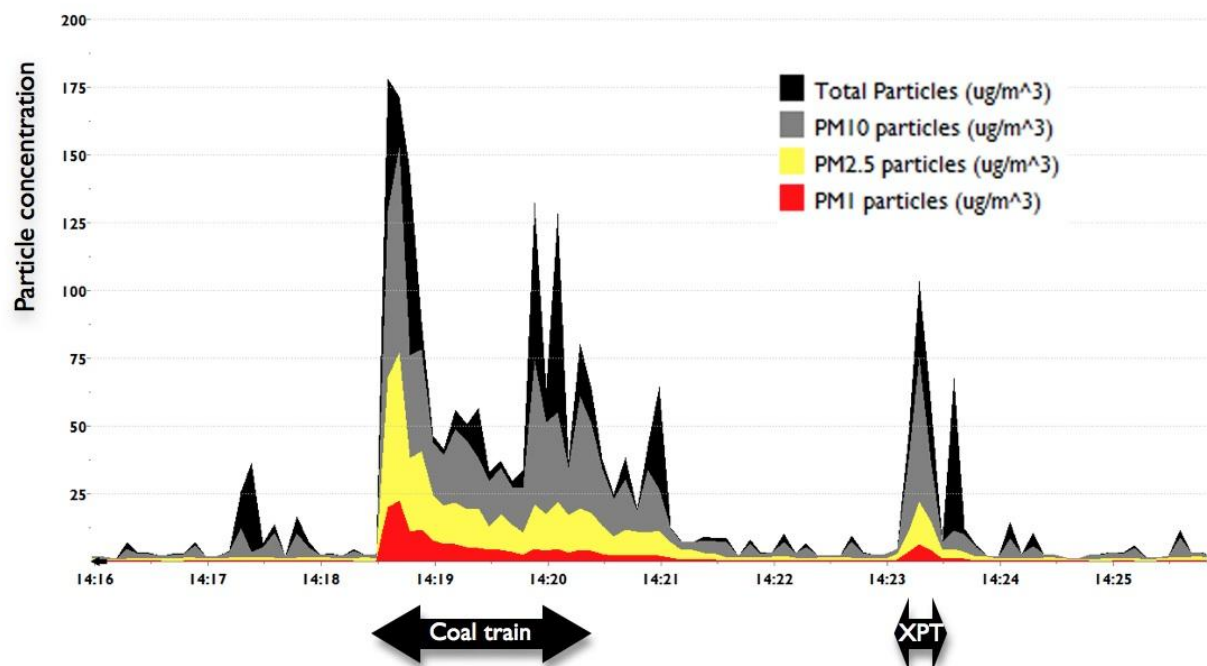


Coal Train Pollution Signature Study



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About the Coal Terminal Action Group (CTAG)

CTAG is an alliance of Newcastle and Hunter Valley community groups including: *The Australian Coal Alliance, Australian Youth Climate Coalition, the Barrington Gloucester Stroud Preservation Alliance, Climate Action Newcastle, Correct Planning and Consultation for Mayfield Group, Gloucester Residents in Partnership, the Green Corridor Coalition, Hunter Bird Observers Club, Hunter Community Environment Centre, Hunter Communities Network, Hunter Environment Lobby, Islington Village Community Group, the National Parks Association (Hunter Branch), the Nature Conservation Council of NSW, Parks and Playgrounds Movement, Rising Tide Newcastle, Singleton Shire Healthy Environment Group, Stockton Community Action Group, Tighes Hill Community Group, and the Wilderness Society Newcastle Branch.*

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- CTAG's Dust and Health Committee.
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Glossary

$\mu\text{g}/\text{m}^3$	micrograms per cubic metre
μm	microns (one millionth of a metre)
Entrainment	time taken for particle pollution levels to return to pre-train background levels
km	kilometre
km/hr	kilometre per hour
m	metre
m/s	metres per second
Mtpa	million tonnes per annum
NE	northeast
NW	northwest
PM ₁₀	Particulate matter with a diameter of 10 micrometres or less
PM _{2.5}	Particulate matter with a diameter of 2.5 micrometres or less
PM ₁	Particulate matter with a diameter 1 micrometre or less
SE	southeast
SW	southwest
TSP	Total suspended particulates (with a diameter 50 micrometres or less)

Acronyms

ARTC	Australian Rail Track Corporation Ltd
BoM	Bureau of Meteorology
EPA	NSW Environmental Protection Authority
PRP	Pollution Reduction Program
OEH	NSW Office of Environment and Heritage

Executive summary

Community groups in Newcastle and the Hunter consider coal dust a significant health problem. With more than 100 coal trains passing through residential areas each day, residents have become increasingly informed about the impacts of pollution from uncovered coal wagons, and supportive of measures to reduce this pollution.

Between Monday 15 July and Wednesday 17 July, members of several community groups monitored particle pollution levels in residential areas of Beresfield, Hexham and Mayfield. With expert advice and assistance, we monitored particle pollution concentrations while 73 loaded and unloaded coal trains passed. The Osiris equipment utilised for the study allowed for concurrent monitoring of various particle sizes: PM_1 and $PM_{2.5}$ that are associated with combustion (e.g. train locomotives) and the larger PM_{10} particles, which are more indicative of coal.

The study was an initiative of the Dust and Health Committee of the Coal Terminal Action Group, an alliance of twenty community and environment groups representing residents throughout Newcastle and the Hunter Valley. The study aimed to answer two research questions:

1. What is the particulate profile (signature) of loaded and unloaded coal trains?
2. What is the increase in particulate matter associated with the passage of loaded and unloaded coal trains, measured by comparing to pre-train particle concentrations? Is the proportion of increase the same across all particulate fractions (PM_{10} , $PM_{2.5}$ and PM_1)?

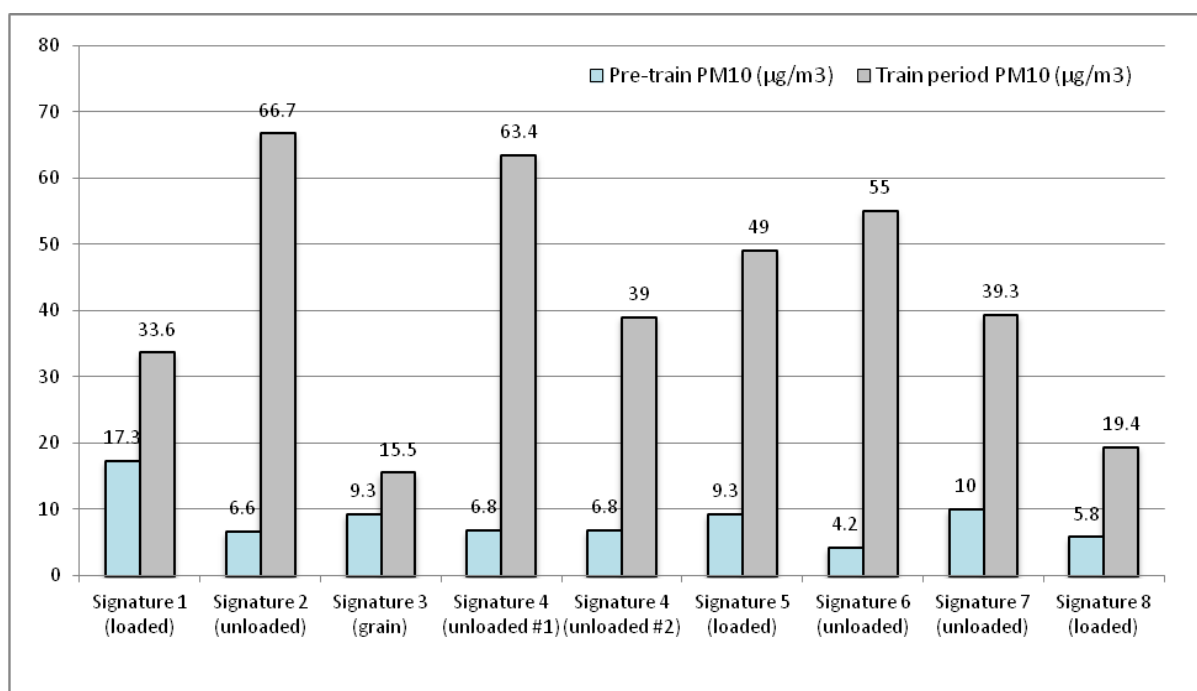
The study was the first of its kind in Australia. Crowd-funded by more than 100 donors, the study was entirely designed and conducted by members of community groups. They were advised and assisted by experts and academics and utilised industry-standard equipment. The results of the study were analysed by public health researchers.

