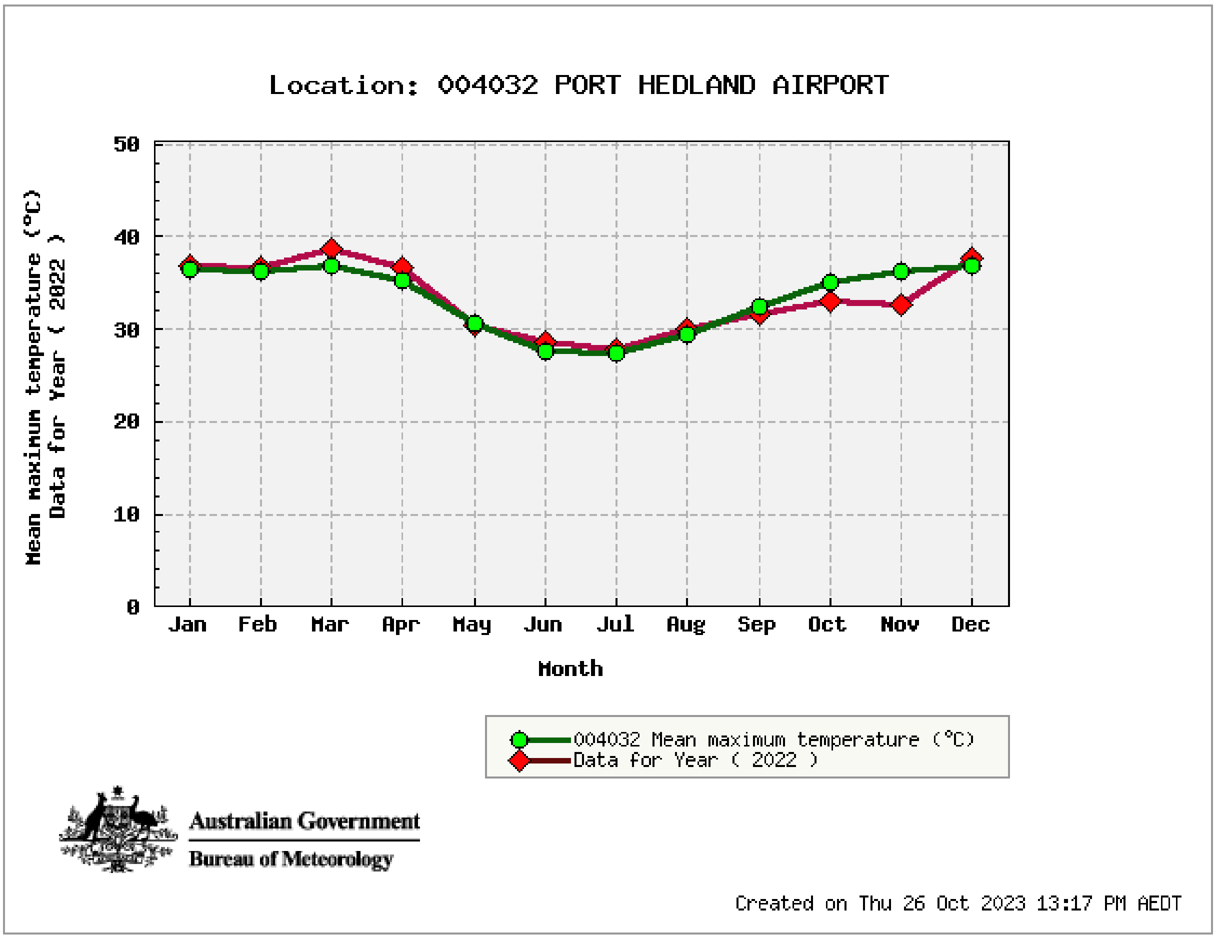


Figure 3 Mean monthly maximum temperature at Port Hedland Airport

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 2022. The selected locations represent a residential site in the West End (Taplin Street), which is influenced by port emissions, and two background sites that reflect a local background (BOM) and a regional background (Yule). All sites can also be influenced by localised emission sources near the monitors.

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 for the distribution and frequency of wind directions.
- In the annual plots the predominant wind directions of north-westerly and westerly are consistent across the sites but there is a greater representation of easterly/south-easterly winds at BOM compared to Taplin and Yule.
- 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.
- Wind speed patterns are also similar across sites with higher wind speeds and their frequencies correlating with the predominant wind directions.
- A comparison of the annual data shows the highest mean wind speed of 4.6 m/s at BOM, with lower annual mean windspeeds of 2.7 m/s at Yule and 2.9 m/s at Taplin Street.
- There is a higher frequency of high wind speeds in summer and spring coming from the predominant north-westerly and westerly directions than in autumn and winter.

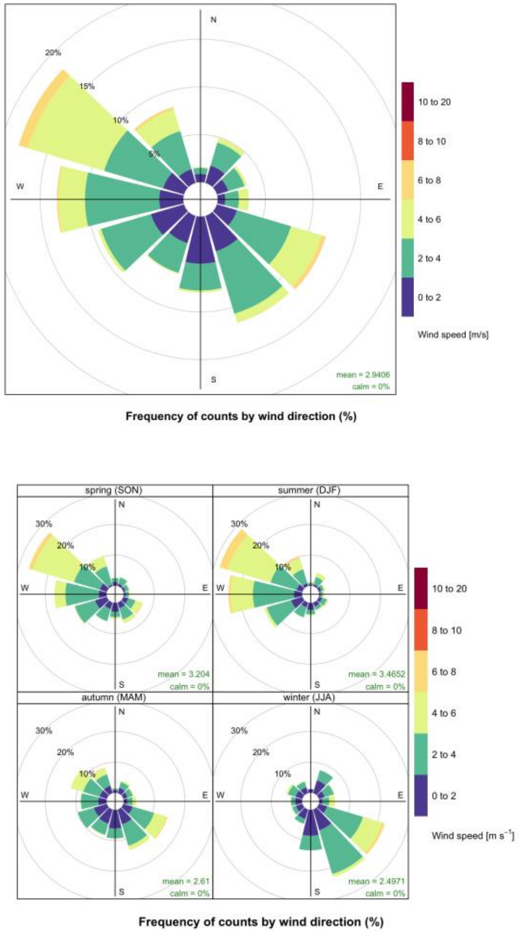


Figure 4 Taplin wind roses

top: annual, bottom: seasonal

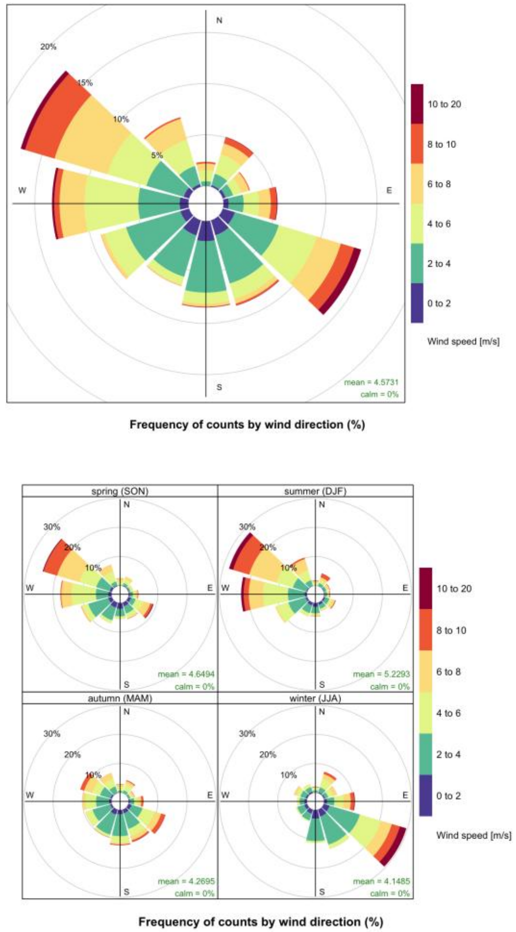


Figure 5 BOM wind roses

top: annual, bottom: seasonal

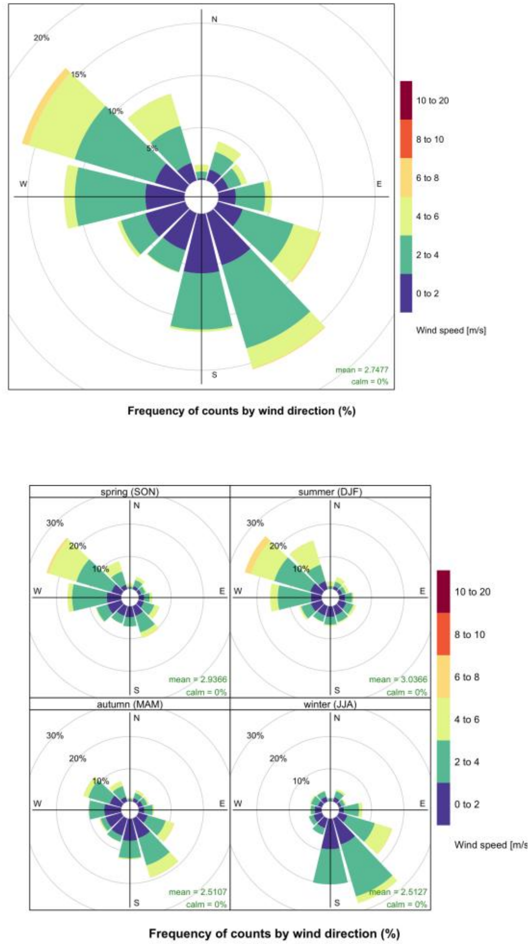


Figure 6 Yule wind roses

top: annual, bottom: seasonal

3.2 Particles as PM_{10}

Particles are classified into different size fractions based on their aerodynamic equivalent diameter (AED) measured in micrometres or microns (μm). PM_{10} 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 PM_{10} monitoring during 2022 met the quarterly and annual thresholds with rates above 90% for both the annual and quarterly data (Table 4).

