BRIDGEWATER BRIDGE PROJECT PARTICULATE MONITORING; A COMPARISON OF REFERENCE BAM AND PARTICULATE PROFILER PERFORMANCE.

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Abstract

Particulate monitoring for major construction sites is becoming increasingly regulated. Ideally, reference equipment is used to ensure accurate, reliable results are available to ensure compliance with regulatory limits. However, cost, site space and availability of power usually limits the number of reference stations where significant benefits may be gained if further sampling locations were available. The use of lower cost instruments that still offer near reference station accuracy can have a number of benefits in the monitoring regime.

In this study we compare the particulate monitoring measurements from reference instruments and collocated simultaneous particle profilers (ES-405) around the Bridgewater Bridge Project - Tasmania's largest ever transport infrastructure project. A reference station running 2 Beta Attenuation Monitors and an ES-405 provides an ideal opportunity to directly compare results, and then consider the measurements from ES-405's located nearby around the construction site.

Initial results suggest an excellent correlation with both $PM_{2.5}$ and PM_{10} data, with much greater time resolved data available from the ES-405's. We present results based on over a year of ambient construction monitoring.

Keywords: Particulate Monitoring, Reference correlation, PM_{10}, $PM_{2.5}$

1. Introduction

During large scale infrastructure projects, environmental monitoring is essential to ensure impact on the local environment is minimised. 'Building a new Bridgewater Bridge is Tasmania's largest ever transport infrastructure project.' (A New Bridgewater Bridge Project). During construction of the 1km long new bridge across the River Derwent, continuous monitoring of $PM_{2.5}$, and PM_{10} has been undertaken at 5 sites as required by the project's environmental permit requirements (MPP 2201).

In this paper, we review 14.5 months of particulate monitoring data collected from 16 March 2023 to 1 June 2024 at the 5 sites.

2. Monitoring Details

The main monitoring site includes both reference monitors (2x Met One BAM1020's with a $PM_{2.5}$ inlet head on one and a PM_{10} inlet head on the second unit), and a near reference particulate profiler (Met One ES-405). The reference site also includes meteorological measurements at two elevations (2 m and 10 m for ambient temperature and relative humidity, and 3 m and 10 m for windspeed and wind direction)

The four satellite monitoring sites are all within 2 km of each other. Each has a single near reference particulate profiler (Met One ES-405), as well as basic meteorological measurements (ambient temperature, relative humidity, barometric pressure, windspeed and wind direction). The ES-405 has a heated inlet that was configured to reduce the inlet humidity to below 40%, thus mitigating the traditional errors introduced by higher relative humidity in near reference optical instruments.

We first compare the results at the reference site, and then consider the measurements from the 4 satellite sites, and what extra information these readings provide.

3. Reference site results

PM_{10} measurements at the reference site: Figure 1 shows the hourly average readings from the BAM plotted against the hourly average readings from the ES-405. A reasonable correlation between the reference and near reference monitors is evident, but there are some clear outliers.

There are over 10,000 hours in our dataset. Figure 2 shows the correlation between the two PM_{10} instruments with just 0.5% of the largest outliers removed. With an R^2 of 0.79, clearly the near reference optical monitor gives a very good indication of PM_{10}.

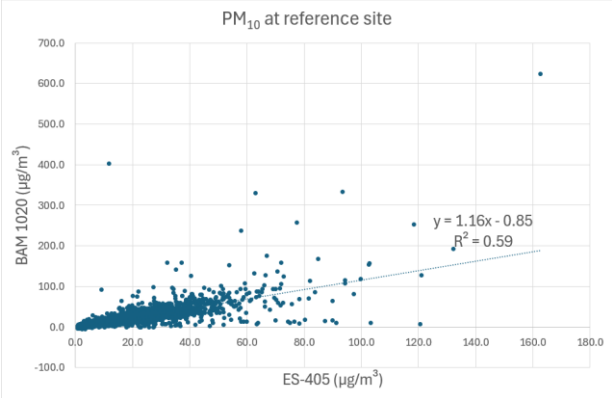

Figure 1. Hourly PM_{10} intercomparison at reference site.

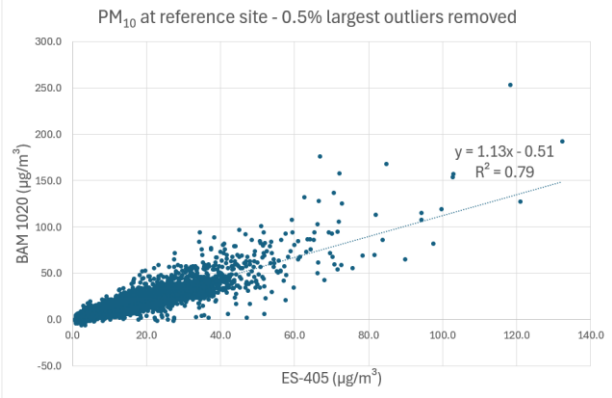

Figure 2. Hourly PM_{10} correlation after removing outliers.