In June 2013, before this study commenced, community members were shocked to learn that an industry study of the particle pollution caused by coal trains had been dramatically modified at the last moment to reverse many of its conclusions and understate the amount of pollution caused by coal trains. Unlike that study, our investigation was not designed to differentiate between train types. It deliberately focused on loaded and unloaded coal trains.

A total of 73 coal trains were observed during the three days of monitoring. The corresponding pollution data was analysed to generate 'signatures' which depict particle concentrations before, and during the trains' pass by. The method compares a two-minute average pollution level before each train to a two-minute average while the trains were passing by the monitoring equipment. Eight signatures are examined in this study. These signatures were selected to demonstrate an indicative range of signatures under various conditions (wind direction, wind speed, train speed, train type etc).

The following chart shows an analysis of particulate concentrations (PM_{10}) associated with each of the 8 signatures. It compares 2 minutes of pre-train air quality with 2 minutes of particulate matter concentrations produced during the train passage (i.e., the signature). All graphs show coal trains, apart from Signature 3, which is a grain freight train.

Chart 1: Particulate concentrations (PM₁₀) associated with train signatures



All coal train signatures were associated with a significant increase in PM₁₀ particle pollution levels. In the case of Signatures 1 and 5, this represents increases of 94% and 427% respectively for loaded coal trains. Signature 6 increased PM₁₀ concentrations significantly, up to 1210%. In sum, coal trains increase PM₁₀ levels by between 94% and 1210%. While coal trains pass, particle pollution concentrations increase up to 13 times pre-coal train levels.

While the study was not intended to compare different types of trains, a number of freight and passenger trains were captured in our signature measurements. We noted city link trains did not produce a definable signature, while freight trains and the XPT did show signatures in some cases, but they were much smaller in comparison to those observed for coal trains, and of shorter duration.

The results of this study warrant decisive action by the New South Wales Government. The Coal Terminal Action Group commends this study to Premier Barry O'Farrell and call on the NSW Government to:

1. Direct the state's coal industry to cover and wash all loaded and unloaded coal wagons
2. Suspend assessment of the proposed fourth coal terminal (T4)
3. Commission an independent assessment of the health impacts of particle pollution in the Hunter to assess the social and economic impacts of current particle concentrations and model the impacts of the proposed fourth coal terminal (T4).

1. Background

This study was initiated and managed by the Coal Terminal Action Group's Dust and Health Committee. The committee was established in August 2012 to respond to widespread concern that Newcastle and other 'coal corridor' communities are exposed to elevated levels of fine particle pollution. Exposure is known to cause a range of serious short-term and long-term health impacts and can occur with peak exposures of short duration (ranging from less than an hour up to a few hours) leading to immediate physiological changes.¹

The coal export capacity for the Port of Newcastle has grown exponentially in recent years, from 77 million tonnes per annum (Mtpa) in 1997 to 210Mtpa in 2012. The Fourth Newcastle Coal Loader (T4) proposal by Port Waratah Coal Services (PWCS) would see this increase to 330Mtpa, resulting in approximately 107 more train movements each day.²

NSW Health has cautioned against the development of T4 due to the impacts of existing pollution levels and the modelled increases in coal dust during its construction and operation.³ However, the coal industry and NSW Environment Protection Authority (EPA) refute these health concerns, alleging that coal trains are not a significant source of fine particle pollution (nor different from other types of trains in terms of pollution) and that particle pollution diminishes rapidly with distance from the coal corridor. These assertions are not supported by scientific evidence.

This is CTAG's second air pollution monitoring study. In late 2012, CTAG conducted air quality monitoring at twelve suburban locations to provide a snapshot of current levels of particle pollution. The alliance hired industry-standard 'Osiris' equipment to monitor particles of up to ten microns in diameter (PM₁₀) and fine particles of up to 2.5 microns and 1 micron in diameter (PM_{2.5} and PM₁) in residential areas between 5 December 2012 and 5 January 2013. The study program was assisted and results analysed by air quality scientists Associate Professor Howard Bridgman and Dr Jill Sweeney of the University of Newcastle.

The results of our first study were alarming. The national standard for PM₁₀ is 50 micrograms per cubic metre (µg/m³) averaged over a 24-hour period (measured using a TEOM monitoring device). This standard was exceeded at seven locations. At some locations, we recorded levels more than 50% higher than the national standard, and the standard was exceeded as often as every day. These findings suggest that residents living within 500 metres of coal trains and stockpiles are experiencing particle pollution at harmful levels. More than 30,000 people reside and 25,000 children attend school within 500 metres of the coal corridor between Rutherford and the Newcastle Port.

Building on our initial snapshot study, we embarked on a second round of air pollution monitoring to provide the community with data on PM₁₀, PM_{2.5} and PM₁ 'signatures' of coal trains. Such signatures show the profile of particulate pollution when repeated measurements are taken during the period when the coal train passes by. This profile reveals the upward development to the peak particulate concentrations, as well as the entrainment of suspended particulates after the train has passed, until they diminish to pre-train levels.

This second snapshot study has been designed to serve as a pilot for a larger investigation into particulate emissions from coal trains.

2. Health Impacts of Air Pollution

According to the Australian Medical Association, air pollution kills more people each year in Australia than car crashes. Fine particles of ten microns or less in diameter (PM_{10}) and 2.5 microns or less in diameter ($PM_{2.5}$) are readily inhaled, causing asthma attacks, hospitalisation, reduced activity days and premature death.⁴ The Australian Medical Association's President Dr Steve Hambleton recently observed that the Newcastle community already experiences high levels of pollution: "It's an especially at-risk population where we know there's already increased rates of respiratory illness."⁵

According to the EPA, mining and transportation of coal contribute 87.6% of the Hunter Valley's PM_{10} and 66% of the Hunter's $PM_{2.5}$.⁶ During 2012, the network of 17 Hunter Valley monitoring stations recorded levels of PM_{10} levels over the national standard on 115 occasions. A Senate Committee examining the health impacts of air pollution conducted a hearing Newcastle on 16 April 2013. Many of the 150 submissions received by the Committee came from residents and community groups in the Hunter. Senators were urged to reduce air pollution by groups including the Clean Air Society of Australia and New Zealand, the CSIRO and the Australian Medical Association.⁷

There is a high level of concern about the health impacts of coal rail dust along Hunter Valley coal rail lines. For decades, residents along the coal corridor have complained about coal dust and its health impacts. On 16 March this year, 1,500 residents rallied to express these concerns and oppose a proposed fourth coal terminal.

3. Objectives

The Dust and Health Committee aims to provide the community with independent information and advice upon which to consider the T4 proposal and other port development projects. The objective of this study was to provide the community with information about the pollutions 'signatures' of coal trains. Pollution signatures show the level of PM_{10} , $PM_{2.5}$ and PM_1 when multiple measurements are taken during the period when a coal train passes by a monitoring point. This profile reveals the upward development to the peak particulate concentrations, as well as the 'entrainment' of suspended particulates after the train has passed, until they diminish to pre-train levels.

4. Method

4.1 Research Questions

1. What is the particulate profile (signature) of a coal train pass-by (loaded and unloaded) as measured by concentrations of PM_{10} , $PM_{2.5}$ and PM_1 ?
2. What is the increase in particulate matter associated with the passage of loaded and unloaded coal trains, measured by comparing two minutes averages, starting three minutes before the train arrives, two minutes averages starting 30 seconds after the train arrives? Is the proportion of increase the same across all particulate fractions (i.e., PM_{10} vs $PM_{2.5}$ vs PM_1)?