Table 4 Data availability for PM_{10}

Monitoring Station	Data availability rates (% of days)				
	Q1	Q2	Q3	Q4	Annual
Kingsmill	99.8	92.7	99.3	99.9	97.9
Richardson	99.6	99.7	96.8	99.7	99.0
Hospital	99.9	96.9	99.9	99.7	99.1
Neptune	94.5	95.3	98.4	99.9	97.1
Taplin	99.6	99.9	97.0	99.8	99.1
Wedgefield	96.9	92.0	99.5	92.9	95.3
BOM	99.7	98.1	99.2	99.1	99.0
South Hedland	99.5	98.9	97.1	99.5	98.7
Yule River	98.8	99.5	97.6	97.6	98.4

Daily averages

PM_{10} monitoring data collected during 2022 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	101	12	42.3
Kingsmill	83	21	40.2
Hospital	72	14	38.6
Taplin	44	6	34
Neptune	25	8	23.7
South Hedland	12	2	21.2
Wedgefield	167	77	53.6
BOM	8	4	29.0
Yule	5	4	16.4

Compliance with the AAQ NEPM guidelines for PM_{10} has not been assessed as these guidelines are not applied in Port Hedland. Comparison against these guideline values serves as a statistical tool only. This comparison shows that:

- The number of exceedances of the AAQ NEPM daily average PM_{10} (50 µg/m^3) guideline decrease on the Port Hedland peninsula from west to east with Richardson at the western end recording 101 exceedances and Neptune at the eastern end recording 25.
- Taplin recorded 44 exceedances of the guideline. The lowest number of exceedances in a residential area occurred at South Hedland (12), which is located approximately five kilometres south-east of the port. The decreasing exceedance gradient aligns with increasing distance from the port operations.
- Of the non-residential locations, Wedgefield shows the highest number of AAQ NEPM exceedances (167), higher than any of the peninsular locations, while BOM and Yule have exceedance numbers below ten.

- Field information and data analysis indicate that Wedgefield is significantly influenced by local dust sources, especially trucks operating on unsealed roads near the monitor.

Regulatory application of the Port Hedland AGV has only been assessed at Taplin (see next section). For the other monitoring locations, the number of days above the AGV serves as a statistical tool to compare dust concentrations at different sites. This comparison shows that:

- The exceedances of the AGV show a similar trend to the AAQ NEPM guideline exceedances on the Port Hedland peninsula, with higher exceedance numbers in the west and lower exceedance numbers in the east.
- The decreasing trend from west to east is not as clear for AGV exceedances, with Kingsmill and Hospital having higher numbers than Richardson, and Neptune showing eight exceedances versus six at Taplin Street.
- Consistent with the AAQ NEPM guideline exceedances, South Hedland had the lowest number of AGV exceedances in monitored residential areas.
- Wedgefield also had the highest number of AGV exceedances (77). The lowest number of AGV exceedances were at BOM (four) and Yule (four).

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.. Broad source categories - namely exceptional (E), regulatory (R) and other exceedance events (O) - are used, with attribution based on whether a source is considered to have made a substantial contribution to the exceedance. Attribution statements therefore reflect likelihood rather than absolute accuracy. A key focus of the method is to ensure that it is clearly defined and replicable. Details of the method are described 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 2022 there were a total of six AGV exceedances, with three of these exceedances most likely exceptional events.

As summarised in Table 6, in 2023 there were a total of 6 AGV exceedances, with 3 of these considered to be due to exceptional events and 3 attributed to industry (regulatory events).

Table 6 AGV exceedance summary at Taplin

Date of exceedance	Daily average PM_{10} µg/m^3	Assessment of result*
08/01/2022	90	E
15/01/2022	84	E
28/02/2022	84	E
22/09/2022	73	R
05/12/2022	104	R
11/12/2022	70	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/m^3. Comparison against this guideline shows that Neptune, South Hedland and Yule remained below the guideline value, while it was exceeded at all other locations. The general trend for the annual averages is consistent with the trends for the daily averages, showing higher concentrations in the west of the Port Hedland peninsula compared to the east. The lowest value occurred at the regional background location (Yule).

PM_{10} trend analysis

The objective of the PM_{10} trend analysis is to describe features of dust concentrations recorded in 2022 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 PM_{10} 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 PM_{10} hourly concentrations at Taplin in the form of a “box and whisker” plot for 2022 and for 2020 - 2021. 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. As illustrated for 2022, the predominant wind direction in summer was from a west/north-westerly direction (Figure 4), which may increase the likelihood of dust contributions at Taplin from port sources, while the predominant south-easterly wind directions in winter (Figure 4), decrease the likelihood of dust contributions from port sources.

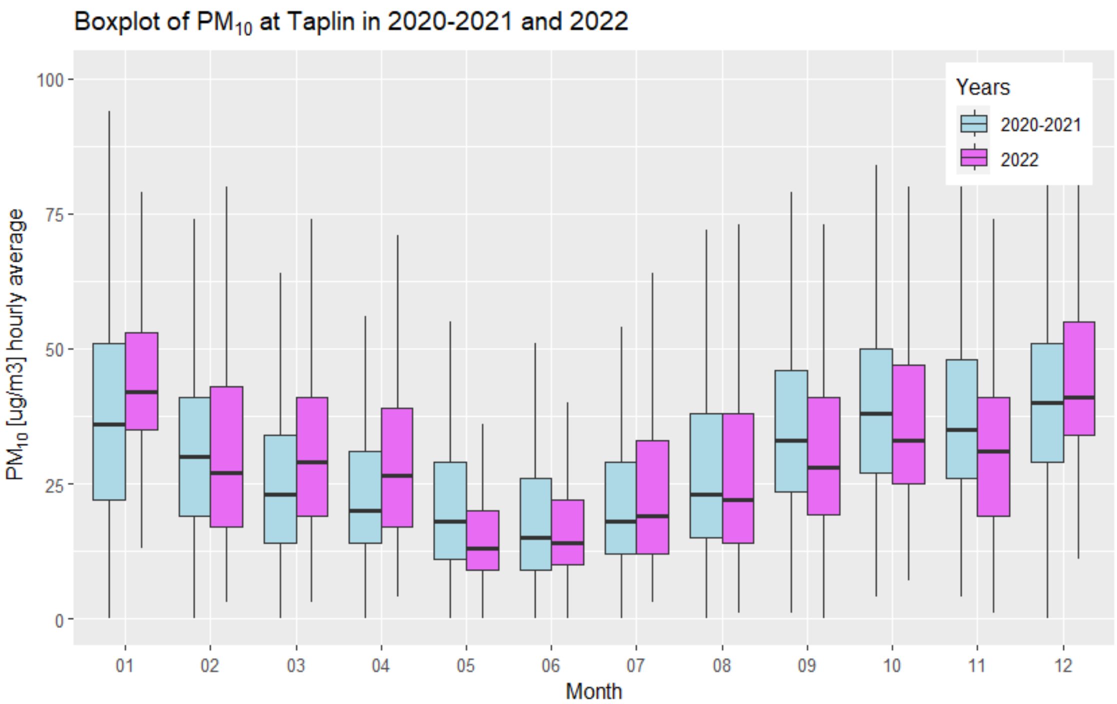


Figure 7 Monthly variability of Taplin PM_{10} hourly averages for 2022 and 2020-2021

Data for each month of 2022 at Taplin can be compared with the previous two years' data for that month. Most notably, this comparison indicates that dust concentrations were higher in March and April 2022 and lower in September and November 2022 compared with the corresponding data from the previous two years.

September and November 2022 experienced higher than the long term mean rainfall (Figure 2), which could have contributed to the lower dust concentrations during these months.

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 2022 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.

Examples of accumulated frequency curves are illustrated in Figure 8, which shows site-specific curves for 2022 comparing peninsular sites in an east to west direction with increasing proximity to port premises (Neptune, Taplin, Hospital, Kingsmill and Richardson).