Figure 3 shows the $PM_{2.5}$ correlation for the same 14.5 month dataset. Unlike the PM_{10}, removing 0.5% of outliers had minimal impact on the R^2 for the $PM_{2.5}$ dataset. This is likely mainly due to the relatively low average concentration (4.9 µg/m³), which is essentially the same as the published LDL (2σ 1 hour) for the BAM 1020 (4.8 µg/m³). In addition to this, there also appears to be few true outliers.

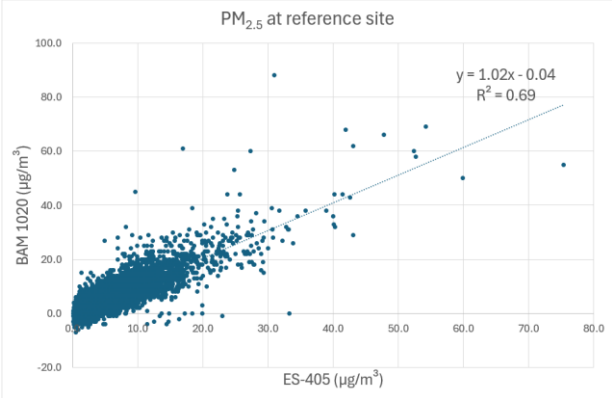

Figure 3. Hourly $PM_{2.5}$ intercomparison at reference site.

The BAM 1020 published LDL (2σ) for daily data is much lower at <1.0 µg/m³. Figure 4 shows the $PM_{2.5}$ correlation after averaging the dataset over this daily period. As expected, this brings the R^2 up to a much better 0.84, confirming the previous hypothesis around the hourly BAM LDL.

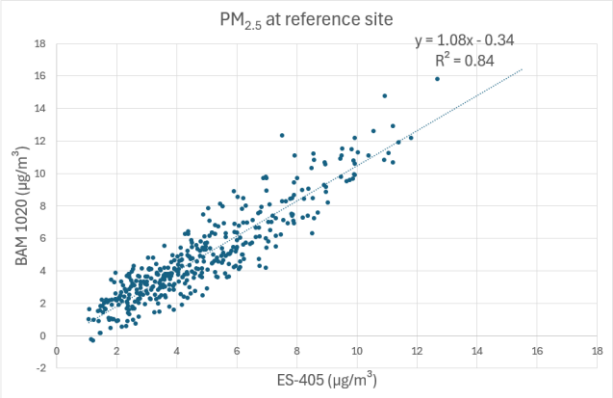

Figure 4. Daily $PM_{2.5}$ averages intercomparison at reference site.

4. Near reference site results

Firstly, let's compare the ambient temperature and relative humidity across the sites. The 5-minute ambient temperature compared to the 2m reference site ambient temperature had an R^2 of 0.99 for 3 sites, and 0.98 for the 4th site (D). So, for comparison of particulate measurements, we can assume temperature was the same across sites.

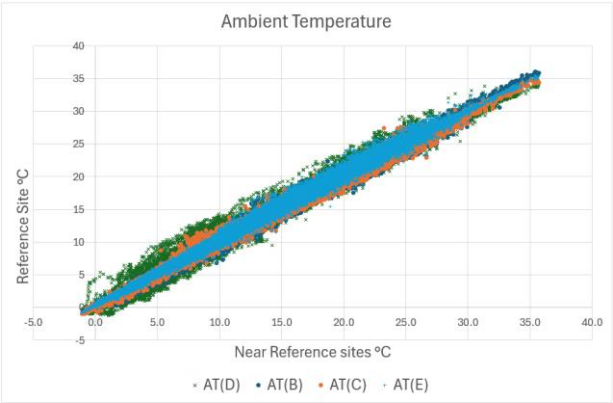

Figure 5. 5-minute Ambient Temperature intercomparison with reference site (@2 m).

Looking at relative humidity in Figure 6, the correlation is not quite as good, but we can still treat the RH as the same across sites for particulate measurements, with an R^2 of 0.98, 0.97, 0.94, and 0.98 respectively for the 14 months of 5-minute data.

The near reference monitors' inlet RH was also recorded and was confirmed to be maintained at or below 40% regardless of the ambient RH.