4.2 Site selection

Criteria for selecting monitoring sites

- Proximity to frequent coal train movements
- Proximity to residential areas
- Sites close to and on downwind side of tracks for optimum capture of PM fraction
- Ability to respond to wind and weather conditions
- Clear of environmental interferences such as trees, houses, localised sources of PM and
- Access to power sources and security.

Selected monitoring sites

- Beresfield train station
- Hexham – near the Shamrock Street crossing
- Waratah train station
- Upfold Street Mayfield

A map showing these four locations is available online here >

<https://www.google.com/maps/ms?msid=210722871585608627393.0004de7533379370e3362&msa=0>

Further monitoring requirements

- Calibration at EPA's TOEM monitoring site at Francis Greenway High School, Beresfield
- Log keeping capturing variables - particularly train movements and also non-target events to help explain changes in PM levels.

4.3 Monitoring duration and techniques

The monitoring equipment was positioned according to the manufacturers' specifications. Mike Fry, the Managing Director of Turnkey Instruments Pty Ltd that hires this equipment to industry and government throughout Australia, oversaw all aspects related to the setting up the monitors and data management. Monitors were set up downwind of the coal tracks to capture emissions from rail trains.

To address the research questions, the monitoring was conducted as close to coal track lines as possible and the monitor was kept in place as long as practicable to capture background air levels and concentrations of particulate pollution specifically from loaded and unloaded coal train movements.

Volunteers received training and supervision in recording log information about the train pass-bys.

Estimating train speed

Train speed was calculated with a stopwatch. The time taken for the passing of 10 cars was recorded and then used to analyse the approximate train speed. Time keepers were reminded that the starting point is gap zero, not car one. Time keepers were instructed to look across the train to the landscape behind (flashes visible in the space between cars) and to choose a flash to start the watch, and count "zero", 1, 2 etc and stop the watch at 10.

Research team tasks

The monitoring required three researchers. Two researchers logged the train details on a recording sheet. The third researcher assisted Mike Fry to ensure that the monitor was functioning during the pass-by recording, and noted any anomalous readings. These were noted and any immediate sources identified, if present. This researcher also noted the imminent arrival of a second train passing by when that occurred, so the person logging will record its passage accurately.

Log sheets recorded start time, stop time, type of train (loaded coal, unloaded coal, freight, passenger), number of locomotives, number of wagons or carriages, train code and company, time for 10 carriages to pass, and multiple or single pass-by.

4.4 Equipment

Osiris air quality monitors were hired from Turnkey Instruments. These instruments are capable of simultaneously measuring Total Suspended Particles (TSP), PM₁₀, PM_{2.5} and PM₁ particulates. The equipment can be set to monitor every one second or every ten seconds with the results saved to memory or immediately transmitted in selected timing averages. Once down-loaded, the stored data was then interpreted using the AirQ32 software which generates trending graphs, tables, and wind inputs. These can also be represented as a pollution rose to indicate the wind direction that the particulates travelled from towards the sampling location at the time of measurement.

4.5 Review Process

Our analysis and conclusions were independently reviewed by Associate Professor Howard Bridgman, one of Australia's leading air quality experts and editor of the Clean Air Society of Australia and New Zealand journal. Independent review was considered of utmost importance following the controversial Australian Rail Track Corporation report published in June 2013. Two weeks after the ARTC report was published, and after the EPA announced their policy response to the report, an independent review by Dr Luke Knibbs of the University of Queensland highlighted fundamental flaws in the study and its analysis.

5. Data analysis and findings

5.1 Osiris versus TEOM

Before undertaking trackside monitoring the Osiris air monitors were positioned next to the permanent EPA monitor at Beresfield on Monday 15 July and set to record 1 minute averages of PM₁₀ and PM_{2.5}, as these are the parameters recorded by the EPA TEOM device that is regarded as industry standard. This was done for 29 minutes to calibrate the Osiris instrument to the EPA's monitoring of background particle concentrations.

µg/m ³	TEOM PM ₁₀	Osiris PM ₁₀	TEOM PM _{2.5}	Osiris PM _{2.5}
Average	19.910	11.417	13.356	5.307
Standard deviation	3.322	1.742	1.462	0.401

The correlation between Osiris readings and TEOM for PM₁₀ was $r=0.676$, and for PM_{2.5} was $r=0.838$, showing that the readings are fairly highly correlated, and that Osiris readings were lower for PM₁₀ by about 40% and for PM_{2.5} by about 60%. Regression of Osiris against TEOM showed that for PM₁₀ $TEOM = 5.2 + Osiris \times 1.28$ and for PM_{2.5} $TEOM = -2.87 + Osiris \times 3.06$.

5.2 Location specifications

For the remainder of the day on Monday 15 July, the Osiris monitor was mounted 0.8m from the fenced perimeter of the railway corridor at Beresfield. Weather conditions were partly cloudy, mostly dry, with light intermittent wind from the north-west, average wind speed 0.2m/s. The Osiris was run from a small portable generator on a 15m extension lead, which was positioned to the southwest, downwind from the monitor. The distances to the rail tracks were 8.6m, 12.3m, 17.3m and 23.0m from the mid-line of the tracks for the coal outbound, coal inbound, passenger outbound and passenger inbound lines respectively. Empty coal trains travelled on the nearest track, and full coal trains on the second nearest track.

On Tuesday 16 July, the Osiris monitor was mounted 0.5m from the fenced perimeter of the railway corridor at Hexham near the Shamrock Street crossing. Weather conditions were partly cloudy in the morning becoming sunny as the day progressed. Conditions were dry. The average wind speed was 1.3m/s with the 75th percentile of wind speed registering 2m/s with a maximum wind speed of 5m/s. The Osiris was run from a small portable generator on a 15m extension lead, which was positioned to the east-northeast, downwind from the monitor. The monitor was located 12m from the inbound coal track and 9m from the inbound passenger train track. The distances to the rail tracks were 27.6m, 23.3m, 19.3m and 15.0m from the mid-line of the tracks for the unloaded coal outbound, loaded coal inbound, passenger outbound and passenger inbound lines respectively.

On Wednesday 17 July, the Osiris monitor was again mounted 0.8m from the fenced perimeter of the railway corridor at Beresfield. Weather conditions were sunny and dry, with light intermittent wind from the NW, with an average wind speed 1.02m/s. Location details including distances from the track were the same as Monday 15 July (see above).

5.3 Data Analysis and Findings

Pollution Signatures

To answer research question one, two technical observers independently assessed graphics of each train pass-by to assess whether it produced a distinguishable signature. Signatures were confirmed for trains that measured a clear rise in particulate concentrations (TSP, PM₁₀, PM_{2.5} and PM₁) compared to the background air prior to and after the train pass-by. Both assessors agreed that more than 80% of coal trains (loaded and unloaded) showed distinguishable increases. A small number of coal trains produced a less pronounced signature, and it was increases in PM_{2.5} that became a defining indicator.