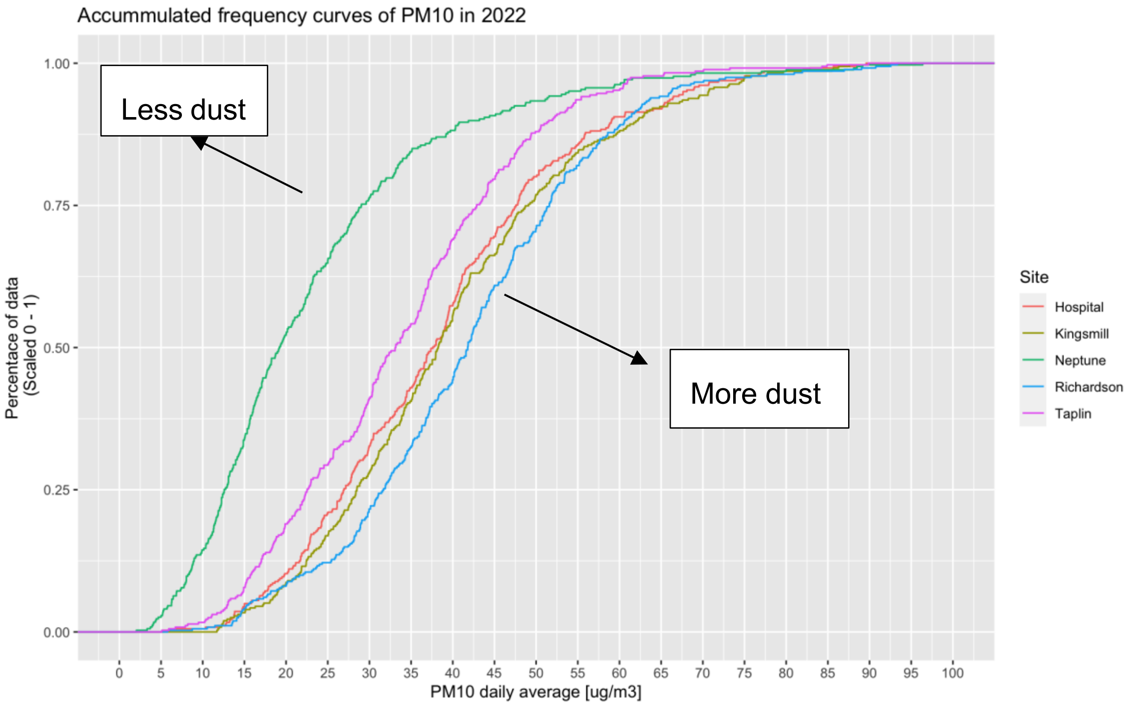


Figure 8 Comparison of dust concentrations at Port Hedland peninsular locations for 2022.

The x-axis represents daily average PM_{10} 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 PM_{10} concentrations will produce a curve that is positioned more to the left of the graph than a curve representing overall higher PM_{10} 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.

Comparing each site's curve in Figure 8, there is a clear differentiation with curves moving from left (less dust) to right (more dust) consistent with the site's distance from the port. Neptune is furthest away from the port with generally lower PM_{10} concentrations (green curve) and Richardson is the closest to the port with generally higher PM_{10} concentration (blue curve). The positions and shapes of the curves indicate lower to higher PM_{10} dust concentrations from east to west.

This finding supports previous observations and the general conclusion that PM_{10} levels on the peninsula are influenced by dust emissions from sources in the direction of the port and the closer the monitoring site is to these sources, the stronger that influence.

For 2022, the frequency distribution analysis indicates that Richardson was the dustiest site and Neptune the least dusty site on the peninsula, with the other three sites reflecting intermediate levels of dustiness that are neither the highest nor lowest.

Interestingly, when comparing the number of AGV exceedances, Neptune experienced more AGV exceedances (eight) than Taplin (six) in 2022, but when comparing accumulated frequency curves, Neptune was overall less dusty than Taplin. This highlights the value of undertaking multiple and comprehensive statistical analyses to extract important information from monitoring data.

Figure 9 shows frequency curves for the years 2018 – 2022 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 except for Taplin where only three complete years of valid data are available within the range.

When comparing key features of the graphs for the peninsular locations Richardson, Hospital, Taplin and Neptune, 2019 appears to be consistently the dustiest year followed by 2018 (excluding Taplin due to invalid data). The curves for 2022, 2021 and 2020 are more closely clustered. Overall, 2021 appears to be the least dusty year at the peninsular locations.

At Taplin, the accumulated frequency curves indicate that 2022 was the dustiest of the last three years, although all three years 2020-2022 are still closely clustered. Data for 2018 and 2019, which were dustier years at other monitoring locations are not available for Taplin.

Accumulated frequency curves for non-peninsular sites are presented in Figure 10. Yule stands out as the least dusty location of all sites analysed, which is expected given it represents regional background and is not influenced by dust from port operations or town activities. Despite experiencing less dust overall, a clear differentiation between dusty and less dusty years is evident. Consistent with all other sites, 2019 was the dustiest year at Yule. This is followed by 2020 and 2018 as less dusty. 2021 was the least dusty year and 2022 the second least dusty at Yule.

BOM recorded significantly more dust than Yule and at both sites 2019 appears to be the dustiest year. The trends for the other years differ between Yule and BOM. When site trends are dissimilar, it indicates that they are influenced by different factors, such as different meteorological conditions and localised dust sources.

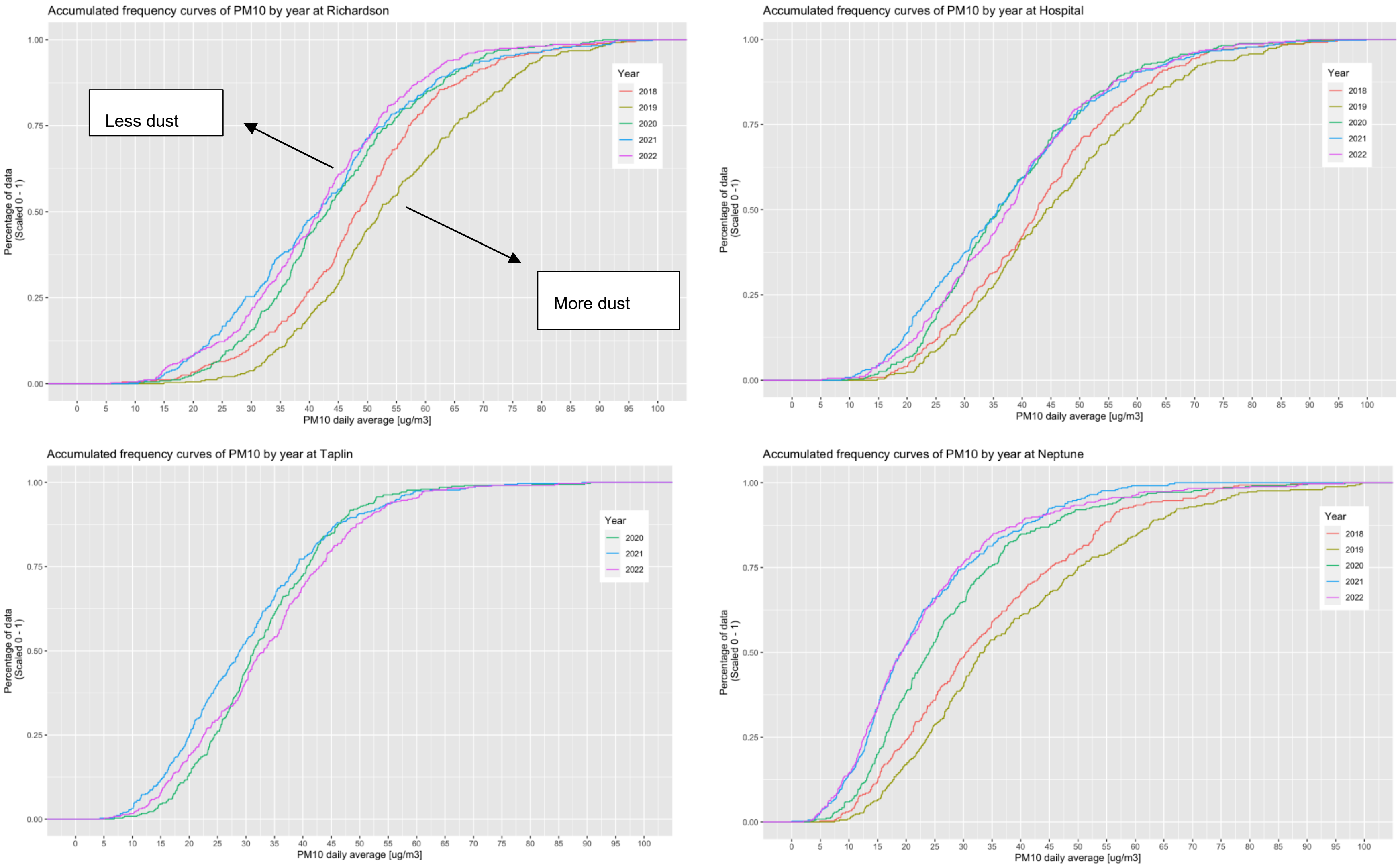


Figure 9 Accumulated frequency curves of PM_{10} for peninsular locations for 2018 – 2022.