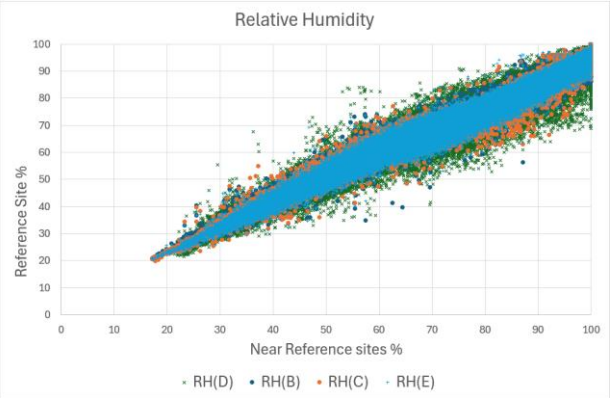

Figure 6. 5-minute Relative Humidity intercomparison with reference site (@2 m)

Figure 7 is only a snapshot of a week's data from the 14 months of data collected from the 5 near reference sites, but it is typical of monitoring throughout the period. On the 10th and 11th, we can see the PM_{10} is fairly consistent across all five sites, suggesting a regional source is responsible for the 10 – 30 µg/m³ readings. On the other days there were multiple localised sources of PM_{10} at different monitoring sites, suggesting the elevated readings then are due to construction works during the day.

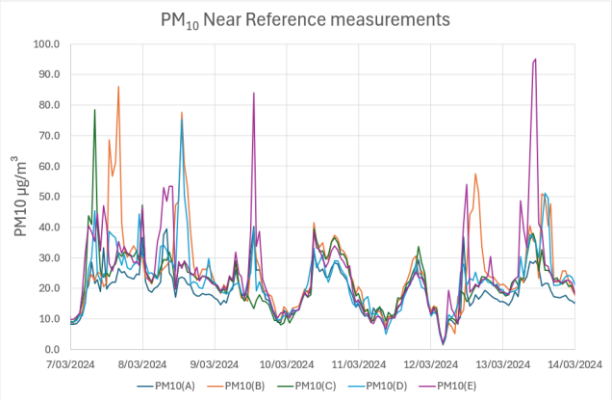

Figure 7. Hourly PM_{10} data for a week, from each of the 5 near reference samplers.

Another advantage of the near reference monitors is their time resolution. Zooming in on a day's worth of the data, we can see in Figure 8 that the individual readings are much higher short spikes, that averaged down in the hourly readings in Figure 7. A lot more detail about when events occurred and at which sites can be extracted from the 5-minute data. From 5am to 11am, most PM_{10} came from activities near site E, in the afternoon, the source of PM_{10} was closer to sites B & D.

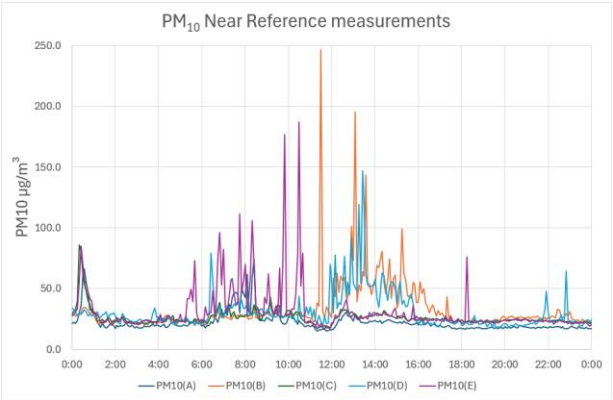

Figure 8. 5-minute PM_{10} data for 8 March 2024, from each of the 5 near reference samplers.

5. Conclusion

Near reference technology often suffers from changes in correlation depending on source composition. By collocating a near reference monitor at the same location as the reference BAM technology, we have been able to confirm that the near reference monitor correlates well with the reference measurements. This then gives greater confidence in the accuracy of the other near reference monitor readings at the sites located nearby. The heated inlets on the ES-405's ensured the RH was kept below levels that impact on the optical properties of particulate samples and likely contributed to these favourable R^2 results.

The fundamental principle of measurement of the BAM technology means its accuracy increases with longer sampling time. However, the optical technology of the near reference equipment is essentially as accurate over a 5 minute period as a 24 hour period. By validating the near reference measurements with daily reference measurements, this provides much greater confidence that the rapid observations from the near reference sites can be used to separate local sources from regional sources.

Although the license conditions for this project did not require a near reference monitor to be run at the same site as the reference monitor, the decision to run the real time spare while it wasn't needed as a drop in service replacement ultimately enabled us to have much greater confidence in the results from the near reference sites.

Acknowledgments

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References

A New Bridgewater Bridge Project, Department of State Growth, Tasmanian Government, Tasmania, viewed 30 June 2024, <https://bridgewaterbridge.tas.gov.au/home>