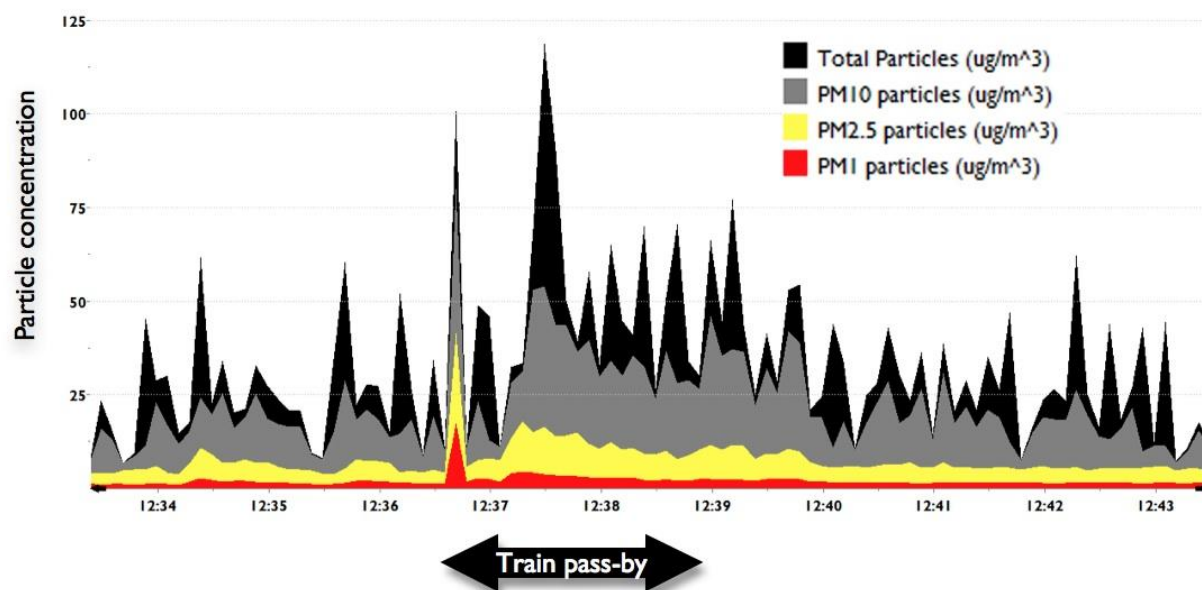
Table 1. Comparison of coal trains producing distinguishable and indistinguishable pollution signatures.

Discernible Signature	Loaded	Unloaded	Total
Yes	26 (72%)	31 (94%)	57 (81%)
No	10 (28%)	3 (6%)	13 (19%)
Totals	36	33	70 (100%)

Note: Further analysis will be undertaken to understand the significance of non-signature producing trains.

The following eight graphs provide an indication of the nature and possible determinants of train pollution signatures.

Figure 1. Signature 1 - Loaded Coal Train Monday 12:36pm



Signature 1 shows a characteristic loaded coal train (3 locomotives and 100 wagons) signature during monitoring. The train pass-by coincided with a brief wind blast of 3.6km/hr that was preceded and followed by relative stillness. The train slowed upon arrival to pass at an average of 42km/hr.

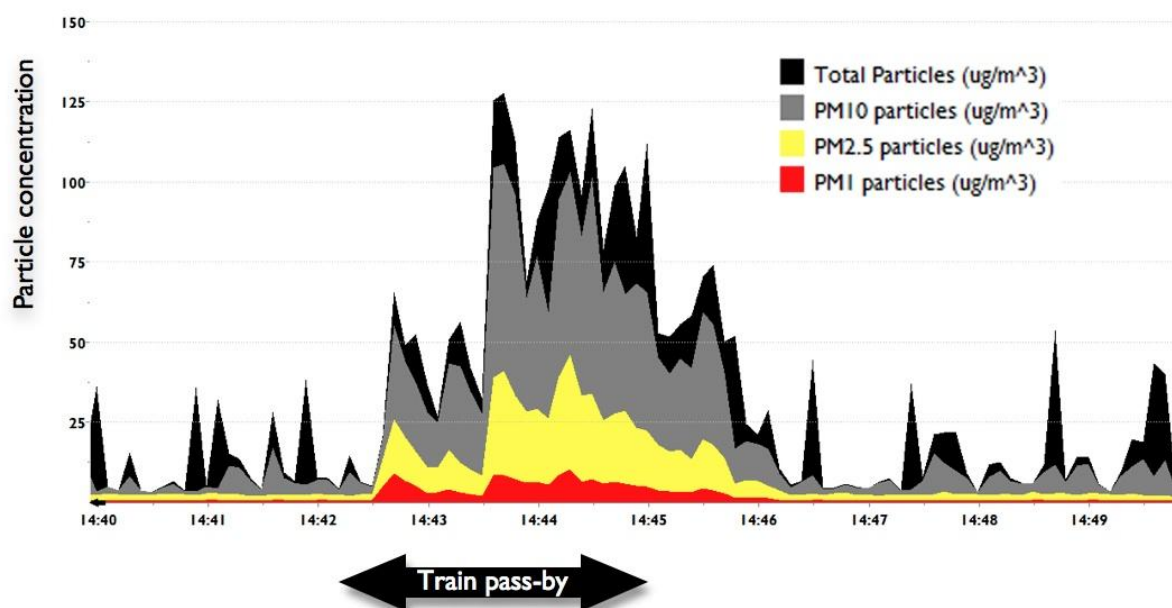
The loaded coal train produced a sharp rise in concentrations of all particulate sizes and produced an entrainment that lasted more than four minutes. This signature stands out against background track air that had residual pollution from an earlier train that had passed by less than two minutes prior.

The short burst of PM_{10} , $PM_{2.5}$ and PM_1 at the onset of the pass by is remarkable. The high ratio of PM_1 to TSP indicates diesel emissions and is positively correlated with the logged observations that noted that this train was producing 'heavy smoke' from the locomotives.

This signature shows continuing high proportions of PM_{10} to TSP, with a gradual decline in $PM_{2.5}$, and a slow return to pre-train background levels. PM_{10} was $33.6\mu g/m^3$ averaged over two minutes and pre-train background PM_{10} levels were $17.3\mu g/m^3$.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 1.	$17.3\mu g/m^3$	$33.6\mu g/m^3$	$16.3\mu g/m^3$

Figure 2. Signature 2 - Unloaded Coal Train Monday 14:42pm

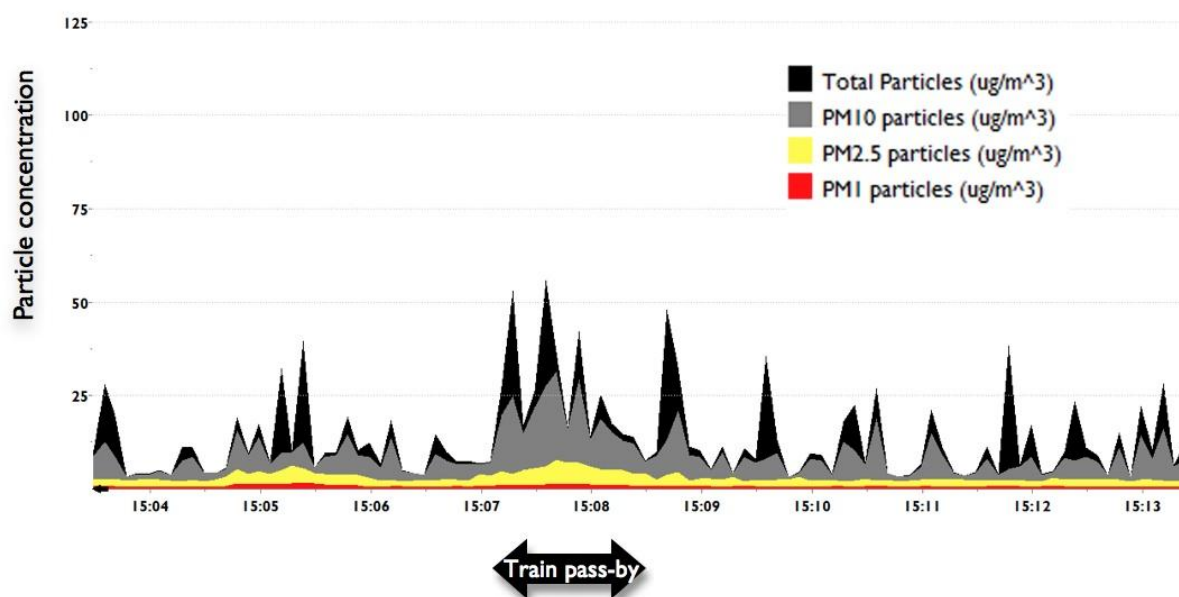


Signature 2 is indicative of an unloaded coal train pass-by. The track for this unloaded coal train was the closest to the Osiris monitor. Unloaded coal trains generally approached the monitor at higher speeds than loaded coal trains. This unloaded coal train (with 3 locomotives and 98 wagons) slowed to an average speed of 35km/hr. The wind was moving at 0.13km/hr and turned from N to the direction of the train, which was SE/SSE during the pass-by.