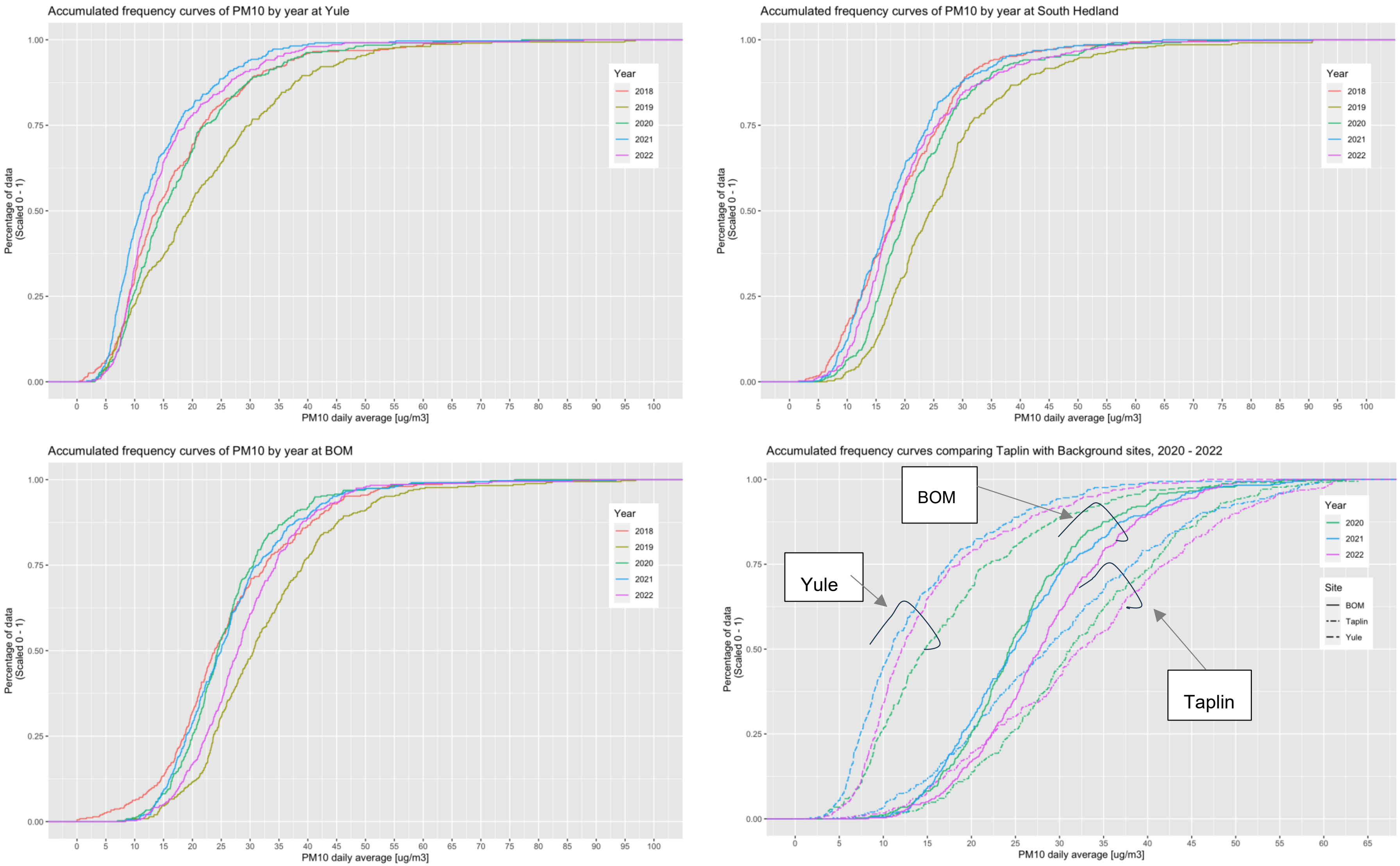


Figure 10 Accumulated frequency curves of PM_{10} for selected non-peninsular locations for 2018 – 2022 and comparison of Taplin with Yule and BOM for 2020 - 2022.

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 PM_{10} and therefore the PM_{10} fraction consists of both coarse particles (PM_{10} 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 PM_{10} 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 PM_{10}, 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 PM_{10} 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, except for South Hedland (Table 7). Limited data availability for this site is due to the $PM_{2.5}$ monitor being installed during Q1.

Table 7 Data availability for $PM_{2.5}$

Monitoring Station	Data availability rates (% of days)				
	Q1	Q2	Q3	Q4	Annual
Richardson	99.0	99.9	98.6	95.4	98.2
Kingsmill	NA				
Hospital	98.8	97.9	99.4	98.1	98.6
Taplin	98.8	99.2	98.7	95.6	98.1
Neptune	NA				
South Hedland	25.9	99.4	98.6	99.8	81.2
Wedgefield	NA				
BoM	98.1	97.3	99.0	98.9	98.4
Yule	98.8	98.9	96.3	93.3	96.8

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

Daily averages

$PM_{2.5}$ monitoring data collected during 2022 are summarised as a simple statistic of AAQ NEPM daily guideline exceedance counts as presented in Table 8. There were no exceedances of this guideline at any of the $PM_{2.5}$ monitoring locations.

Annual averages

Table 8 shows the annual average concentrations for each station to allow comparison with the AAQ NEPM annual guideline. Comparison against this guideline shows that all locations except Richardson were below the guideline value. The general trend for the annual average shows a higher concentration in the west of the Port Hedland peninsula (Richardson) compared to further east (Hospital). The lowest value occurred at the regional background location (Yule).

Compliance with the AAQ NEPM guidelines for $PM_{2.5}$ has been assessed in Table 8.

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	0	met	8.1	not met
Kingsmill	NA	NA	NA	NA
Hospital	0	met	7.7	met
Taplin	0	met	6.2	met
Neptune	NA	NA	NA	NA
South Hedland	NA	NA	NA	NA
Wedgefield	NA	NA	NA	NA
BOM	0	met	6.1	met
Yule	0	met	2.7	met

NA = Not Applicable (no monitor at this station)

$PM_{2.5}$ analysis

Figure 11 presents monthly summary statistics for $PM_{2.5}$ hourly concentrations at Taplin in the form of a “box and whisker” plot for 2022 and for 2018 - 2021. 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, with lower concentrations in winter and higher concentrations in summer is evident in both data sets. Higher ambient temperatures in summer (Figure 3) are likely to contribute to these increased concentrations.

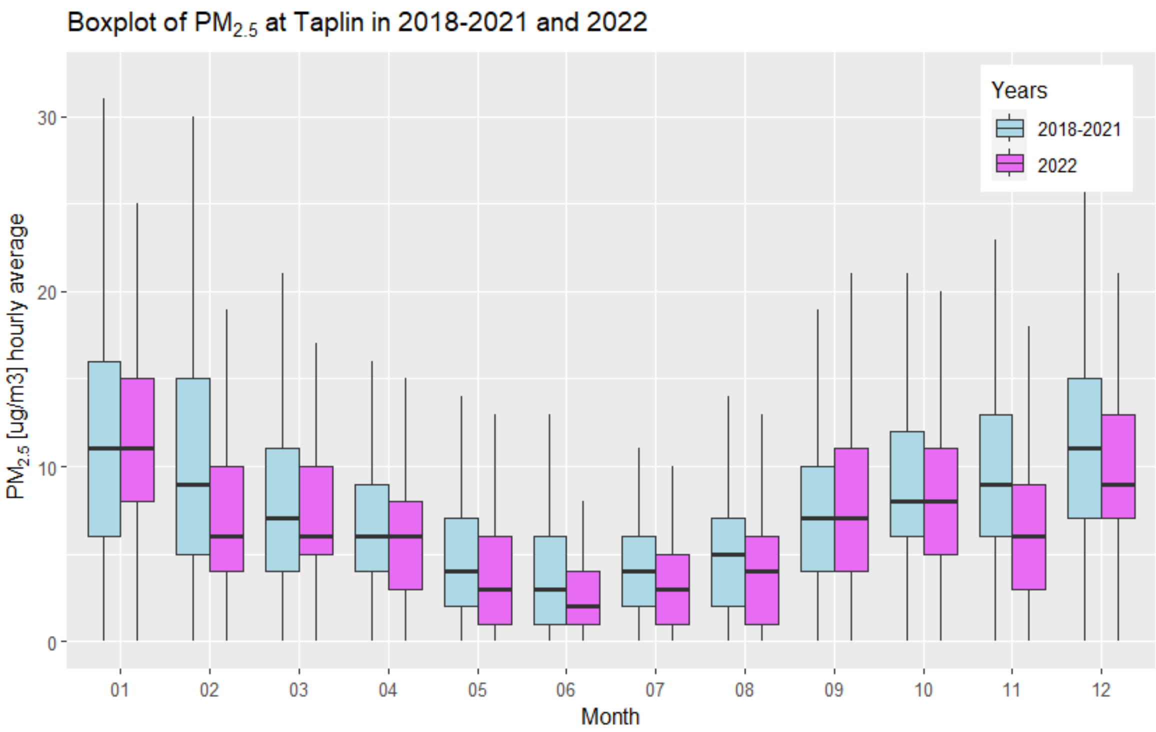


Figure 11 Comparison of monthly variability of $PM_{2.5}$ hourly concentrations.

Data for each month of 2022 can be compared with the previous four years' data for that month. This comparison indicates that dust concentrations were notably lower in February, August and especially in November 2022 compared with corresponding data from the previous four years.

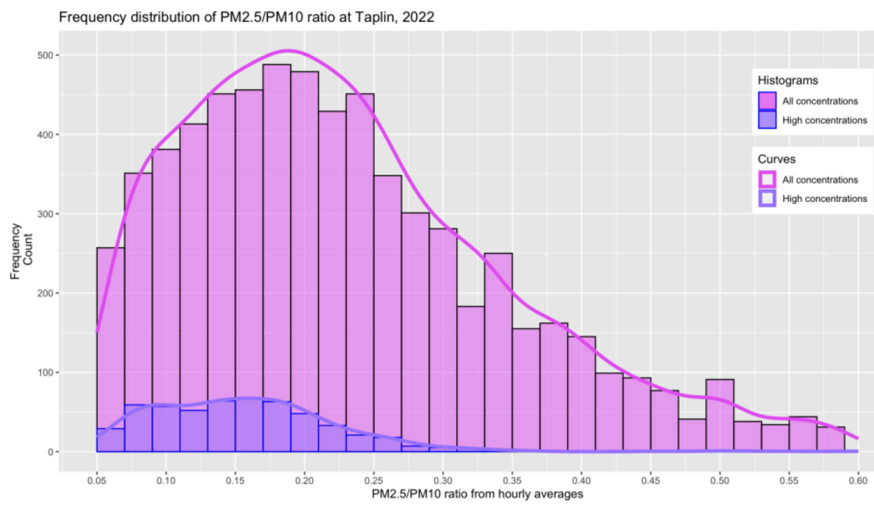
February and November 2022 experienced higher than long term mean rainfall (Figure 2), which could have contributed to the lower concentrations during these months.

Another possible reason for variation in $PM_{2.5}$ concentrations is the level of bushfire activity in each year.

Bushfires and prescribed burns are common events in the Pilbara that can create elevated concentrations of $PM_{2.5}$ in smoke.

Airborne particles created by combustion sources such as fires generally have a high proportion of $PM_{2.5}$. This means that the $PM_{2.5}/PM_{10}$ ratio can be used as an indicator of the contribution from combustion sources when analysing $PM_{2.5}$ and PM_{10} 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.

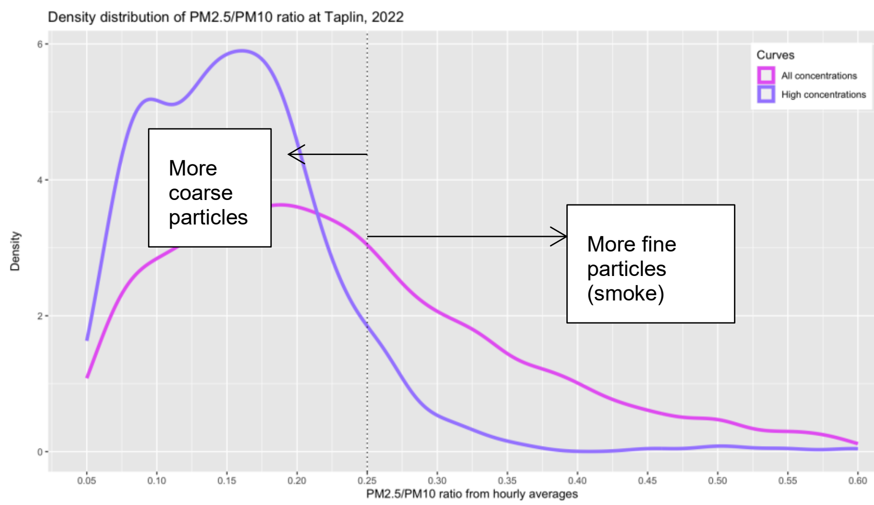
To investigate whether fine particles ($PM_{2.5}$) play a significant role in PM_{10} events that exceed guidelines a targeted statistical approach examining $PM_{2.5}/PM_{10}$ ratios is applied. The approach is illustrated and explained in Figure 12.



Histogram bars representing the frequency of $PM_{2.5}/PM_{10}$ ratios calculated from all concentrations (pink) show the majority of 2022 data are skewed to the left side of the plot, where the $PM_{2.5}/PM_{10}$ ratio is low, representing high proportions of coarse dust.

A subset of the 2022 dataset representing $PM_{2.5}/PM_{10}$ ratios calculated from high concentrations (PM_{10} > 70µg/m^3) are represented by a second set of histogram bars (mauve). This histogram is also skewed to the left.

Curves fitting the histograms have been overlaid on the plot.



In this plot the fitted curves from the above plot are shown on a normalised scale, which allows for simpler comparison. These types of curves are referred to as density curves. Both curves are skewed to the left of the plot, indicating a high proportion of coarse dust. The 'High concentrations' curve is skewed even further left than the 'All concentrations' curve, indicating that coarse particles were the driver for high concentrations, not fine particles (smoke).

Figure 12 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 13, 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 70µg/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 2018 - 2022, except for Taplin where only 2020 - 2022 data were available.

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.

For example, Figure 13 graphs (a) and (b) for Richardson shows that there were lower proportions of $PM_{2.5}$ in the PM_{10} fraction in 2020 (green curve) than for 2022 (blue curve). Graph (a) for Yule shows that the peak of the 2018 curve (red) is to the right of all other curves, indicating that there were overall higher proportions of $PM_{2.5}$ in PM_{10} for that year.

A curve with a narrow tall peak indicates a higher frequency of closely clustered values, whereas a flatter plateau-like peak describes a broader spread of values from lower to higher. Examples of curves with tall narrow peaks are illustrated in the (b) graphs for Richardson and BOM. Examples of flatter curves are shown in the (a) graph for Hospital for 2018 and 2019.

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

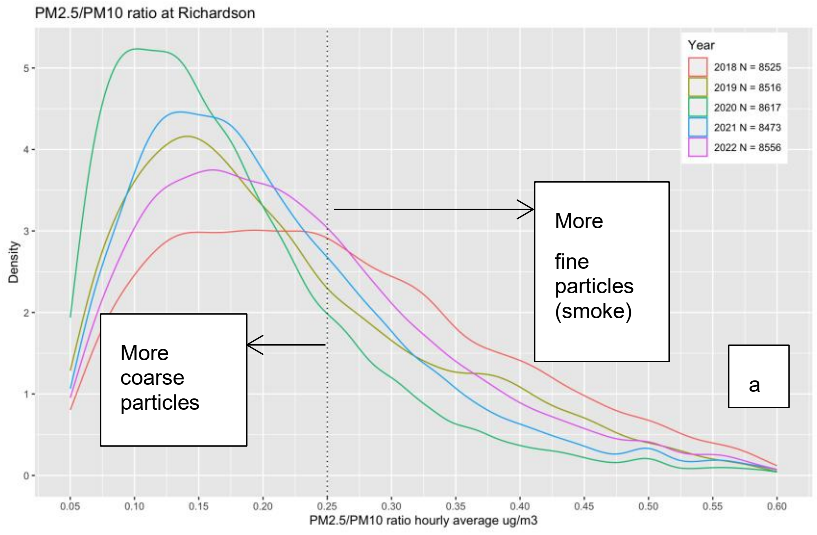
To further understand the influence of fine particles on overall particle levels during periods of elevated concentrations, a subset of data where PM_{10} hourly averages were high (>70 µg/m^3) are presented in the Figure 13 (b) graphs. The objective of this analysis is to assess whether the $PM_{2.5}/PM_{10}$ ratio changes when dust concentrations are higher.

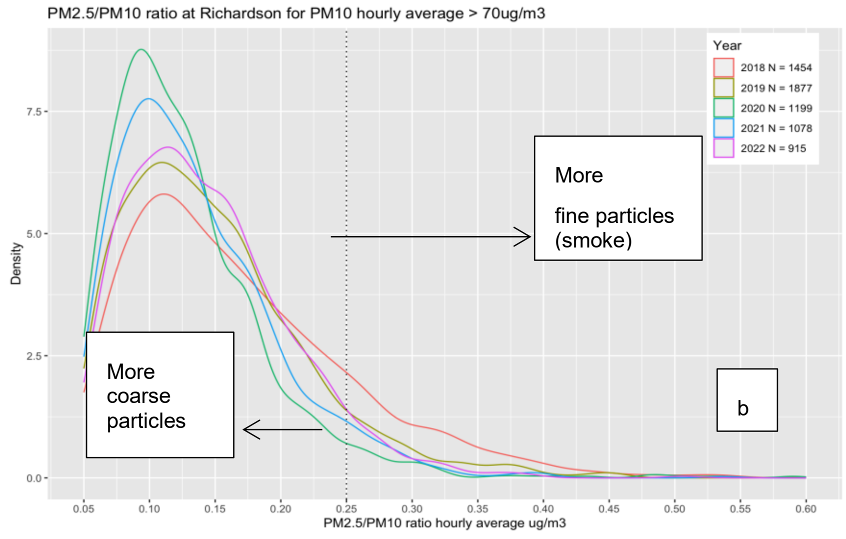
If $PM_{2.5}/PM_{10}$ ratios are higher when PM_{10} concentrations are high, then this would result in differences between the (a) and (b) curves, with (b) curves having peaks shifted to the right. If the curves for the (a) and (b) graphs are similar, or if (b) curves have peaks more to the left side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

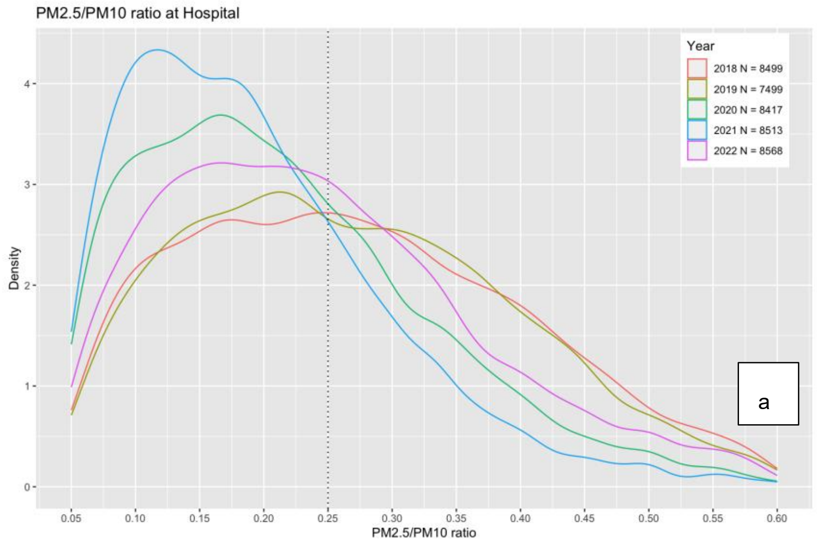
When comparing the (a) and (b) graphs for the peninsular locations, it is evident that they are quite similar, with no significant shift of any curve peaks to the right for the (b) graphs. This indicates that higher PM_{10} concentrations at these locations are driven by the coarse particle fraction of PM_{10}, not the $PM_{2.5}$ fraction. At Richardson the (b) curves are shifted further to the left than the (a) curves, indicating a dominant influence of coarse particles at elevated dust concentrations.