This signature shows two initial spikes in particulate matter with a one minute delay and then a third, larger and more sustained pollution plume. Signature shows a strong indication of diesel emissions (PM_{10}) and strong $PM_{2.5}$ levels accompanying the high levels of PM_{10} . The two-minute average of PM_{10} was $66.7\mu\text{g}/\text{m}^3$ compared to the two minute average pre-train level of $6.6\mu\text{g}/\text{m}^3$. An entrainment of more than four minutes is noted.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 2.	$6.6\mu\text{g}/\text{m}^3$	$66.7\mu\text{g}/\text{m}^3$	$60.1\mu\text{g}/\text{m}^3$

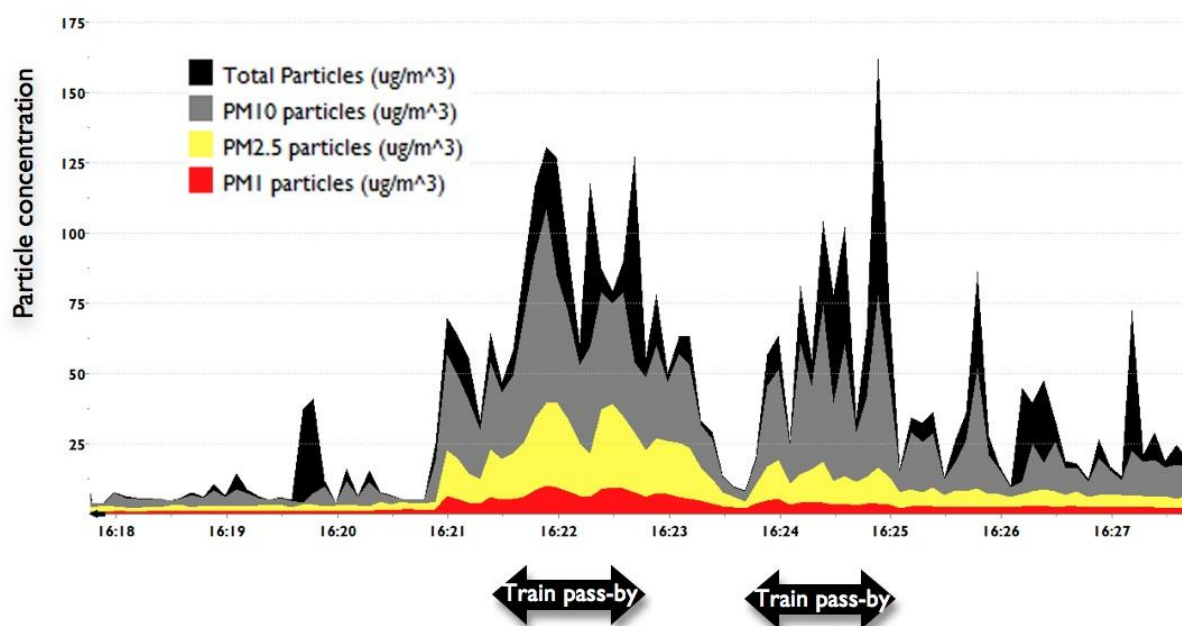
Figure 3. Signature 3 – Grain Train Monday 15:07pm



Signature 3 represents the affects of a freight train carrying grain. This AWB grain train (4 locomotives and 36 enclosed wagons) was travelling on the track closest to monitor. The train was moving at an average speed of 31km/hr. The air was still and the blast of air that accompanied the train changed the wind direction from NNE to SE during the pass-by. It gives a modest signature against the background, with two-minute average PM_{10} levels of $15.5\mu\text{g}/\text{m}^3$ and average pre-train background levels of $9.3\mu\text{g}/\text{m}^3$.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 3.	$9.3\mu\text{g}/\text{m}^3$	$15.5\mu\text{g}/\text{m}^3$	$6.2\mu\text{g}/\text{m}^3$

Figure 4. Signature 4 – Multiple Unloaded Coal Trains Monday 16:21pm

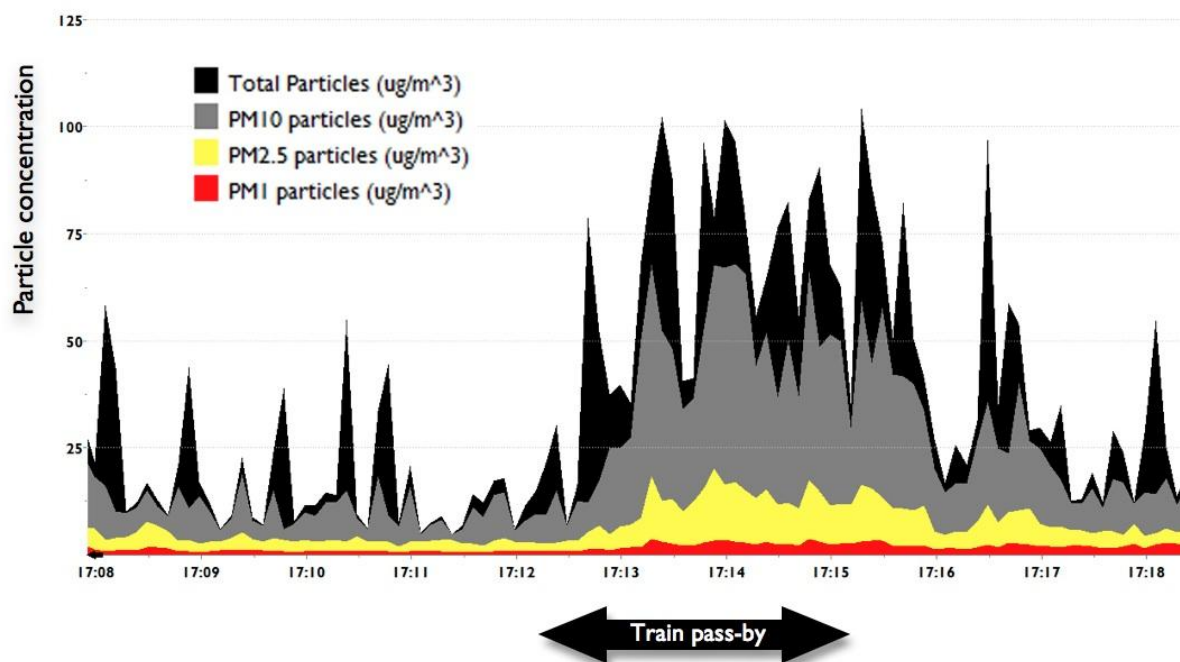


Signature 4 captures two back-to-back unloaded coal trains. The first unloaded coal train (3 locomotives and 104 wagons) approached at 69km/hr and then slowed to an average speed of 40km/hr. The second unloaded coal train (2 locomotives and 72 wagons) passed by at a constant speed of 67-68km/hr. The combination of the two trains generated their own wind, increasing from 1.9 to 4.3km/hr (ESE).