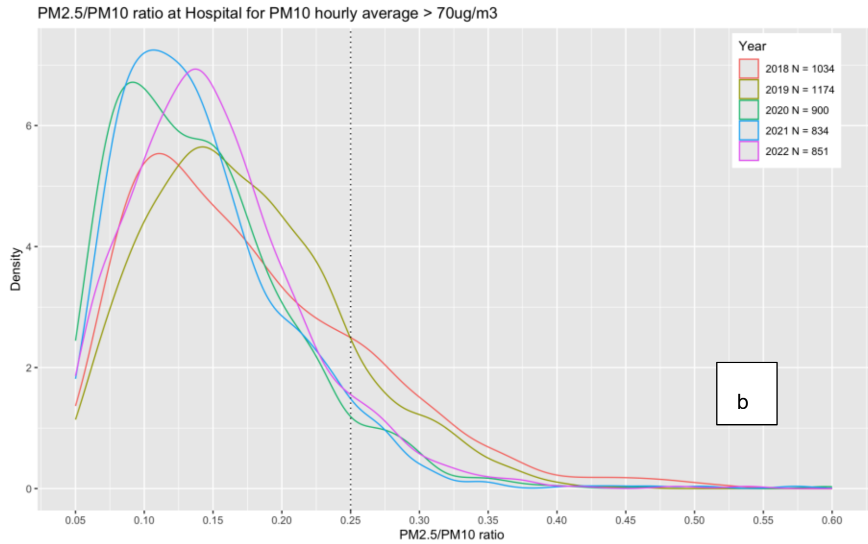
When comparing BOM and Yule (a) and (b) graphs, the curve peaks do not shift to the right in the (b) graphs indicating no significant influence of fine particles on high particle concentrations. Rather, (b) curves are at the left-hand side of the graphs indicating a dominant influence of coarse particles at elevated dust concentrations.

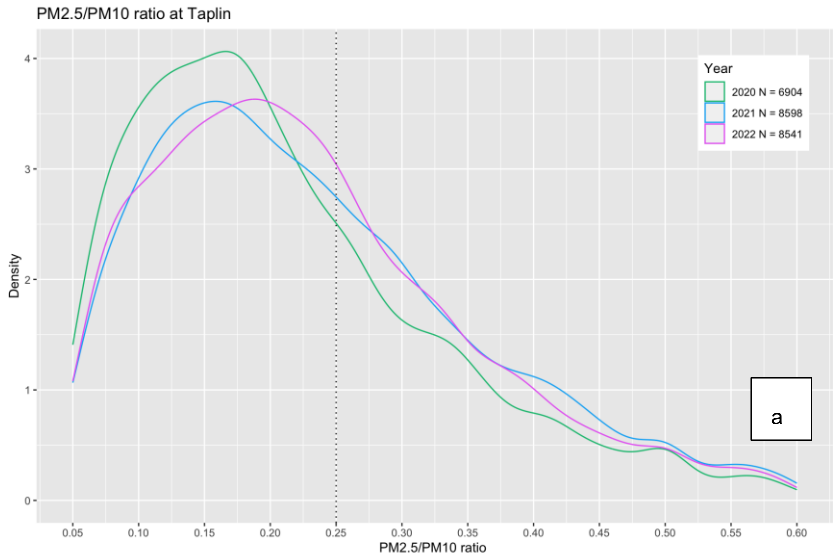
As the (b) graphs use only a subset of the data used in the (a) graphs, there are fewer data points in the (b) graphs, which can affect the shape of the curves and make them taller and narrower. This is most apparent at Yule and BOM as there are fewer high PM_{10} concentrations.

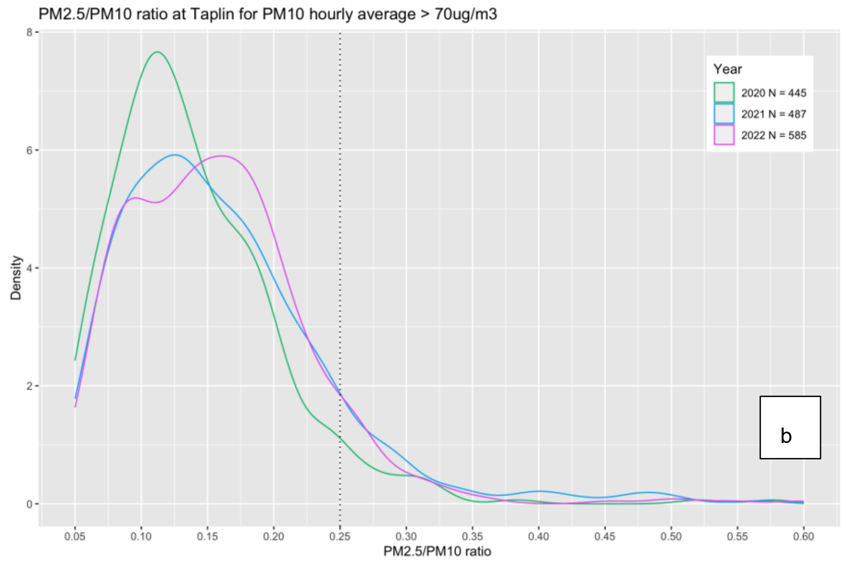

PM2.5/PM10 ratio at Richardson
Year
2018 N = 8525
2019 N = 8516
2020 N = 8617
2021 N = 8473
2022 N = 8556
More
fine particles (smoke)
More coarse particles
a
Density
PM2.5/PM10 ratio hourly average ug/m3

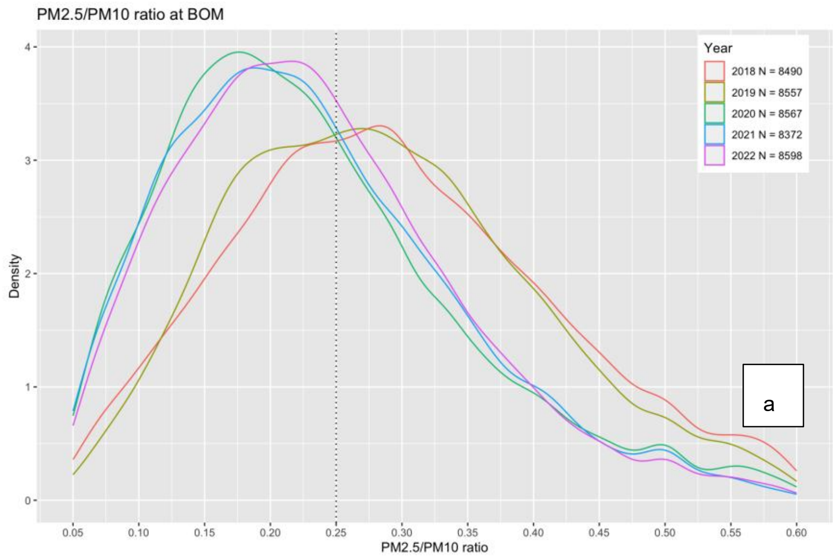

PM2.5/PM10 ratio at Richardson for PM10 hourly average > 70ug/m3
Year
2018 N = 1454
2019 N = 1877
2020 N = 1199
2021 N = 1078
2022 N = 915
More
fine particles (smoke)
More coarse particles
b
Density
PM2.5/PM10 ratio hourly average ug/m3

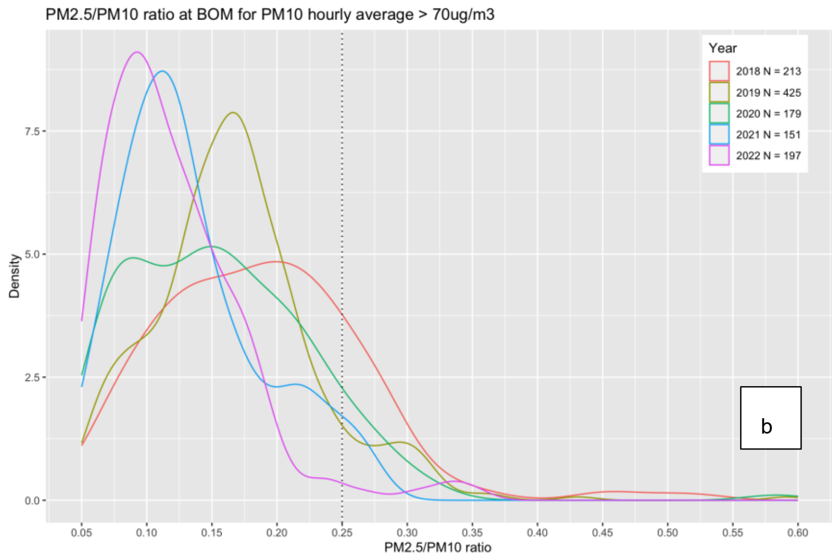

PM2.5/PM10 ratio at Hospital
Year
2018 N = 8499
2019 N = 7499
2020 N = 8417
2021 N = 8513
2022 N = 8568
a
Density
PM2.5/PM10 ratio


PM2.5/PM10 ratio at Hospital for PM10 hourly average > 70ug/m3
Year
2018 N = 1034
2019 N = 1174
2020 N = 900
2021 N = 834
2022 N = 851
b
Density
PM2.5/PM10 ratio


PM2.5/PM10 ratio at Taplin
Density
PM2.5/PM10 ratio
Year
2020 N = 6904
2021 N = 8598
2022 N = 8541
a


PM2.5/PM10 ratio at Taplin for PM10 hourly average > 70ug/m3
Density
PM2.5/PM10 ratio
Year
2020 N = 445
2021 N = 487
2022 N = 585
b


PM2.5/PM10 ratio at BOM
Density
PM2.5/PM10 ratio
Year
2018 N = 8490
2019 N = 8557
2020 N = 8567
2021 N = 8372
2022 N = 8598
a


PM2.5/PM10 ratio at BOM for PM10 hourly average > 70ug/m3
Density
PM2.5/PM10 ratio
Year
2018 N = 213
2019 N = 425
2020 N = 179
2021 N = 151
2022 N = 197
b

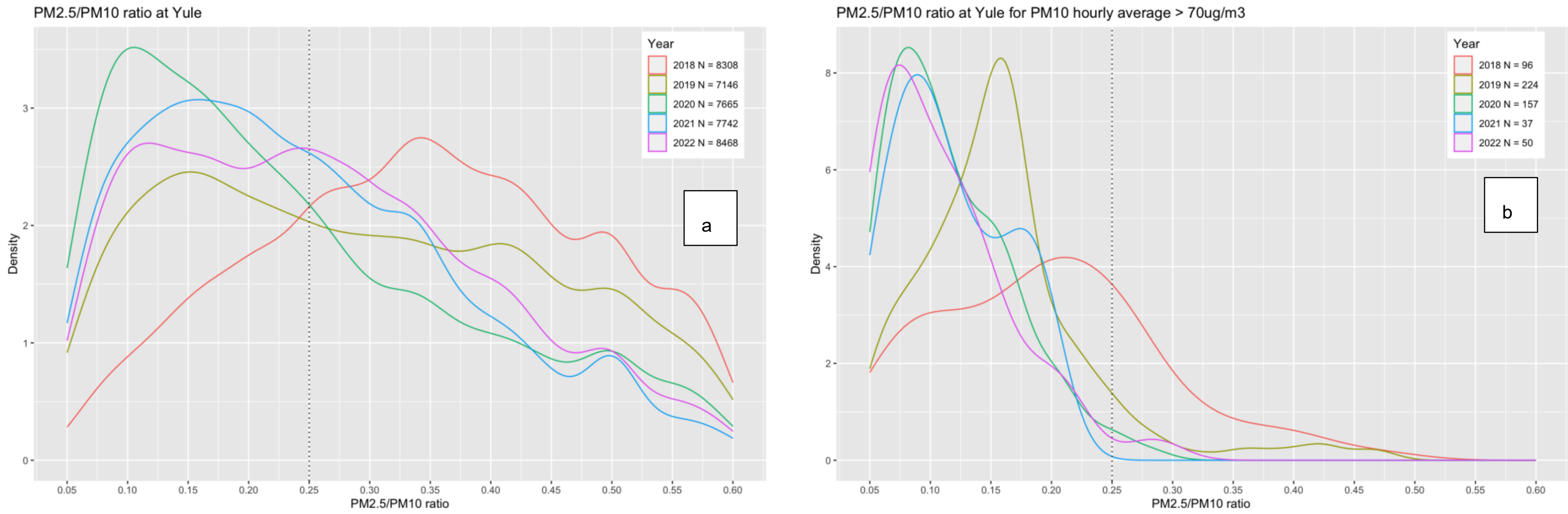


Figure 13 Comparison of $PM_{2.5}/PM_{10}$ ratio as density curves

3.4 Nitrogen dioxide

Nitrogen oxides, comprising nitric oxide (NO) and nitrogen dioxide (NO_2) 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 NO_2 is an air pollutant. NO_2 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 NO_2 monitoring met the thresholds with rates above 90% for all annual and quarterly data at Taplin. Limited data availability for Richardson is due to the NO_2 monitor being installed during Q3 of 2022 (Table 9).

Table 9 Data availability for NO_2

Monitoring Station	Data availability rates (%)				
	Q1	Q2	Q3	Q4	Annual
Richardson	0	0	69.2	91.7	40.6
Taplin Street	95.3	95.6	93.5	91.6	94.0

Concentrations compared against guidelines

Owing to the limited data availability, comparison with the guidelines was not assessed for NO_2 at Richardson. The maximum hourly average recorded in the available data set was 36.9 ppb.

An overview of NO_2 concentrations and compliance 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 NO_2 concentrations compared with guidelines at Taplin

Monitoring Station	Max 1 hr average NO2 ppb	Comparison with AAQ NEPM 1 hr average 80 ppb	Annual average NO2 ppb	Comparison with AAQ NEPM annual NO2 15 ppb
Taplin	35.5	met	7.7	met

NO_2 trend analysis

Figure 14 presents monthly summary statistics for NO_2 hourly concentrations at Taplin in the form of a "box and whisker" plot for 2022 and for 2018 - 2021. 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.

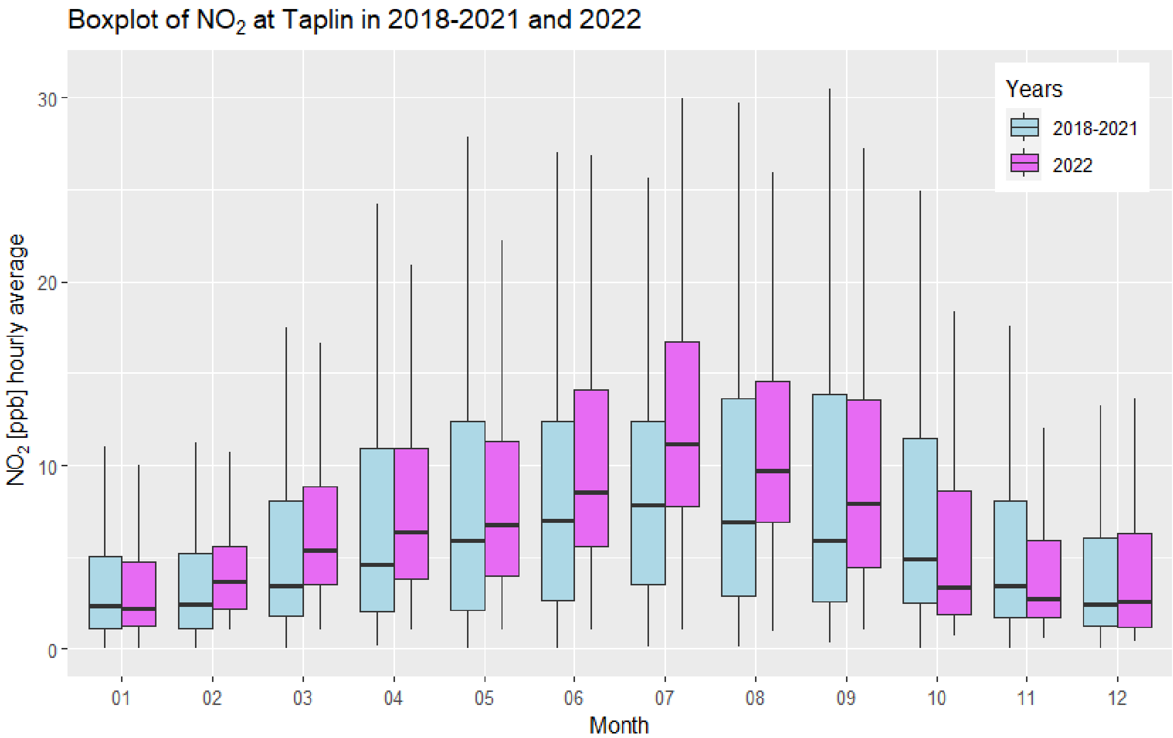


Figure 14 Variability of NO_2 hourly average by month

The 2022 and 2018 - 2021 datasets are broadly similar with generally higher NO_2 concentrations in winter than in summer.

The largest variation between the two data sets occurs in winter, in particular June and July 2022 have higher concentrations compared with the corresponding data from 2018 – 2021.

Reduced concentrations of NO_2 in summer occur because of photochemical reactions under the influence of high solar radiation that produce ozone, which is formed from NO_2. Seasonal changes in the predominant wind direction can also influence NO_2 concentration, especially if the change in wind direction places the monitor downwind from an emission source.

3.5 Sulfur dioxide

The largest anthropogenic source of SO_2 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 SO_2 emissions.

Data availability

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

Sulfur dioxide monitors were installed in Q3 of 2022 resulting in limited data availability as presented in Table 11.

Table 11 Data availability for SO_2

Monitoring Station	Data availability rates (%)				
	Q1	Q2	Q3	Q4	Annual
Richardson	0	0	65.4	87.5	38.6
Taplin	0	0	2.8	89.1	23.2

Concentrations compared against guidelines

Owing to the limited data availability, compliance with AAQ NEPM guidelines for SO_2 (Table 3) was not assessed.

However, a comparison of the available data against the AAQ NEPM guidelines is presented in Table 12. Based on the available data, there were no guideline exceedances.