The signature shows high levels of TSP containing PM_{10} and high initial levels of $PM_{2.5}$ that is slow to diminish. The first train PM_{10} level was $63.4\mu\text{g}/\text{m}^3$ while the pre-train level was $6.8\mu\text{g}/\text{m}^3$. The second train measured an average PM_{10} level of $39\mu\text{g}/\text{m}^3$.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 4. Train 1	$6.8\mu\text{g}/\text{m}^3$	$63.4\mu\text{g}/\text{m}^3$	$56.6\mu\text{g}/\text{m}^3$
Signature 4. Train 2	$6.8\mu\text{g}/\text{m}^3$	$39\mu\text{g}/\text{m}^3$	$32.2\mu\text{g}/\text{m}^3$

Figure 5. Signature 5 – Loaded Coal Train Monday 5:12pm

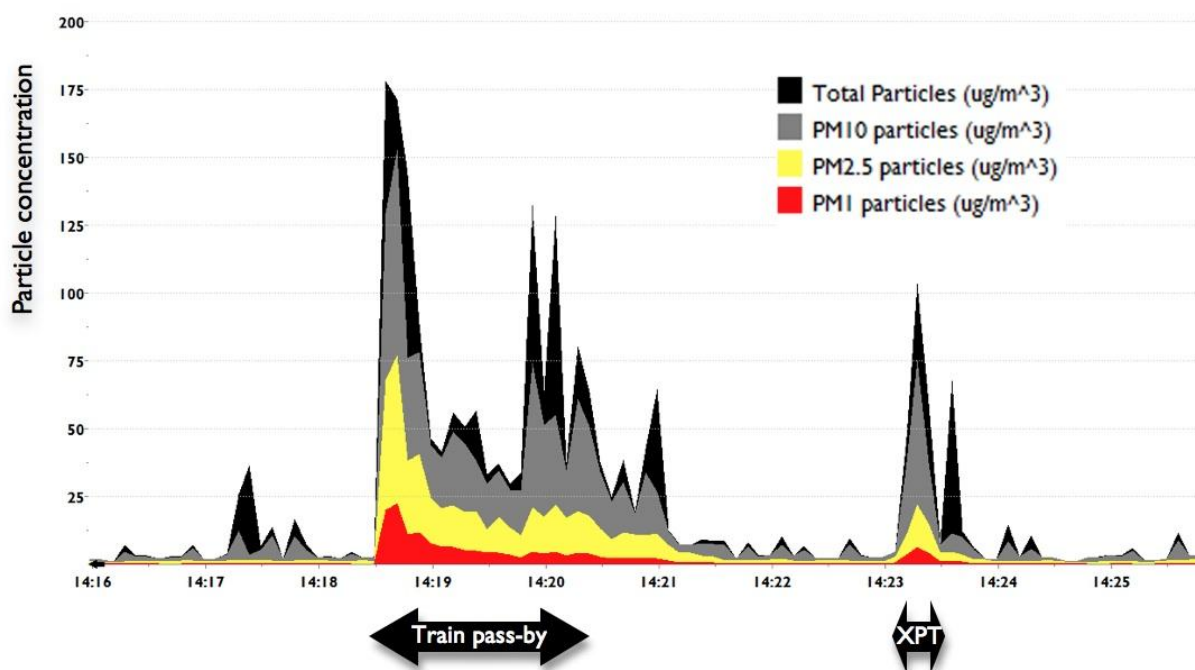


Signature 5 shows a loaded train (3 locomotives and 92 wagons) travelling at an average speed of 29km/hr. The wind speed was 0.7km/hr from the NNW, following the train. This signature was capture at the end of the first day of monitoring. Wind conditions were very still. The loaded coal signature is evident against increased background pollution levels from previous trains.

This signature shows a delay in plume arrival carrying a large proportion of PM₁₀ with a long entrainment. A 30 second gap was added to adjust for plume delay, two minute average of train pass-by measured PM₁₀ at 49µg/m³ and two minute average for pre-train background levels at 9.3µg/m³.

Pollution Signature	Pre-train period (PM ₁₀)	Train period (PM ₁₀)	Difference (PM ₁₀)
Signature 5.	9.3µg/m ³	49µg/m ³	39.7µg/m ³

Figure 6. Signature 6 – Unloaded Coal Train Tuesday 2:18pm



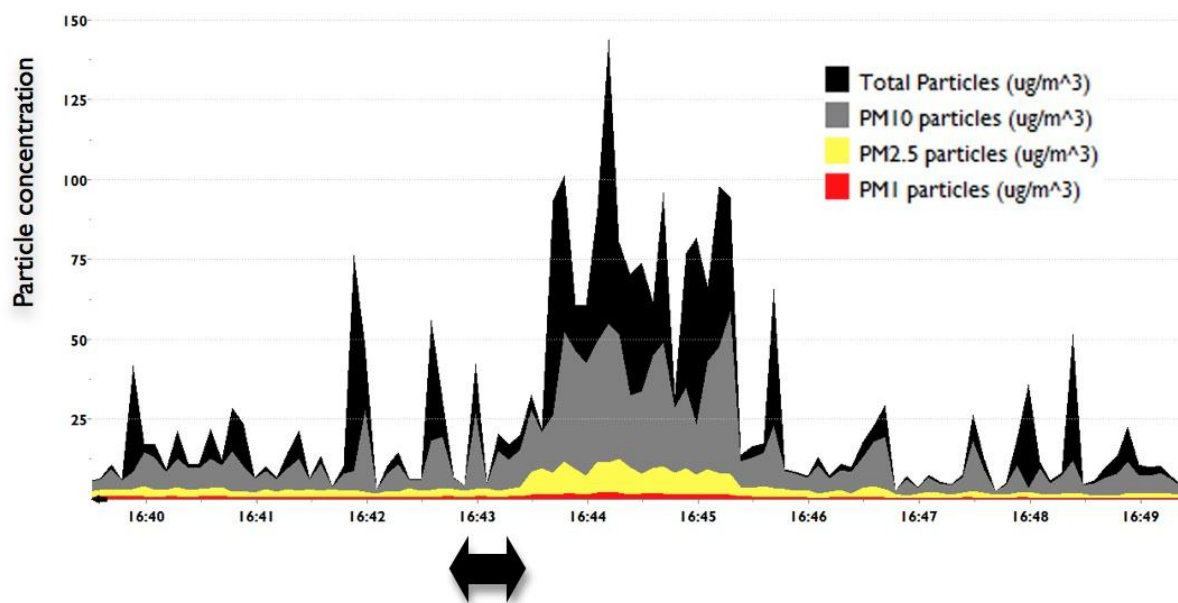
Signature 6 was termed the ‘Midnight Oil’ signature by an atmospheric scientist in honor of the band’s 1987 hit album ‘Diesel and Dust’. The unloaded coal train (3 locomotives and 82 wagons) approached the monitoring site travelling at 59km/hr and was heading into a NW 7.9km/hr wind. Logged observations noted that billowing smoke could be seen from the locomotives as the train approached and that the smell of diesel was distinguishable at the onset of the train pass-by.

The signature shows that the initial plume contained high concentration of PM_{10} indicating diesel combustion. The wind speed was significantly stronger and this may account for the absence of a delay in the arrival of the initial pollution plume and also for the rapid dispersion of particulates back to baseline in less than three minutes. Average PM_{10} for the train pass-by was measured as $55\mu\text{g}/\text{m}^3$ and pre-train average was $4.2\mu\text{g}/\text{m}^3$.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 6.	$4.2\mu\text{g}/\text{m}^3$	$55\mu\text{g}/\text{m}^3$	$50.8\mu\text{g}/\text{m}^3$

In the wake of the ‘Midnight Oil’ train described above, a fast moving XPT CountryLink train was captured. This train produced a clear signature of very short duration, evident toward the right side of figure 6 above. This signature shows a diesel combustion spike and high proportion of PM_{10} , followed by a second short dust burst.