Table 12 Maximum 1 hr average and maximum daily average for SO_2 at Richardson and Taplin

Monitoring Station	Max 1 hr average SO2 [ppb] AAQ NEPM 100 ppb	Max daily average SO2 [ppb] AAQ NEPM 20 ppb
Richardson	8.1	2.9
Taplin	5.6	1.7

Glossary

Term	Description
Air Quality Guideline (AGV)	Daily average of 70 μg/m^3 PM_{10} 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: [Port Hedland Dust Management Taskforce Report]()
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 PM_{10} describing particles that have an aerodynamic equivalent diameter of up to 10 μm.
Micrograms per cubic metre (μg/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 μg/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: *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.* 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 PM_{10} 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/m³] 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 PM_{10}. Conclusion: 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/m³] 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 $PM_{2.5}/PM_{10}$ ratio at Taplin was 0.5. High $PM_{2.5}$ concentrations and high $PM_{10}/PM_{2.5}$ 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. Conclusion: 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 PM_{10}, wind speed and wind direction are visualised. Figure 15 illustrates these time series data for an exceedance day.

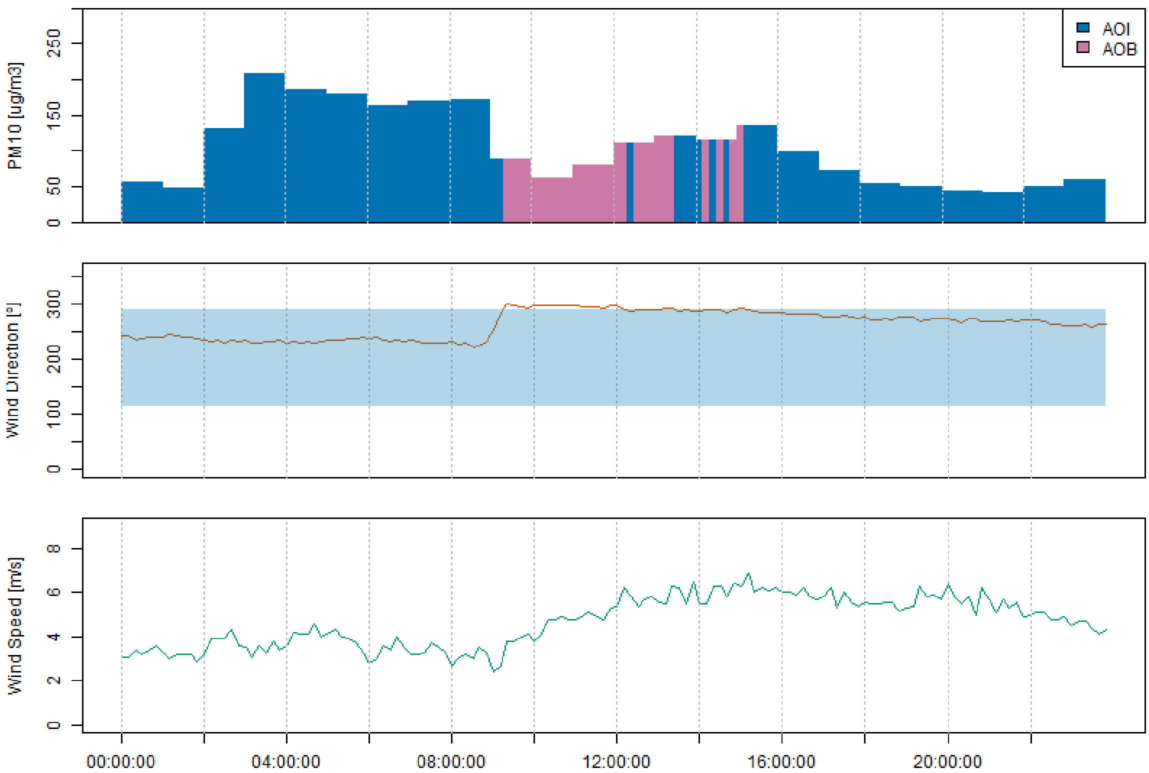


Figure 15 Summary graph for PM_{10}, wind direction and wind speed as 10-min average data

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

Time series data for PM_{10}, 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 PM_{10} 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.

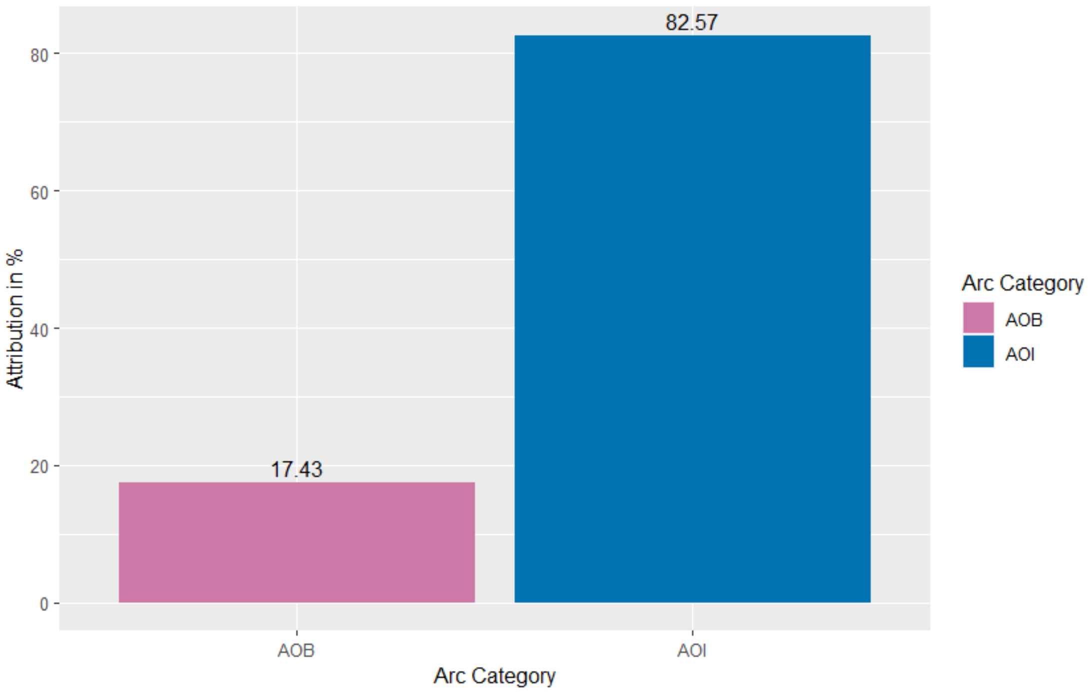


Figure 16 Dust load attribution according to arc of influence

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

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. A comparison of concentrations at Taplin and Yule indicated that it was not an exceptional event, owing to the PM_{10} 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 [μg/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.

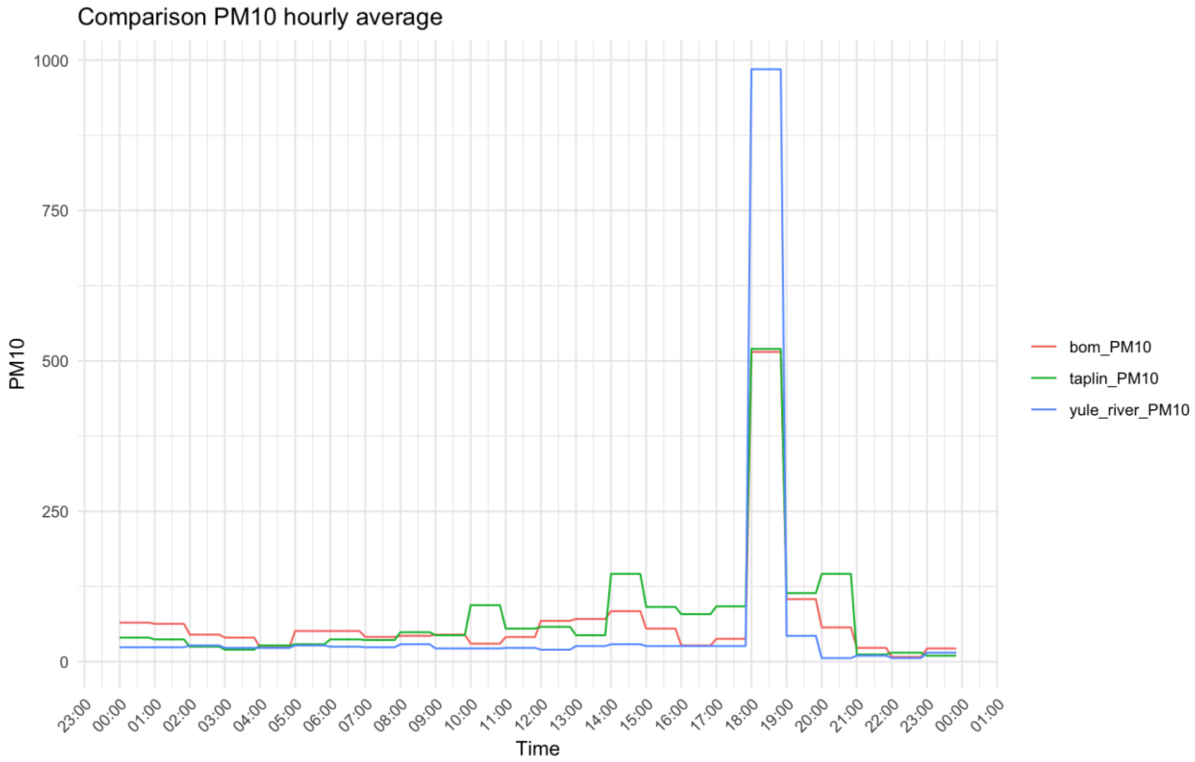


Figure 17 Hourly averages for Taplin Street, BOM and Yule River