Figure 7. Signature 7 – Unloaded Coal Train Tuesday 16:42pm

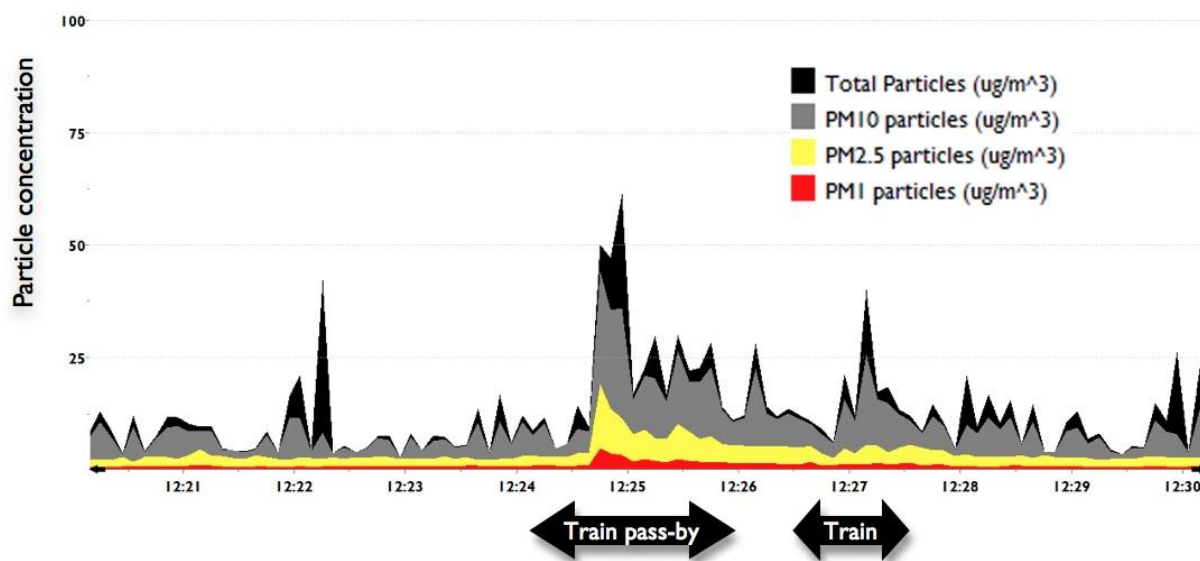


Signature 7 corresponds to a fast unloaded coal train (2 locomotives and 39 wagons) captured at Hexham on Tuesday. Initial train speed was calculated as 71km/hr with an average pass-by speed of 57km/hr. There was no wind during the pass-by.

The signature shows that the train had almost completely passed by before the pollution plume registered. The signature depicts high levels of PM_{10} and TSP and shows a relatively fast return to baseline levels. Two-minute averages of PM_{10} during train pass-by were measured as $39.3\mu\text{g}/\text{m}^3$ and two minute pre-train background PM_{10} levels were $10\mu\text{g}/\text{m}^3$.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 7.	$10\mu\text{g}/\text{m}^3$	$39.3\mu\text{g}/\text{m}^3$	$29.3\mu\text{g}/\text{m}^3$

Figure 8. Signature 8 – Loaded Coal and Freight Trains Wednesday 12:24pm



Signature 8 is a loaded coal train (3 locomotives and 96 wagons) captured at Beresfield on Wednesday. This train moved at a steady pace averaging 46km/hr. Wind speed was 4.4km/hr and followed the train from a NNW direction.

This signature is modest. TSP peaks at $63\mu\text{g}/\text{m}^3$. High concentrations of PM_{10} are observed and there is a clear rise in PM_1 and $\text{PM}_{2.5}$. A 30 second gap was added to adjust for plume delay, two minute average of train pass-by measured PM_{10} at $19.4\mu\text{g}/\text{m}^3$ and two minute average for pre-train background levels at $5.8\mu\text{g}/\text{m}^3$.

Pollution Signature	Pre-train period (PM_{10})	Train period (PM_{10})	Difference (PM_{10})
Signature 8.	$5.8\mu\text{g}/\text{m}^3$	$19.4\mu\text{g}/\text{m}^3$	$13.6\mu\text{g}/\text{m}^3$

Summary of signatures

All coal train signatures were associated with a significant increase in PM₁₀ particle pollution levels. In the case of Signatures 1 and 5, this represents increases of 94% and 427% respectively for loaded coal trains. Signature 6 increased PM₁₀ concentrations significantly, up to 1210%. In sum, coal trains increase PM₁₀ levels by between 94% and 1210%. While coal trains pass, particle pollution concentrations increase up to 13 times pre-coal train levels.

While the study was not intended to compare different types of trains, a number of freight and passenger trains were captured in our signature measurements. We noted city link trains did not produce a definable signature, while freight trains and the XPT did show signatures in some cases, but they were much smaller in comparison to those observed for coal trains, and of shorter duration.

The following chart and table provides a summary of PM₁₀ particulate concentrations of the eight pollution signatures.

Chart 2: Particulate concentrations (PM₁₀) associated with train signatures

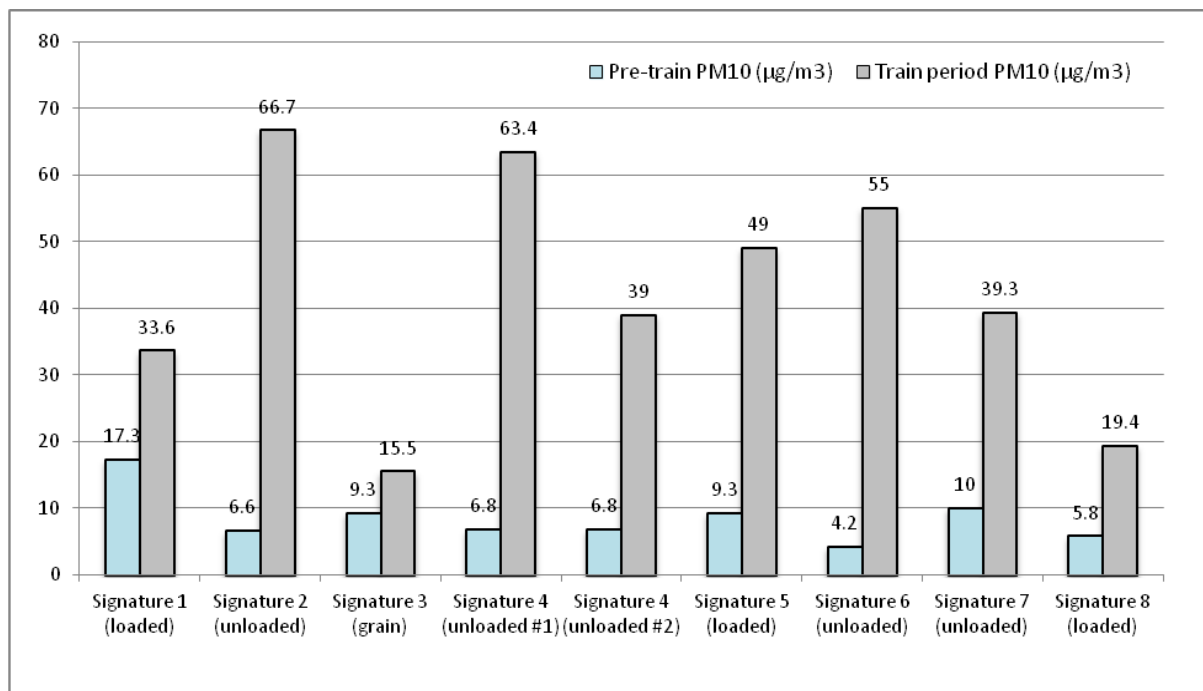


Table 6. Percentage differences of particulate concentrations (PM₁₀) associated with train signatures

Signatures	Pre-train PM ₁₀ (µg/m ³)	Train period PM ₁₀ (µg/m ³)	Difference	Difference (%)
1 – loaded	17.3	33.6	16.3	94%
2 – unloaded	6.6	66.7	60.1	911%
3 – grain	9.3	15.5	6.2	67%
4 – unloaded #1	6.8	63.4	56.6	832%
4 – unloaded #2	6.8	39	32.2	474%
5 – loaded	9.3	49	39.7	427%
6 – unloaded	4.2	55	50.8	1210%
7 – unloaded	10	39.3	29.3	293%
8 – loaded	5.8	19.4	13.6	234%

Note: The PM₁₀ levels depicted above are two minutes averages of pre-train and train pass-by and are not peak levels recorded.

Statistical analysis

To answer research question two, the full day's data for Monday and Tuesday was examined to compare the air quality in the time before each train arrived with the air during the train's passing. The data for Wednesday is still undergoing analyses and further results will be released at a later date. Data were analysed by calculating **pre-train periods** defined as the two minutes starting three minutes before the train arrived, and **train pass-by periods** defined as the two minutes starting 30 seconds after the locomotive passed. **Trains were excluded from analysis if another train was present during the prior period** (40% did not meet criterion). The analysis was repeated with criteria for maximum allowable average wind speed during the pre-train period, however this was not consequential as there was very light or no wind throughout the monitoring periods. All analysis was performed in Microsoft Excel except statistical testing which was performed in Stata 11.

Table 1: Full coal trains, pre-train period and train pass-by period PM₁₀ in µg/m³ for those 10 trains on 15th July where there was no other train present during the prior period.

Train time	Pre-train period (µg/m ³)	Train pass-by (µg/m ³)	Difference (µg/m ³)
12:27:11 PM	12.5	12.8	0.2
12:53:17 PM	12.9	14.9	2.0
1:40:47 PM	9.8	11.3	1.5
3:28:23 PM	6.6	34.8	28.3
3:37:05 PM	7.1	15.6	8.4
3:50:05 PM	11.5	26.1	14.6
4:03:17 PM	10.8	14.3	3.5
4:56:17 PM	12.5	21.3	8.8
5:12:17 PM	9.7	48.7	39.0
Averages	10.38	22.2	11.81

The average PM₁₀ during the prior period was 10.38µg/m³ and during the train period was 22.2µg/m³ with a difference of 11.81µg/m³ (p= 0.031, paired t test, 2 sided).

Table 2: Empty trains, pre-train period and train pass-by period PM₁₀ for those 11 empty coal trains on 15th July where there was no other train present during the prior period.

Train time	Pre-train PM ₁₀ (µg/m ³)	Train pass-by PM ₁₀ (µg/m ³)	Difference (µg/m ³)
12:02:35 PM	15.2	16.9	1.7
12:12:11 PM	14.0	14.3	0.3
12:33:17 PM	10.7	17.8	7.1
1:04:17 PM	12.2	30.7	18.5
1:21:35 PM	13.3	45.9	32.6
1:54:53 PM	6.6	15.7	9.1
2:42:17 PM	6.6	66.7	60.1
2:58:17 PM	6.8	18.0	11.1
3:55:17 PM	10.7	48.2	37.5
4:21:17 PM	6.9	51.9	45.0
4:36:17 PM	6.7	30.1	23.4
Averages	9.97	32.38	22.4

The average PM₁₀ during the prior period was 9.97µg/m³, and during the train period was 32.38µg/m³, with a difference of 22.41 (p=0.0032, paired t test, 2 sided).

When comparing additional particulates associated with loaded and unloaded trains, increases were greater for unloaded trains. Unloaded coal trains showed a mean increase of 11.78µg/m³ (95% ci - 3.51, 27.07). It should be noted however, that this result is not statistically significant.

Table 3: Loaded trains, prior period and train period PM₁₀ and PM_{2.5} for those 11 empty coal trains on 16th July where there was no other train present during the prior period.

Time	Pre-train PM ₁₀ µg/m ³	Train PM ₁₀ µg/m ³	Difference µg/m ³	Pre-train PM _{2.5} µg/m ³	Train PM _{2.5} µg/m ³	Difference µg/m ³
9:24:01 AM	22.6	24.5	1.9	7.6	9.3	1.7
10:09:01 AM	18.2	18.7	0.5	6.3	7.1	0.8
10:26:49 AM	16.0	22.4	6.4	5.4	7.6	2.2
11:18:47 AM	15.6	16.8	1.2	5.4	5.8	0.4
11:39:17 AM	18.9	20.7	1.7	5.2	5.6	0.5
11:55:47 AM	11.7	15.0	3.3	4.2	5.3	1.1
12:12:29 PM	8.8	14.1	5.3	3.1	5.4	2.3
1:00:11 PM	9.9	21.8	11.9	3.1	7.1	4.1
1:20:35 PM	6.4	8.6	2.1	2.6	3.4	0.8
3:16:41 PM	3.1	10.6	7.5	1.2	3.3	2.1
3:31:11 PM	5.2	32.2	27.0	1.8	13.3	11.5
3:56:23 PM	6.4	22.8	16.4	2.1	10.3	8.2
4:11:59 PM	11.3	20.3	9.0	3.7	6.3	2.6
Averages	11.9	19.1	7.2	4.0	6.9	2.9

The average PM₁₀ during the pre-train period was 11.9µg/m³, and during the train period was 19.1µg/m³, with a difference of 7.2µg/m³. The average PM_{2.5} during the pre-train period was 4.0µg/m³, and during the train period was 6.9µg/m³, with a difference of 2.9µg/m³.

Table 4: Unloaded trains, prior period and train period PM₁₀ and PM_{2.5} for those 11 empty coal trains on 16th July where there was no other train present during the prior period.

Time	Pre-train PM₁₀ (µg/m³)	Train PM₁₀ (µg/m³)	Difference (µg/m³)	Pre-train PM_{2.5} (µg/m³)	Train PM_{2.5} (µg/m³)	Difference (µg/m³)
10:40:43 AM	11.1	25.6	14.5	4.8	11.4	6.6
11:00:59 AM	18.0	26.0	8.1	6.0	9.9	3.9
12:59:59 PM	9.4	22.0	12.6	3.0	7.2	4.2
1:28:23 PM	8.0	15.0	7.0	2.8	7.3	4.5
2:04:17 PM	2.8	18.9	16.1	1.1	5.4	4.3
2:18:29 PM	4.2	39.2	35.0	1.3	15.9	14.6
2:29:11 PM	3.0	22.4	19.4	1.3	8.0	6.7
3:22:41 PM	4.0	7.0	3.0	1.3	2.9	1.6
3:51:59 PM	4.1	35.3	31.1	1.4	17.6	16.1
4:02:53 PM	5.1	37.4	32.3	1.6	10.7	9.0
4:42:47 PM	10.0	39.3	29.2	2.9	9.2	6.3
Average	7.3	26.2	18.9	2.5	9.6	7.1

The average PM₁₀ during the pre-train period was 7.3µg/m³, and during the train period was 26.2µg/m³, with a difference of 18.9µg/m³. The average PM_{2.5} during the pre-train period was 2.5µg/m³, and during the train period was 9.6µg/m³, with a difference of 7.1µg/m³.

6. Conclusions

This study found that 80% of coal trains produced a recognisable pollution signature. The signatures compromise a sharp rise in TSP, PM₁₀, PM_{2.5} and PM₁ particulates, lasting 3.5 to 5 minutes. They show initial bursts of ultrafine PM₁ and fine PM_{2.5} particulates indicating diesel combustion and chemical reaction processes. The ultrafine and fine particulates are contained within larger spikes of dust, mostly PM₁₀. Associate Professor Howard Bridgman has stated that coal dust is most likely to be associated with particle sizes between PM_{2.5} and PM₁₀. Signature magnitude was seen to be influenced by factors such as wind speed and direction, train speed and distance from the monitor. The analysis of two minute segments of these signatures showed that PM₁₀ levels were at least double pre-train particulate levels, and ranged up to 13 times larger.

Statistical analysis was performed on 60% of coal trains that met the inclusion criteria (i.e., no other train movement three minutes prior to arrival of the coal train). Analysis involved comparison of two minute pre-train background air quality with two minutes of train pass-by particulates. The results demonstrate a clearly measurable and statistically significant increase in particulate pollution during the time that coal trains pass through residential areas.

The results from the Osiris device used showed acceptable correlation to the reference TEOM but did not record identical particle concentrations. The use of a conversion equation could be applied. For instance, if applied to the Monday measurements this indicate an average increase of 18.8µg/m³ for full trains and 33.9µg/m³ for empty trains.

Incremental additions of air pollution of this magnitude into the airshed can add up to a large health problem, as everyone in the population is exposed. Health effects of air pollution are well documented, even below current standards. There is probably no lower threshold for adverse effects of pollution on human health. Even short-term exposures can be harmful, especially to vulnerable people with existing disease, children and the elderly.

Further analysis of the full dataset is ongoing and those results will be forthcoming.

7. Recommendations

1. That the NSW Government directs the state's coal industry to cover and wash all coal wagons (loaded and unloaded).
2. That the NSW Government suspend assessment of the proposed fourth coal terminal (T4). Particle pollution in Newcastle and elsewhere in the Hunter already regularly exceeds the national standard and measures are urgently required to improve urban air quality.
3. An independent assessment of the health impacts of particle pollution in the Hunter must be commissioned to assess the social and economic impacts of current particle concentrations and to model the impacts of the proposed T4.

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